

UK Greenhouse Gas Inventory, 1990 to 2024

Annual Report for Submission under the United Nations Framework Convention on Climate Change

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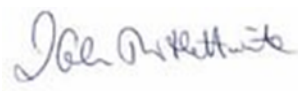
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Preface

This is the United Kingdom's National Inventory Document (NID) submitted in 2026 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2024, and descriptions of the methods used to produce the estimates. This report and the accompanying Common Reporting Tables (CRT) are submitted to meet the UK's reporting requirements under the UNFCCC and the Paris Agreement.

The greenhouse gas inventory (GHGI) is based on the same datasets used by the UK in the National Atmospheric Emissions Inventory (NAEI) for reporting atmospheric emissions under other international agreements. The GHGI is therefore consistent with these other air emissions inventories where they overlap.

The greenhouse gas inventory is compiled on behalf of the UK Department for Energy Security and Net Zero (DESNZ) by Ricardo. We acknowledge the positive support and advice from DESNZ throughout the work, and we are grateful for the help of all those who have contributed to this NID. A list of the contributors can be found in **Chapter 12**.

The GHGI is compiled according to the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines (IPCC, 2006). Each year the inventory is updated to include the latest data available. Improvements to the methodology are backdated as necessary to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new guidance from IPCC, and new research, sponsored by DESNZ or otherwise.

Units and Conversions

Emissions of greenhouse gases presented in this report are normally given in kilotonnes (kt), megatonnes (Mt). Global Warming Potential (GWP) weighted emissions are also provided. To convert between the units of emissions, use the conversion factors given below.

Prefixes and multiplication factors

Multiplication factor	Abbreviation	Prefix	Symbol
1,000,000,000,000,000	10^{15}	peta	P
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^9	giga	G
1,000,000	10^6	mega	M
1,000	10^3	kilo	k
100	10^2	hecto	h
10	10^1	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ

1 kilotonne (kt) = 10^3 tonnes = 1,000 tonnes

1 Mega tonne (Mt) = 10^6 tonnes = 1,000,000 tonnes

1 Gigagram (Gg) = 1 kt

1 Teragram (Tg) = 1 Mt

Conversion of carbon emitted to carbon dioxide emitted

To convert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

Conversion of Gg of greenhouse gas emitted into Gg CO₂ equivalent

Gg (of GHG) * GWP = Gg CO₂ equivalent.

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of greenhouse gases used in this report are given in **Table 1.10**.

Abbreviations for Greenhouse Gases and Chemical Compounds

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH ₄	Methane
Direct	CO ₂	Carbon dioxide
Direct	N ₂ O	Nitrous oxide
Direct	HFCs	Hydrofluorocarbons
Direct	PFCs	Perfluorocarbons
Direct	NF ₃	Nitrogen trifluoride
Direct	SF ₆	Sulphur hexafluoride
Precursor	CO	Carbon monoxide
Precursor	NMVOG	Non-methane volatile organic compound
Precursor	NO _x	Nitrogen oxides (reported as nitrogen dioxide)
Precursor	SO ₂	Sulphur oxides (reported as sulphur dioxide)

HFCs, PFCs, NF₃ and SF₆ are collectively known as the 'F-gases'.

Common Reporting Table (CRT) categories

CRT Category ¹²	Source Description
1	Energy
1A	Fuel combustion activities
1A1	Energy industries fuel use
1A1a	Public electricity and heat generation fuel use
1A1ai	Public electricity generation fuel use
1A1aiii	Public heat plants fuel use
1A1b	Petroleum refining fuel use
1A1c	Manufacture of solid fuels and other energy industries fuel use
1A1ci	Manufacture of solid fuels fuel use
1A1cii	Oil and gas extraction fuel use
1A1ciii	Other energy industries fuel use
1A2	Manufacturing industries and construction fuel use
1A2a	Iron and steel industries fuel use
1A2b	Non-ferrous metals industries fuel use
1A2c	Chemicals industries fuel use
1A2d	Pulp, paper and print industries fuel use
1A2e	Food, drink and tobacco industries fuel use
1A2f	Non-metallic minerals industries fuel use
1A2g	Other manufacturing industries and construction fuel use
1A2giii	Mining and quarrying machinery fuel use
1A2gv	Construction machinery fuel use
1A2gvii	Off-road vehicles and other machinery fuel use
1A2gviii	Other manufacturing industries and construction stationary fuel use
1A3	Transport fuel use
1A3a	Domestic aviation fuel use

¹ Note that for most UK reporting we present CRT codes without full stops between characters, however, the formal CRT includes these. For example, we present 2B10b in this table, but in the formal CRT this would appear as 2.B.10.b.

² Note that for most UK reporting we present LULUCF CRT codes with a modification where the roman numerals in brackets appear in the code when it starts deviating from what the categories without roman numerals in brackets mean, whereas in the formal CRT, the roman numerals in brackets always appear immediately after the first character. For example, we present 4A1(IV)b in this table and the in formal CRT this would appear as 4(IV).A.1.b; in this example, 4A1 has the same meaning as elsewhere (i.e. Forest Land remaining Forest Land), but the b after the (IV) has a different meaning to a b after (I) (i.e. wildfires and organic N fertilisation respectively).

CRT Category¹²	Source Description
1A3b	Road transportation fuel use
1A3bi	Car fuel use
1A3bii	Light duty truck fuel use
1A3biii	Heavy duty trucks and bus fuel use
1A3biv	Motorcycle fuel use
1A3bv	Other road transport fuel use
1A3c	Railway fuel use
1A3d	Domestic navigation fuel use
1A3e	Other transportation fuel use
1A3ei	Pipeline transport fuel use
1A3eii	Other Transportation fuel use
1A4	Other sectors fuel use
1A4a	Commercial/institutional fuel use
1A4ai	Commercial/Institutional stationary fuel use
1A4aii	Commercial/Institutional mobile machinery fuel use
1A4b	Residential fuel use
1A4bi	Residential stationary fuel use
1A4bii	Residential mobile machinery fuel use
1A4c	Agriculture/forestry/fishing fuel use
1A4ci	Agriculture/Forestry/Fishing Stationary fuel use
1A4cii	Agriculture/Forestry mobile machinery fuel use
1A4ciii	Fishing fuel use
1A5	Other (not elsewhere specified) fuel use
1A5a	Other stationary fuel use
1A5b	Other mobile fuel use
1B	Fugitive emissions from fuels
1B1	Fugitive emissions from solid fuels
1B1a	Coal mining and handling
1B1ai	Underground mines
1B1ai1	Underground mining activities
1B1ai2	Underground post-mining activities
1B1ai3	Underground abandoned mines
1B1aii	Surface mines
1B1aii1	Surface mining activities
1B1b	Fuel transformation
1B1bi	Charcoal and biochar production
1B1bii	Coke production
1B1c	Other fuel transformation
1B2	Fugitive emissions from oil and natural gas
1B2a	Oil
1B2ai	Oil exploration fugitive emissions
1B2aii	Oil production and upgrading fugitive emissions
1B2aiii	Oil transport fugitive emissions
1B2aiv	Oil refining/storage fugitive emissions
1B2av	Distribution of oil products
1B2avi	Other fugitive emissions from oil
1B2avi1	Abandoned oil wells
1B2b	Natural gas
1B2bi	Gas exploration fugitive emissions
1B2bii	Gas production and gathering fugitive emissions
1B2biii	Gas processing fugitive emissions
1B2biv	Gas transmission and storage fugitive emissions
1B2bv	Gas distribution fugitive emissions
1B2bvi	Other fugitive emissions from natural gas
1B2bvi1	Gas post-meter fugitive emissions

Abbreviations

CRT Category¹²	Source Description
1B2bvi2	Abandoned gas wells
1B2c	Venting and flaring
1B2ci	Venting
1B2ci1	Oil industry venting
1B2ci2	Gas industry venting
1B2cii	Flaring
1B2cii1	Oil industry flaring
1B2cii2	Gas industry flaring
1B2d	Other fugitive emissions from oil and natural gas
1D	International transport
1D1	International bunkers
1D1a	International Aviation
1D1b	International Navigation
2	Industrial processes and product use
2A	Mineral products
2A1	Cement Production
2A2	Lime Production
2A3	Glass production
2A4	Other process uses of carbonates
2A4a	Ceramics process uses of carbonates
2A4b	Other process uses of soda ash
2A4d	Other process uses of carbonates
2B	Chemical industry
2B1	Ammonia Production
2B2	Nitric Acid Production
2B3	Adipic Acid Production
2B4	Caprolactam, glyoxal and glyoxylic acid production
2B5	Carbide production
2B6	Titanium dioxide production
2B7	Soda ash production
2B8	Petrochemical and carbon black production
2B8a	Methanol production
2B8b	Ethylene production
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer production
2B8d	Ethylene Oxide production
2B8e	Acrylonitrile production
2B8f	Carbon black production
2B8g	Other petrochemical production
2B8gi	Styrene
2B8gii	Petrochemical and carbon black production
2B9	Fluorochemical production
2B9a	By-product emissions
2B9ai	HCFC-22 production by-product emissions
2B9aii	Fluorochemical production by-product emissions
2B9b	Fugitive emissions
2B9bi	Production of HFC-134a
2B9bii	Production of SF ₆
2B9biii	Production of NF ₃
2B9biv	Fluorochemical production fugitive emissions
2B10	Other chemical industry
2B10a	Hydrogen production
2B10b	Other chemical industries process emissions
2C	Metal production
2C1	Iron and steel production
2C1a	Steel production

CRT Category¹²	Source Description
2C1b	Pig iron production
2C1d	Sinter production
2C3	Aluminium production
2C3a	Aluminium production by-product emissions
2C3b	Aluminium production emissions from F-gases used in foundries
2C4	Magnesium production
2C5	Lead production
2C6	Zinc production
2C7	Other metal industries
2D	Non-energy products from fuels and solvent use
2D1	Lubricant non-energy use
2D2	Paraffin wax non-energy use
2D3	Other non-energy products from fuels and solvent use
2D3a	Solvent use
2D3d	Other non-energy use of fuels
2E	Electronics industry
2E1	Integrated circuit or semiconductor
2E2	TFT flat panel display
2E3	Photovoltaics
2E4	Heat transfer fluid
2E5	Other electronics industry
2F	Product uses as substitutes for ODS
2F1	Refrigeration and air-conditioning
2F1a	Commercial refrigeration refrigerant leakage
2F1b	Domestic refrigeration refrigerant leakage
2F1c	Industrial refrigeration refrigerant leakage
2F1d	Transport refrigeration refrigerant leakage
2F1e	Mobile air conditioning refrigerant leakage
2F1f	Stationary air conditioning refrigerant leakage
2F2	Foam blowing agents
2F2a	Closed cell foam blowing agents
2F2b	Open cell foam blowing agents
2F3	Fire Protection release of fire suppressant
2F4	Aerosols
2F4a	Metered dose inhaler propellant release
2F4b	Other aerosols propellant release - non-medical aerosols
2F5	Solvents F-gas emissions
2F6	Other product uses as substitutes for ODS
2F6a	Other emissive application leakage
2F6b	Other contained application leakage
2G	Other product manufacture and use
2G1	Electrical equipment insulating gas leakage
2G2	SF ₆ and PFCs from other product use
2G2a	Military application leakage
2G2b	Particle accelerators leakage
2G2c	Soundproof windows
2G2d	Adiabatic properties: shoes and tyres
2G2e	Other SF ₆ and PFCs from product use
2G2ei	Waterproofing electric circuits
2G2eii	Other SF ₆ and PFCs from product use
2G3	N ₂ O from product uses
2G3a	Medical applications
2G3b	Other N ₂ O from product uses
2G3bi	N ₂ O propellant release
2G3bii	Other N ₂ O from product uses

CRT Category¹²	Source Description
2G4	Other product manufacture and use
3	Agriculture
3A	Enteric Fermentation
3A1	Cattle
3A1a	Enteric Fermentation dairy cattle
3A1b	Enteric Fermentation non-dairy cattle
3A2	Enteric Fermentation sheep
3A3	Enteric Fermentation swine
3A4	Other livestock
3A4a	Enteric Fermentation buffalo
3A4b	Enteric Fermentation camels
3A4c	Enteric Fermentation deer
3A4d	Enteric Fermentation goats
3A4e	Enteric Fermentation horses
3A4f	Enteric Fermentation mules and asses
3A4g	Enteric Fermentation poultry
3A4h	Enteric Fermentation other livestock
3B	Manure management
3B1	Cattle
3B1a	Manure Management dairy cattle
3B1b	Manure Management non-dairy cattle
3B2	Manure Management sheep
3B3	Manure Management swine
3B4	Other livestock
3B4a	Manure management buffalo
3B4b	Manure management camels
3B4c	Manure management deer
3B4d	Manure management goats
3B4e	Manure management horses
3B4f	Manure management mules and asses
3B4g	Manure management poultry
3B4h	Manure management other livestock
3B5	Manure Management Indirect Emissions
3C	Rice cultivation
3D	Agricultural soils
3D1	Direct N ₂ O emissions from managed soils
3D1a	Agricultural Soils Inorganic N Fertilisers
3D1b	Organic N fertilisers
3D1bi	Agricultural Soils Manure Applied to Soils
3D1bii	Agricultural Soils Sewage Sludge Applied to Soils
3D1biii	Agricultural Soils Other Organic Fertilisers Applied to Soils
3D1c	Agricultural Soils Manure Deposited by Grazing Animals
3D1d	Agricultural Soils Residues
3D1e	Agricultural soils Mineralization/Immobilization
3D1f	Agricultural soils Cultivation of Organic Soils
3D2	Indirect N ₂ O emissions from managed soils
3D2a	Agricultural Soils Indirect emissions from atmospheric deposition
3D2b	Agricultural Soils Indirect emissions from leaching and run-off
3E	Prescribed burning of savannas
3F	Field burning of agricultural residues
3F1	Cereals
3F1a	Field burning of wheat residues
3F1b	Field burning of barley residues
3F1d	Field burning of other cereal residues
3F2	Field burning of pulses

Abbreviations

CRT Category¹²	Source Description
3F3	Field burning of tubers and roots
3F4	Field burning of sugar cane
3F5	Field burning of other residues
3G	Liming
3G1	Liming - limestone
3G2	Liming - dolomite
3H	Urea application
3I	Other carbon containing fertilisers
3J	Other agricultural emissions
4	Land use, land use change and forestry
4A	Forest land
4A1	Forest Land remaining Forest Land carbon stock change
4A1(I)	Forest Land remaining Forest Land direct & indirect N ₂ O emissions from N input to managed soil
4A1(I)a	Forest Land remaining Forest Land - Inorganic N fertilizers N fertilisation
4A1(I)b	Forest Land remaining Forest Land - Organic N fertilizers N fertilisation
4A1(II)	Forest Land remaining Forest Land drainage and rewetting
4A1(III)	Forest Land remaining Forest Land N mineralization/immobilization
4A1(IV)	Forest Land remaining Forest Land biomass burning
4A1(IV)a	Forest Land remaining Forest Land controlled burning
4A1(IV)b	Forest Land remaining Forest Land Wildfires
4A2	Land converted to forest land
4A2(I)	Land converted to Forest Land direct & indirect N ₂ O emissions from N input to managed soil
4A2(I)a	Land converted to Forest Land - Inorganic N Fertilisers N fertilisation
4A2(I)b	Land converted to Forest Land - Organic N Fertilisers N fertilisation
4A2a	Cropland converted to Forest Land carbon stock change
4A2a(II)	Cropland converted to Forest Land drainage and rewetting
4A2a(III)	Cropland converted to Forest Land N mineralization/immobilization
4A2b	Grassland converted to Forest Land carbon stock change
4A2b(II)	Grassland converted to Forest Land drainage and rewetting
4A2b(III)	Grassland converted to Forest Land N mineralization/immobilization
4A2c	Wetlands converted to Forest Land carbon stock change
4A2c(II)	Wetlands converted to Forest Land drainage and rewetting
4A2c(III)	Wetlands converted to Forest Land N mineralization/immobilization
4A2d	Settlements converted to Forest Land carbon stock change
4A2d(II)	Settlements converted to Forest Land drainage and rewetting
4A2d(III)	Settlements converted to Forest Land N mineralization/immobilization
4A2e	Other land converted to Forest Land carbon stock change
4A2e(II)	Other land converted to Forest Land drainage and rewetting
4A2e(III)	Other land converted to Forest Land N mineralization/immobilization
4A2(IV)	Land converted to Forest Land biomass burning
4A2(IV)a	Land converted to Forest Land controlled burning
4A2(IV)b	Land converted to Forest Land Wildfires
4B	Cropland
4B1	Cropland remaining Cropland carbon stock change
4B1(I)	Cropland remaining Cropland direct & indirect N ₂ O emissions from N input to managed soil
4B1(I)a	Cropland remaining Cropland - Inorganic N fertilizers N fertilisation
4B1(I)b	Cropland remaining Cropland - Organic N fertilizers N fertilisation
4B1(II)	Cropland remaining Cropland drainage and rewetting
4B1(III)	Cropland remaining Cropland N mineralization/immobilization
4B1(IV)	Cropland remaining Cropland biomass burning
4B1(IV)a	Cropland remaining Cropland controlled burning
4B1(IV)b	Cropland remaining Cropland Wildfires

Abbreviations

CRT Category¹²	Source Description
4B2	Land converted to cropland
4B2a	Forest Land converted to Cropland carbon stock change
4B2a(II)	Forest Land converted to Cropland drainage and rewetting
4B2a(III)	Forest Land converted to Cropland N mineralization/immobilization
4B2b	Grassland converted to Cropland carbon stock change
4B2b(II)	Grassland converted to Cropland drainage and rewetting
4B2b(III)	Grassland converted to Cropland N mineralization/immobilization
4B2c	Wetlands converted to Cropland carbon stock change
4B2c(II)	Wetlands converted to Cropland drainage and rewetting
4B2c(III)	Wetlands converted to Cropland N mineralization/immobilization
4B2d	Settlements converted to Cropland carbon stock change
4B2d(II)	Settlements converted to Cropland drainage and rewetting
4B2d(III)	Settlements converted to Cropland N mineralization/immobilization
4B2e	Other land converted to Cropland carbon stock change
4B2e(II)	Other land converted to Cropland drainage and rewetting
4B2e(III)	Other land converted to Cropland N mineralization/immobilization
4B2(IV)	Forest land converted to Cropland biomass burning
4B2(IV)a	Forest Land converted to Cropland Controlled Burning
4B2(IV)b	Forest Land converted to Cropland Wildfires
4C	Grassland
4C1	Grassland remaining Grassland carbon stock change
4C1(I)	Grassland remaining Grassland direct & indirect N ₂ O emissions from N input to managed soil
4C1(I)a	Grassland remaining Grassland - Inorganic N fertilizers N fertilisation
4C1(I)b	Grassland remaining Grassland - Organic N fertilizers N fertilisation
4C1(II)	Grassland remaining Grassland drainage and rewetting
4C1(III)	Grassland remaining Grassland N mineralization/immobilization
4C1(IV)	Grassland remaining Grassland biomass burning
4C1(IV)a	Grassland remaining Grassland Controlled Burning
4C1(IV)b	Grassland remaining Grassland Wildfires
4C2	Land converted to grassland
4C2a	Forest Land converted to Grassland carbon stock change
4C2a(II)	Forest Land converted to Grassland drainage and rewetting
4C2a(III)	Forest Land converted to Grassland N mineralization/immobilization
4C2b	Cropland converted to Grassland carbon stock change
4C2b(II)	Cropland converted to Grassland drainage and rewetting
4C2b(III)	Cropland converted to Grassland N mineralization/immobilization
4C2c	Wetlands converted to Grassland carbon stock change
4C2c(II)	Wetlands converted to Grassland drainage and rewetting
4C2c(III)	Wetlands converted to Grassland N mineralization/immobilization
4C2d	Settlements converted to Grassland carbon stock change
4C2d(II)	Settlements converted to Grassland drainage and rewetting
4C2d(III)	Settlements converted to Grassland N mineralization/immobilization
4C2e	Other land converted to Grassland carbon stock change
4C2e(II)	Other land converted to Grassland drainage and rewetting
4C2e(III)	Other land converted to Grassland N mineralization/immobilization
4C2(IV)	Forest Land converted to Grassland biomass burning
4C2(IV)a	Forest Land converted to Grassland Controlled Burning
4C2(IV)b	Forest Land converted to Grassland Wildfires
4D	Wetlands
4D1	Wetlands remaining wetlands
4D1(I)	Wetlands remaining wetlands direct & indirect N ₂ O emissions from N input to managed soil
4D1(I)a	Wetlands remaining wetlands - Inorganic N fertilizers N fertilisation
4D1(I)b	Wetlands remaining wetlands - Organic N fertilizers N fertilisation

Abbreviations

CRT Category¹²	Source Description
4D1(III)	Wetlands remaining wetlands N mineralization/immobilization
4D1a	Peat Extraction Remaining Peat Extraction carbon stock change
4D1a(II)	Peat Extraction Remaining Peat Extraction drainage and rewetting
4D1b	Flooded land remaining flooded land carbon stock change
4D1b(II)	Flooded land remaining flooded land drainage and rewetting
4D1c	Other Wetlands Remaining Other Wetlands carbon stock change
4D1c(II)	Other Wetlands Remaining Other Wetlands drainage and rewetting
4D2	Land converted to wetlands
4D2(I)	Land Converted to wetlands direct & indirect N ₂ O emissions from N input to managed soil
4D2(I)a	Land converted to wetlands - Inorganic N fertilizers N fertilisation
4D2(I)b	Land converted to wetlands - Organic N fertilizers N fertilisation
4D2a	Land Converted to Peat Extraction carbon stock change
4D2a(II)	Land Converted to Peat Extraction drainage and rewetting
4D2b	Land converted to flooded land
4D2biii	Grassland Converted to Other Wetlands carbon stock change
4D2b(II)	Land Converted to flooded land drainage and rewetting
4D2c	Land converted to Other Wetlands
4D2ci	Forest Land Converted to Other Wetlands carbon stock change
4D2ci(II)	Forest Land Converted to Other Wetlands drainage and rewetting
4D2cii	Cropland Converted to Other Wetlands carbon stock change
4D2cii(II)	Cropland Converted to Other Wetlands drainage and rewetting
4D2c(III)	Grassland Converted to Wetlands N mineralization/immobilization
4D2(IV)	Forest Land Converted to Other Wetlands biomass burning
4D2(IV)a	Forest Land Converted to Other Wetlands Controlled Burning
4D2(IV)b	Forest Land Converted to Other Wetlands Wildfires
4E	Settlements
4E1	Settlements remaining Settlements carbon stock change
4E1(I)	Settlements remaining settlements direct & indirect N ₂ O emissions from N input to managed soil
4E1(I)a	Settlements remaining settlements - Inorganic N fertilizers N fertilisation
4E1(I)b	Settlements remaining settlements - Organic N fertilizers N fertilisation
4E1(II)	Settlements remaining Settlements drainage and rewetting
4E1(III)	Settlements remaining Settlements N mineralization/immobilization
4E1(IV)	Settlements remaining Settlements biomass burning
4E1(IV)a	Settlements remaining Settlements Controlled Burning
4E1(IV)b	Settlements remaining Settlements Wildfires
4E2	Land converted to settlements
4E2(I)	Land converted to Settlements direct & indirect N ₂ O emissions from N input to managed soil
4E2(I)a	Land converted to Settlements - Inorganic N Fertilisers N fertilisation
4E2(I)b	Land converted to Settlements - Organic N Fertilisers N fertilisation
4E2a	Forest Land converted to Settlements carbon stock change
4E2a(II)	Forest Land converted to Settlements drainage and rewetting
4E2a(III)	Forest Land converted to Settlements N mineralization/immobilization
4E2b	Cropland converted to Settlements carbon stock change
4E2b(II)	Cropland converted to Settlements drainage and rewetting
4E2b(III)	Cropland converted to Settlements N mineralization/immobilization
4E2c	Grassland converted to Settlements carbon stock change
4E2c(II)	Grassland converted to Settlements drainage and rewetting
4E2c(III)	Grassland converted to Settlements N mineralization/immobilization
4E2d	Wetlands converted to Settlements carbon stock change
4E2d(II)	Wetlands converted to Settlements drainage and rewetting
4E2d(III)	Wetlands converted to Settlements N mineralization/immobilization
4E2e	Other land converted to Settlements carbon stock change

Abbreviations

CRT Category¹²	Source Description
4E2e(II)	Other land converted to Settlements drainage and rewetting
4E2e(III)	Other land converted to Settlements N mineralization/immobilization
4E2(IV)	Forest Land converted to Settlements biomass burning
4E2(IV)a	Forest Land converted to Settlements Controlled Burning
4E2(IV)b	Forest Land converted to Settlements Wildfires
4F	Other land
4F1	Other land carbon stock change
4F2	Land converted to other land
4F2a	Forest land converted to other land carbon stock change
4F2a(II)	Forest Land converted to other land drainage and rewetting
4F2a(III)	Forest Land converted to other land N mineralization/immobilization
4F2b	Cropland converted to other land carbon stock change
4F2b(II)	Cropland converted to other land drainage and rewetting
4F2b(III)	Cropland converted to other land N mineralization/immobilization
4F2c	Grassland converted to other land carbon stock change
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4F2(IV)a	Land converted to other land Controlled Burning
4F2(IV)b	Land converted to other land Wildfires
4G	Harvested wood products
4G1	Solid wood
4G1a	Sawnwood
4G1a(I)	HWP Produced and Consumed Domestically - Sawnwood carbon stock change
4G1a(II)	HWP Produced and Exported - Sawnwood carbon stock change
4G1b	Wood panels
4G1b(I)	HWP Produced and Consumed Domestically - Wood panels carbon stock change
4G1b(II)	HWP Produced and Exported - Wood panels carbon stock change
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5A	Solid disposable waste
5A1	Managed waste disposal sites
5A1a	Managed anaerobic waste disposal sites
5A1b	Managed semi-aerobic waste disposal sites
5A1c	Managed active-aeration waste disposal sites
5A2	Unmanaged waste disposal sites
5A3	Uncategorized waste disposal sites
5B	Biological treatment of solid waste
5B1	Composting
5B1a	Municipal solid waste composting
5B1b	Other composting
5B2	Anaerobic digestion at biogas facilities
5B2a	Municipal solid waste anaerobic digestion
5B2b	Other anaerobic digestion

CRT Category¹²	Source Description
5C	Incineration and open burning of waste
5C1	Waste incineration
5C1a	Biogenic waste incineration
5C1ai	Biogenic municipal solid waste incineration
5C1aii	Other incineration of biogenic waste
5C1aii1	Biogenic industrial solid waste incineration
5C1aii2	Biogenic hazardous waste incineration
5C1aii3	Biogenic clinical waste incineration
5C1aii4	Biogenic sewage sludge incineration
5C1aii5	Other biogenic waste incineration
5C1b	Non-biogenic waste incineration
5C1bi	Non-biogenic municipal solid waste incineration
5C1bii	Other incineration of non-biogenic waste
5C1bii1	Non-biogenic industrial solid waste incineration
5C1bii2	Non-biogenic hazardous waste incineration
5C1bii3	Non-biogenic clinical waste incineration
5C1bii4	Non-biogenic sewage sludge incineration
5C1bii5	Non-biogenic fossil liquid waste incineration
5C1bii6	Other non-biogenic waste incineration
5C2	Open burning of waste
5C2a	Biogenic waste open burning
5C2ai	Biogenic municipal solid waste open burning
5C2aii	Other biogenic open burning
5C2b	Non-biogenic waste open burning
5C2bi	Non-biogenic municipal solid waste open burning
5C2bii	Other non-biogenic open burning
5D	Wastewater treatment and discharge
5D1	Domestic wastewater treatment and discharge
5D2	Industrial wastewater treatment and discharge
5D3	Other wastewater treatment and discharge
6	Other

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Executive Summaries

ES 1 BACKGROUND INFORMATION

ES 1.1 Climate Change

The UK has domestic targets for reducing greenhouse gas emissions under the Climate Change Act 2008 (CCA)³. The CCA established a long-term legally binding framework to reduce total UK net greenhouse gas emissions by at least 100% below 1990 levels by 2050. The UK was the first major economy in the world to legislate for a 'net zero' target. The CCA also established the Climate Change Committee (CCC) to provide independent advice on the setting and meeting of Carbon Budgets. These are legally binding limits on total UK net greenhouse gas emissions over five-year periods and are required to be set 12 years in advance of the start of each period⁴. The UK has met its first, second and third Carbon Budgets covering the periods 2008-12, 2013-17 and 2018-22 respectively.

Further information on the UK's action to tackle climate change can be found on the Department for Energy Security and Net Zero (DESNZ) website⁵. Information about climate adaptation can be found on the UK Government's topic page⁶.

UK greenhouse gas emissions statistics are published annually by DESNZ as Official Statistics⁷. The UK's geographical coverage in these statistics differs to that reported under the UNFCCC and Paris Agreement, with emissions from the UK's Crown Dependencies and Overseas Territories typically excluded.

Under the Paris Agreement, the UK is required to set emission reduction targets every five years, known as Nationally Determined Contributions (NDCs). For its First NDC, the UK has committed to reduce total net greenhouse gas emissions by at least 68% in 2030, compared to 1990 levels⁸. For its Second NDC, the UK has committed to reduce total net greenhouse gas emissions by at least 81% in 2035⁹, compared to 1990 levels.

Further information on the UK Devolved Governments (DGs) action to tackle climate change can be found on the CCC's website¹⁰.

ES 1.2 Greenhouse Gas Inventories

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993, and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish, and regularly update national emission inventories of greenhouse gases (GHGs).

This is the United Kingdom's National Inventory Document (NID), submitted in 2026 to the UNFCCC. It contains national greenhouse gas emission estimates for the period 1990-2024,

³ <https://www.legislation.gov.uk/ukpga/2008/27/contents>

⁴ <https://www.gov.uk/guidance/carbon-budgets>

⁵ <https://www.gov.uk/government/organisations/department-for-energy-security-and-net-zero>

⁶ <https://www.gov.uk/environment/climate-change/adaptation>

⁷ <https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics>

⁸ <https://www.gov.uk/government/publications/the-uks-nationally-determined-contribution-communication-to-the-unfccc>

⁹ <https://www.gov.uk/government/publications/uks-2035-nationally-determined-contribution-ndc-emissions-reduction-target-under-the-paris-agreement>

¹⁰ <https://www.theccc.org.uk/climate-action/>

and the descriptions of the methods used to produce the estimates. This report and the accompanying Common Reporting Tables (CRT) are submitted to meet the UK's reporting requirements under the UNFCCC and the Paris Agreement. This document has been prepared in accordance with Decision 18/CMA.1 and Annex V from Decision 5/CMA.3¹¹. Consistent with decision 7/CP.27¹², the UK uses AR5 Global Warming Potentials (GWPs) for reporting under the UNFCCC, and the Paris Agreement.

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo – the **Inventory Agency** – under contract to DESNZ. Ricardo is directly responsible for producing the emissions estimates for CRT categories Energy (CRT sector 1), Industrial Processes and Product Use (CRT Sector 2), and Waste (CRT Sector 5). Ricardo is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Aether, a member within the consortium, is responsible for compiling emissions from railways and for the UK's Overseas Territories (OTs) and Crown Dependencies (CDs). Ray Gluckman (Gluckman Consulting) advises on F-gas emissions.

Forestry emissions and removals in the Land-Use, Land-Use Change and Forestry sector (CRT sector 4) are calculated by Forest Research and the remainder of the sector is calculated and compiled by the UK Centre for Ecology and Hydrology (UKCEH), both partners within the consortium. Agricultural sector emissions estimates (CRT sector 3) are produced by a consortium led by ADAS, under contract to the UK Department for Environment, Food and Rural Affairs (Defra).

DESNZ, Defra and the DGs also fund research contracts to provide improved emissions estimates which are fed into the inventory via the National Inventory System (**Section 1.2.1.2**).

The inventory covers the seven direct greenhouse gases in the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention. These are as follows:

- Carbon dioxide (CO₂);
- Methane (CH₄);
- Nitrous oxide (N₂O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF₆); and
- Nitrogen trifluoride (NF₃).

These gases contribute directly to climate change owing to their positive radiative forcing effect. Also reported are four greenhouse gas precursors:

- Nitrogen oxides (NO_x);
- Carbon monoxide;
- Non-Methane Volatile Organic Compounds (NMVOC); and
- Sulphur oxides (reported as SO₂).

Emissions of indirect N₂O from emissions of NO_x and Ammonia (NH₃) are estimated as a memo item, and aggregated emissions of NH₃ are also reported to the UNFCCC. These emissions are not included in the national total.

Unless otherwise indicated, percentage contributions and changes quoted refer to net emissions (i.e. emissions minus removals), based on the full coverage of UK emissions including all relevant OTs and CDs, consistent with the UK's submission to the UNFCCC.

¹¹ <https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review/reporting-and-review-under-the-paris-agreement/national-inventory-reports>

¹² FCCC Decision 7/CP.27. Common metrics used to calculate the carbon dioxide equivalence of anthropogenic greenhouse gas emissions by sources and removals by sinks <https://unfccc.int/documents/626561>

The UK inventory provides data to assess progress towards the UK Government's own Carbon Budgets and to meet commitments as a Party to the UNFCCC. Note also, that not all UK OTs and CDs that have ratified the UNFCCC have also ratified the Paris Agreement. The geographical coverage of these submissions are as follows:

1. **UNFCCC** Coverage Includes UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and the Overseas Territories (Bermuda, Cayman Islands, Falkland Islands, Gibraltar).
2. **Paris Agreement** Coverage Includes UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and the Overseas Territory Gibraltar.
3. The UK Government **Carbon Budgets** apply to the UK only and exclude all emissions from the UK's OTs and CDs.

Emissions data for the first geographical coverage above is used for the data in the CRT submitted to the UNFCCC under the Convention, and the second coverage is used for the data in the CRT submitted to the UNFCCC under the Paris Agreement. **Table ES 1** and **Table ES 2** show CO₂ and the direct greenhouse gases, disaggregated by gas and by sector for the UNFCCC scope. **Table ES 3** presents data for the Paris Agreement scope. Table 3.3 in the UK Greenhouse Gas statistics⁷ includes further detail of how emissions between geographical scopes compare.

Table ES 4 has data on precursor gas emissions, for the UNFCCC scope.

ES 2 SUMMARY OF NATIONAL EMISSION AND REMOVAL RELATED TRENDS

Table ES 1 Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2024. (Mt CO₂ Equivalent)

	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024	% change 1990 – 2024
CO ₂ (Inc. net LULUCF)	602.4	562.5	563.4	563.8	505.6	416.0	320.9	321.4	302.7	294.4	-51%
CO ₂ (Exc. net LULUCF)	599.5	561.9	565.1	568.2	511.6	423.3	327.9	328.3	309.4	301.1	-50%
CH ₄ (Inc. net LULUCF)	132.6	130.6	116.4	98.2	76.7	64.8	60.0	58.2	57.3	55.8	-58%
CH ₄ (Exc. net LULUCF)	127.0	125.0	110.9	92.7	71.1	59.2	54.3	52.5	51.5	50.1	-61%
N ₂ O (Inc. net LULUCF)	46.4	37.7	29.1	25.9	23.5	23.2	22.0	21.5	21.4	21.0	-55%
N ₂ O (Exc. net LULUCF)	44.5	35.9	27.4	24.3	22.1	21.9	20.6	20.1	20.1	19.7	-56%
HFCs	12.1	15.5	6.4	8.2	10.8	11.3	8.5	7.4	7.0	6.5	-46%
PFCs	1.5	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1	-91%
SF ₆	1.2	1.3	1.9	1.1	0.7	0.4	0.4	0.3	0.3	0.3	-78%
NF ₃	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-42%
Total (Inc. net LULUCF)	796.2	748.1	717.7	697.5	617.5	516.0	411.9	409.0	388.8	378.2	-53%
Total (Exc. net LULUCF)	785.8	740.2	712.2	694.8	616.6	516.4	412.0	408.9	388.4	377.8	-52%

1. One Mt equals one Tg, which is 10¹² g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Tables
3. Geographical coverage of this table includes the OTs and CDs which are included in the scope of the UK's ratification of the UNFCCC
4. Values presented in this table are rounded to 1 decimal place and % trends are calculated from unrounded values, so these might appear inconsistent when comparing to the rounded values

Table ES 1 presents the UK Greenhouse Gas Inventory totals by gas, including and excluding net emissions from LULUCF. The largest contribution to total emissions is CO₂, which contributed 78% to total net emissions in 2024. Methane emissions account for the next largest share (15%), and N₂O emissions make up a further 6%. Emissions of all these gases have decreased since 1990, contributing to an overall decrease of 53%.

ES 3 OVERVIEW OF SOURCE AND SINK CATEGORY EMISSION ESTIMATES AND TRENDS

Table ES 2 details total net emissions of GHGs, aggregated by CRT sector.

Table ES 2 Aggregated emission trends per source category, including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories (Mt CO₂ equivalent)

Source Category	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
1. Energy	599.1	553.0	548.7	546.7	496.9	404.5	314.1	316.1	299.5	294.6
2. Industrial Processes and Product Use	80.4	73.8	53.0	49.4	40.5	41.5	31.6	27.6	24.3	20.6
3. Agriculture	51.1	50.1	48.8	46.7	44.2	44.8	42.9	42.6	42.0	41.0
4. LULUCF	10.3	8.0	5.5	2.7	1.0	-0.4	-0.1	0.1	0.4	0.3
5. Waste	55.3	63.2	61.7	52.0	35.0	25.6	23.5	22.6	22.6	21.7
Total (net emissions)	796.2	748.1	717.7	697.5	617.5	516.0	411.9	409.0	388.8	378.2

Footnotes: Geographical coverage of this table includes the OTs and CDs which are included in the scope of the UK's ratification of the UNFCCC

The largest contribution to greenhouse gas emissions is from the energy sector. In 2024 this contributed 78% to the total net emissions. Emissions of CO₂, CH₄ and N₂O all arise from this sector, but CO₂ is the dominant gas consisting of 97% of emissions. Since 1990, emissions from the energy sector have declined by 51%.

Industrial processes and product use contributed 5% to the national total in 2024. Emissions of all seven direct greenhouse gases occur from this sector. Since 1990, emissions from this sector have declined by 74%.

The second largest source of greenhouse gases is the agricultural sector, contributing 11% in 2024. Emissions from this sector are mostly CH₄ and N₂O, contributing 67% and 30% respectively. Only a small amount of CO₂ is emitted in comparison. Since 1990, emissions from this sector have declined by 20%.

Land-Use, Land-Use Change, and Forestry contains sinks as well as sources of CO₂ emissions. LULUCF was a net source in both the base year and 2024. Emissions from this sector occur for CO₂, N₂O and CH₄.

The waste sector contributed 6% to the national total in 2024. This sector leads to emissions of CO₂, CH₄ and N₂O, with emissions occurring from waste incineration (without energy

recovery¹³), biological treatment of solid waste and wastewater handling. CH₄ is the dominant gas consisting of 77% of all emissions. Emissions from this sector have declined and in 2024 were 61% below 1990 levels.

Table ES 3 below shows the total net GHG emissions by CRT sector consistent with the Paris Agreement scope.

Table ES 3 Aggregated emission trends per source category, including all estimated GHG emissions – Paris Agreement scope (Mt CO₂ equivalent)

Source Category	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
1. Energy	597.7	551.7	547.2	545.0	495.1	402.6	312.5	314.3	297.5	292.6
2. Industrial Processes and Product Use	80.4	73.8	53.0	49.4	40.3	41.2	31.3	27.3	24.0	20.4
3. Agriculture	50.8	49.9	48.6	46.5	44.0	44.6	42.7	42.4	41.8	40.8
4. LULUCF	10.2	7.9	5.5	2.6	0.7	-0.5	-0.2	0.0	0.3	0.2
5. Waste	55.2	63.1	61.6	51.9	34.9	25.5	23.4	22.4	22.5	21.5
Total (net emissions)	794.3	746.3	715.8	695.5	615.1	513.5	409.7	406.5	386.2	375.5

Footnotes: Geographical coverage of this table includes the OTs and CDs which have ratified the Paris Agreement at the time of writing.

ES 4 OTHER INFORMATION

Table ES 4 lists the precursor gases for which the UK has made emissions estimates. Nitrogen oxides, carbon monoxide and NMVOCs are included in the inventory because they can result in an increase in tropospheric ozone concentration, increasing radiative forcing. Sulphur oxides are included because they contribute to aerosol formation.

Table ES 4 Emissions of Precursor Greenhouse Gases in the UK, 1990-2024 (in kt).

Precursor Gas	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
NO _x	2988	2601	2171	2030	1593	1373	861	921	909	904
CO	7507	6270	4649	3120	2018	1660	1303	1288	1258	1193
NMVOC	2909	2433	1840	1365	1050	950	911	866	866	852
SO ₂	3612	2549	1318	851	541	348	125	119	116	107

Footnotes:

Geographical coverage of the emissions in the table includes emissions from the Crown Dependencies and Overseas Territories that are included in the UK's ratification of the UNFCCC.

Since 1990, emissions of all precursor gases have decreased. The largest source of emissions for NO_x, CO and SO₂ is the energy sector, with 85% of emissions or more arising from activities within this sector in 2024. For NMVOC, 50% of emissions in 2024 are from the industrial processes and product use sector, with other significant contributions from the energy and agriculture sectors.

¹³ Waste incineration with energy recovery is considered an energy process under UNFCCC reporting, and reported in the Energy sector

ES 5 KEY CATEGORY ANALYSIS

As part of the compilation of the National Inventory Document, key category analyses have been conducted using both approach 1 and 2.

For a full description of the key category analyses performed along with the complete results, please see **Annex 1**.

ES 6 IMPROVEMENTS INTRODUCED

Several improvements have been implemented in this year's publication. The overall impact of all recalculations is a decrease of 18.7 Mt CO₂ equivalent in 1990, and a decrease of 0.3 Mt CO₂ equivalent in 2023.

For a further information on improvements made and their impacts to emissions on a CRT category and gas basis, see **Section 10**.

Contacts

This work is delivered by a consortium led by Ricardo for the Department for Energy Security and Net Zero. The Land-Use Change and Forestry estimates were provided by the UK Centre for Ecology and Hydrology (UKCEH) in Edinburgh with the support of Forest Research. Rothamsted Research provide the estimates of agricultural emissions.

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A copy of this report and related data may be found on the website maintained by Ricardo for Defra and DESNZ: <http://naei.energysecurity.gov.uk/>

1 National circumstances, institutional arrangements and cross-cutting information

This is the UK's 2026 National Inventory Document (NID). The NID is one element of the annual greenhouse gas inventory (GHGI) that is compulsory to submit to the UNFCCC by signatories to the Convention by 15 April of each year. This report and the accompanying Common Reporting Tables (CRT) are submitted to meet the UK's reporting requirements under the UNFCCC and the Paris Agreement. This document has been prepared in accordance with Decision 18/CMA.1 and Annex V from Decision 5/CMA.3¹⁴. Consistent with decision 7/CP.27¹⁵, the UK uses AR5 Global Warming Potentials (GWPs) for reporting under the UNFCCC, and the Paris Agreement (PA).

The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the Common Reporting Tables (CRT), and any other additional information in support of this submission.

1.1 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, AND CLIMATE CHANGE

1.1.1 Background Information on Climate Change

The UK has domestic targets for reducing greenhouse gas emissions under the Climate Change Act 2008 (CCA)¹⁶. The CCA established a long-term legally binding framework to reduce total UK net greenhouse gas emissions by at least 100% below 1990 levels by 2050. The UK was the first major economy in the world to legislate for a 'net zero' target. The CCA also established the Climate Change Committee (CCC) to provide independent advice on the setting and meeting of Carbon Budgets. These are legally binding limits on total UK net greenhouse gas emissions over five-year periods and are required to be set 12 years in advance of the start of each period¹⁷. The UK has met its first, second and third Carbon Budgets covering the periods 2008-12, 2013-17 and 2018-22 respectively.

Further information on the UK's action to tackle climate change can be found on the Department for Energy Security and Net Zero (DESNZ) website¹⁸. Information about climate adaptation can be found on the UK Government's topic page¹⁹.

¹⁴ <https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review/reporting-and-review-under-the-paris-agreement/national-inventory-reports>

¹⁵ FCCC Decision 7/CP.27. Common metrics used to calculate the carbon dioxide equivalence of anthropogenic greenhouse gas emissions by sources and removals by sinks <https://unfccc.int/documents/626561>

¹⁶ <https://www.legislation.gov.uk/ukpga/2008/27/contents>

¹⁷ <https://www.gov.uk/guidance/carbon-budgets>

¹⁸ <https://www.gov.uk/government/organisations/department-for-energy-security-and-net-zero>

¹⁹ <https://www.gov.uk/environment/climate-change/adaptation>

UK greenhouse gas emissions statistics are published annually by DESNZ as Official Statistics²⁰. The UK's geographical coverage in these statistics differs to that reported under the UNFCCC and Paris Agreement, with emissions from the UK's Crown Dependencies and Overseas Territories typically excluded. As well as presenting emissions on a source basis, emissions are also presented on an 'end-user' basis, where emissions from energy supply are reallocated to the sectors where the energy is used.

Further information on emissions trends, performance against Carbon Budgets and 'end-user' methodology can be found in DESNZ UK greenhouse gas emissions statistics.

Up until 2020, the UK had emissions reduction targets under the Kyoto Protocol to the UNFCCC. The UK, collectively with the EU, met its emissions reduction targets under the First Commitment Period (2008-12) and Second Commitment Period (2013-20). For further information, see the UK's 2022 National Inventory Report²¹.

Under the Paris Agreement, the UK is required to set emission reduction targets every five years, known as Nationally Determined Contributions (NDCs).

For its First NDC, the UK has committed to reduce total net greenhouse gas emissions by at least 68% in 2030, compared to 1990 levels²². For its Second NDC, the UK has committed to reduce total net greenhouse gas emissions by at least 81% in 2035, compared to 1990 levels²³.

1.1.2 Background Information on Greenhouse Gas Inventories

1.1.2.1 Reporting of the UK Greenhouse Gas Inventory

The UK ratified the UNFCCC in December 1993 and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish, and regularly update national emission inventories of GHGs.

This report and the CRT are submitted to meet the UK's reporting requirements under the UNFCCC and the Paris Agreement. This document has been prepared in accordance with Decision 18/CMA.1 and Annex V from Decision 5/CMA.3¹⁴. In addition, the UK also reports GHG emissions by sources and removals by sinks in the CRT tables. The GHG emissions reported are estimated using methodologies which are either directly from the 2006 IPCC Guidelines, or a methodology that is in accordance with 2006 IPCC guidelines, such as those set out in the 2019 refinement to the 2006 IPCC guidelines.

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo – the **Inventory Agency** – under contract to the Department for Energy Security and Net Zero (DESNZ). Full details of the institutional arrangements for the preparation of the GHG inventory are explained in **Section 1.2**.

This report and corresponding CRTs provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2024. The geographical coverage of these submissions are as follows:

²⁰ <https://www.gov.uk/government/collections/uk-territorial-greenhouse-gas-emissions-statistics>

²¹ <https://unfccc.int/documents/461922>

²² <https://www.gov.uk/government/publications/the-uks-nationally-determined-contribution-communication-to-the-unfccc>

²³ <https://www.gov.uk/government/publications/uks-2035-nationally-determined-contribution-ndc-emissions-reduction-target-under-the-paris-agreement>

1. **UNFCCC** Coverage Includes UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and the Overseas Territories (Bermuda, Cayman Islands, Falkland Islands, Gibraltar).
2. **Paris Agreement** Coverage Includes UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and the Overseas Territory Gibraltar.

The main section of this report presents GHG emissions for the years 1990-2024, discusses the reasons for the trends, and documents any changes in the estimates due to revisions made since the last inventory submission. The Annexes provide supplementary detail regarding the methodology of the estimates and include sections on the estimation of uncertainties and atmospheric verification of the inventory. Full time series of emission factors and other background data are included on the NAEI website²⁴ and are uploaded as part of the UK's official submission.

The CRT consists of a series of detailed spreadsheets, with one set for each year. A copy of the CRT accompanies this report and is available on the NAEI website.

1.1.2.2 Geographical coverage of UK emissions

The UK prepares and reports two CRTs, one for UNFCCC scope, and the second for Paris Agreement scope.

A major source of activity data (AD) for the UK inventory is provided through the publication of the Digest of UK Energy Statistics (DUKES) (see **Table 1.4**). The geographical coverage of DUKES is the United Kingdom. Shipments to the Channel Islands and the Isle of Man from the United Kingdom are not classed as exports and supplies of solid fuel and petroleum to these islands are therefore generally included as part of the United Kingdom inland consumption or deliveries.

The definition of the UK used for DUKES accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics (ONS), which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

Depending on the required reporting framework, the geographical coverage of the UK inventory presented in this NID includes emissions from territories associated with the UK. These are the:

- **Crown Dependencies (CDs)**
The Crown Dependencies are the Isle of Man and the Channel Islands (Jersey and Guernsey). They are not part of the United Kingdom and are largely self-governing with their own legislative assemblies and systems of law. The British Government, however, is responsible for their defence and international relations.
- **Overseas Territories (OTs)** (formerly called Dependent Territories)
The relevant Overseas Territories are the Cayman Islands, Bermuda, Falkland Islands, and Gibraltar. Other Overseas Territories have not signed up to the UNFCCC or the Paris Agreement and are not included in the NID. Overseas Territories are constitutionally not part of the United Kingdom having separate constitutions, and most have elected governments with varying degrees of responsibilities for domestic matters. The Governor, who is appointed by, and represents, His Majesty the King, retains responsibility for external affairs, internal security, defence, and in most cases the public service.

²⁴ UK NAEI - National Atmospheric Emissions Inventory, available at: <https://naei.energysecurity.gov.uk/>

Activity data estimates for individual OTs and CDs are provided by their respective government departments, through direct communications with the Inventory Agency. These data are used to supplement UK national statistics (such as DUKES) to compile and report a complete inventory for all territories.

1.1.2.3 Greenhouse Gases Reported in the UK Inventory

The greenhouse gases reported are:

- **Direct greenhouse gases**
 - Carbon dioxide (CO₂);
 - Methane (CH₄);
 - Nitrous oxide (N₂O);
 - Hydrofluorocarbons (HFCs);
 - Perfluorocarbons (PFCs);
 - Sulphur hexafluoride (SF₆); and,
 - Nitrogen trifluoride (NF₃).
- **Precursor gases**
 - Nitrogen oxides (NO_x, reported as NO₂);
 - Carbon monoxide (CO);
 - Non-Methane Volatile Organic Compounds (NMVOCs); and,
 - Sulphur oxides (reported as SO₂).

Precursor gases have indirect effects on radiative forcing and estimates are requested by the UNFCCC guidelines.

Emissions of indirect N₂O from emissions of NO_x and Ammonia (NH₃) are estimated as a memo item, and ammonia is also reported at a high level to the UNFCCC. These emissions are not included in the national total.

Emissions estimates are made using methodologies corresponding mostly to the detailed sectoral Tier 2 or Tier 3 methods in the IPCC Guidelines.

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

1.2.1 National entity or focal point

1.2.1.1 Single National Entity – DESNZ

In 2023, the Department for Energy Security and Net Zero (DESNZ) was formed and assumed the role of Single National Entity, acting on behalf of the UK Government. DESNZ has overall responsibility for the UK Greenhouse Gas Inventory, its strategic development, and the institutional, legal, and procedural arrangements for the national system. It assumed this role on the dissolution of the previous Single National Entity, the Department for Business, Energy & Industrial Strategy (BEIS).

DESNZ coordinates expertise from across Government and manages research contracts to ensure that the UK Greenhouse Gas Inventory meets international standards set out in the UNFCCC reporting guidelines, and the IPCC 2006 Guidelines.

As the designated Single National Entity for the UK GHG National Inventory System (NIS), DESNZ has the following roles and responsibilities:

- **National Inventory System management and planning**
 - Overall control of the NIS development and function;
 - Management of contracts and delivery of the GHG inventory; and,
 - Definition of performance criteria for NIS key organisations.
- **Development of legal and contractual infrastructure**
 - Review of legal and organisational structure; and,
 - Implementation of legal instruments and contractual developments as required to meet guidelines.

The contact point for the Single National Entity is provided on the **Contacts** page of the NID.

The UK greenhouse gas inventory is compiled and maintained by a consortium led by Ricardo – the **Inventory Agency** – under contract to DESNZ. Ricardo is a member of WSP following WSP's acquisition of Ricardo on 9th of October 2025. Ricardo is responsible for producing the emissions estimates for CRT categories of Energy (CRT sector 1), Industrial Processes and Product Use (CRT sector 2), and Waste (CRT sector 5). Land-Use, Land-Use Change and Forestry emissions (CRT sector 4) are calculated by the UK Centre for Ecology and Hydrology (UKCEH) with the support of Forest Research. Ricardo is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving.

Agricultural sector emissions (CRT sector 3) are produced by a consortium led by ADAS, under contract to the Department for Environment, Food & Rural Affairs (Defra).

1.2.1.2 The UK Greenhouse Gas National Inventory System (UK NIS)

Figure 1.1 summarises the key organisational structure of the UK National Inventory System. **Figure 1.2** summarises the governance structure. **Section 1.2.2** includes further detailed information on the roles and responsibilities of each of the key organisations.

Figure 1.1 Key organisational structure of the UK National Inventory System

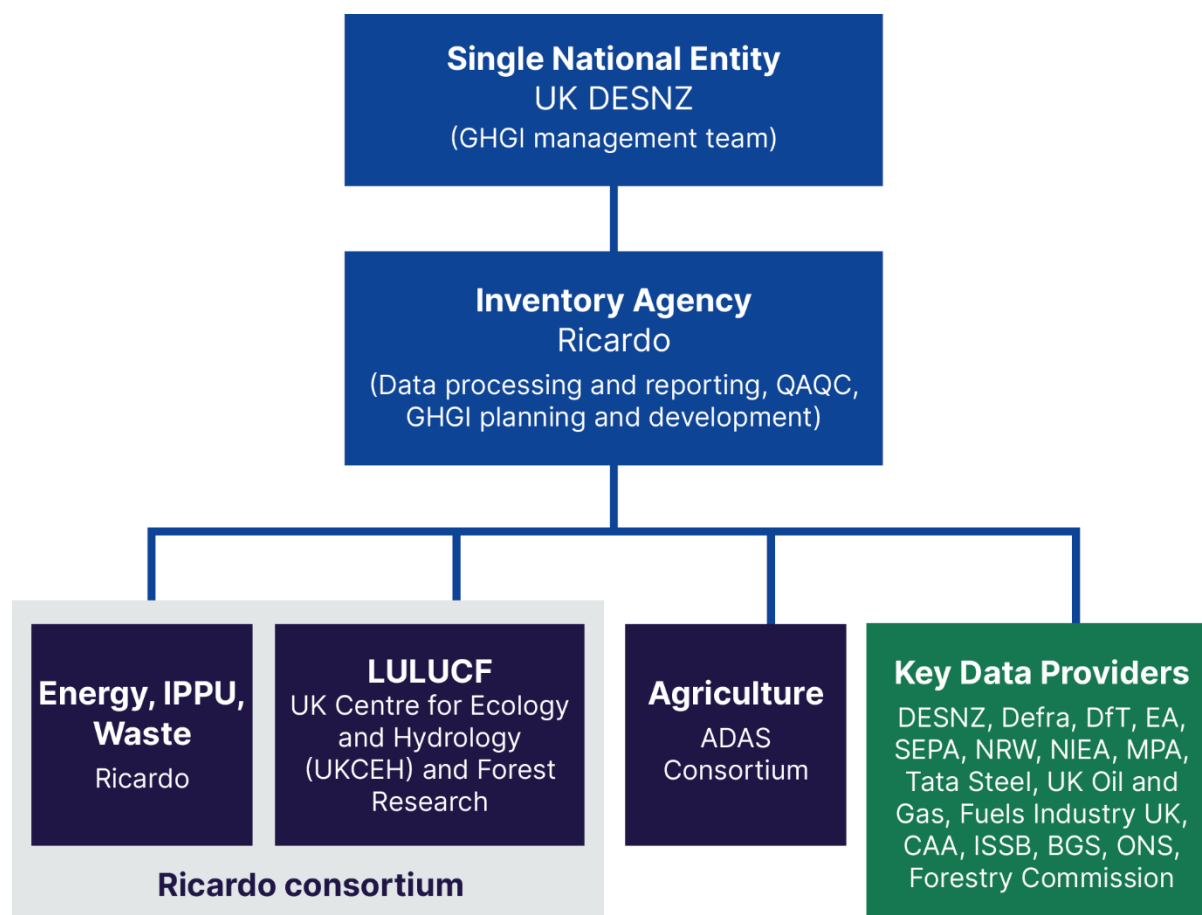


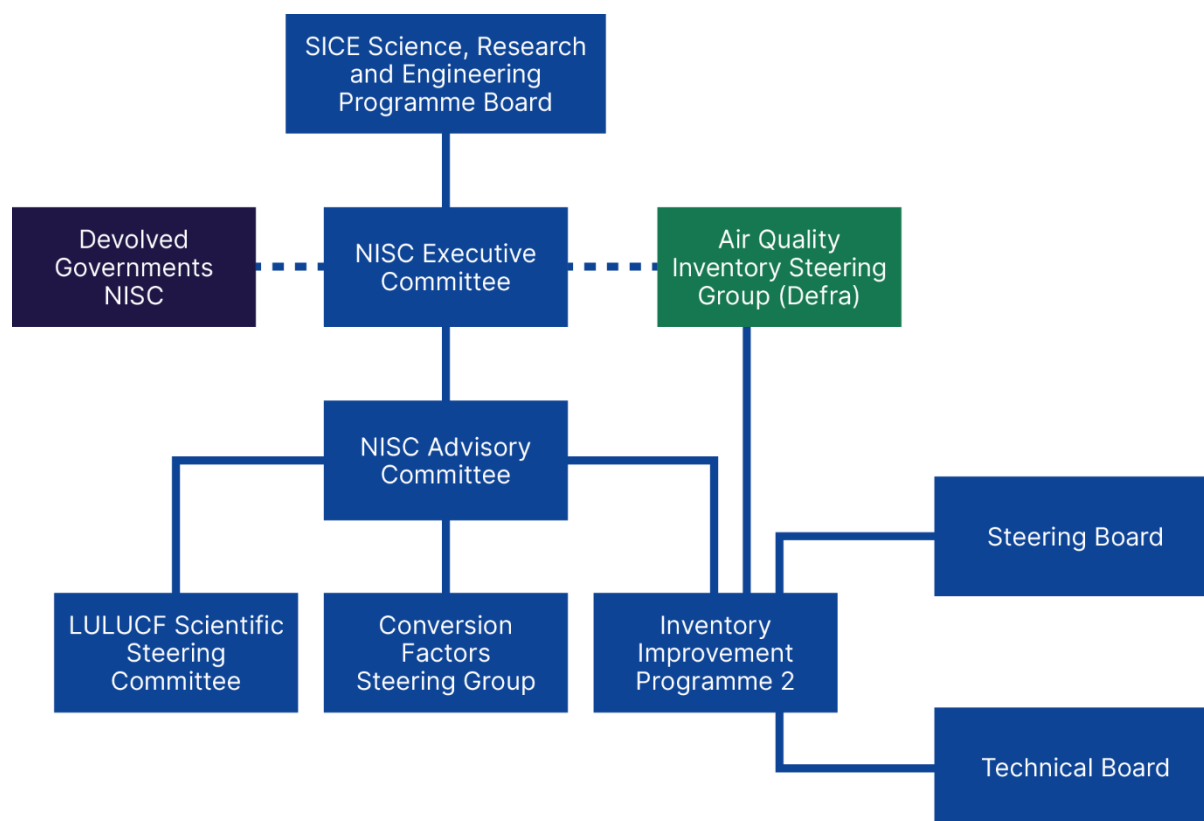
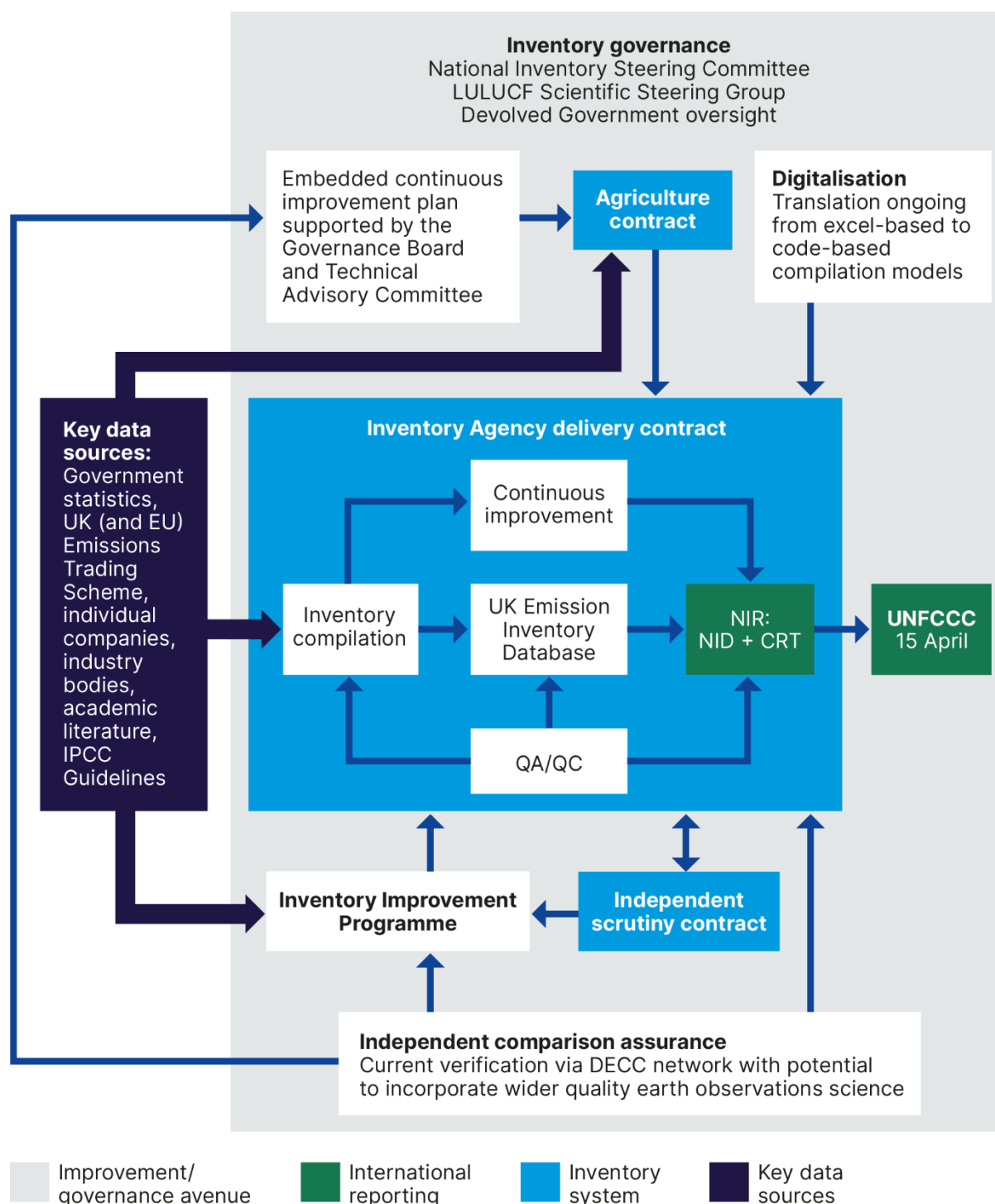
Figure 1.2 Governance structure of the UK National Inventory System

Figure 1.3 shows the main elements of the UK National Inventory System. DESNZ is the Single National Entity responsible for submitting the UK's GHGI to the UNFCCC. The Inventory Agency compiles the GHGI on behalf of DESNZ and produces disaggregated estimates for the Devolved Governments (DGs) within the UK.

Figure 1.3 Main elements for the preparation of the UK greenhouse gas inventory²⁵

The National Inventory Steering Committee (NISC) is formed of two groups, the Advisory Body and the Executive Body. The secretariat function for the NISC is provided by the Lot 2 – Assurance contractors, led by The PSC. Both groups meet twice per year, in April/May and

²⁵ DECC network: Deriving Emissions linked to Climate Change
<https://www.bristol.ac.uk/chemistry/research/acrg/current/decc.html>

November/December. The Advisory Body brings together technical experts on the inventory while the Executive Body membership consists of government stakeholders and end users of inventory data. The purpose of the Advisory Body is to advise on how proposed changes to the inventory should be prioritised and delivered, discussing any risks to the data supply chain as well as reviewing the inventory to identify any potential issues. The Executive Body reviews and discusses modifications to the inventory methodology and resulting recalculations, making recommendations as to whether these modifications should be accepted. It also advises the DESNZ Greenhouse Gas Inventory Team on how improvements to the inventory should be prioritised. The Executive Body aims to ensure that a rigorous science and evidence base remains central to decision-making on the future of the inventory, and stakeholders remain up to date with any significant risks to the Inventory.

The LULUCF scientific steering group brings together LULUCF experts and relevant government stakeholders to discuss the latest scientific developments on the topic and develop plans to improve the UK LULUCF estimates. The group meets once a year ahead of the April/May NISC meeting so that improvement proposals are ready to be put forward to the NISC.

Many policy and regulatory areas in the UK are devolved to the Devolved Governments (DGs) and in addition to this the Inventory Agency produce DG-level emissions estimates for domestic statistics, making the DGs key stakeholders for the GHGI. Representatives from the DGs are included in the NISC and LULUCF scientific steering group, and in addition to this we hold an annual steering group specifically focussed on the DGs.

The independent scrutiny contract, led by The PSC is responsible for:

- Secretariat duties for the NISC advisory;
- Developing the improvement strategy and assisting DESNZ in prioritising improvements to take forward; and,
- Auditing the Inventory Agency's QA/QC processes.

1.2.1.3 Legal Framework

The UK GHGI has been reported annually since 1994, and historically the acquisition of the data required has been based on a combination of existing environmental and energy legislation and informal arrangements with industry contacts and trade associations.

The legislation relied upon has been set up for other purposes, such as:

- Integrated Pollution Prevention and Control (IPPC) regulations (industrial point source emission data from UK environmental regulatory agencies); and,
- Statistics of Trade Act (UK energy statistics from DESNZ).

To meet the standards required under the Kyoto Protocol (KP), the UK introduced legislation²⁶ specifically for national inventory purposes, which took effect from November 2005. These standards are maintained beyond the end of the KP commitment periods. This legislation grants the Inventory Agency access to detailed data underpinning the greenhouse gas Emissions Trading Scheme (ETS) and makes provision for DESNZ's Secretary of State to issue a notice in the event that information required for the inventory that has been sought voluntarily is not provided. The UK values voluntary participation and this legislation is intended as a last resort once all other avenues to elicit the required data, in the format and to the timing specified, have failed. To ensure that the system works most effectively and to

²⁶ Greenhouse Gas Emissions Trading Scheme (Amendment) and National Emissions Inventory Regulations 2005
<http://www.opsi.gov.uk/si/si2005/20052903.htm>, amended in 2013
(<https://www.legislation.gov.uk/uksi/2013/3135/contents/made>)

minimise the need for legislative action, DESNZ establishes data supply agreements (DSAs) with relevant organisations to build upon existing relationships with data supply organisations. These agreements formalise the acquisition of data and clarify the main requirements of quality, format, security, and timely delivery of data for the national inventory. This process is on-going, through the NISC (see **Section 1.2.4**).

There are currently DSAs in place with the Scottish Environment Protection Agency, the Northern Ireland Environment Agency and Department for Transport. During late 2025 and early 2026, the Inventory Agency has reviewed the scope and content of Data Supply Agreements and are now exploring whether formal agreements are warranted with other data supply organisations; an update will be provided in future submissions.

1.2.2 Inventory preparation process

As summarised in **Section 1.1**, the UK has designated authorities with clear roles and responsibilities. The following sections summarise the roles and responsibilities of key stakeholders in the UK's National Inventory System (NIS).

1.2.2.1 Inventory Agency – Ricardo Consortium

A 10-year contract starting in 2025 was established for the Inventory Agency in 2024 following a competitive tendering exercise. Ricardo leads the consortium responsible for compiling the inventory, under contract to DESNZ. Ricardo is responsible for all aspects of national inventory preparation, reporting and quality management. The current consortium consists of:

- Ricardo – lead contractor;
- UKCEH – overall responsibility for the LULUCF estimates.
- Forest Research – responsible for forestland estimates that feed into the LULUCF estimates.
- Aether – responsible for estimates from railways and the OTs and CDs; and DG inventories.
- Ray Gluckman Consulting – contributions to the F-gas inventory.

Ricardo, together with the project partners, prepares the NAEI which is the core air emissions database from which the GHGI is extracted. This arrangement ensures consistency in reporting across all air emissions for different reporting purposes (UNFCCC, United Nations Economic Commission for Europe, UK statistics etc.). Activities include: collecting and processing data from a wide range of sources; selecting appropriate emission factors and estimation methods according to IPCC guidance; compiling the inventory; managing inventory Quality Assurance (QA) and Quality Control (QC) including QC of raw and processed data and data management tools, documentation and archiving, prioritisation of methodology and data improvements; carrying out uncertainty assessments; delivering the NID (including CRT tables) by deadlines set to the UNFCCC on behalf of DESNZ.

As the designated Inventory Agency for the UK GHG National Inventory System (NIS), Ricardo has the following roles and responsibilities:

Planning

- Co-ordination with DESNZ to deliver the NIS;
- Review of current NIS performance and assessment of required development action; and,
- Scheduling of tasks and responsibilities to deliver GHG inventory and NIS.

Preparation

- Drafting of agreements with key data providers; and,
- Review of source data and identification of developments required to improve GHG inventory data quality.

Management

- Documentation and archiving;
- Dissemination of information regarding NIS to Key Data Providers; and,
- Management of inventory QA/QC plans, programmes, and activities.

Inventory compilation

- Data acquisition, processing, and reporting; and,
- Delivery of NID (including associated CRT tables) to time and quality.

The Inventory Agency has formal systems in place to ensure that staff working on the inventory are well trained and able to carry out their duties effectively and efficiently. The technical competence of the staff is facilitated through a combination of the formal Ricardo and inventory-specific staff management and training systems. Roles and responsibilities for all inventory team members are clearly defined, and a comprehensive system of QA/QC is in place. **Annex 4** sets out the QA/QC plan in detail. Ricardo systems ensure subcontractors are managed actively and deliver inputs to the inventory on time and to the specified quality.

The contact point for the Inventory Agency is provided on the **Contacts** page of the NID.

The ADAS Consortium, under contract to Defra, is responsible for the preparation and development of the agriculture inventory. The ADAS Consortium conducts specific research in the agriculture sector and provides finalised GHG emissions data to Ricardo for inclusion within the UK GHGI, is directly responsible for compiling the agriculture sections of the CRT, and for maintaining documentation and archiving of their models and processes. Ricardo is responsible for checking consistency between outputs.

The ADAS consortium includes:

- ADAS – lead contractor, modelling and database management, sheep, arable and grassland estimates;
- Rothamsted Research – dairy, pig, poultry and other livestock estimates, liming and histosols (organic soils);
- Cranfield University – Cattle Tracing System²⁷(CTS) pre-processing and beef estimates;
- UKCEH - June Agricultural Census (JAC) and Robust Farm Type (RFT) pre-processing, sector-wide data analysis and high-resolution mapping;
- Ricardo – QA/QC support.

1.2.2.2 Key Data Providers and Reference Sources

The organisations that provide the raw data to the UK GHGI include a wide range of government departments, non-departmental public bodies and government agencies, private companies, and industrial trade associations.

²⁷ <https://www.gov.uk/cattle-tracing-online>

Within the UK GHG NIS, organisations that are Key Data Providers have the following roles and responsibilities:

Data quality, Format, Timeliness, Security

- delivery of source data in the appropriate format and in time for inventory compilation, allowing for completion of required QA/QC procedures;
- assessment of their data acquisition, processing and reporting systems, having regard for QA/QC requirements;
- identification of any required organisational or legal development and resources to meet more stringent NIS data requirements, notably the security of data provision in the future; and,
- communication with DESNZ, Ricardo and their peers or members to help to disseminate information regarding the GHG inventory and NIS.

Energy statistics required for compilation of the GHGI are obtained from DUKES, which is compiled and published annually by a team of energy statisticians within DESNZ.

Information on industrial processes is provided either directly to the Inventory Agency by the individual plant operators or from:

- The Environment Agency's (EA) Pollution Inventory for England (PI);
- Natural Resources Wales's (NRW) Emissions Inventory for Wales (WEI);
- The Scottish Environment Protection Agency's (SEPA) Scottish Pollutant Release Inventory (SPRI);
- The Northern Ireland Environment Agency's (NIEA) Northern Ireland Pollution Inventory (NIPI); and
- The DESNZ Offshore Petroleum Regulator for Environment & Decommissioning (DESNZ OPRED) Environmental and Emissions Monitoring System (EEMS)

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries under the Environmental Permitting Regulations (EPR). The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to Ricardo.

In addition, the Inventory Agency receives energy, fuel compositional data and emission estimates from all UK installations that operate within the UK Emissions Trading Scheme (UK ETS), from detailed annual operator returns to the UK regulators of UK ETS (EA, SEPA, NRW, NIEA, DESNZ OPRED)²⁸. These data are used by the Inventory Agency and the DESNZ energy statistics team to improve the UK energy balance and emission estimates for high-emitting source categories in the Energy and IPPU sectors (see **Annex 5.2** for further details).

The UK Centre for Ecology and Hydrology (UKCEH) compiles estimates of emissions and removals from LULUCF as part of the Ricardo consortium using land-use data and information on forestry from the Forestry Commission Research Agency (an executive agency of the Forestry Commission, known as Forest Research), Government Departments, DGs and from other sources.

²⁸ The UK Emissions Trading Scheme (UK ETS) replaced the UK's participation in the EU ETS on 1 January 2021. UK based operators (except for electricity generators in Northern Ireland, who remain in EU ETS in accordance with the terms of the Protocol on Ireland/Northern Ireland to the Withdrawal Agreement) continue to report their emissions under the UK ETS. For the purposes of calculating UK emissions statistics, EU ETS data are used for emissions arising up to December 31st, 2020, and UK ETS data for emissions emitted from 1st January 2021. As the UK ETS was initially designed to provide a smooth transition for relevant sectors from the EU to the UK scheme, the two data sets are compatible.

The ADAS consortium compiles the inventory for agricultural emissions using agricultural statistics from Defra, Scottish Government, Welsh Government and the Northern Ireland Department of Agriculture, Environment and Rural Affairs (NI DAERA).

1.2.2.3 UK Inventory Improvement Programme

Each year the inventory is updated to include the latest data available. Improvements to the methodology are made and are backdated to ensure a consistent time series. Methodological changes are made to take account of new research and data sources, any new guidance from IPCC, relevant work, or emission factors from sources such as EMEP – the European Monitoring and Evaluation Programme, which sits under the Convention on Long Range Transboundary Air Pollution (CLRTAP), the European Environment Agency (EEA) and the US Environmental Protection Agency (EPA), or from specific research programmes sponsored by DESNZ and other UK Departments.

The UK NIS has a formal Inventory Improvement Programme, overseen by the NISC. This achieves the dual aims of (i) progressing research to improve the UK GHGI data quality, and (ii) developing inter departmental/agency working relationships to integrate inventory-related information from across Government. An improvement strategy is also under development to consider the longer-term direction for the inventory.

The NISC helps prioritise improvements across the inventory. These improvements are designed to improve the transparency, accuracy, consistency, comparability, and completeness of the inventory²⁹. Incremental improvements are made routinely to ensure the inventory uses the most accurate activity data and emission factors. A detailed and prioritised list of larger inventory improvement tasks is maintained by the Inventory Agency. The list is kept under review continually and is formally reviewed annually at a NISC meeting. This list is prioritised by taking into account the Key Category Analysis (see **Section 1.4**), the quantitative uncertainty analysis, sector and pollutant expert judgements, and the future obligations of the inventory. The process of prioritising improvements and aligning with the longer-term strategy is currently under review, to develop a rational framework with more process-based weighting of considerations for ranking improvement options. The timing of the improvements and resourcing of the work are important considerations for the NISC. The Single National Entity takes the final decision on timing and implementation of improvements to the inventory.

1.2.2.4 Overview of Inventory Preparation and Management

For details of inventory preparation, see **Section 1.1**.

The Environment Agency was appointed as the UK Registry Administrator for the Kyoto Registry and EU/UK ETS by BEIS³⁰. While it has now been established that a Registry could be used under PA article 6.2, it is yet to be confirmed whether this will be used by the UK. The UK for this purpose comprises England, Wales, Scotland, Northern Ireland, offshore oil and gas installations and Gibraltar. The Environment Agency is a Government Agency.

1.2.2.5 Inventory Preparation

1.2.2.5.1 GHG Inventory

The present UK GHG inventory for the period 1990-2024 was compiled in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). As discussed in paragraph 12 (a) in the fifty-second to fifty-fifth session of the UNFCCC

²⁹ As detailed in chapter 6.5 of the 2006 IPCC Guidelines. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf

³⁰ BEIS has since been dissolved, and the relevant responsibilities of BEIS have been granted to DESNZ

Subsidiary Body for Scientific and Technological Advice³¹, while the IPCC have since published a refinement to the 2006 IPCC guidelines (IPCC, 2019), these are yet to be adopted for use in historic inventory reporting under the UNFCCC but can be used in some cases if specifically justified.

1.2.2.5.2 Data collection, processing, and storage

The data acquisition task provides the fundamental activity data from which the GHGI is constructed. The process starts by June with the annual requests for data. A database which contains a list of contacts and datasets is used to track progress of the data acquired.

The following activities are carried out each year, in order, as the inventory is compiled:

Method improvement

Improvements to calculation methods are implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC reviews, peer reviews, bilateral reviews and relevant research sponsored by DESNZ, Defra or other organisations.

Data request

Requests for activity data and background data are issued to a wide range of data suppliers. Each request is issued with a unique code, and a database is used to track the request and the data supplied from that request.

Data verification

Activity data received are examined. Anomalies are investigated, such as time series discrepancies, or large changes in values from the previous to the current inventory year.

Data processing

Data are prepared to allow emissions of direct GHG and precursor gas emissions to be estimated.

Emission estimation

Provisional emissions are estimated using the most recent activity data available.

Emissions review

A series of internal reviews are carried out to detect anomalies in the estimates (time series variations and year to year changes). Errors and omissions are then rectified.

Emissions reporting (including background data)

Estimates of emissions are prepared for the various reporting formats (e.g. UNFCCC, UNECE etc. including differing geographical coverages).

Report generation

Draft reports are written to satisfy the reporting criteria of the various agencies, e.g. the UNFCCC.

Report review

The reports are reviewed internally, by external contributing agencies, and by DESNZ. Errors and omissions are then rectified.

³¹ https://unfccc.int/sites/default/files/resource/sbsta2021_inf04.pdf

Report publication

Final reports and data sets are then submitted via approved reporting routes, published in print and made available on publicly accessible web sites.

1.2.3 Archiving of Information

At the end of each inventory cycle, all data, spreadsheets, databases and reports are archived, allowing all data to remain traceable, should it be needed in future years.

The system outlined above complies with the QA/QC procedures outlined in Volume 1, Chapter 6 of IPCC, 2006.

The ADAS consortium and UKCEH, who are the sector experts for agriculture and LULUCF, respectively, have their own systems in place for data collection. As the Inventory Agency responsible for compiling the overall inventory estimates, Ricardo receives completed emission estimates from these organisations as part of the annual data collection process.

Ricardo has work programmes in place with UKCEH and Rothamsted to help harmonise the quality systems used with those used by Ricardo in the core GHG inventory delivery process.

1.2.4 Process for Official Consideration and Approval of Inventory

To meet the detailed requirements of a National System and to ensure the UK efficiently and effectively works towards implementing best practices, a formal cross-Government body, the National Inventory Steering Committee (NISC) was formed in 2006. The NISC is tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. This pre-submission review is achieved at a NISC meeting prior to the finalisation of the inventory, and any recalculations to the inventory are presented and discussed at this meeting.

One of the main roles of the committee is to assist the DESNZ GHG inventory management team to manage and to prioritise the over-arching inventory QA and facilitate review and improvement and better communication between inventory stakeholders across government departments and agencies.

Members of the Steering Committee include the Inventory Agency team at Ricardo, other contractors, plus appropriate sector, legal and economic experts. These experts are responsible for reviewing methodologies, activity data, emission factors and emission estimates at a sectoral level and for reporting their findings and recommendations to the Steering Committee on a regular basis. The committee is responsible for ensuring that the inventory meets international standards of quality, accuracy, and completeness, and is delivered on time each year to the UNFCCC. The NISC is responsible for agreeing the priorities for the UK GHGI improvement programme. Where inventory improvement research is commissioned by the NISC, the research reports are reviewed and approved for use within the UK GHGI compilation by members of the NISC, managed by DESNZ, as part of the pre-submission review process.

Following the NISC meeting in the autumn, any changes to the inventory methodology are signed off by a Director in DESNZ who acts as the Senior Responsible Officer.

Final technical sign-off of inventory outputs rests with the Inventory Agency, as part of the governance procedures agreed with DESNZ as Single National Entity:

- Any outputs relating to financial mechanisms are signed off by the Senior Responsible Officer at the Inventory Agency, as evidence that all quality control has been conducted on these outputs
- National inventory outputs and technical delivery sign-off (e.g. on improvement projects) are signed off by either the inventory Senior Analyst or Technical Director at the Inventory Agency

Table 1.1 and **Table 1.2** below shows the main organisations engaged in the UK NISC, and their roles and responsibilities in relation to the preparation and development of the national inventory. These tables include organisations from the following categories, many of which are classed as key data providers:

- UK government departments – including DESNZ, the Department for Environment, Food and Rural Affairs (Defra), and Department for Transport (DfT)
- DGs in Scotland, Wales, and Northern Ireland
- Inventory contractors (who compile data for the Inventory among other tasks)
- Government agencies (e.g. environmental regulators)
- Industry bodies or associations
- Consultants and invited experts

The development of the inventory is driven through the NISC, which meets twice a year to discuss the outcomes of recent peer, internal and expert reviews and to agree the prioritisation, funding, implementation, and review of items on the UK inventory improvement programme. The Key Category Analysis and the uncertainty analysis, qualitative analysis from Inventory Agency experts as well as recommendations from reviews of the UK GHGI are used as guidance to help the members of the NISC make decisions on which improvements are the most important. Key categories with high uncertainty are given priority over non-key categories or categories with a low uncertainty. The annual inventory review feedback from the UNFCCC and outcomes from QA/QC checks, as well as sector-specific peer- or bilateral review findings are also considered to guide decisions on UK GHGI improvement priorities.

A qualitative uncertainty analysis of the inventory is implemented by the Inventory Agency. This qualitative uncertainty analysis supports the Key Category Analysis and helps determine the highest priority emission sources in the UK where methodological improvements could be applied to improve the accuracy of emission estimates, or more detailed reporting used to improve transparency. This qualitative assessment is conducted by experts of the inventory team within the inventory cycle, including through a post-submission review of data sources, methods and feedback from the UNFCCC ERTs.

In spring each year, DESNZ and the Inventory Agency hold a review meeting, at which the findings of the UN reviews, other peer reviews commissioned by DESNZ, internal post-submission review and qualitative analysis of source categories are discussed in order to develop a comprehensive list of inventory improvement items for discussion, prioritisation and implementation via the NISC.

Table 1.1 UK GHG National Inventory Steering Committee composition and responsibilities

Organisation	Role in relation to NISC	Key NISC responsibilities
DESNZ – Climate Science team	• GHG inventory manager • Manager of GHG research contracts • DESNZ annual climate change statistics and indicators	• Administer functions of Single National Entity for the UK National Inventory System • Overall responsibility for inventory development, compilation, and reporting • Manage GHG inventory research contracts • Act as NISC Chair • Secretariat for NISC Executive • Ensure that UK GHGI conforms to UN international standards and requirements
Defra – Air Quality & Industrial Emissions Team in the Environmental Quality Directorate	• Air quality (AQ) inventory manager • Manager of AQ research contracts	• Ensure that UK AQ inventory conforms to UN international standards and requirements • Overall responsibility for AQ inventory development, compilation, and reporting • With DESNZ, ensure coordinated approach to improvements across GHG and AQ inventories, where relevant.
Defra	• Liaison between Defra and NISC	• Provide an analytical overview of sectors that Defra have responsibility for (such as agriculture and waste management) • Provide link with Defra climate change mitigation team

Organisation	Role in relation to NISC	Key NISC responsibilities
DESNZ – Carbon Budgets	- UK Climate Change Programme - Climate Change Act - Carbon budgets	- Inform NISC of UK programme developments - Explore links between inventory and carbon budgets and potential requirements for either area
DESNZ – Industrial Energy	- UK Emissions Trading System (UK ETS) - UK ETS Registry	- Provide UK ETS fuel use and fuel characterisation datasets for determining industrial fuel use statistics and GHG emission from combustion sources - Improve links between UK ETS registry and GHG inventory
DESNZ – International Net Zero (INZ)	- International negotiations - UNFCCC - Paris Agreement	- Feed international emissions inventory expectations back to the NISC to ensure the UK complies and develops the inventory accordingly - Provide information on future international developments and changes to expectations - Provide advice on the implications of domestic changes to the inventory in an international arena
DESNZ – Climate Science team	LULUCF Inventory manager	- Provide LULUCF inventory data that conforms to UNFCCC international standards and requirements - Work with the NISC to ensure highest quality data
Defra – Farming and Food Science	Agriculture Inventory Manager	- Providing agriculture inventory data that conforms to UN international standards and requirements - Work with the NISC to ensure highest quality data

Organisation	Role in relation to NISC	Key NISC responsibilities
Defra – Waste	Waste	- To provide waste policy expertise to the inventory, including landfill waste - To assist in improving landfill waste data quality
DESNZ – Energy Statistics (DUKES)	Energy statistics	- Annual publication of Digest of UK Energy Statistics (DUKES) - Providing energy statistics to inform the UK inventory
Regulators: - Environment Agency for England - Natural Resources Wales - Scottish Environment Protection Agency - Northern Ireland Environment Agency	- Regulator inventories - UK ETS Registry	- Management, compilation, QA/QC and reporting of pollutant emission inventories/registers under the Integrated Pollution Prevention and Control (IPPC) regulations, and EU ETS annual emission reporting - Ensure that the pollutant emission inventories for industrial processes regulated under IPC/IPPC (PI, SPRI, ISR) are presented in the required format and timescale for inventory estimation and reporting - Collate information in annual emission reports for UK ETS
DESNZ OPRED	Offshore oil and gas regulator (EEMS, UK ETS) and technical expertise	- Providing offshore oil and gas industry annual activity and emission data to inform the UK inventory - Regulation of the offshore oil and gas industry, including management of the Environmental and Emissions Monitoring System (EEMS) of environmental emissions from that sector

Organisation	Role in relation to NISC	Key NISC responsibilities
Department for Transport (DfT)	Transport	- Publication of transport statistics each year - Providing transport statistics to inform the UK inventory
Devolved Governments	- Inventories for Devolved Governments - Devolved government climate change legislation and statutory GHG targets	- General review function for completeness and accuracy of UK inventory from a devolved perspective, including ensuring the integration of local datasets and specific research where appropriate. - Aid NISC in understanding the implications of the UK inventory for the devolved government inventories, legislation, GHG targets and other relevant context.
GHG inventory contractor (Ricardo)	UK greenhouse gas inventory compilation and development	- Contractor responsible for the UK GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving - Compile the annual National Inventory Document (NID) and Common Reporting Tables (CRT) submission to the UN - Participate in sectoral expert panels as required

Organisation	Role in relation to NISC	Key NISC responsibilities
GHG inventory project partners (Aether)	Inputs to GHG inventory compilation and development	- Contractor responsible for emissions from railways, and from Overseas Territories and Crown Dependencies - Joint role in managing the inventory improvement programme and development of QA/QC procedures, with necessary firewalls between work areas, to avoid conflicts of interest.
GHG inventory project partners (UKCEH)	LULUCF inventory	- Contractor responsible for LULUCF inventory, activity data, methods, emission factors and removals estimation - Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into the national inventory - Participate in sectoral expert panels as required
GHG inventory project partners (Forest Research)	LULUCF inventory (forestry component)	- Contractor responsible for forestry elements of the LULUCF inventory - Participate in sectoral expert panels as required
Agricultural inventory contractor (ADAS, Rothamsted Research)	Agriculture Inventory compilation and development	- Contractor responsible for agriculture inventory; activity data, methods, emission factors and emission estimation - Prepare and develop agriculture inventory and deliver on time for incorporation into national inventory - Participate in sectoral expert panels as required

Organisation	Role in relation to NISC	Key NISC responsibilities
Inventory Lot 2 contractor (The PSC)	Independent auditors of the Inventory Agency contractors	- Secretariat for NISC Advisory - Lead delivery of the inventory improvement strategy - Deliver annual improvement recommendations lists, according to the strategy - Externally quality assure the inventory through spot-checks
DESNZ – Analysis	Energy modelling and projections	Produce UK CO₂ projections
Defra – Stratospheric Ozone and Fluorinated Gases	F-gases	- To provide F-gas policy expertise to the inventory - To assist in improving F-gas data quality

Table 1.2 Special Advisors to the UK GHG National Inventory Steering Committee

Organisation	Role in relation to NISC	Key NISC responsibilities
Met Office/University of Bristol	Atmospheric measurements and interpretation at Mace Head, Ireland, and other tall tower sites.	- Provide atmospheric measurements and interpretation of these data collected at Mace Head and other tall tower sites, for use in inventory data verification - Prepare comparison between estimated and observed emissions for the NID
External reviewers	Representation of industries, industry organisations and independent experts in the development of the national inventory	Other experts or representatives may be asked to participate in sectoral expert panels or to review key sources or sources where significant changes to methods, activity data or emission factors have occurred e.g. ONS, Fuels industry UK, Offshore Energies UK, Tata Steel, Electricity Supply Industry, international inventory experts etc.

1.3 METHODOLOGIES AND DATA SOURCES

1.3.1 GHG Inventory

The methods used to estimate emissions are described in detail in the relevant sections of this report. The GHGs emissions reported are estimated using methodologies which are either directly from the 2006 IPCC Guidelines, or a methodology that is in accordance with 2006 IPCC guidelines, such as those set out in the 2019 refinement to the 2006 IPCC guidelines.

Table 1.3 provides a summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Annexes.

Table 1.3 Summary of methods used to estimate emissions of the direct greenhouse gases

CRT sector	Comments on methods
1A	- Basic combustion module (fuel use * emission factor); - Transport models (see MS 6 to MS 10); and, - Carbon balance approach (See MS 4).
1B	- Carbon Balance approach (See MS 4); - DESNZ EEMS inventory (See Annex 5.1.1.2.2); and, - Gas leakage data from network operators (See MS 18).
2A	- Cement production: IPCC Tier 2 approach (see Section 4.2.2); - Lime production: Approach is comparable to IPCC Tier 2, although the Tier 1 default factor is used in the reporting of emissions; - Glass: IPCC Tier 2 approach, UK-specific factors from UK and EU ETS; - Brickmaking: IPCC Tier 2 approach, UK-specific factors from UK and EU ETS; and, - Other carbonates – FGD: Tier 1 approach for earlier part of time-series, Tier 2 for years covered by UK and EU ETS.
2B	- Emissions calculated based on emissions data from industry, UK and EU ETS, and the environmental regulators' inventories, except for: - Use of EU and other MS statistics to estimate methanol manufactured in the UK - Use of IPCC default factors for CH₄ from ethylene oxide, acrylonitrile, carbon black in years where no environmental regulators' inventories data available; and, - Use of IPCC default factor for CO₂ from ethylene dichloride across full time-series.
2C	- Iron and Steel - 2 stage carbon balance and UK and EU ETS/operator carbon factors for carbonate use and arc furnaces (see MS 4); - Spreadsheet model and operator reported emissions for aluminium and magnesium production; and, - Tier 1 approach for non-ferrous metal production.
2D	- Emissions calculated based on IPCC defaults for non-energy use of fuels; and, - IPCC method based as a proportion of the amount of fuel consumed for urea consumption in road transport.
2E, 2F	Spreadsheet models to estimate emissions of F-gases.

CRT sector	Comments on methods
2G	• Spreadsheet models to estimate emissions of F-gases; • NHS research into anaesthetic use; • Pollution inventory data for other uses of N₂O; and, • Statistics on cream consumption and Danish inventory assumptions for N₂O as a propellant for whipped cream.
3A	• Emissions calculated based on animal population data and appropriate EFs.
3B	• Emissions calculated based on animal population data and appropriate EFs.
3D	• Emissions calculated based on animal population data, fertilizer data and appropriate EFs.
3F	• Emissions calculated based on IPCC methodologies.
3G	• Tier 1 approach for liming.
4	• Mathematical models used to estimate emissions and removals from Land-Use and Land-Use Change; and, • CARBINE model used to estimate emissions and removals from Forestry, provided by Forest Research.
5A	• The Methane Emissions from Landfill model (MELmod).
5B	• UK waste activity data and IPCC default emission factors.
5C	• Country specific emission factors, partially based on Pollution Inventory data and IPCC default/other literature emission factors.
5D	• IPCC default method using country specific activity data for all N₂O and CH₄ from industrial waste-water treatment; and, • 2019 refinement to the 2006 IPCC guidelines methodologies, and some literature emission factors where IPCC guidance is incomplete.

The sources of data used are documented in the relevant sections of this NID. Much of the activity data are taken from the key publications listed in **Table 1.4**. All sources are updated annually. References to these sources are hereafter abbreviated as shown in **Table 1.4**.

Table 1.4 Summary of sources of activity data used to estimate greenhouse gas emissions

Source (and publisher) <i>Short name/acronym</i>	Relevant activity data contained in the source
Digest of UK Energy Statistics (UK Department for Energy Security and Net Zero) <i>DUKES</i>	• Energy statistics for the UK (imports, exports, production, consumption, demand) of liquid, solid and gaseous fuels; and, • Calorific values of fuels and conversion factors.

Source (and publisher) <i>Short name/acronym</i>	Relevant activity data contained in the source
Emissions Trading Scheme (UK ETS regulatory agencies in the UK; data supplied via UK Department for Energy Security and Net Zero) <i>UK and EU ETS</i>	- Emissions from installations and characteristics of fuels consumed; - Energy data are aggregated by sector and used to inform inventory estimates; and, - Fuel quality data are used to derive up to date carbon emission factors for major fuels in energy intensive sectors. - The UK was part of the EU ETS up until 2020, and from 2021 onwards formed the UK ETS. Both sources are used across the time series within the inventory, and therefore there are references to both within this report.
Transport Statistics GB (UK Department for Transport) <i>TSGB</i>	- Vehicle km according to vehicle type and road type; - Vehicle licensing statistics (split in vehicle km by fuel type); and, - Selected domestic and international civil aviation aircraft km flown.
Northern Ireland Statistics: Inventory of Statutory Releases, transport data (NI Department of Agriculture, the Environment and Rural Affairs, NI Department for Regional Development) <i>ISR</i>	- Traffic count and vehicle km data for Northern Ireland; and, - Information on regulated processes in NI.
Civil Aviation Authority <i>CAA</i>	Detailed domestic and international civil aviation aircraft km flown.
Pollution Inventory (Environment Agency) <i>PI</i>	Information on emissions from regulated processes in England.
Emissions Inventory for Wales (Natural Resources Wales) <i>WEI</i>	Information on emissions from regulated processes in Wales.
Scottish Pollutant Release Inventory (Scottish Environment Protection Agency) <i>SPRI</i>	Information on regulated processes in Scotland.
Fuels Industry UK <i>Formerly UKPIA</i>	- Refinery emissions; and - Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol.

Source (and publisher) <i>Short name/acronym</i>	Relevant activity data contained in the source
Environmental and Emissions Monitoring System (DESNZ OPRED) <i>EEMS</i>	Detailed inventory of oil and gas emissions.
UK Iron and Steel Industry Annual Statistics (International Steel Statistics Bureau) <i>ISSB</i>	- Energy production and consumption in the Iron and Steel industry; and, - Other statistics regarding the Iron and Steel industry.
United Kingdom Minerals Yearbook (British Geological Society) <i>UKMY</i>	Statistical data on minerals production, consumption, and trade.
Department for Transport <i>ANPR</i>	- Vehicle km data by vehicle type and road type - Automatic Number Plate Recognition (ANPR) data used to help define fleet composition on different road types in the UK.

Key data sources within the Energy sector are further elaborated in **Annex 5.1**. These include the annually updated data sets EEMS, the PI, SPRI and ISR listed above, and other one-off studies that are used across several source categories (such as Baggott et al., 2004). DUKES is described in more detail in **Annex 5.2**.

1.4 DESCRIPTION OF KEY SOURCE CATEGORIES

1.4.1 GHG Inventory

Key categories are defined as the sources of emissions that have a significant influence on the inventory, in terms of the absolute level of the emissions, uncertainty or the trend. **Table 1.5** to **Table 1.8** summarise the key source categories, for the latest reported year, and the base year, derived from the IPCC Approach 1 and 2 key category analyses. Tables are included for the analysis with and without LULUCF and for the base year and most recent year estimated. Details of the key source category analysis are given in **Annex 1**. A trend cannot be calculated for the base year alone, and so the tables for the base year only contain key source categories identified by level.

Note that **Table 1.5** to **Table 1.8** indicate key source categories only for the submission to the Convention (UNFCCC scope). A second analysis for the submission under the Paris Agreement (PA) scope has also been undertaken; however, further details of this analysis are not presented here as the analysis did not affect the key categories list.

A key category ranking has been carried out; this is set out in **Annex 1, Table A 1.5.1**, and is explained below; it is referred to in **Table 3.1** when referencing which categories are, or contain, key categories within the energy sector.

The Key Category Analysis (KCA) ranking system is an additional tool that the UK has developed to aid in the prioritisation of improvement work. The KCA ranking system works by allocating a score based on how high categories rank in the base year and most recent year level assessments and the trend assessment for the approach 1 KCA including LULUCF. For example, if CO₂ from road transport liquid fuel use is the 4th highest by the base year level assessment, 3rd highest by the most recent year level assessment and has the 5th highest trend assessment then its score would be 4+3+5=12. The categories are then ranked from lowest score to highest, with draws in score resolved by the most recent year level assessment. The assessments excluding LULUCF are ignored for this exercise, as the LULUCF sectors would only be included in half of the assessments and would therefore give an unrepresentative weighting.

Following IPCC good practice, a qualitative analysis of the inventory has also been made to identify key categories. Details of this analysis are given in **Annex 1**. This has not identified any further categories that are not already identified as part of the Approach 1 or Approach 2 analyses.

Table 1.5 Key Source Categories for the latest reported year (including LULUCF) – UNFCCC scope

CRT Category	Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO ₂	L2, T2
1A	Coal	CO ₂	T2
1A	Natural Gas	CO ₂	L2, T2
1A	Other (waste)	CO ₂	L2, T2
1A1	Energy industries: solid fuels	CO ₂	L1, T1
1A1	Energy industries: liquid fuels	CO ₂	L1, T1
1A1	Energy industries: gaseous fuels	CO ₂	L1, T1
1A1	Energy industries: other fuels	CO ₂	L1, T1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	CH ₄	L2
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N ₂ O	L2
1A2	Manufacturing industries and construction: solid fuels	CO ₂	L1, T1
1A2	Manufacturing industries and construction: liquid fuels	CO ₂	L1, T1
1A2	Manufacturing industries and construction: gaseous fuels	CO ₂	L1, T1

Background and cross-cutting information

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CRT Category	Category	Greenhouse Gas	Identification Criteria
1A2	Manufacturing industries and construction: other fuels	CO ₂	T1
1A3a	Domestic aviation: liquid fuels	CO ₂	L1
1A3b	DERV	CO ₂	L2, T2
1A3b	DERV	N ₂ O	L2, T2
1A3b	Gasoline/ LPG	CO ₂	L2
1A3b	Gasoline/ LPG	CH ₄	T2
1A3b	Road transportation: liquid fuels	CO ₂	L1, T1
1A3d	Marine fuel	CO ₂	L2
1A3d	Domestic Navigation: liquid fuels	CO ₂	L1, T1
1A4	Other sectors: solid fuels	CO ₂	T1
1A4	Other sectors: liquid fuels	CO ₂	L1, T1
1A4	Other sectors: gaseous fuels	CO ₂	L1, T1
1A5	Other: liquid fuels	CO ₂	T1
1B1	Coal mining and handling	CH ₄	T1, T2
1B2	Natural Gas Transmission	CH ₄	L2, T2
1B2	Oil and gas extraction	CO ₂	L1
1B2	Oil and gas extraction	CH ₄	L1, T1
2A1	Cement production	CO ₂	L1
2B	Chemical industries	CO ₂	T2
2B	Chemical industries	N ₂ O	T2
2B	Chemical industry	HFCs	T2
2B2	Nitric acid production	N ₂ O	T1
2B3	Adipic acid production	N ₂ O	T1
2B8	Petrochemical and carbon black production	CO ₂	L1, T1

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CRT Category	Category	Greenhouse Gas	Identification Criteria
2B9	Fluorochemical production	HFCs, PFCs, SF ₆ and NF ₃	T1
2C	Metal Industries	CO ₂	T2
2C1	Iron and steel production	CO ₂	L1, T1
2F	Product Uses as Substitutes for ODS	HFCs	L2, T2
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF ₆ and NF ₃	L1, T1
2G	Other Product Manufacture and Use	N ₂ O	L2, T2
3A	Enteric Fermentation	CH ₄	L2, T2
3A1	Enteric fermentation from Cattle	CH ₄	L1, T1
3A2	Enteric fermentation from Sheep	CH ₄	L1, T1
3B	Manure Management	N ₂ O	L2
3B1	Manure management from Cattle	CH ₄	L1, T1
3B1	Manure management from Cattle	N ₂ O	L1
3D	Agricultural soils	N ₂ O	L1, T1, L2, T2
4A	Forest land	CO ₂	L1, T1, L2, T2
4B	Cropland	CO ₂	L1, T1, L2, T2
4C	Grassland	CO ₂	L1, T1
4C	Grassland	CH ₄	L1, T1, L2, T2
4D	Wetlands	CH ₄	L1, T1, L2, T2
4E	Settlements	CO ₂	L1, T1, L2, T2
4G	Harvested wood products	CO ₂	L1
5A	Solid waste disposal	CH ₄	L1, T1, L2, T2
5B	Biological treatment of solid waste	CH ₄	L1, T1, L2, T2
5B	Biological treatment of solid waste	N ₂ O	L2, T2
5C	Waste Incineration	CO ₂	T2

CRT Category	Category	Greenhouse Gas	Identification Criteria
5D	Wastewater treatment and discharge	CH ₄	L1, T1, L2, T2
5D	Wastewater treatment and discharge	N ₂ O	L1, T1, L2, T2

Table 1.6 Key Source Categories for the base year (including LULUCF) – UNFCCC scope

CRT Category	Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO ₂	L2
1A	Coal	CO ₂	L2
1A	Natural Gas	CO ₂	L2
1A1	Energy industries: solid fuels	CO ₂	L1
1A1	Energy industries: liquid fuels	CO ₂	L1
1A1	Energy industries: gaseous fuels	CO ₂	L1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N ₂ O	L2
1A2	Manufacturing industries and construction: solid fuels	CO ₂	L1
1A2	Manufacturing industries and construction: liquid fuels	CO ₂	L1
1A2	Manufacturing industries and construction: gaseous fuels	CO ₂	L1
1A3b	Gasoline/ LPG	CO ₂	L2
1A3b	Gasoline/ LPG	CH ₄	L2
1A3b	Road transportation: liquid fuels	CO ₂	L1
1A3d	Marine fuel	CO ₂	L2
1A3d	Domestic Navigation: liquid fuels	CO ₂	L1
1A4	Other sectors: solid fuels	CO ₂	L1
1A4	Other sectors: liquid fuels	CO ₂	L1
1A4	Other sectors: gaseous fuels	CO ₂	L1

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CRT Category	Category	Greenhouse Gas	Identification Criteria
1A5	Other: liquid fuels	CO ₂	L1
1B1	Coal mining and handling	CH ₄	L1, L2
1B2	Natural Gas Transmission	CH ₄	L2
1B2	Offshore Oil & Gas	CH ₄	L2
1B2	Oil and gas extraction	CH ₄	L1
1B2	Oil and gas extraction	CO ₂	L1
2A1	Cement production	CO ₂	L1
2B	Chemical industries	CO ₂	L2
2B	Chemical industries	N ₂ O	L2
2B	Chemical industry	HFCs	L2
2B2	Nitric acid production	N ₂ O	L1
2B3	Adipic acid production	N ₂ O	L1
2B8	Petrochemical and carbon black production	CO ₂	L1
2B9	Fluorochemical production	HFCs, PFCs, SF ₆ and NF ₃	L1
2C	Metal Industries	CO ₂	L2
2C1	Iron and steel production	CO ₂	L1
2G	Other Product Manufacture and Use	N ₂ O	L2
3A	Enteric Fermentation	CH ₄	L2
3A1	Enteric fermentation from Cattle	CH ₄	L1
3A2	Enteric fermentation from Sheep	CH ₄	L1
3B1	Manure management from Cattle	CH ₄	L1
3D	Agricultural soils	N ₂ O	L1, L2
4A	Forest land	CO ₂	L1, L2
4B	Cropland	CO ₂	L1, L2
4C	Grassland	CH ₄	L1, L2

CRT Category	Category	Greenhouse Gas	Identification Criteria
4D	Wetlands	CH ₄	L1, L2
4E	Settlements	CO ₂	L1, L2
5A	Solid waste disposal	CH ₄	L1, L2
5C	Waste Incineration	CO ₂	L2
5D	Wastewater treatment and discharge	N ₂ O	L1, L2
5D	Wastewater Handling	CH ₄	L2

Table 1.7 Key Source Categories for the latest reported year (excluding LULUCF) – UNFCCC scope

CRT Category	Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO ₂	L2, T2
1A	Coal	CO ₂	T2
1A	Natural Gas	CO ₂	L2, T2
1A	Other (waste)	CO ₂	L2, T2
1A1	Energy industries: gaseous fuels	CO ₂	L1, T1
1A1	Energy industries: liquid fuels	CO ₂	L1, T1
1A1	Energy industries: other fuels	CO ₂	L1, T1
1A1	Energy industries: solid fuels	CO ₂	L1, T1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	CH ₄	L2
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N ₂ O	L2
1A2	Manufacturing industries and construction: gaseous fuels	CO ₂	L1, T1
1A2	Manufacturing industries and construction: liquid fuels	CO ₂	L1, T1
1A2	Manufacturing industries and construction: other fuels	CO ₂	T1

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CRT Category	Category	Greenhouse Gas	Identification Criteria
1A2	Manufacturing industries and construction: solid fuels	CO ₂	L1, T1
1A3	Other diesel	CO ₂	L2
1A3a	Domestic aviation: liquid fuels	CO ₂	L1
1A3b	Gasoline/ LPG	CO ₂	L2
1A3b	Road transportation: liquid fuels	CO ₂	L1, T1
1A3b	DERV	CO ₂	L2, T2
1A3b	DERV	N ₂ O	L2, T2
1A3c	Railways: liquid fuels	CO ₂	L1
1A3d	Domestic Navigation: liquid fuels	CO ₂	L1, T1
1A3d	Marine fuel	CO ₂	L2
1A4	Other sectors: gaseous fuels	CO ₂	L1, T1
1A4	Other sectors: liquid fuels	CO ₂	L1, T1
1A4	Other sectors: solid fuels	CO ₂	T1
1A5	Other: liquid fuels	CO ₂	T1
1B1	Coal mining and handling	CH ₄	T1, T2
1B2	Offshore Oil & Gas	CH ₄	L2
1B2	Oil and gas extraction	CH ₄	L1, T1
1B2	Oil and gas extraction	CO ₂	L1
1B2	Natural Gas Transmission	CH ₄	L2, T2
2A1	Cement production	CO ₂	L1
2B	Chemical industries	CO ₂	T2
2B	Chemical industries	N ₂ O	T2
2B	Chemical industry	HFCs	T2
2B2	Nitric acid production	N ₂ O	T1
2B3	Adipic acid production	N ₂ O	T1

CRT Category	Category	Greenhouse Gas	Identification Criteria
2B8	Petrochemical and carbon black production	CO ₂	L1, T1
2B9	Fluorochemical production	HFCs, PFCs, SF ₆ and NF ₃	T1
2C	Metal Industries	CO ₂	L2, T2
2C1	Iron and steel production	CO ₂	L1, T1
2F	Product Uses as Substitutes for ODS	HFCs	L2, T2
2F1	Refrigeration and air conditioning	HFCs, PFCs, SF ₆ and NF ₃	L1, T1
2G	Other Product Manufacture and Use	N ₂ O	L2, T2
3A	Enteric Fermentation	CH ₄	L2, T2
3A1	Enteric fermentation from Cattle	CH ₄	L1, T1
3A2	Enteric fermentation from Sheep	CH ₄	L1, T1
3B	Manure Management	N ₂ O	L2
3B1	Manure management from Cattle	CH ₄	L1, T1
3B1	Manure management from Cattle	N ₂ O	L1
3D	Agricultural soils	N ₂ O	L1, T1, L2, T2
5A	Solid waste disposal	CH ₄	L1, T1, L2, T2
5B	Biological treatment of solid waste	CH ₄	L1, T1, L2, T2
5B	Biological treatment of solid waste	N ₂ O	L2, T2
5C	Waste Incineration	CO ₂	T2
5D	Wastewater Handling	CH ₄	L1, T1, L2, T2
5D	Wastewater Handling	N ₂ O	L1, T1, L2, T2

Table 1.8 Key Source Categories for base year (excluding LULUCF) – UNFCCC scope

CRT Category	Category	Greenhouse Gas	Identification Criteria
1A	(Stationary) Oil	CO ₂	L2

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CRT Category	Category	Greenhouse Gas	Identification Criteria
1A	Coal	CO ₂	L2
1A	Natural Gas	CO ₂	L2
1A1	Energy industries: solid fuels	CO ₂	L1
1A1	Energy industries: liquid fuels	CO ₂	L1
1A1	Energy industries: gaseous fuels	CO ₂	L1
1A1 & 1A2 & 1A4 & 1A5	Other Combustion	N ₂ O	L2
1A2	Manufacturing industries and construction: solid fuels	CO ₂	L1
1A2	Manufacturing industries and construction: liquid fuels	CO ₂	L1
1A2	Manufacturing industries and construction: gaseous fuels	CO ₂	L1
1A3b	Gasoline/ LPG	CO ₂	L2
1A3b	Gasoline/ LPG	CH ₄	L1
1A3b	Road transportation: liquid fuels	CO ₂	L2
1A3d	Domestic Navigation: liquid fuels	CO ₂	L1
1A4	Other sectors: solid fuels	CO ₂	L1
1A4	Other sectors: liquid fuels	CO ₂	L1
1A4	Other sectors: gaseous fuels	CO ₂	L1
1A5	Other: liquid fuels	CO ₂	L1
1B1	Coal Mining	CH ₄	L1, L2
1B2	Oil and gas extraction	CO ₂	L1
1B2	Oil and gas extraction	CH ₄	L1
1B2	Natural Gas Transmission	CH ₄	L2
1B2	Offshore Oil& Gas	CH ₄	L2
2A1	Cement production	CO ₂	L1

CRT Category	Category	Greenhouse Gas	Identification Criteria
2B	Chemical industries	CO ₂	L2
2B	Chemical industries	N ₂ O	L2
2B	Chemical industry	HFCs	L2
2B2	Nitric acid production	N ₂ O	L1
2B3	Adipic acid production	N ₂ O	L1
2B8	Petrochemical and carbon black production	CO ₂	L1
2B9	Fluorochemical production	HFCs, PFCs, SF ₆ and NF ₃	L1
2C	Metal Industries	CO ₂	L2
2C1	Iron and steel production	CO ₂	L1
2G	Other Product Manufacture and Use	N ₂ O	L2
3A	Enteric Fermentation	CH ₄	L2
3A1	Enteric fermentation from Cattle	CH ₄	L1
3A2	Enteric fermentation from Sheep	CH ₄	L1
3B1	Manure management from Cattle	CH ₄	L1
3D	Agricultural soils	N ₂ O	L1, L2
5A	Solid waste disposal	CH ₄	L1, L2
5C	Waste Incineration	CO ₂	L2
5D	Wastewater Handling	CH ₄	L2
5D	Wastewater Handling	N ₂ O	L2

1.5 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Within the NAEI, QA/QC activities comprise:

- **Quality Control** (e.g. raw data checks, calculation checks, output checks) to minimise the risk of errors within the available resources to deliver the inventory;
- **Quality Assurance** (e.g. peer reviews, bilateral reviews, expert reviews) whereby independent experts periodically review all or part of the inventory to identify potential areas for improvement;

- **Verification** where alternate independent datasets are available to compare against inventory data and trends.

The UK inventory QA/QC system is consistent with the general QC procedures set out in the 2006 IPCC Guidelines (Vol 1, Ch. 6, Table 6.1) (IPCC, 2006). All UK GHGI source and sink estimates are subject to QC; for details, please see source category information throughout the NID. Consistent with good practice, the UK also prioritises resources to conduct category-specific QC procedures where the UK applies higher tier methods and/or where significant methodological or data revisions have taken place, in order to help evaluate the quality of national data and methods. Ricardo, the Inventory Agency, is also fully accredited to ISO 9001:2015 and ISO 14001: 2015. This accreditation provides additional institutional standards which the Inventory Agency is required to apply to all projects and ensures that the wider company conforms to good practice in project management and quality assurance.

For more information on QA/QC, please refer to **Annex 4**.

1.6 GENERAL UNCERTAINTY EVALUATION

1.6.1 GHG Inventory

The UK GHG inventory estimates uncertainties using both Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation) described by the IPCC. Approach 1 provides estimates of uncertainty by GHG according to CRT sector. Approach 2 considers the correlations between sources and provides estimates of uncertainty according to GHG in 1990 and the latest reporting year, and by CRT sector.

Approach 2 (Monte Carlo simulation) suggests that the uncertainty in the combined GWP weighted emissions of all the greenhouse gases is 4.0% in 1990 and 2.6% in 2024. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2024 is -53%, with a 95% confidence interval of between -57% and -49%.

A full description of the uncertainty analysis is presented in **Annex 2**.

1.7 GENERAL ASSESSMENT OF COMPLETENESS

The UK GHG inventory aims to include all anthropogenic sources of GHGs. This section discusses sources of greenhouse gases not currently included in reporting. **Table 1.9** below outlines the sources assessed as 'Not Estimated'.

Table 1.9 Summary of sources reported as Not Estimated (NE)

Source	2006 IPCC guideline methodology available Y/N	Explanation for not estimating	Estimate of Emission (Mt CO ₂ e)	% of national total ³²	Comments on how this estimate was determined
2.C.4 Magnesium Production - PFCs	N	It is estimated that the decomposition of 1 t of the fire suppression agent FK 5-1-12 generates about 400 t CO ₂ eq PFCs. As this product is used only at one small magnesium production plant and has been trialled at one larger plant, total emissions in the United Kingdom due to the decomposition of FK 5-1-12 could be up to about 2 kt CO ₂ eq per year since 2012 and zero before 2012.	0.0020	0.001%	Based on consultation with the small number of magnesium manufacturers in the UK.
2.E.2 TFT Flat Panel Display	Y	When deriving an estimate of emissions based on the IPCC default methodology and using the largest of the 2003-5 UK production capacities given in Table 6.7 of Volume 3 in the 2006 IPCC guidelines the estimate of emissions is smaller than the thresholds (both as a percentage of national emissions and as an absolute value of emissions) to be considered insignificant. Consultation with industry has indicated that current UK production capacity is zero.	0.0084	0.002%	Based on data for 2003-5, no other data identified
2.E.3 Photovoltaics	Y	When deriving an estimate of emissions based on the IPCC default methodology and using the 2003 UK production capacity given in Table 6.8 of Volume 3 in the 2006 IPCC guidelines the estimate of emissions is 3 orders of magnitude smaller than the thresholds (both as a percentage of national emissions and as an absolute value of emissions) to be considered insignificant. Consultation with industry has indicated that current UK production capacity is smaller than in 2003, and the limited remaining production processes do not require any F-Gases.	0.0004	0.000%	Based on data for 2004, no other data identified.
2.E.4 Heat Transfer fluid	Y	Very small quantities of PFCs are sold in the UK market for this application, but it is believed that these are sold exclusively for hermetically sealed applications and products that are sold on to outside the UK.	0.0020	0.001%	This is a conservative assumption that the upper limit of PFC sales to the UK is entirely used and emitted within the UK for heat transfer fluids, although our understanding is that the majority of this PFC is emitted outside the UK.

³² Specifically the lowest national total annual emissions excluding LULUCF since 1990

Source	2006 IPCC guideline methodology available Y/N	Explanation for not estimating	Estimate of Emission (Mt CO ₂ e)	% of national total ³²	Comments on how this estimate was determined
3.D Agricultural Soils - CH ₄	N	Not estimated due to insufficient data. Emissions are expected to be very small	NE	NE	No suitable data identified to generate even an indicative value.
3.F Field burning - Overseas Territories	Y	Data on Overseas Territory activity for this source are not available.	0.0005	0.000%	Estimate is made by applying the highest annual UK emissions from this source to the ratio of UK and OT and CD cropland areas.
3.G Liming - Overseas Territories	Y	Data on Overseas Territory activity for this source are not available.	0.0026	0.001%	Estimate is made by applying the highest annual UK emissions from this source to the ratio of UK and OT and CD cropland areas.
3.H Urea application - Overseas Territories	Y	Data on Overseas Territory activity for this source are not available.	0.0007	0.000%	Estimate is made by applying the highest annual UK emissions from this source to the ratio of UK and OT and CD cropland areas.
Drained Organic Soils/Overseas Territories and Crown Dependencies	Y	Insufficient information for reporting.	NE	NE	The UK is developing an approach to estimating emissions from this source, but do not currently have suitable data to present.
Peat Extraction Lands/Overseas Territories and Crown Dependencies	Y	Insufficient activity data for reporting.	NE	NE	The UK is developing an approach to estimating emissions from this source, but do not currently have suitable data to present.

Source	2006 IPCC guideline methodology available Y/N	Explanation for not estimating	Estimate of Emission (Mt CO ₂ e)	% of national total ³²	Comments on how this estimate was determined
1.B.1.a.i Underground Mines - CO ₂	N	There are no data available on CO ₂ content of coal mine methane in the UK, and therefore we have considered the 2006 Guidelines, section 4.1.2: "The following sections focus on methane emissions, as this gas is the most important fugitive emission for coal mining. CO ₂ emissions should also be included in the inventory where data are available". CO ₂ from combustion of coal mine methane is included in the UK GHGI under 1A1c and 1A2g.	0.0044	0.001%	This is the highest value since 1990 when estimated by assuming that colliery methane has a similar CO ₂ content to natural gas.
2.D.3 Other/Solvent use	N	Indirect CO ₂ emissions from the oxidation of VOCs are not mandatory for reporting under the UNFCCC reporting guidelines.	0.1843	0.049%	Estimate of emissions due to abatement of NMVOC by oxidation presented. This estimate is based on the differences in emissions of NMVOC reported for 2017 for each source category within 2D3 compared with emissions reported for 1990 (when solvent emissions will not have been abated). For almost all source categories, NMVOC emissions are lower in 2017 than in 1990 and expert judgement was applied as to what proportion of the reductions in each category was driven by sector decline, reformulation of products, changes in practices to minimise solvent requirement, recovery or destruction by oxidation. Emissions from oxidation of solvents may have been higher in some years in the past but only from the late nineties onwards (since most processes did not abate emissions before then). Since total emissions were also significantly higher in the past, we believe that it is likely that emissions from abatement of NMVOC would represent a similar % of total emissions in those earlier years.

Source	2006 IPCC guideline methodology available Y/N	Explanation for not estimating	Estimate of Emission (Mt CO ₂ e)	% of national total ³²	Comments on how this estimate was determined
2.H.2 Food and beverages industry - CO ₂	N	No appropriate data available	NE/IE ³³	NE/IE	Use of CO ₂ by-products from industrial processes (e.g. ammonia production) in the food and drink industry (e.g. carbonated drinks). For simplicity, the UK currently includes all CO ₂ by-product from UK ammonia production in the national total, but this estimate is not necessarily the same as UK final consumption of products containing CO ₂ by-product. In order to generate an accurate and complete estimate of UK emissions of CO ₂ from by-products we would need to estimate the imports and exports of CO ₂ by-product and imports and exports of products containing by-product CO ₂ . There are also sources of CO ₂ of biogenic origin in this source, but these would not contribute to the national total, so have not been considered.
4.B and 4.C/4(V) Biomass Burning/Wildfires - CO ₂	Y	Assumed to be replaced by re-growth within the year.	0	0.000%	Assumed to be replaced by re-growth within the year. No evidence of wildfires on permanent crops.
5.A Solid Waste Disposal - CO ₂	N	Emissions of CO ₂ are biogenic and therefore are excluded.	0	0.000%	As sources of non-LULUCF CO ₂ of biogenic origin are not included in the national total, the impact on the national total is 0.
5.C Underground oil shale fires	N	Insufficient information for reporting. Data on quantity of material burned over the period of time that the fire was burning is unavailable.	0.0286	0.008%	A conservative estimate has been derived by taking the reported amount of material removed from the site, assuming that an equal mass of shale oil was burned during the fire, and applying the IPCC guideline values for its net calorific value and carbon emission factor.
Total			0.2339	0.062%	

³³ Where IE means "included elsewhere"

Source	2006 IPCC guideline methodology available Y/N	Explanation for not estimating	Estimate of Emission (Mt CO ₂ e)	% of national total ³²	Comments on how this estimate was determined
Total excluding sources for which there is no 2006 IPCC guidelines methodology			0.0145	0.004%	

1.7.1 Information on completeness

Table 1.9 summarises sources that are reported as not estimated in the inventory, what their expected level of emissions would be relative to the national total, and the UK's justification for not estimating these sources. Paragraph 32 of the Modalities, procedures and guidelines³⁴ (MPGs) stipulates that Parties may report emissions as not estimated if an activity occurs in the Party, and:

- the likely level of emissions is below 0.05 per cent of the national total GHG emissions, excluding LULUCF, or 500 kilotonnes of carbon dioxide equivalent (kt CO₂ eq), whichever is lower; and,
- The total national aggregate of estimated emissions for all gases from categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions, excluding LULUCF

The MPGs specify that default IPCC emission factors should be used to make this determination, implicitly implying that the absence of a 2006 IPCC methodology for a source would be a justification for not estimating a source, as the estimated emissions using this approach would necessarily be zero.

1.7.2 Description of insignificant sources

The sources identified as insignificant are described in **Table 1.9** above.

1.7.3 Total aggregate emissions considered insignificant

The total emissions from sources that have been identified as insignificant is 0.2339 Mt CO₂e, as outlined in **Table 1.9** above.

This summary confirmed that there are no sources for which emissions are not estimated which would be expected to be above 0.05% of the UK national total in any year, and that the sum of the sources is estimated to be under 0.1%. Note that many of the sources included are reported as "NE" (Not Estimated) due to there not being a suitable methodology to generate an estimate, when including only sources for which are not reported due to insignificance, the likely proportion of emissions omitted is much lower than 0.1% of the UK national total in any year. Therefore, the UK inventory's use of 'NE' in the CRT is compliant with paragraph 32 of the MPGs.

1.7.4 Sources Outside the Scope of the National Total

The following sections discuss sources of emissions relating to UK activities relevant to climate change which are excluded from the national total due to being outside of the scope of greenhouse gas inventory reporting requirements.

1.7.4.1 International Aviation and Shipping

International shipping and aviation refer to emissions associated with travel from a location within the geographic scope of the inventory to a location outside that scope. The approach adopted by the UNFCCC is that combustion emissions from these journeys are to be reported as 'memo items' but not included in Party's national totals. The UNFCCC separately engages

³⁴ <https://unfccc.int/resource/tet/0/00mpg.pdf>

with the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) regarding these emissions³⁵.

Emissions from processes other than fuel combustion can occur on these international journeys (e.g. fugitive emissions of HFCs used in refrigeration or air conditioning in shipping), however these emissions are comparatively small, and many of these source are likely to be indirectly captured by territorial emissions estimates for those sources.

In accordance with UNFCCC reporting requirements, the UK GHGI reports emissions and activity relating to due to fuel combustion in international aviation and shipping as a 'memo item' in CRT Table1.D, and the methodology is presented in **MS 7** and **MS 12**, but these are not included in national totals. The UK does not make specific estimates of, or report greenhouse gas emissions from sources that occur on international journeys other than fuel combustion and lubricant use.

1.7.4.2 Aviation-Induced Radiative Forcing

Almost all anthropogenic emissions occur at or near ground level, and therefore emissions are reported using Global Warming Potentials (GWPs) that reflect how pollutants contribute to global warming when released at ground level. However, emissions that are emitted at high altitudes (i.e. fuel combustion emissions from the cruise stage of flights) contribute to atmospheric chemistry differently to ground level emissions due to contrails and their impact on cloud formation, although precisely how strong this effect is sensitive to a number of factors and remains uncertain³⁶.

The UK GHGI reports emissions and activity from emissions due to aviation cruise in CRT Table1.A(a)s3 and Table1.D and the methodology is presented in **MS 7**. However, these emissions reported do not account for the aviation-specific impact as there is no approach to account for this in the 2006 IPCC guidelines and it is not facilitated in the reporting mechanisms adopted by the UNFCCC.

1.7.4.3 Carbon Dioxide of Biogenic Origin

Carbon dioxide contributes to the greenhouse gas effect independently of whether originating from a mineral (e.g. fossil fuels) or biogenic (e.g. wood burning) origin. The main difference between mineral and biogenic carbon is that without anthropogenic intervention, mineral carbon generally remains stored in a solid form and does not interact with atmospheric chemistry, whereas without anthropogenic intervention, biogenic carbon is part of a natural cycle where some is released to the atmosphere as CO₂, and CO₂ is absorbed from the atmosphere to be stored in organic matter. Because of this, anthropogenic activity contributes to higher levels of CO₂ from these sources differently; i.e. anthropogenic mineral CO₂ sources are effectively increasing the total carbon in circulation, whereas anthropogenic contribution of biogenic CO₂ are a shifting of the split in the carbon cycle to have a higher proportion in the atmosphere.

One approach to estimate the net change to carbon in the atmosphere is to estimate the changes in carbon stored in vegetation, soils and other organic matter. This approach accounts for emissions of CO₂ by assuming that carbon in vegetation removed is eventually emitted via combustion, animal consumption and respiration, or decomposition, and simultaneously accounts for CO₂ sequestered and stored by vegetation. The 2006 IPCC guidelines sets out a methodology to account for carbon stock changes in this way, and the

³⁵ <https://unfccc.int/topics/mitigation/workstreams/emissions-from-international-transport-bunker-fuels#eq-2>

³⁶ <https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-06.pdf>

UNFCCC agreed that this method should be used, the net carbon stock change reported against Land Use, Land Use Change and Forestry (LULUCF) and included in Party's national totals.

The approach for accounting for carbon stock changes in land means that including estimates of emissions of CO₂ from fuels of biogenic origin at the point of release would be a double count of this carbon stock approach, and therefore estimates of CO₂ of biogenic origin at the point of release is excluded from national totals but can be reported as a 'memo item'.

The UK uses the UNFCCC agreed LULUCF approach for accounting for CO₂ of biogenic origin, which is reported in CRT Table4 to Table4(IV) and the methodology is discussed in **Section 6**. The UK also reported CO₂ of biogenic origin from fuel use or incineration against the various sectors in which they are combusted as 'memo items' the total of which is presented in CRT Table10s1, but these values are not included in the national total.

1.7.4.4 Ozone Depleting Substances (ODS) regulated under the Montreal Protocol

These substances are explicitly excluded from requirements to report under UNFCCC³⁷:

- "The UNFCCC agreed that all Parties shall develop national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol..."; and,
- Where the Montreal Protocol is a UN agreement for the control of ODS.

Many ODS are additionally potent greenhouse gases, for which we estimate peak emissions in the 90s to be over 20Mt CO₂e. Almost all emissive uses of ODS have been discontinued, many using HFCs as a substitute (also potent greenhouse gases, but with zero ozone depleting potential).

ODS emissions are not reported in the UK Greenhouse Gas inventory, but some ODS use is modelled as part of understanding emissions of ODS-substitutes.

1.7.4.5 Other Substances with Non-Zero GWPs

These substances are not included in the products required to be reported under UNFCCC or otherwise. Most of these products are believed to be only used in small quantities, have modest GWPs, or both. For example, key substitutes for high GWP HFCs include hydrofluoroolefins and hydrocarbons, which typically have GWPs two orders of magnitude smaller than the HFC being replaced. It is estimated that in recent years total emissions from these pollutants exceed 0.1 Mt CO₂e.

Emissions of these products are not reported in the UK Greenhouse Gas inventory, but some use is modelled by the Inventory Agency as part of understanding emissions of products they are used to substitute.

1.7.4.6 Water Vapour

Water vapour is abundant in the atmosphere, significantly contributes to the Earth's Greenhouse effect, and there are anthropogenic sources of water vapour (e.g. from the combustion of most fossil fuels). However, it is believed that atmospheric concentrations of water vapour are primarily driven by temperature (warmer air can maintain higher humidity, and warmer water evaporates at a greater rate)³⁸, and anthropogenic emissions do not

³⁷ <https://unfccc.int/process-and-meetings/transparency-and-reporting/methods-for-climate-change-transparency/methodological-issues-relating-to-fluorinated-gases>

³⁸ https://www.nasa.gov/topics/earth/features/vapor_warming.html

contribute significantly³⁹. Because of this, water vapour is key to understand for climate modelling, including how water vapour can contribute to a warming feedback loop, but not important for estimating anthropogenic emissions in greenhouse gas inventories. Therefore, no estimate is made or reported for water vapour emissions in the UK GHGI.

1.7.4.7 Precursor Gases

In addition to the direct GHGs, scientists also consider the effects of precursor gases on atmospheric concentrations of greenhouse gases. Although they are not included in GWP weighted greenhouse gas emissions totals, these GHG precursors affect the overall radiative balance of the atmosphere. There are four precursor gases which must be reported under the UNFCCC, and estimates of their emissions are reported in across the CRT tables, and the NID against the various sources where these pollutants arise. They are:

- Nitrogen oxides (NO_x)
- Carbon monoxide (CO)
- Non-Methane Volatile Organic Compounds (NMVOC)
- Sulphur oxides (reported as SO₂).

In addition to this Ammonia (NH₃) is reported at the sector level. The indirect contribution to atmospheric N₂O due to NH₃ emissions is only included in the national total for the agriculture and LULUCF sectors (the main sources of NH₃ emissions), but not included for NH₃ emissions occurring from Energy, IPPU and Waste sources.

The effects of these gases on radiative forcing are complex. CO, NO_x and NMVOC control in part the abundance of ozone (O₃) and the oxidising capacity of part of the upper atmosphere called the troposphere. These pollutants contribute to climate forcing through their influence on atmospheric chemistry; for example, through the formation of tropospheric O₃ or changing the lifetime of CH₄. The emissions of NO_x and CO are dominated by human activities⁴⁰. Sulphate aerosols, formed from releases of SO₂ which because of their small size are effective scatterers of sunlight and have relatively long lifetimes compared to other aerosols, are responsible for radiative forcing. Volcanic eruptions that inject substantial amounts of SO₂ gas into the stratosphere are the dominant natural cause of externally forced climate change on annual and multi-decadal time scales⁴¹.

A reduction in SO₂ emissions leads to more warming. NO_x emission control has both a cooling (through reducing of tropospheric ozone) and a warming effect (due to its impact on methane lifetime and aerosol production)⁴¹.

1.7.4.8 Other Climate Forcing Pollutants

Particulate matter also plays a part in radiative forcing. The colour or reflectivity of the particles is important and the effects on forcing are complicated. Air pollution control measures to limit the levels of particulate matter emitted in turn will affect the emissions and atmospheric

³⁹ IPCC FAQs, Q1-2-3 at <https://www.ipcc-nggip.iges.or.jp/faq/faq.html>.

⁴⁰ <https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-04.pdf> "Atmospheric Chemistry and Greenhouse Gases" Executive Summary

⁴¹ https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf. Chapter 8 Anthropogenic and Natural Radiative Forcing. Section 8.4.2 Volcanic Radiative Forcing. FAQ 8.2 | Do Improvements in Air Quality Have an Effect on Climate Change?

concentrations of several pollutants, including: NO_x, NMVOCs, ammonia, black carbon, organic carbon, and SO₂. In some cases, this can result in both heating and cooling effects.

Aerosol cooling occurs through aerosol–radiation, and aerosol–cloud interactions. On the other hand, black carbon (BC) or soot, absorbs heat in the atmosphere leading to radiative forcing. When BC is deposited on snow, it reduces its or ability to reflect sunlight. Reductions of BC emissions can therefore have a cooling effect, but the additional interaction of black carbon with clouds is uncertain and could lead to some counteracting warming.

Some couplings between the air quality pollutant emissions and climate are still poorly understood or identified, including the effects of air pollutants on precipitation patterns, making it difficult to fully quantify these consequences⁴¹.

Particulate emission and black carbon are not included in the GHGI but are reported in the UK submissions under the Convention on Long-range Transboundary Air Pollution (CLRTAP).

The IPCC is currently developing guidance for estimating emissions of Short-Lived Climate Forces⁴² (SLCFs), which includes all of the substances discussed in this section.

1.7.4.9 Carbon fluxes from underwater terrain

Currently, carbon dioxide fluxes (i.e. sequestration or emissions) from sea, lake and river beds (also referred to as ‘blue carbon’) are not included in the UK national atmospheric emissions inventory. This is primarily driven by the omission of a methodology for estimating these in the IPCC guidelines (the methodological guidance for national inventory reports adopted by the UNFCCC), where the omission of the methodology means that national inventories are not required to generate an estimate. Countries would have to go out of their way to develop the evidence based upon which to make an estimate if they wanted to include it.

The UK can and does estimate emissions and sinks from sources not included in the IPCC guidelines where suitable data and methodologies are identified, and in some cases commissions research to develop those data and methodologies. In this case, our understanding is that doing so for underwater terrain would be complicated by:

- a) the high uncertainty in estimates for CO₂ fluxes (e.g. the chemistry is fundamentally different to above water fluxes, as water absorbs atmospheric CO₂, so the location in the water column would impact the quantity eventually released to the atmosphere, but it would also indirectly impact the atmospheric CO₂ which can be absorbed by water);
- b) the challenge in understanding what proportion of these fluxes are anthropogenic (we consider all on land fluxes in the UK to be anthropogenic as the entirety of the UK is populated, but this is less clear for underwater terrain);
- c) the question of territorial boundaries, noting that UK fishing vessels operate outside UK waters, and non-UK fishing vessels operate within UK waters; and,
- d) the reporting systems for inventory reporting do not provide a framework for reporting such fluxes (it would most naturally fit with Land Use, Land Use Change and Forestry, but there are no reporting categories for non-land).

Some of these are less of an issue for coastal wetlands, and therefore inclusion of these is more likely than other underwater terrain fluxes.

⁴² <https://www.ipcc.ch/report/methodology-report-on-short-lived-climate-forcers/>

1.8 METRICS

The direct greenhouse gases have different effectiveness in radiative forcing. The GWP is a means of providing a simple measure of the relative radiative effects of the emissions of the various gases. The index is defined as the cumulative radiative forcing between the present and a future time horizon caused by a unit mass of gas emitted now, expressed relative to that of CO₂. It is necessary to define a time horizon because the gases have different lifetimes in the atmosphere. **Table 1.10** shows GWPs defined on a 100-year horizon without climate-carbon feedback, according to the Fifth Assessment Report (IPCC, 2013). These are the GWP values that are required for reporting under the Paris Agreement and the UNFCCC from 2024. By weighting the emission of a gas with its GWP it is possible to estimate the total contribution to global warming of UK greenhouse gas emissions.

Table 1.10 GWP of Greenhouse Gases on a 100-Year Horizon used in the UK NID

Gas		GWP
Carbon dioxide	CO ₂	1
Methane	CH ₄	28
Nitrous oxide	N ₂ O	265
Sulphur hexafluoride	SF ₆	23,500
Nitrogen trifluoride	NF ₃	16,100
Hydrofluorocarbons		
HFC-23	CHF ₃	12,400
HFC-32	CH ₂ F ₂	677
HFC-41	CH ₃ F	116
HFC-43-10mee	CF ₃ CHFCHFCF ₂ CF ₃	1,650
HFC-125	C ₂ HF ₅	3,170
HFC-134	C ₂ H ₂ F ₄	1,120
HFC-134a	C ₂ H ₂ F ₄	1,300
HFC-143	C ₂ H ₃ F ₃	328
HFC-143a	C ₂ H ₃ F ₃	4,800
HFC-152	CH ₂ FCH ₂ F	16
HFC-152a	C ₂ H ₄ F ₂	138
HFC-161	CH ₃ CH ₂ F	4
HFC-227ea	C ₃ HF ₇	3,350
HFC-236cb	CH ₂ FCF ₂ CF ₃	1,210
HFC-236ea	CHF ₂ CHFCF ₃	1,330
HFC-236fa	C ₃ H ₂ F ₆	8,060
HFC-245ca	C ₃ H ₃ F ₅	716
HFC-245fa	CHF ₂ CH ₂ CF ₃	858
HFC-365mfc	CH ₃ CF ₂ CH ₂ CF ₃	804
Perfluorocarbons		
Perfluoromethane	PFC-14 - CF ₄	6,630
Perfluoroethane	PFC-116 - C ₂ F ₆	11,100
Perfluoropropane	PFC-218 - C ₃ F ₈	8,900
Perfluorobutane	PFC-3-1-10 - C ₄ F ₁₀	9,200
Perfluorocyclobutane	PFC-318 - c-C ₄ F ₈	9,540
Perfluoropentane	PFC-4-1-12 - C ₅ F ₁₂	8,550
Perfluorohexane	PFC-5-1-14 - C ₆ F ₁₄	7,910

Gas		GWP
Perfluorodecalin	PFC-9-1-18b - C ₁₀ F ₁₈	>7,190
Perfluorocyclopropane	c-C ₃ F ₆	>9,200

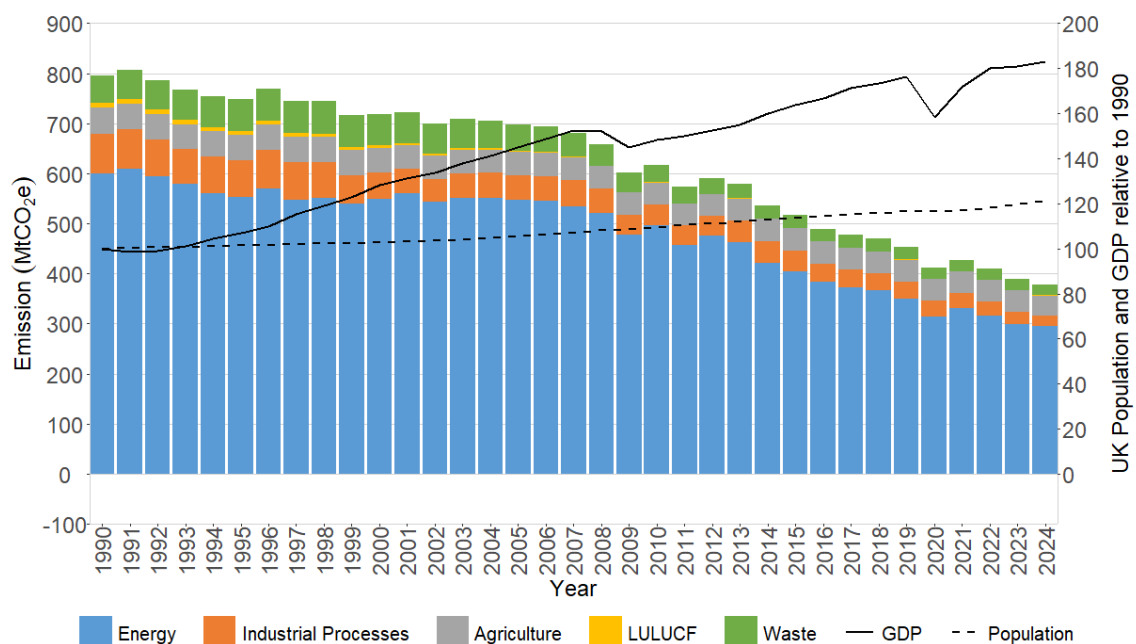
1.9 SUMMARY OF FLEXIBILITY APPLIED

In accordance with Article 13, paragraph 2 of the Paris Agreement, developing country parties are able to apply for flexibilities with regards to their emissions reporting. As the UK is an Annex I party under the UNFCCC, it is not eligible for flexibilities. Therefore, no flexibilities have been applied in this submission.

2 Trends in Greenhouse Gas Emissions

2.1 DESCRIPTION OF EMISSION AND REMOVAL TRENDS FOR AGGREGATED GHG EMISSIONS AND REMOVALS

Figure 2.1 Total GWP weighted emissions by sector⁴³



¹ [Population](#) and [GDP](#) figures from ONS

Figure 2.2 Trends in emissions by sector relative to 1990

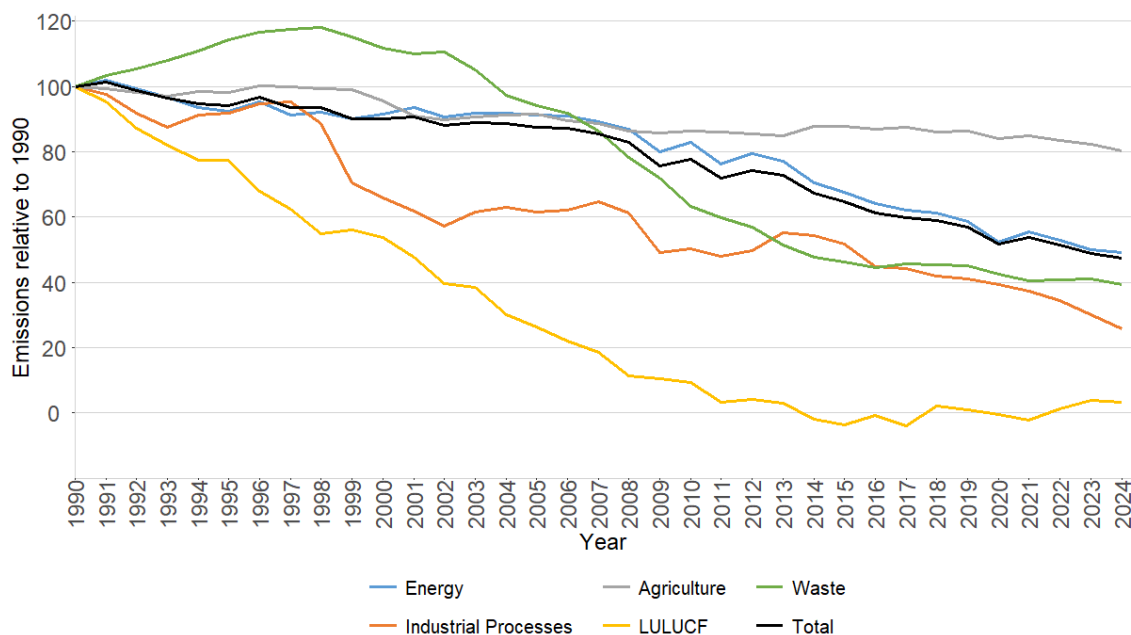
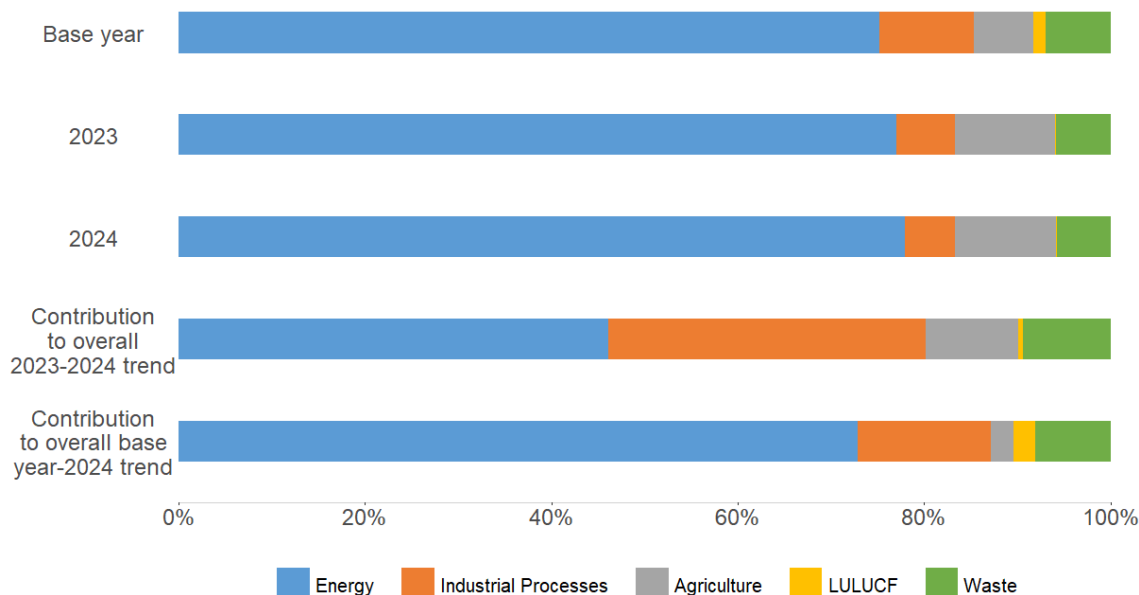


Figure 2.3 Contribution to National totals in the selected years and to overall trends between selected years by sector⁴⁴



As shown in **Figure 2.1** and **Figure 2.2**, total emissions of direct GHGs have decreased since 1990. **Figure 2.3** illustrates that this decline is driven predominantly by a decrease in

⁴⁴ 'Base year' refers to 1990 for CO₂, CH₄ and N₂O, or 1995 for F-gases. F-gases are fluorine containing compounds which are potent greenhouse gases, including: Sulphur Hexafluoride (SF₆), Nitrogen Trifluoride (NF₃), Perfluorocarbons (PFCs) and Hydrofluorocarbons (HFCs).

emissions from the energy sector – particularly from power stations. Total emissions are dominated by the energy sector across the time series. Emissions from all sectors have declined since 1990, with the largest decline in percentage terms from LULUCF.

Unless otherwise indicated, percentages that are quoted relate to net emissions (i.e. accounting for carbon sinks). The geographical coverage of the inventory is the UK and the Crown Dependencies and Overseas Territories to whom the UK's ratification of the UNFCCC has been extended.

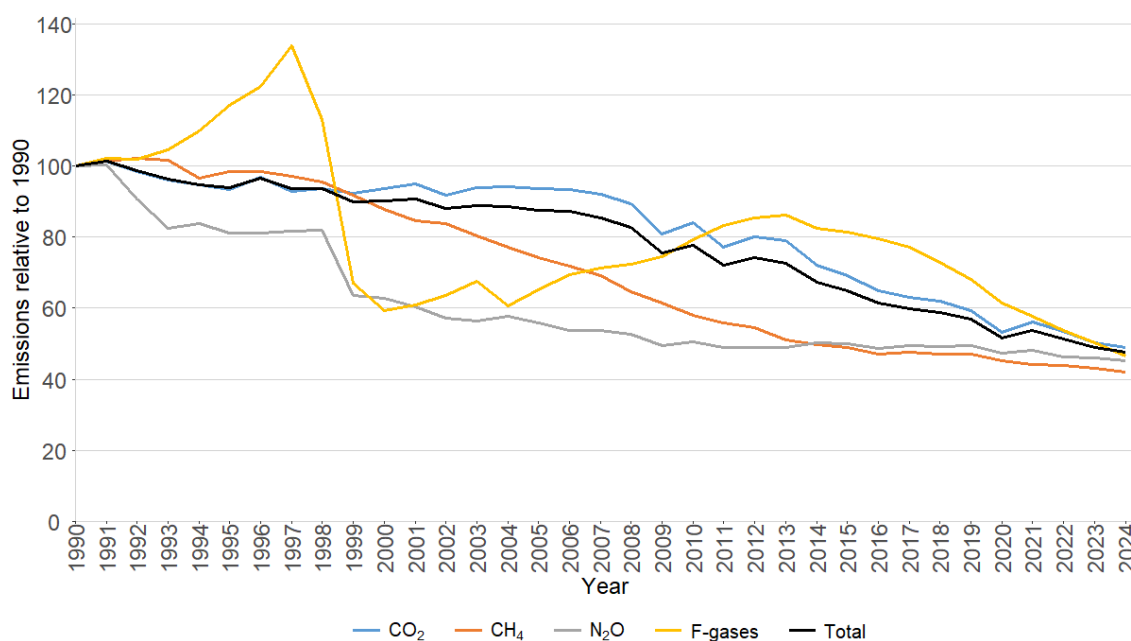
The percentage changes presented in this chapter are calculated from original emission estimates within the inventory database. They may, therefore, differ slightly from those that could be calculated from rounded figures in this report.

2.2 DESCRIPTION OF EMISSION AND REMOVAL TRENDS BY SECTOR AND BY GAS

2.2.1 Emission Trends for Direct Greenhouse Gases

A summary of the contribution of each GHG to the emission trends is provided below. The subsequent sections of this chapter provide an interpretation of emission trends, primarily focusing on the trends by source sector.

Figure 2.4 Trends in emissions by gas relative to 1990⁴⁵



⁴⁵ F-gases are fluorine containing compounds which are potent greenhouse gases, including: Sulphur Hexafluoride (SF₆), Nitrogen Trifluoride (NF₃), Perfluorocarbons (PFCs) and Hydrofluorocarbons (HFCs).

Figure 2.5 Contribution to National totals in the selected years and to overall trends between selected years by gas

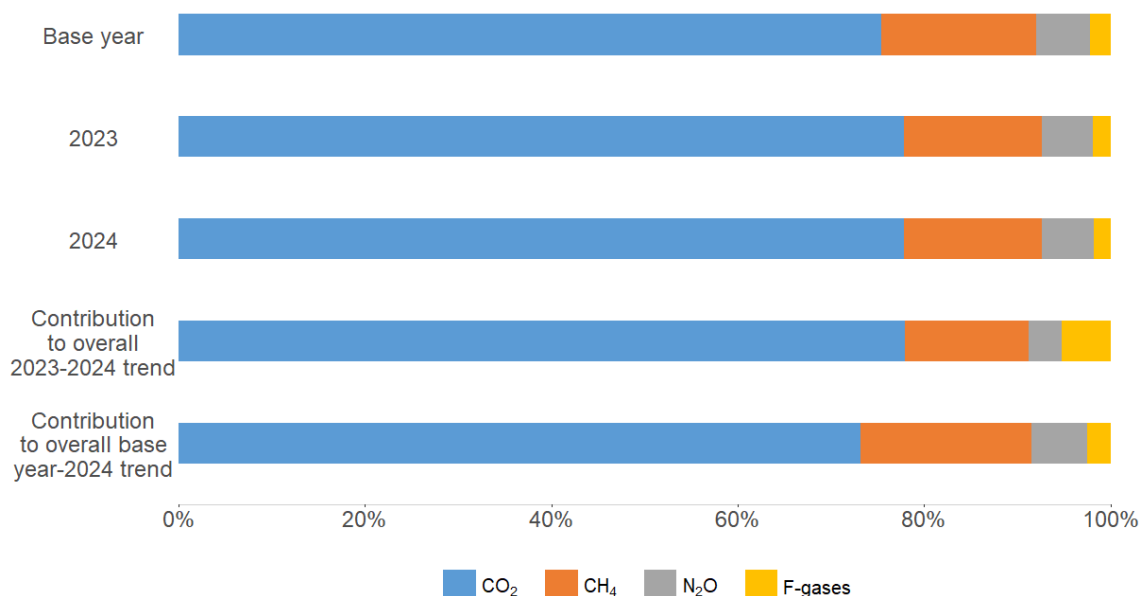


Figure 2.5 presents the contribution of each GHG to the UK emissions trend:

- Emissions of CO₂ are by far the largest component of total GHG emissions, of which the largest sources over the period since 1990 are power generation and road transport. Emissions have reduced across the time series due to fuel switching, structural change, and improvements in end-use efficiency. The strong link between power generation, heating buildings and CO₂ emissions means that short term trends can be dominated by UK temperatures. In cold years like 1996 and 2010 there was an increase in demand for electricity and gas for heating and in warm years like 2011 and 2014 there was a decrease.
- The second most important source of greenhouse gases is **methane (CH₄)**. Annual emissions of CH₄ have reduced by over half since 1990. The main sources of CH₄ since 1990 are agriculture, waste disposal, leakage from the gas distribution system and coal mining. Reductions in CH₄ emissions in the UK are driven by the increased utilisation of methane from landfills, a large decline in UK coal mining, investment in improvements to the natural gas supply infrastructure to reduce leakage and a reduction in livestock numbers.
- Emissions of **nitrous oxide (N₂O)** have also reduced by over half since 1990. Most N₂O emissions are generated from the agriculture sector. Agriculture sector N₂O emissions have decreased primarily due to reduced emissions from synthetic fertiliser application. N₂O is also released during the production of nitric and adipic acid, a significant source in 1990 contributing to nearly half of all N₂O emissions. Due to a decline in production together with the installation of abatement equipment, the Industrial Processes and Other Product Use (IPPU) sector now only contribute around 4% of N₂O emissions.
- Emissions of **F-gases**: HFCs, PFCs, NF₃ and SF₆, have also reduced by over half since 1990. All F-gas emissions are accounted for under the IPPU sector. F-gas emissions peaked in 1997 and have fallen since then, due mainly to the fall in F-gas manufacture in the UK and the installation of abatement equipment at two of the three UK manufacturers. These emission reductions have been to some extent offset by the

increases in the use of HFCs as substitutes for ozone depleting substances, particularly in refrigeration and air conditioning. Although this has also been decreasing in recent years.

2.2.2 Energy

2.2.2.1 Overview

Figure 2.6 Total GWP weighted emissions in the energy sector compared to primary energy demand

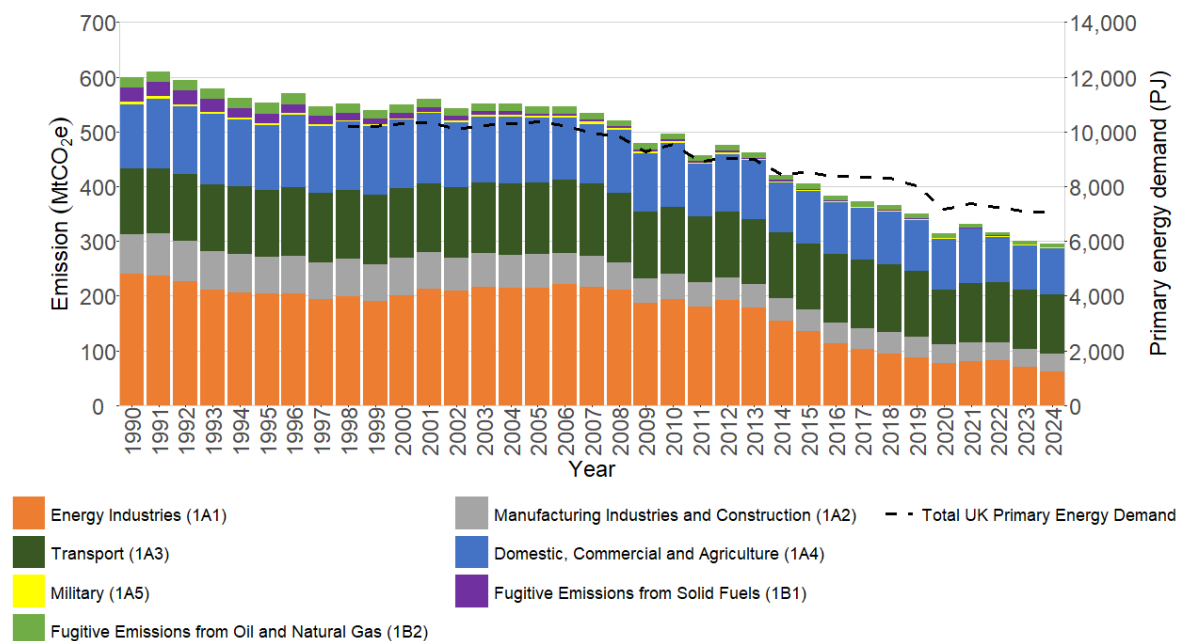


Figure 2.7 Trends in Energy emissions by sub-sector relative to 1990

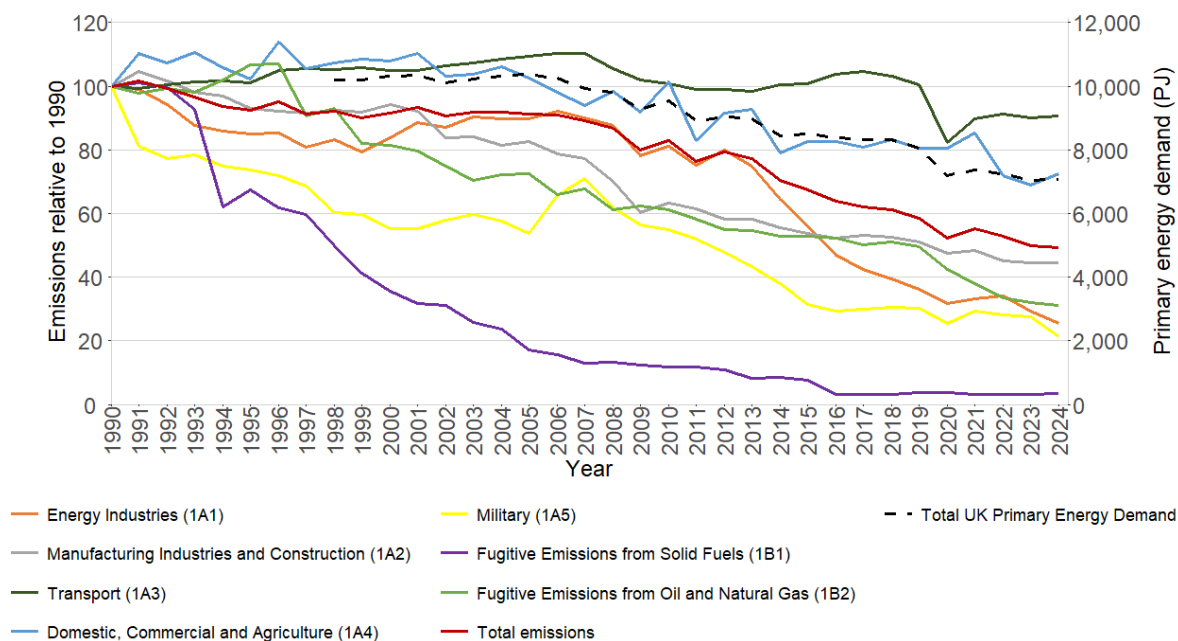
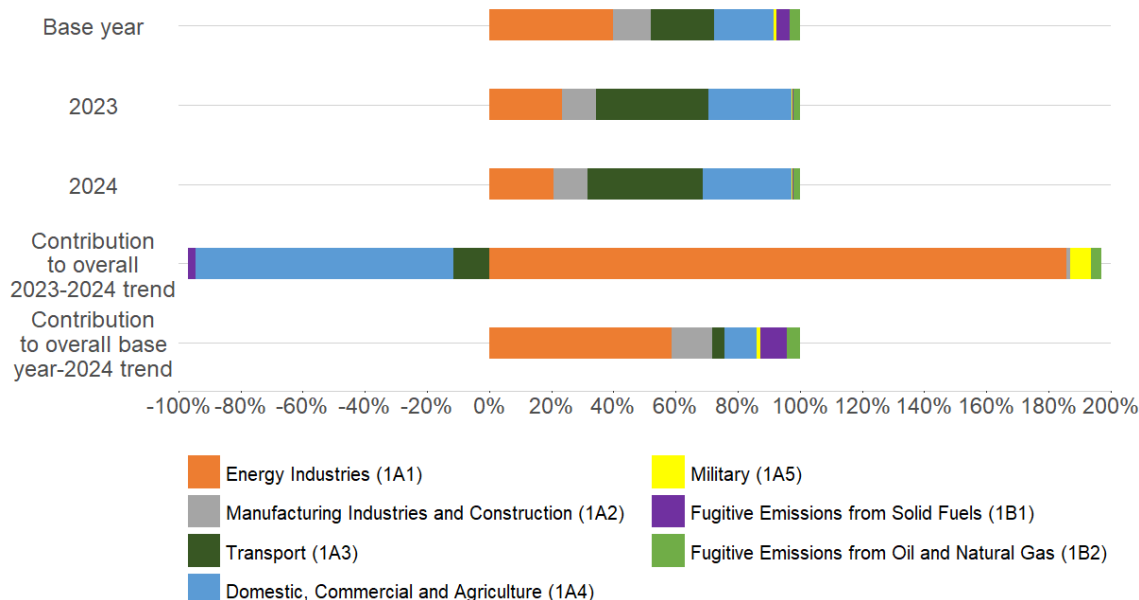
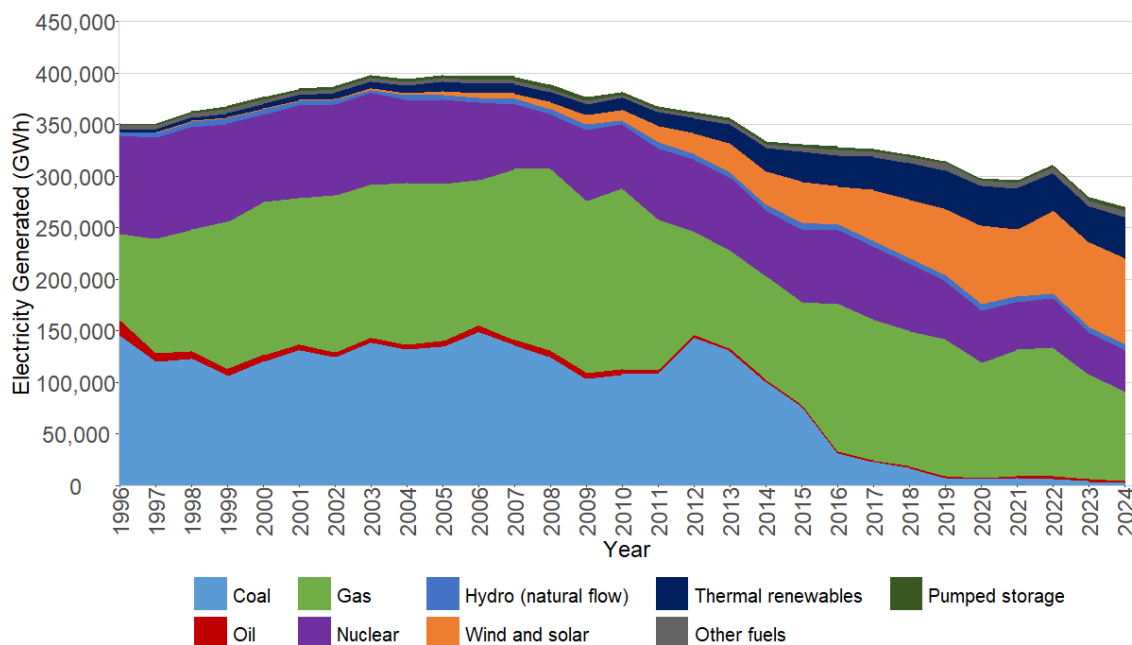


Figure 2.8 Contribution to totals in the selected years and to overall sectoral trends between selected years by sub-sector for Energy



The energy sector GHG emissions are primarily CO₂ from fossil fuel combustion in power generation, transport, manufacturing and construction, and other stationary and mobile fuel combustion. The supply of fossil fuels also leads to significant emissions of CH₄ from fugitive emission sources, such as from coal mining, oil and gas extraction and from the natural gas transmission and distribution system.

Figure 2.7 shows that energy sector emissions have declined since 1990. Emission reductions are due primarily to improvements in energy efficiency, and economy-wide fuel-switching from carbon-intensive fossil fuels such as coal, to greater proportional use of natural gas, nuclear power, and renewables. There have also been large reductions in fugitive CH₄ emissions due to a large decline in coal mining, with the last large UK deep mine closing in 2015, and the reduction in leakage from the natural gas distribution network through a UK-wide programme of infrastructure improvements.

2.2.2.2 Emission trends in Energy sub-sectors**2.2.2.2.1 Electricity generation****Figure 2.9 Fuel mix of electricity generation⁴⁶**

There are several reasons for the decline in emissions from the power generation sector since 1990, including:

- The UK power sector fuel mix has shifted towards use of Combined Cycle Gas Turbine (CCGT) stations rather than conventional steam stations burning coal or oil. CCGT stations operate at a higher thermal efficiency, for example in 2018 they operated on average at 48.9% efficiency, whilst coal-fired stations operated on average at 34.1% efficiency;
- The shift in fuel mix away from more carbon-intensive fuels such as coal and oils, to less carbon-intensive fuels such as natural gas; the calorific value of natural gas per unit mass carbon is higher than that of coal and oil;
- There has been an increase in electricity generated from non-fossil fuel energy sources, due to increased use of wastes and renewable energy sources.

2.2.2.2.2 Manufacturing Industries and Construction

Since 1990, emissions from Manufacturing Industries and Construction fuel combustion have declined, with lower fuel use and emissions reported across all sub-sectors including: iron and steel, non-ferrous metals, chemicals, food and drink, paper and pulp, minerals and from mobile machinery. This reflects the general decline in UK manufacturing output (e.g. of steel, aluminium) as well as a shift away from carbon-intensive fuels such as coal and oils to greater use of natural gas, as well as waste-derived and renewable fuels.

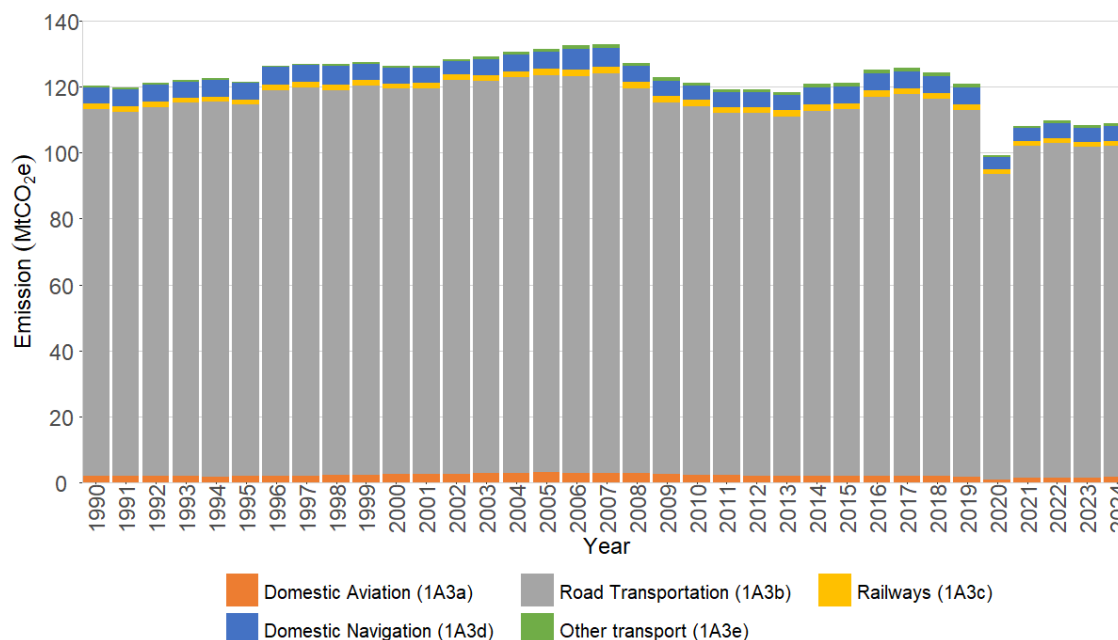
Reductions in emissions from unclassified industrial combustion also made a large contribution to the overall trend in emissions from the Manufacturing Industries and Construction sector. Emissions have declined by over 50% since 1990. This is largely a result

⁴⁶ From DUKES table 5.6 (DESNZ, 2025a)

of reduced consumption of gas oil, fuel oil, coal, and natural gas, partly offset by increases in burning oil, LPG and waste within the sector.

2.2.2.2.3 Transport

Figure 2.10 Transport emissions by sub-sector



Emissions from the Transport sector are dominated by road transport, which peaked in 2007, but have declined since 2007, and by 2019 were just below 1990 levels. Emissions increased in 2021 after a large decrease in 2020 due to the COVID-19 pandemic and have since remained relatively stable. This trend prior to 2020 was driven by a number of factors, including:

- Increases in vehicle kilometres in most years, except for a few years after 2007;
- Improvements in the fuel efficiency of engines in the UK fleet;
- Increases in the typical weight of passenger cars, increasing the energy needed to propel them;
- Increase in energy requirement for additional applications, like air conditioning;
- Fuel switching from petrol to diesel, improving fuel efficiency, but in some cases resulting in higher N₂O emissions due to NO_x abatement technology;
- Increasing sizes of heavy goods vehicles; and,
- The increasing displacement of fossil fuels by biofuels across the time series, since 2002, as CO₂ emissions from the consumption of biofuels are not included in the UK totals⁴⁷.

Emissions from domestic aviation increased between 1990 and 2005 but subsequently decreased to levels comparable to 1990 by 2019. This is because of a move to use more fuel-efficient aircraft in 2006 and a lower number of air miles being flown. There has been an increase in emissions from domestic aviation since 2021 after a large reduction in air travel in 2020 due to the COVID-19 pandemic.

⁴⁷ Carbon of biogenic origin are accounted for in the carbon stock calculations in the Land Use, Land-Use Change and Forestry Sector, see **Section 2.2.5**.

Shipping emissions in the UK peaked in 2006 and have decreased since then. The reductions are driven by lower shipping activity in several key sectors, notably the support vessels to the offshore oil and gas sector and oil tanker movements. Shipping emissions increased in 2021 and 2022 after a notable drop in 2020 due to the COVID-19 pandemic.

2.2.2.2.4 Domestic, Commercial and Agriculture

Emissions from domestic fuel combustion dominate emissions from the Domestic, Commercial and Agriculture sector. Emissions from this sector changed little between 1990 and 2010 but have declined more recently. The effect of annual temperatures can produce large inter-annual variations. Fuel consumption data since 1990 indicates a general trend in fuel switching in these sectors, away from more carbon-intensive fuels such as coal, coke, fuel oil and gas oil, towards natural gas. This shift has partly been driven by fuel prices but also through the growth of the UK gas supply network.

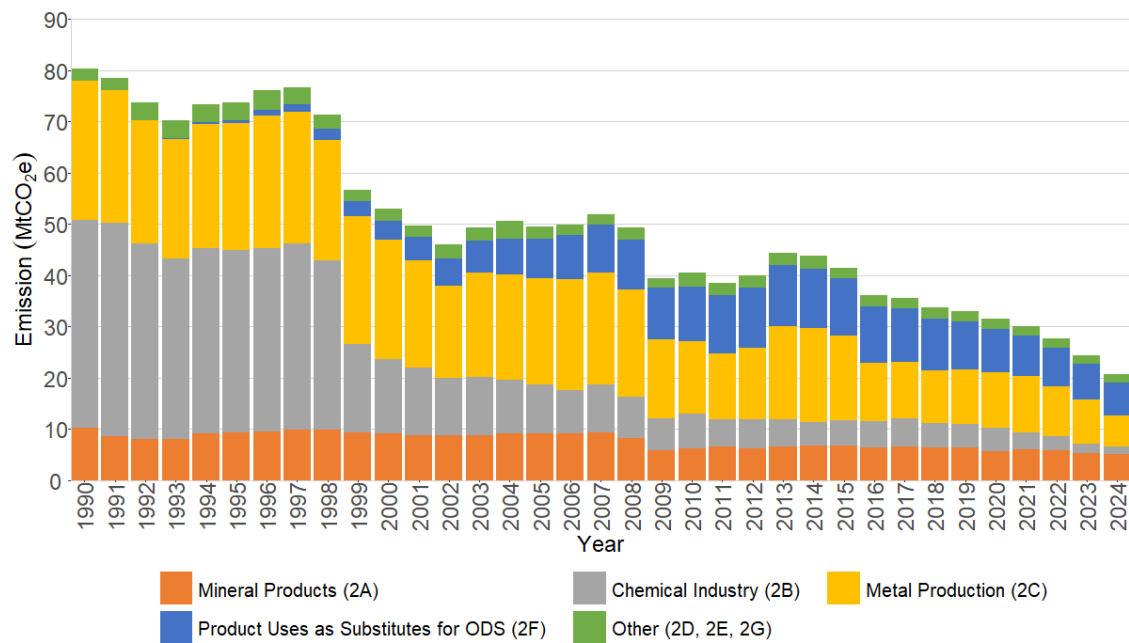
2.2.2.2.5 Fugitives (Energy exploration, production, and distribution)

Fugitive energy sector emissions mostly consist of methane released from coal mining, oil and gas extraction and natural gas distribution. In 1990, the majority of these emissions came from the production of solid fuels; however, these emissions have decreased significantly, due to the closure of UK deep coal mines. Another notable trend arises from the reductions in leakage of methane from the natural gas distribution network. Over the time series, the UK gas transporters have invested significantly in replenishment of the gas pipeline infrastructure, replacing leakier cast iron pipework with low-leakage plastic pipelines. The fugitive emissions from upstream oil and gas exploration and production have tracked UK production, declining since a peak in 2004.

2.2.3 Industrial Processes and Product Use

2.2.3.1 Overview

Figure 2.11 Total GWP weighted emissions in the Industrial Process and Product Use sector⁴⁸



⁴⁸ Other includes 2D – Non-energy Products from Fuels and Solvent Use, 2E – Electronics Industry, and 2G – Other Product Manufacture and Use.

Figure 2.12 Trends in emissions from Industrial Processes and Product Use by sub-sector, relative to 1990⁴⁹

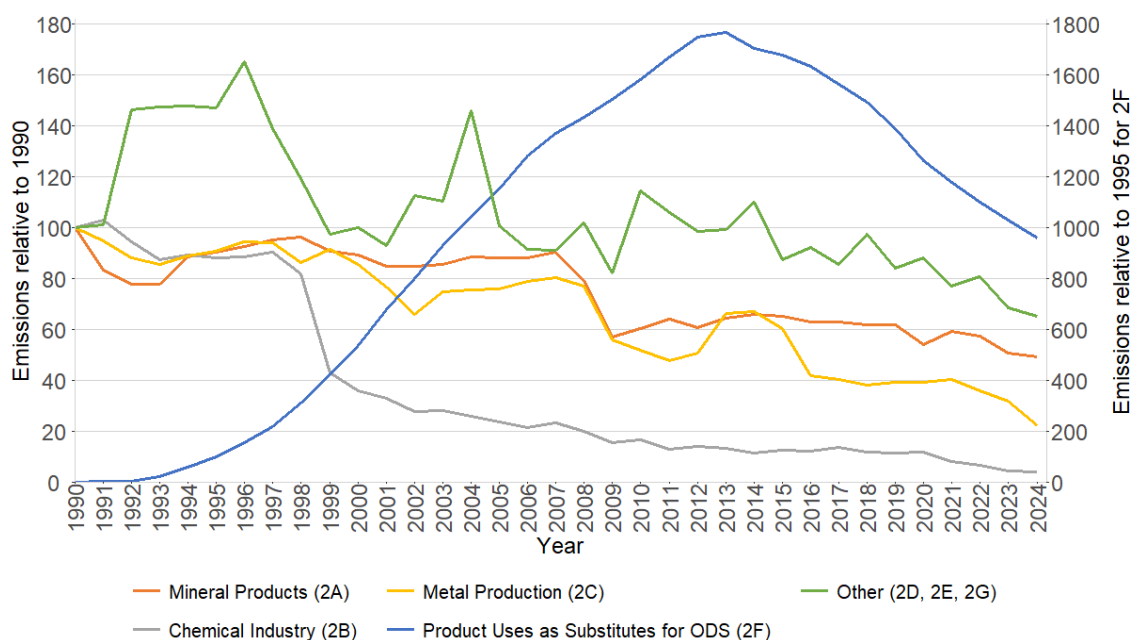
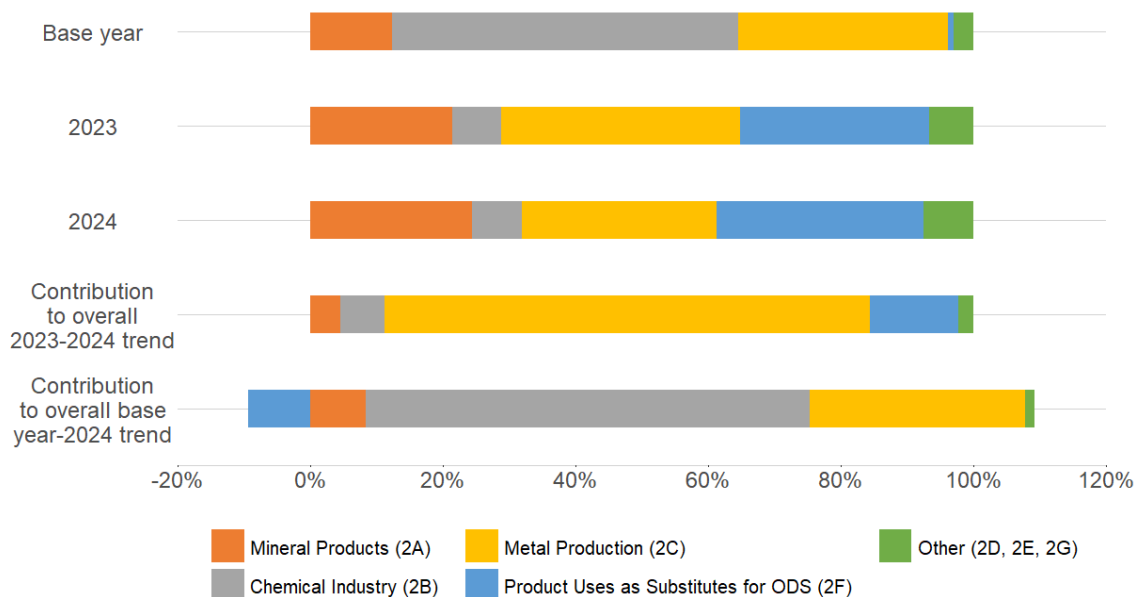


Figure 2.13 Contribution to totals in the selected years and to overall sectoral trends between selected years by sub-sector for Industrial Processes and Product Use



⁴⁹ Emissions from sector 2F are dominated by F-gas emissions, whose base year is 1995. See Section 2.2.2.2.1 for information on the driver of this trend.

The Industrial Processes and Product Use (IPPU) sector accounts for all GHG emissions from industrial sources other than fuel combustion which is allocated to the energy sector (1A2)⁵⁰, and emissions from product use including solvents. Around two thirds of IPPU emissions are now CO₂, although this only contributes to small proportion of total CO₂ emissions. All F-gas emissions are generated from IPPU sources, and there are small quantities of CH₄ and N₂O emissions.

The number of industrial process sites in the UK has been declining since 1990 (see **Figure 2.14 - Figure 2.16**). The declining trend in IPPU emissions in the UK (see **Figure 2.11**) is partly due to the closure of numerous UK installations, including several integrated steelworks, primary aluminium works, chemical production sites and cement kilns, as well as the installation of abatement equipment, for example at adipic and nitric acid plant and by F-gas manufacturers. The declining trend in emissions is also a reflection of decreasing production of many industrial materials in the UK, most notably in the chemicals and steel sectors. A large number of closures in the period 2007-2009 were due to decreased demand for many products as a result of the general economic situation in the UK and elsewhere, with falling demand for steel, cement, bricks, and aluminium, for example, leading to plant closures. The large step-change in chemical sector emissions in 1998-1999 was due to the fitting of N₂O abatement equipment at a major adipic acid manufacturing facility, which has subsequently closed.

2.2.3.2 Emission trends in IPPU sub-sectors

2.2.3.2.1 Refrigeration, Air-Conditioning and Heat Pumps (RACHP)

Until the early 1990s, Ozone Depleting Substances (ODS) were used as refrigerants for RACHP applications, but in response to the Montreal Protocol these products were phased out in the UK in favour of products with no ozone depleting potential. The main substitutes for ODS were hydrofluorocarbons (HFCs), which have similar properties, but are still potent greenhouse gases. As a result of this there is a steep increase in HFC use since the mid-90s, plateauing and subsequently decreasing in recent years as almost all ODS-based systems are thought to have been retired or retrofitted.

Since 2008 an increasing number of applications have been restricted from using higher GWP HFCs by EU regulation of F-gases⁵¹. EU regulation also became more stringent regarding the management of HFCs and HFC-using systems, and since 2015 a quota system was introduced, limiting the total HFC (on a GWP basis) allowed to be sold on the EU market. These regulations have since been carried through to UK law so still apply after the UK's exit from the EU. All of these actions are believed to have contributed to the plateaux in HFC emissions and subsequent downturn in recent years.

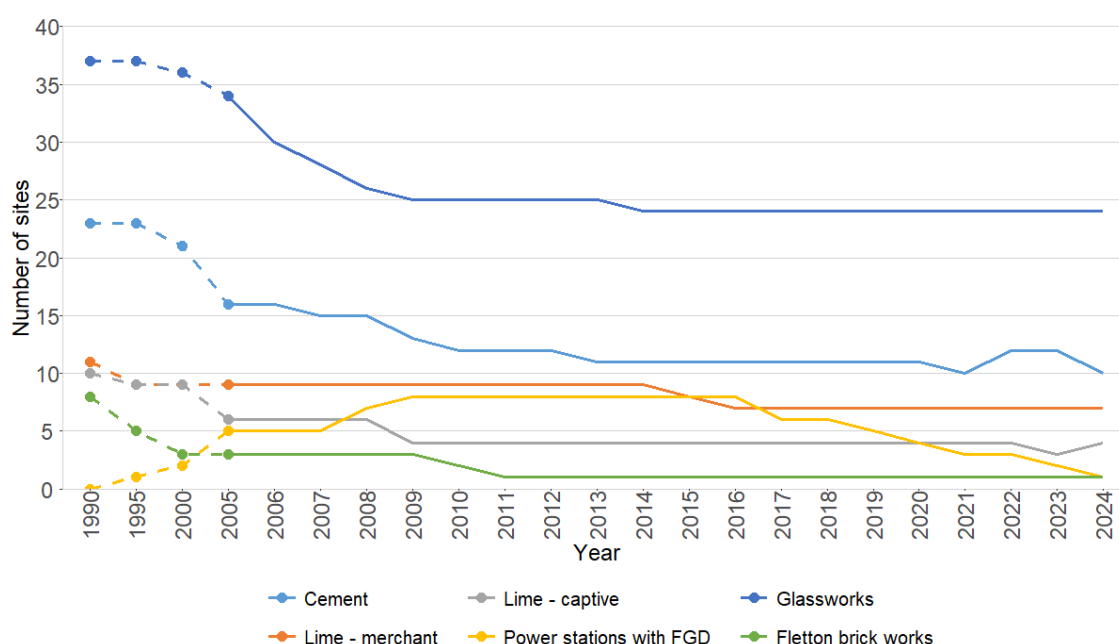
Further discussion of these trends, including how they compare to atmospheric measurements, and other European countries subject to HFC-quota systems can be found in **Section 4.29.4**.

⁵⁰ For more information, see: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_1_Ch1_Introduction.pdf

⁵¹ Which was transposed into UK law via the Withdrawal Agreement Bill (2019)

2.2.3.2 Mineral Industry

Figure 2.14 Trends in the number of mineral process sites⁵²



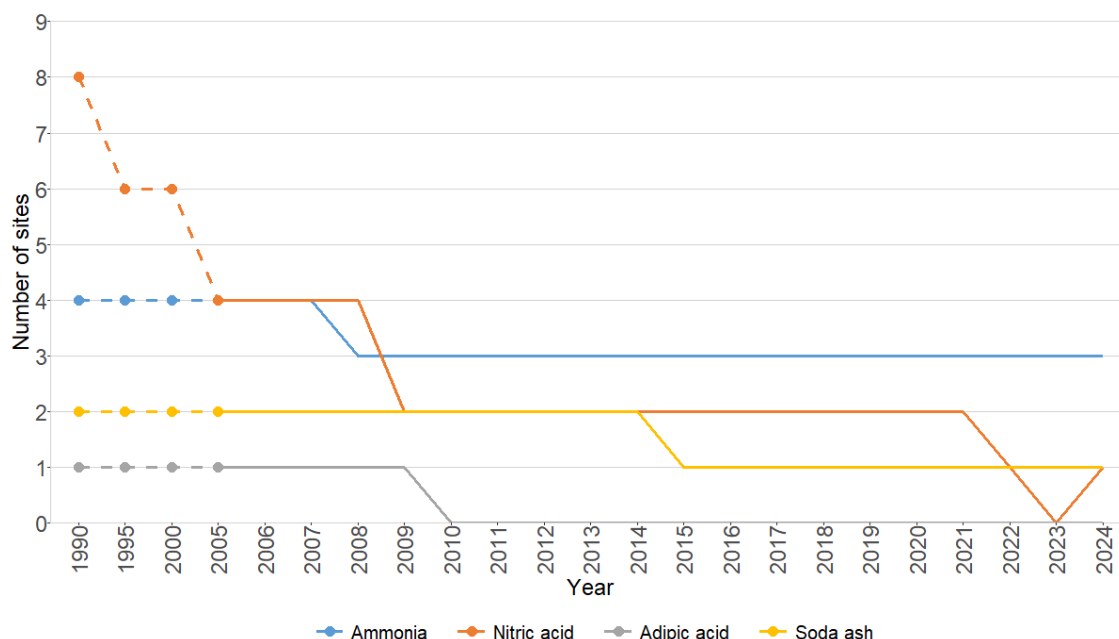
Annual CO₂ emissions from cement manufacture comprised 69% of total mineral sector CO₂ emissions in 2024 but have fallen by 52% since 1990 due to the closure of many kilns and decreasing UK clinker production. Emissions fell to what was then a low point of 3.7 MtCO₂ in 2009 due to the impact of the recession in 2008-2009, and then increased again and have stabilised in recent years at around 3.5 to 4.5 MtCO₂. Other mineral source categories do not have a significant impact on the UK GHG trends; lime production CO₂ emissions have reduced by around 26% since 1990, glass production emissions are down by around 27%; brick manufacturing emissions are down by 75%.

⁵² Merchant refers to sites selling lime and emitting CO₂, captive refers to sites using lime and CO₂ in-situ so in theory no emissions result.

FGD is an abbreviation of Flue Gas Desulphurisation

Excludes very small glassworks producing lead crystal glass, frits etc.

Some early site numbers are estimates

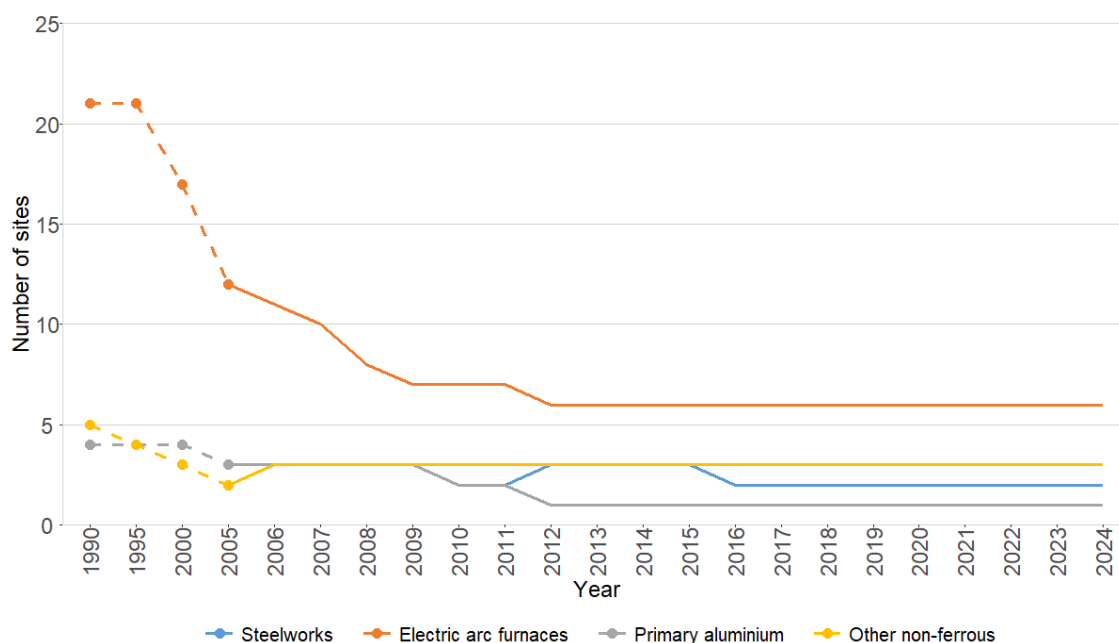
2.2.3.2.3 Chemical Industry**Figure 2.15 Trends in the number of chemical process sites**

Emissions from adipic acid manufacture were reduced significantly in 1999, over half of the total fall in chemical sector emissions in that year, due to the retrofitting of an emissions abatement system to the only adipic acid plant in the UK, which subsequently closed in April 2009.

By-product emissions from the manufacture of HFCs and HCFCs have decreased since 1990, due to plant closures and the installation of abatement equipment. Approximately half of the fall in chemical sector emissions in 1999 was due to the installation of a thermal oxidiser at the UK's only HCFC-22 plant in that year, with emissions in 2000 falling again due to a full year of operation with the new abatement technology. Due to the phase out of HCFC-22 for many applications, production and emissions at this site fell and after a closure and reopening in 2010 and 2013 respectively, the plant permanently closed in 2016, ending emissions from this process.

N₂O emissions from nitric acid manufacture show falls due to the closure of 4 plants between 2000 and 2008 and due to the installation of abatement technology in the larger of the remaining plants in 2011.

Aside from these specific examples of emissions abatement, there has also been an underlying shrinkage in the UK chemical production sector over the time series, with many chemical and petrochemical installations closing since the 1990s. For example, all UK manufacturing of methanol ceased in 2001, whilst the installations producing carbon black and ethylene oxide closed in 2009.

2.2.3.2.4 Metal Production**Figure 2.16 Trends in the number of metal process sites⁵³**

GHG emissions from across the UK metal production sector have fallen by around 78% since 1990, with every sector showing a marked reduction in production levels and emissions over the time series. The largest contributor to the UK trends is the closure of several large integrated steelworks and a decline in UK steel output, leading to Iron & Steel (I&S) sector IPPU CO₂ emissions down by 75% (across 2C1a-2C1d), which accounts for 91% of the total UK metal production sector CO₂ reductions since 1990. Emission trends in the sector in recent years reflect the volatility of UK steel production since the economic down-turn from 2008, including a 27% reduction in CO₂ emissions in 2008-2009 followed by several years of uncertainty regarding plant investments and possible closures; the sector increased production and emissions during 2013 to 2015 but the closure of the Redcar steelworks in 2015 and closures of coke ovens and lower production across UK sites led to a 31% decline in CO₂ emissions in 2015-2016. Total I&S IPPU emissions (2c1a-2C1d) were subsequently stable until 2022 and have since started decreasing.

The production of primary aluminium has also declined significantly across the time series, with CO₂ emissions down by 90% and only one smelter now remaining in operation in Lochaber, Scotland. In recent years a large step-down in emissions in 2011-2012 reflects the closure of the large Lynemouth smelter in March 2012, with sector emissions gradually decreasing since.

There are no other primary non-ferrous metal processes in the UK since the closure of a large zinc and lead smelter complex in 2003; this one site closure accounts for 7% of total metal sector IPPU CO₂ emission reductions in the UK since 1990. A number of secondary lead processes are in operation but these merely recover lead from batteries and clean scrap and there is no evidence of any process emissions of CO₂ from any of them.

⁵³'Other non-ferrous' includes primary production of non-ferrous metals other than aluminium, or large-scale secondary smelting of lead only

2.2.4 Agriculture

2.2.4.1 Overview

Figure 2.17 Total GWP weighted emissions in the Agriculture sector⁵⁴

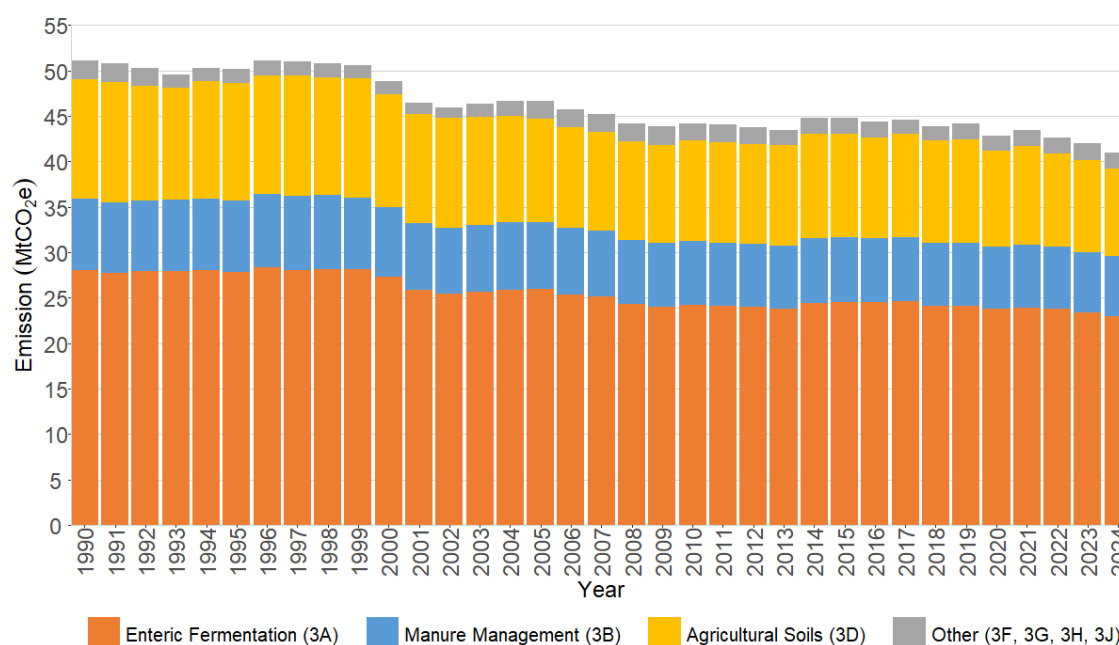
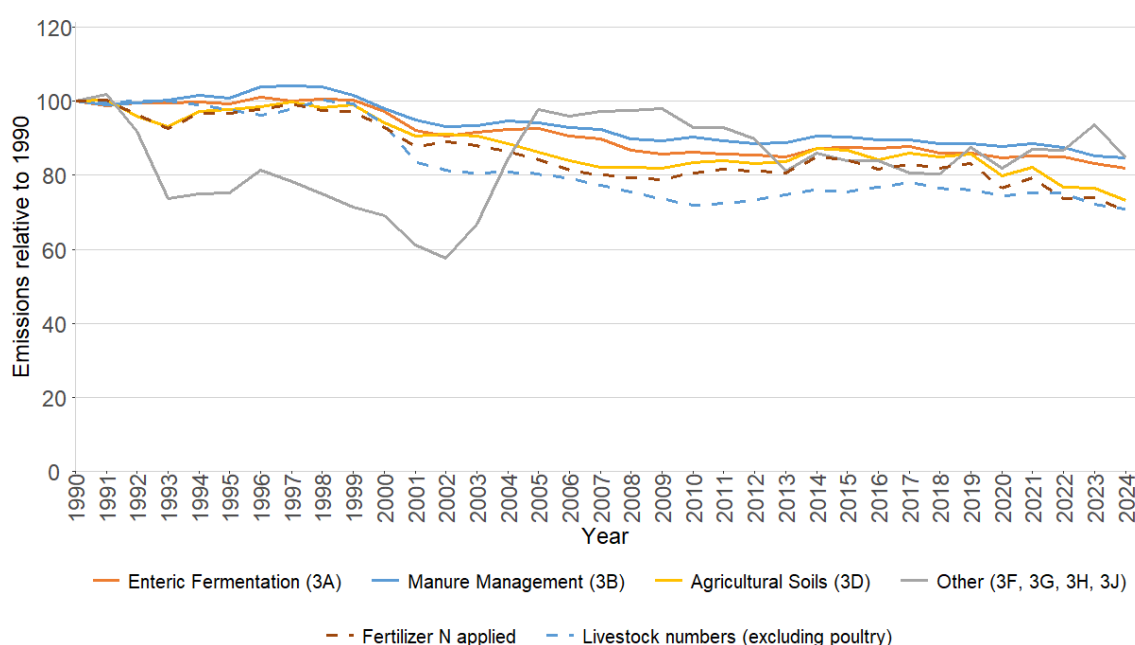
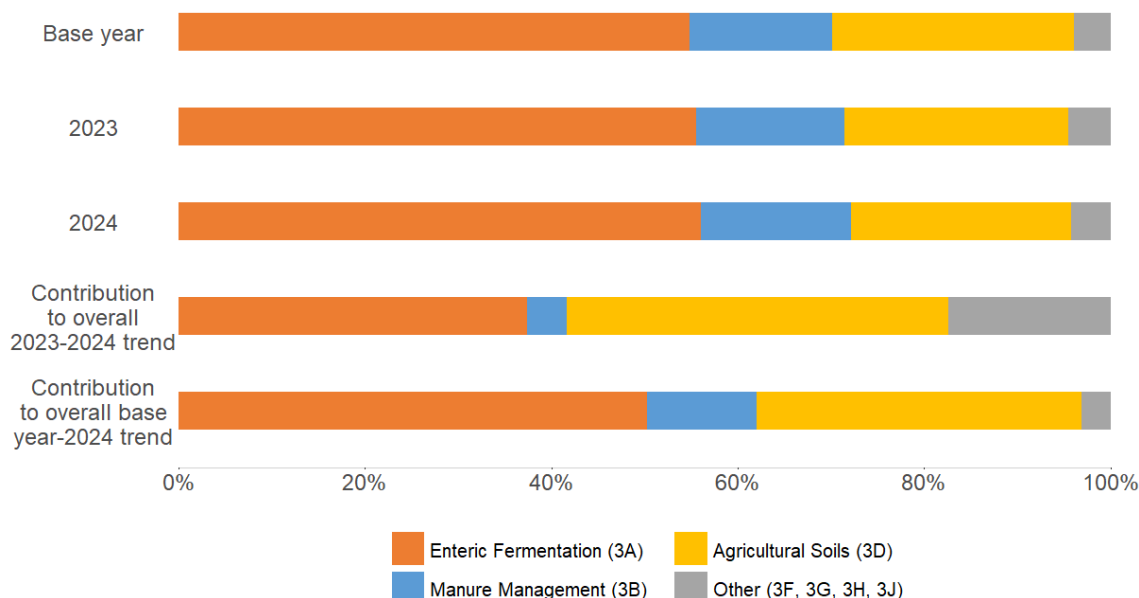


Figure 2.18 Trends in emissions from Agriculture by sub-sector, relative to 1990⁵⁴



⁵⁴ 'Other' refers to the following CRT sectors: Field Burning of Agricultural Wastes (3F), Liming (3G), Urea Application (3H), and Overseas Territory and Crown Dependency Agriculture Emissions (3J)

Figure 2.19 Contribution to totals in the selected years and to overall sectoral trends between selected years by sub-sector for Agriculture⁵⁴



In the UK, the Agriculture sector is dominated by CH₄ emissions from livestock generated through enteric fermentation (animal digestion processes) and N₂O emissions from manure management and fertiliser application. The emissions from this sector have shown an overall decrease since 1990, reflecting trends in livestock numbers and fertiliser application.

2.2.4.2 Emission trends in Agriculture sub-sectors

2.2.4.2.1 Livestock: Enteric fermentation and Manure Management

Emissions from livestock have declined over the time series primarily due to a decline in emissions from enteric fermentation (CH₄) (3A) and manure (N₂O) (3B) from cattle. This is, in turn, due to decreased cattle numbers.

2.2.4.2.2 Agricultural Soils

Annual emissions from fertiliser use (3H) have fluctuated across the time series but have overall increased since 1996. This is driven by an increase in synthetic fertiliser application, particularly to grasslands.

2.2.5 Land Use, Land-Use Change and Forestry

2.2.5.1 Overview

Figure 2.20 Total GWP weighted emissions in the LULUCF sector

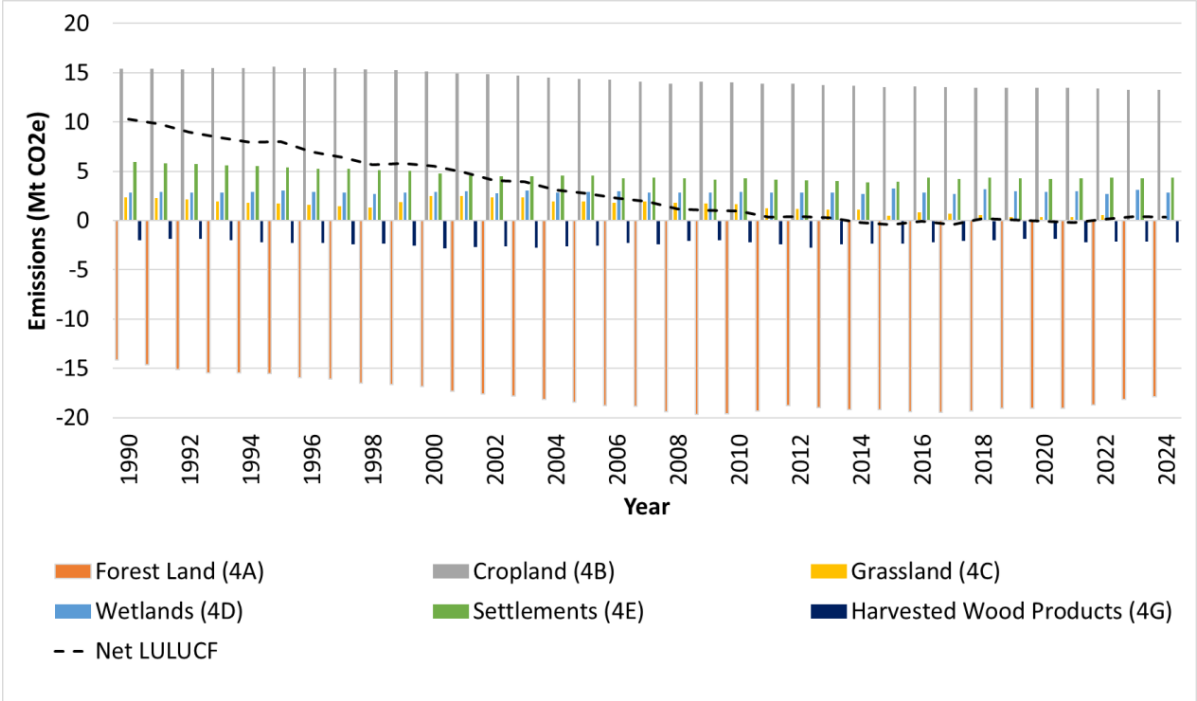
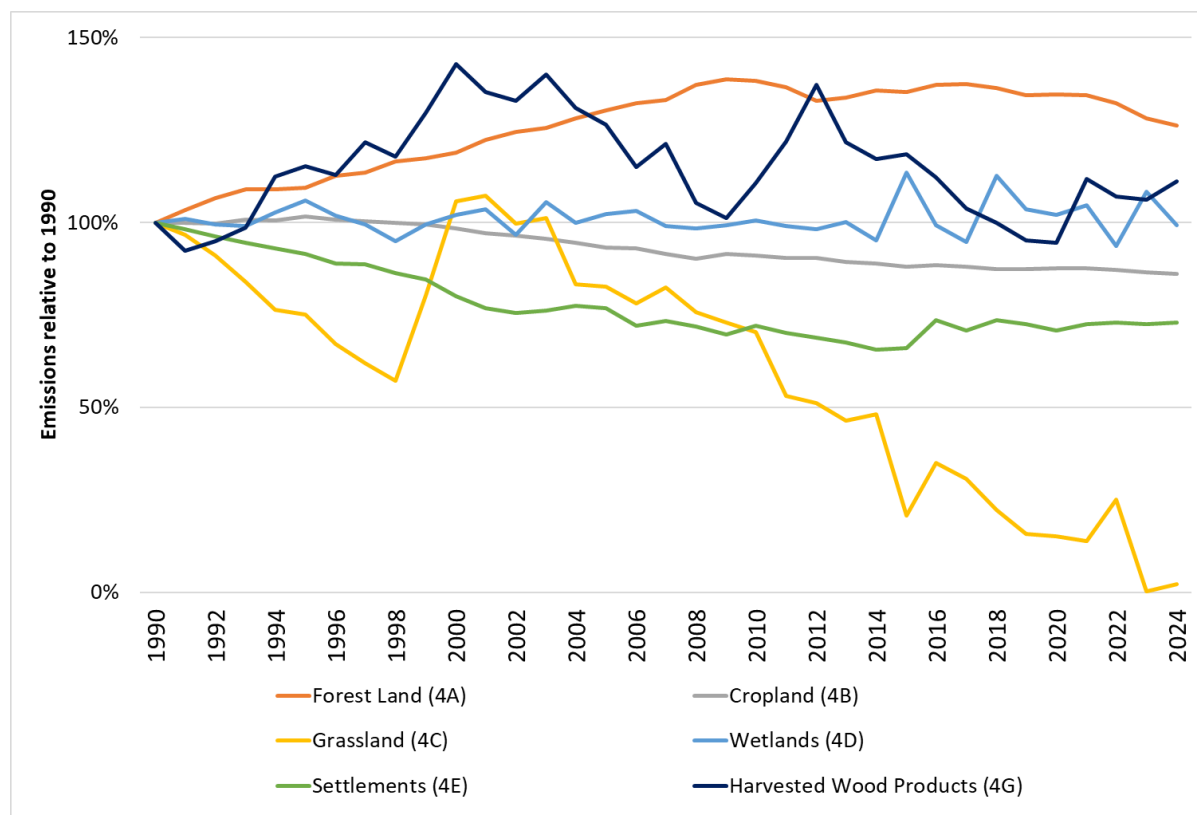


Figure 2.21 Trends in net emissions/removals from LULUCF by sub-sector, relative to 1990⁵⁵

The Land Use, Land-Use Change and Forestry (LULUCF) sector is the only sector which reports both emissions and removals. Removals are from carbon stock gains in above- and below-ground biomass, litter, deadwood, soils and harvested wood products, emissions are from carbon stock losses and GHG emissions from LULUCF activities. The sector was a net source until 2013, and has fluctuated between being a small net source and sink in subsequent years.

The LULUCF sector covers emissions and removals of direct GHGs under six categories, of which Forest Land and Harvested Wood Products are net sinks, and Cropland, Grassland, Wetlands, and Settlements are net sources (**Figure 2.20**). The UK does not report any emissions or removals from the Other Land category. Emissions from the LULUCF sector have shown an overall decrease since 1990, largely driven by an increase in the Forest Land net sink and a reduction in the Cropland, Grassland and Settlement net sources (Figure 2.21).

2.2.5.1.1 Forest land

The majority of Forest Land net removals are from the carbon sink in tree biomass and soils. The annual net removal from Forest land increased significantly by 39% between 1990 and 2009 but levelled off to around 35% above the 1990 level until 2022 and declining to 26% above 1990 levels in 2024. The variation in the net sink is driven by afforestation in earlier decades and the effect on the age structure of the present forest area, particularly conifer plantations. High levels of conifer afforestation between 1950 and 1990 resulted in increasing carbon stocks (and CO₂ removals) up to 2009 but these forests are now reaching harvesting age, with associated carbon losses and transfer to the Harvested Wood Products category. Harvested areas are replanted but these young trees have much lower rates of carbon

⁵⁵ Some of these are trends in the size of the net removals rather than net emissions.

sequestration than the mature trees they have replaced. As a result, there is a progressively decreasing carbon sink in tree biomass and litter, offset by an increasing carbon sink in soils. Afforestation rates have reduced substantially since 1990 but have started to increase again in recent years.

2.2.5.1.2 Cropland, grassland and settlements

Annual net emissions from Cropland have decreased by 14% since 1990 (net carbon emissions dominate). Net emissions from the Grassland category decreased between 1990 and 1998, returned to 1990 levels in 2000-2003, and have decreased steadily since then to 2% of 1990 net emissions. In this category the increasing net carbon sink is offset by large emissions of CH₄ from organic soils. Annual net emissions from Settlements have decreased by 27% relative to 1990 (net carbon emissions dominate). The changes in these categories are due to lower rates of land use conversion since 2000 (compared to rates of conversion before 2000) and increased restoration/rewetting of organic soils in the Grassland category.

2.2.5.1.3 Wetlands

Land included in the Wetlands category are areas of near-natural bog and fen habitat with organic soils, current and former areas of peat extraction, areas of organic soils that have been rewetted from forest land and cropland and areas of open water. CH₄ emissions dominate net emissions from the sector. The Wetlands category has relatively stable emissions compared to 1990 levels, with occasional annual spikes (e.g. 2015, 2018). These result from emissions associated with felling of forests for peatland habitat restoration and rewetting, which result in an immediate loss of carbon stocks and cause a spike in net emissions. Although restoration/rewetting of organic soils has increased in the UK over the last decade, the majority of this occurs on organic soils reported under the Grassland sector.

2.2.5.1.4 Harvested wood products

Annual removals due to harvested wood products (HWP) are variable over time. This is due to increased harvesting rates as the substantial areas of afforestation reach the age to be felled, but the removals are still low in absolute terms (see **Figure 2.20**). The carbon gains in the HWP pools are consistent with the carbon losses from Forest Land. Both are estimated using the CARBINE model with tree carbon losses on harvest transferred to the HWP, litter and deadwood pools and modelled accordingly.

2.2.6 Waste

2.2.6.1 Overview

Figure 2.22 Total GWP weighted emissions in the Waste sector

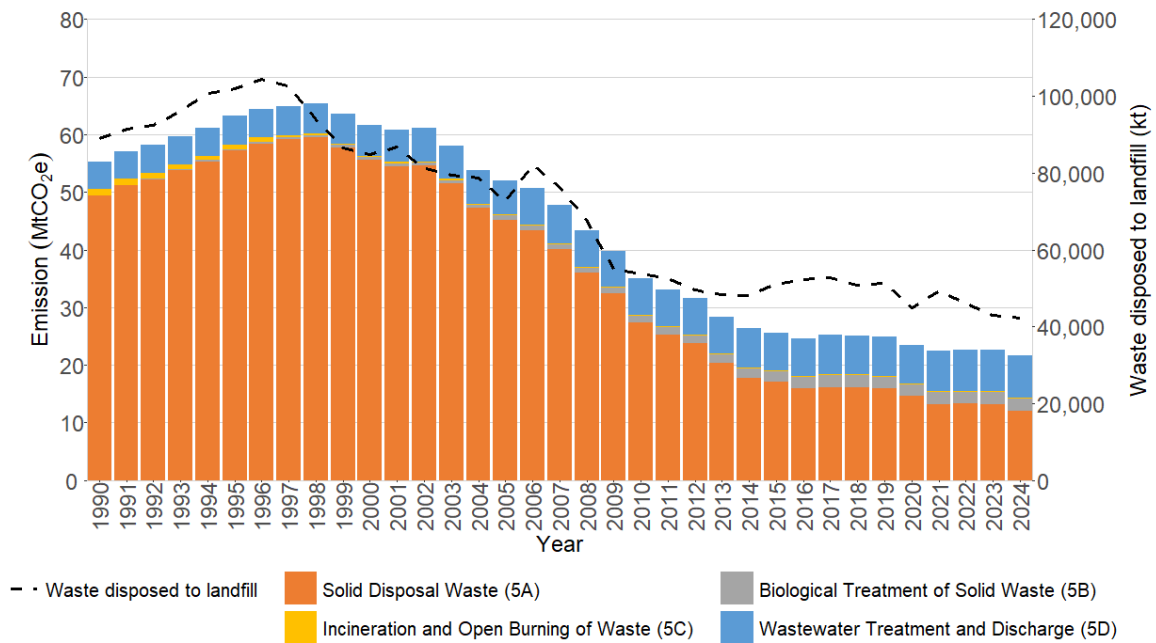


Figure 2.23 Trends in emissions from Waste by sub-sector, relative to 1990

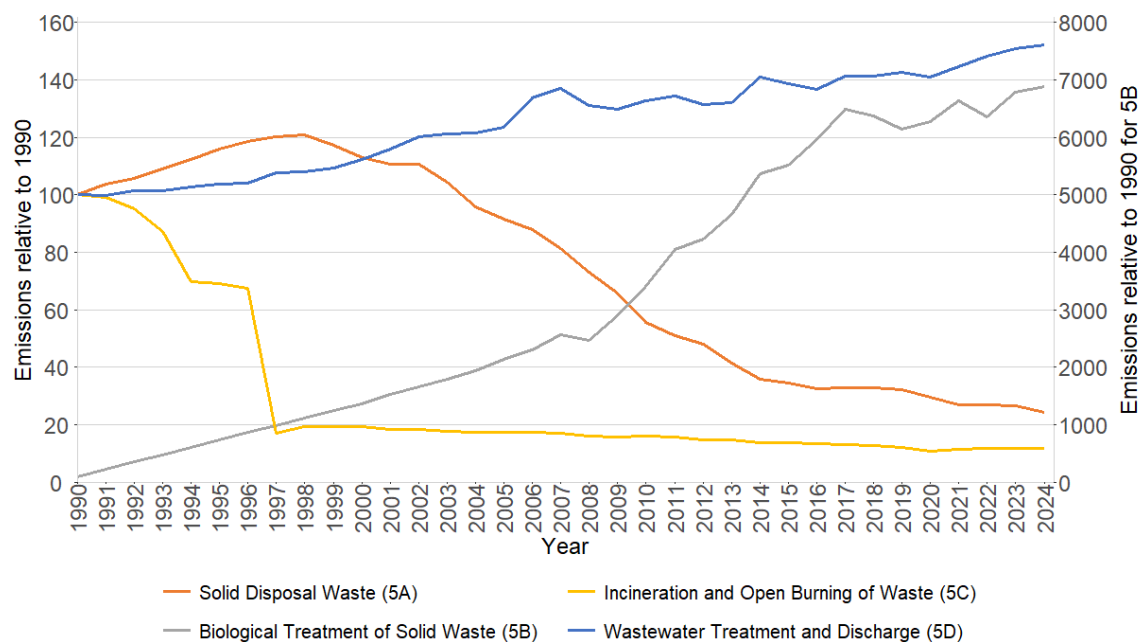
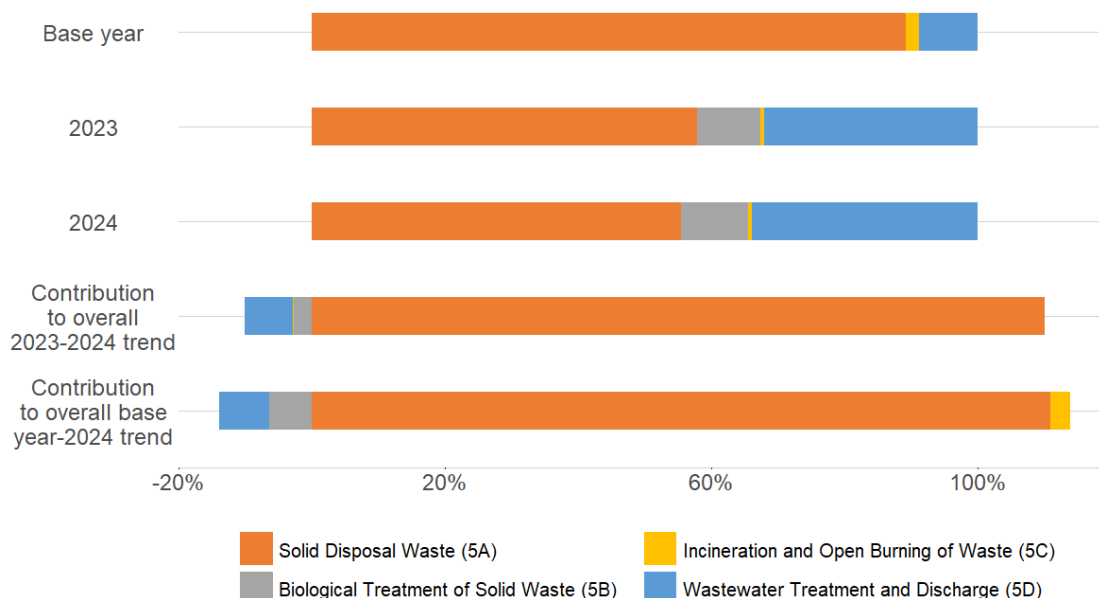


Figure 2.24 Contribution to totals in the selected years and to overall sectoral trends between selected years by sub-sector for Waste

The Waste sector accounts for all emissions generated from waste treatment and disposal. Emissions generated from energy recovery from waste are accounted for in the Energy sector. In the UK, emissions from the waste sector are dominated by CH₄ emissions from landfill sites.

Overall, annual emissions from the waste sector have decreased significantly since 1990 but have flattened out in recent years (**Figure 2.22**).

2.2.6.2 Emission trends in Waste sub-sectors

2.2.6.2.1 Solid waste disposal

Almost all of the reduction in UK GHG emissions across the Waste sector is due to a decline in CH₄ emissions from landfill. Emissions estimates from landfill are derived from the amount of biodegradable wastes disposed of to landfill, and the method takes account of the recovery of landfill gas for energy generation or in flares.

Since 1990, CH₄ emissions from landfill have declined significantly due to the implementation of landfill gas recovery systems, flares and also due to the reduction in biodegradable wastes disposed to UK landfills through greater regulation and an increase in recycling and composting rates. Landfill gas capture rates have plateaued in recent years, which is a key driver of the recent flattening out of emissions from waste.

2.2.6.2.2 Waste water treatment

The UK activity and GHG emissions from industrial wastewater treatment (5D2) shows no significant trend across the time series. For municipal wastewater treatment (5D1), however, a major change in regulation, with the introduction of the EU Urban Wastewater Treatment Directive, led to a ban on disposal of untreated sewage to the waterways. This led to the step-change in estimated emissions between 2000 and 2001. Since then, there has been a slight decline in emissions, but in recent years the emission estimates have levelled off.

2.2.6.2.3 Waste incineration

Waste incineration is a minor source of GHG emissions in the UK.

The most notable impact on the UK GHGI trend arises from the ban on the incineration of MSW without energy recovery in 1996; this regulatory change led to all UK MSW incinerators either closing or retrofitting boilers to raise electricity, and therefore from 1997 onwards all “energy from waste” plant emissions from the incineration of MSW are reported in the power generation sector of the inventory, in 1A1a.

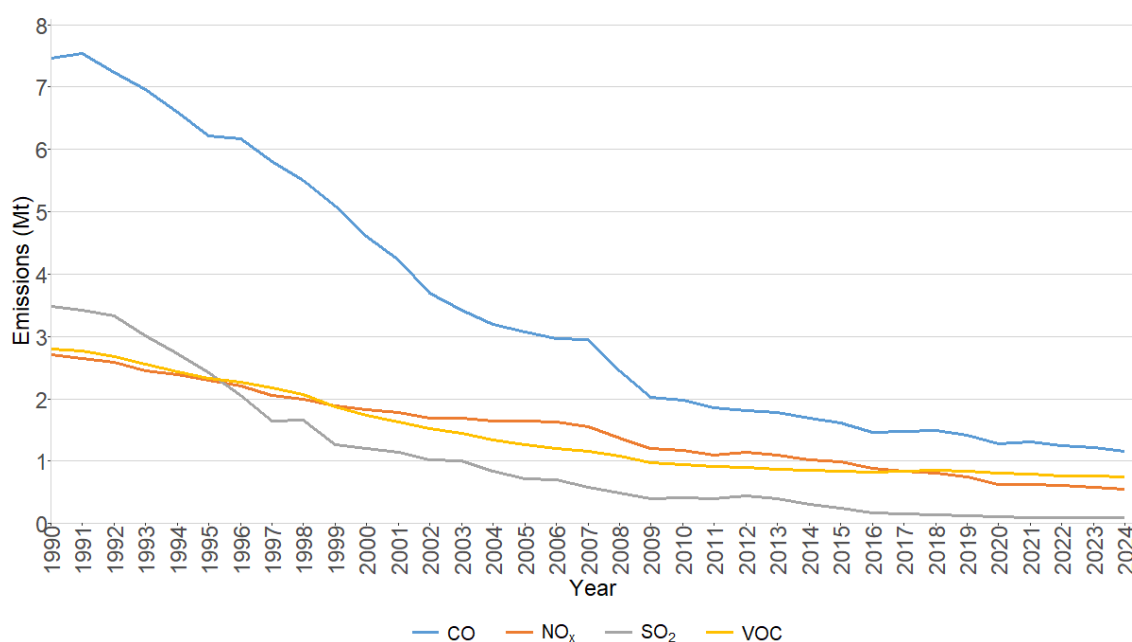
2.2.6.2.4 Biological treatment of solid waste

Since 1990 emissions from the biological treatment of waste sector has sharply grown from almost exclusively small-scale composting to a widespread and large-scale alternative practice for the treatment of biodegradable wastes, the generation of energy and the efficient generation of biogas as an alternative fuel. The continued increase in emissions from this source is part of the reason why total emissions from the waste sector have flattened out in recent years.

2.2.7 Emission Trends for Precursor Gases

The precursor gases in the UK consist of Carbon Monoxide (CO), Nitrogen Oxides (NO_x), Non-Methane Volatile Organic Compounds (NMVOC) and Sulphur dioxide (SO₂). Of these, NO_x, CO and NMVOC can increase tropospheric ozone concentration and hence radiative forcing. SO₂ contributes to aerosol formation in the atmosphere. This is believed to have a negative net radiative forcing effect, tending to cool the surface. Emission trends for the precursor gases are shown in **Figure 2.25**. Significant reductions of all precursor gases have occurred since 1990.

Figure 2.25 UK Emissions of Precursor Gases



2.2.7.1 Carbon Monoxide

Annual emissions of CO have decreased by 85% since 1990. In 2024 86% of UK emissions of CO were from the energy sector. The largest source of CO emissions in the UK is from manufacturing and construction which contributed 32% of total CO emissions in 2024. Emissions from within this category mostly come from biomass combustion and off-road vehicles used in manufacturing and construction.

Another large source of CO emissions in the UK is from transport which contributed 23% of total CO emissions in 2024. Since 1990, annual emissions from transport have decreased by 95%. This is mainly because of the increased use of three-way catalysts, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.

2.2.7.2 Nitrogen Oxides

Annual emissions of NO_x have decreased by 80% since 1990. In 2024, 95% of NO_x emissions in the UK came from the energy sector with the greatest contribution from road transport. The reduction in NO_x emissions is primarily due to abatement measures on power stations, three-way catalysts fitted to cars and stricter emission regulations on heavy duty vehicles.

Emissions from the energy industries contributed 20% of total NO_x emissions in the UK in 2024. Since 1990, annual emissions from this sector have decreased by 87% mainly due to a decrease in emissions from public electricity and heat production. Since 1998 the electricity generators adopted a programme of progressively fitting low NO_x burners to their coal fired units. Since 1990, further changes in the electricity supply industry such as the increased use of nuclear and renewable generation and the introduction of CCGT plant have resulted in additional reduction in NO_x emissions.

Emissions from Manufacturing, Industry and Construction have fallen by 72% since 1990. Over this period, the industrial sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

2.2.7.3 Non-Methane Volatile Organic Compounds

Annual emissions of NMVOCs have decreased by 73% since 1990. In 2024, 57% of emissions were from industrial processes and other product use. Around 68% of emissions in this sector were from the Non-energy Products from Fuels and Solvent Use sector whose emissions have more than halved since 1990. Most of the remaining NMVOC emissions in the industrial processes and other product use sector are from the food and drink and chemicals industries.

In 2024, 25% of NMVOC emissions originated from the energy sector. Of these, the largest contribution arose from the fugitive emissions of oil and natural gas which comprised 47% of NMVOC emissions from the sector. Fugitive emissions of oil and natural gas includes emissions from gas leakage along with the transportation, refining, and storage of oil

2.2.7.4 Sulphur Dioxide

Since 1990, total annual emissions of SO₂ have decreased by 98%. In 2024, 90% of SO₂ emissions originated from the energy sector, with the greatest contribution from Energy Industries. Since 1990, emissions from power stations have declined by almost 100%. This decline has been due to the increase in the proportion of electricity generated by CCGT stations, other gas fired plants, the increase in the proportion of electricity generated in nuclear plants, and the application of Flue Gas Desulphurisation abatement equipment on several of the largest coal-fired power stations in the UK. CCGTs run on natural gas and are more efficient than conventional coal and oil stations and have negligible SO₂ emissions.

Emissions from Manufacturing, Industry and Construction were responsible for 23% of UK SO₂ emissions in 2024. Since 1990, emissions from this category have declined by 95%. This decline is due to the reduction in the use of coal and oil in favour of natural gas, and also some improvement in energy efficiency.

3 Energy (CRT Sector 1)

3.1 OVERVIEW OF SECTOR

Table 3.1 gives an overview of the energy sector. The Key Category Analyses (KCA) rank combines the KCAs, and gives an indication of which categories contain or are a Key Category. Smaller numbers relate to a higher ranking. More detail on how they're derived along with a KCA ranking summary table can be found in **Section 1.4.1**. The uncertainty estimate has been taken from Monte Carlo analysis.

Emission trends are presented for 1990-2024 and 2023-2024. A description of the trends and the main drivers behind these can be found in **Chapter 2**.

Table 3.1 Energy Sector Overview

Energy GREENHOUSE GAS SOURCE AND SINK CATEGORIES	KCA Rank (UNFCCC) scope	Uncertainty (MC)	Latest year total (MtCO ₂ e)	1990- Latest year trend	2023 to 2024 trend	Recalculation- : 2023	Recalculation- : 1990	Methodology reference (NID Section)
Total Energy			295	-51%	-2%	0%	-1%	
A. Fuel combustion activities (sectoral approach)			288	-48%	-2%	0%	-1%	
1. Energy industries			61	-74%	-13%	2%	0%	
a. Public electricity and heat production	5, 6, 9, 33	4%	39	-81%	-16%	2%	0%	MS 1
b. Petroleum refining	5, 6, 9, 33	14%	12	-36%	-4%	0%	0%	MS 1
c. Manufacture of solid fuels and other energy industries	5, 6, 9, 33	2%	11	-35%	-12%	5%	0%	MS1, MS 2
2. Manufacturing industries and construction			32	-56%	0%	-2%	0%	
a. Iron and steel	4, 10, 15, 39	5%	1	-66%	-9%	14%	-1%	MS 4
b. Non-ferrous metals	4, 10, 15, 39	5%	1	-53%	1%	-9%	3%	MS 3
c. Chemicals	4, 10, 15, 39	5%	3	-72%	2%	-11%	0%	MS 3
d. Pulp, paper and print	4, 10, 15, 39	6%	1	-79%	0%	3%	0%	MS 3
e. Food processing, beverages and tobacco	4, 10, 15, 39	5%	4	-49%	5%	2%	-2%	MS 3
f. Non-metallic minerals	4, 10, 15, 39	10%	2	-71%	-3%	0%	0%	MS 3
g. Other (<i>please specify</i>)	4, 10, 15, 39	5%	20	-45%	-1%	-3%	1%	MS 3, MS 6
3. Transport			109	-9%	1%	-1%	-3%	
a. Domestic aviation	35	20%	2	-20%	4%	-3%	0%	MS 7
b. Road transportation	1	2%	101	-10%	0%	0%	0%	MS 8
c. Railways	32	21%	2	13%	5%	-2%	0%	MS 9
d. Domestic navigation	20	17%	4	-11%	3%	-10%	-35%	MS 10, MS 11, MS 12

Energy	KCA Rank (UNFCCC) scope	Uncertainty (MC)	Latest year total (MtCO ₂ e)	1990- Latest year trend	2023 to 2024 trend	Recalculation- : 2023	Recalculation- : 1990	Methodology reference (NID Section)
GREENHOUSE GAS SOURCE AND SINK CATEGORIES								
e. Other transportation		21%	1	70%	6%	-17%	-43%	MS 6
4. Other sectors			84	-27%	5%	0%	-1%	
a. Commercial/institutional	2, 8, 18	4%	23	-25%	6%	-3%	-1%	MS 5
b. Residential	2, 8, 18	4%	55	-32%	4%	2%	0%	MS 5, MS 6
c. Agriculture/forestry/fishing	2, 8, 18	29%	6	33%	12%	-8%	-9%	MS 5, MS 6, MS 10, MS 13
5. Other (as specified in table 1.A(a) sheet 4)			1	-79%	-22%	0%	0%	
a. Stationary	27	N/A	IE	N/A	N/A	N/A	N/A	
b. Mobile	N/A	7%	1	-79%	-22%	0%	0%	MS 15, MS 16
B. Fugitive emissions from fuels			7	-85%	-1%	-6%	0%	
1. Solid fuels		13%	1	-96%	15%	0%	0%	
a. Coal mining and handling	16		1	-97%	20%	0%	0%	MS 17
b. Solid fuel transformation	16		0	-96%	-68%	-86%	-91%	MS 4
c. Other (as specified in table 1.B.1)	N/A	N/A	0	-93%	1%	100%	100%	
2. Oil and natural gas and other emissions from energy production		22%	6	-69%	-3%	-6%	0%	
a. Oil	17, 31		0	-90%	-5%	-64%	0%	MS 5
b. Natural gas	17, 31		4	-71%	-1%	-6%	0%	MS 5, MS 20
c. Venting and flaring	17, 31		2	-59%	-4%	1%	0%	MS 5
d. Other (as specified in table 1.B.2)	N/A	N/A	0	100%	0%	0%	N/A	
C. CO₂ Transport and storage	N/A	N/A	NO	N/A	N/A	N/A	N/A	
1. Transport of CO ₂	N/A	N/A	NO	N/A	N/A	N/A	N/A	
2. Injection and storage	N/A	N/A	NO	N/A	N/A	N/A	N/A	
3. Other	N/A	N/A	NO	N/A	N/A	N/A	N/A	
Memo items:⁽¹⁾	N/A	N/A	45	83%	7%	69%	-42%	
International bunkers	N/A	N/A	45	83%	7%	69%	-42%	
Aviation	N/A	N/A	36	133%	9%	114%	-53%	MS 7
Navigation	N/A	N/A	8	-5%	0%	-8%	0%	MS 14
Multilateral operations	N/A	N/A	NE	N/A	N/A	N/A	N/A	
CO₂ emissions from biomass	N/A	N/A	54	1550%	10%	1%	-31%	MS 1, MS 3, MS 6, MS 8
CO₂ captured	N/A	N/A	NO	N/A	N/A	N/A	N/A	

3.2 FUEL COMBUSTION (CRT 1.A)

3.2.1 Comparison of Sectoral and Reference Approaches

A detailed description of the reference approach and comparison with the sectoral approach can be found in **Annex 3**.

3.2.2 International Bunker Fuels (memo item)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately.

These estimates are consistent with the Tier 3 method adopted for aviation and described in **MS 7** and the Tier 3 method adopted for shipping as described in **MS 12**. The methods for the calculation of international bunker fuels are presented in the relevant method statements.

Each year the Inventory Agency confirms that the UK energy balance is consistent with data submitted to the IEA and that the total fuel consumption used for the GHG estimates is consistent with the UK energy balance. The UK energy statistics and IEA data relate to deliveries in the UK, excluding international journeys from the UK's Overseas Territories. This leads to a difference compared to the Inventory Agency, which includes some Overseas Territories that have ratified the UNFCCC and/or the Paris Agreement.

3.2.3 Feedstock and Non-Energy Use of Fuels

The methodology for estimating emissions from fuels used for non-energy purposes is set out in the relevant sections of this NID. A summary of the method, including all non-energy uses is included in **Annex 5.1**.

The UK energy statistics (DESNZ, 2025a) contain an allocation for non-energy use for each fuel in the commodity balance tables. The UK inventory estimates emissions from fuels, including emissions arising from non-energy uses. In some cases, the inventory estimate for non-energy use does not agree with the DUKES allocation, and reallocations are made between energy and non-energy use for inventory reporting, if inventory estimates lead to more conservative emission estimates. The activity data used for the national inventory and any deviations from the UK energy balance are presented and explained in **Annex 5.2**.

The evidence that the Inventory Agency uses to make estimates for non-energy use includes:

- annual reporting by plant operators (e.g., UK ETS returns, which include data on the use of process off-gases in the chemical and petrochemical production sector);
- periodic surveys or research by trade associations / research organisations / environmental regulators, such as to assess the fate of coal tars and benzoles, petroleum coke or waste oils, or the impact of regulations on solvents, waste, product design and use; and,
- information from literature sources on the estimated split of stored to emitted carbon (and therefore CO₂) related to use of chemical feedstocks, including other country NIDs, where UK-specific information is not available.

In many cases, the energy statistics allocate fuels to non-energy use that are used in chemical and petrochemical production processes where either:

- fossil carbon-containing off-gases are used for combustion in facility boilers; or
- products containing the “stored” carbon are subsequently used / partly combusted / disposed and degraded with some proportion of the “stored carbon” in products ultimately emitted to atmosphere.

In some cases, statistical evidence from industry or surveys is used to inform UK inventory activity data, leading to deviations from the UK energy balance, where commodities are allocated to “non energy use”. For example, evidence from environmental reporting and from research indicates that several industries use petroleum coke directly as a fuel or process input (e.g.: cement kilns, chemical manufacturing processes, domestic fuel manufacturers), and that petroleum coke is supplied as a fuel for the residential market. These data are used to compile UK inventory estimates, whereas the UK energy balance does not report the use of petroleum coke within those sectors; hence we deviate from the UK energy statistics and re-allocate some of the reported “non energy use” of petroleum coke to these emission sources.

3.2.4 Use of UK Energy Statistics in the GHG inventory

The main source of official national statistics and energy balances data used in the UK inventory is the Digest of UK Energy Statistics (DESNZ, 2025a), hereafter referred to as DUKES. This annual publication gives detailed sectoral energy consumption broken down by fuel type, covering the entire period relevant to the inventory. In many cases, these data are used directly in the inventory without modification. However, the activity data used to derive emission estimates in the UK inventory may not exactly match the fuel consumption figures given in DUKES and other official statistics. This occurs for one of four reasons:

- Data in DUKES and other official statistics are not always available to the level of detail required for inventory reporting. *For example, activity data within DUKES do not distinguish between fuel used in stationary and mobile combustion units. Emissions from these distinct types of appliances have to be separately reported in the inventory and furthermore they may exhibit very different combustion characteristics (for non-CO₂ gases) and therefore require application of different emission factors in the UK inventory.*
- Data in DUKES and other official statistics are subject to varying levels of uncertainty, especially at the sector-specific level, and in some cases alternative data suggesting higher fuel consumption are available from other sources, which we use in preference. *For example, the UK ETS indicates higher fuel use for several high-emitting industrial sectors which is used in preference to DUKES data.*
- DUKES and other official statistics do not include any data for a given source. *For example, DUKES does not provide complete information on secondary fuels such as process off-gases that are derived from petroleum feedstocks and are commonly used as fuels in petrochemical and chemical industries.*
- Where the DUKES team make improvements to national energy statistics, they typically do not revise the full time series of data; usually, DUKES data are typically retrospectively revised for up to the 5 most recent years. This can lead to step changes in the DUKES time-series that are due to methodological differences rather than reflecting real changes in fuel use. Therefore, to ensure time series consistency of reported emissions, the Inventory Agency works with the DESNZ energy statistics team to derive a defensible historic time series back to at least 1990 for use in the UK inventory.

The rationale for those modifications or deviations from DUKES data, and the sources of alternative data used to inform UK inventory estimates, are discussed in the sections detailing the methodology for each CRT source category that follow **Section 3**. A summary of modifications by fuel is given in **Annex 5.2**.

The modifications described above involve changes to the sector-level estimates of fuel use used in the UK inventory, when compared with the original source data from DUKES. As a

general rule, the overall demand for each fuel in the UK inventory is kept consistent with the overall demand for that fuel in DUKES; the Inventory Agency approach is such that in almost all cases, any modifications to the sector allocation of DUKES data are matched by an equal and opposite allocation change in another sector, to ensure a zero net change in fuel demand relative to DUKES. **Annex 5.2** includes a series of tables that demonstrate this consistency between the UK inventory and DUKES.

There are some exceptions to the general rule of consistency with DUKES, for petroleum coke, natural gas, and for other petroleum gases (OPG), where other statistical evidence indicates that the energy balance data for fuel combustion sources may be too low, and where re-allocations of fuel use from the “non-energy use” lines in DUKES are made by the Inventory Agency (see **Annex 5.2**).

Apart from DUKES, the other main data source of fuel use estimates in the inventory is the installation-level data available for processes covered by the UK Emissions Trading System (UK ETS) (DESNZ, 2025b), which has been analysed and compared with the data from DUKES. Details of the analysis of the UK ETS and use of the data within the UK GHG inventory are given in **Annex 7**. Further fuel consumption data are taken from the Environmental Emissions Monitoring System (EEMS) data set (DESNZ OPRED, 2025) and from data supplied by the UK Mineral Products Association (MPA, 2025), and from the UK solid fuel supply sector (CPL, 2025). These are used to modify fuel use and emission estimates for 1A1c, 1A2f, and 1A4b respectively, and are described more fully in the sections below that deal with those source categories.

Fuel use estimates for transport sources also rely upon data taken from DUKES, with some further detail provided from other sources.

3.2.5 Overview of UK Emission Factors in the Energy Sector

The details of emission factors applied per emission source are provided within the Method Statements, later in this chapter, and source-specific EF values and data source references are documented in the supplementary file that accompanies the NID. For non-CO₂ gases, the UK widely uses IPCC default factors in the energy sector for stationary and mobile combustion sources, except where country-specific modelling enables more representative EFs to be applied, for example in road transport.

For carbon dioxide emission estimates, the UK applies many country-specific EFs in order to implement higher-Tier methods, especially for key source categories. The approach to estimating and reporting emissions from biogenic fuels, and regarding fuel oxidation factors are discussed below. Details of some of the key EF references, including periodic research studies over the time series are presented in **Annex A5.1.1**.

For country-specific EFs, the UK has a rich resource of data provided via the 1000+ installations that report annually on their fossil fuel compositional analysis via the UK Emissions Trading Scheme (and the EU Emissions Trading System in Northern Ireland, and up to 2020 in other parts of the UK as well); these facilities make up the majority of the high-emitting combustion and industrial process sources in the UK, with close-to complete coverage of all major UK power stations, refineries, upstream oil & gas facilities (production sites and terminals), cement and lime kilns, iron and steelworks, chemical and petrochemical facilities. The annual ETS data provides the Inventory Agency with detailed CEFs for all of the main UK fossil fuels, including coal, natural gas, fuel oil, gas oil, petroleum coke and also for carbon-containing process off-gases (e.g. in the petrochemical sector) and flare gas (e.g. in upstream oil and gas facilities). The ETS dataset provides annual data since 2005 for all participating facilities, which does also include some of the larger facilities in other sections of the UK economy such as the food and drink sector, public sector, and the paper & pulp sector.

These data are also useful to help the Inventory Agency to understand the likely variation over time of the composition of these main fuels within the non-ETS sections of society. For example, the large evidence-base of facility-level analysis over a long period, of fuels such as fuel oil and gas oil, enables the Inventory Agency to understand the range of carbon-content in UK fuel supplies. The composition of most UK fuels does not vary considerably over time and hence are associated with relatively low uncertainty; this is the case for gas oil, where the evidence from ETS reporting indicates a very narrow range of CEFs across time and across different facilities. This supports the data selection for earlier parts of the UK GHGI time series, where we have fewer data points for the carbon content of major fuels, and hence there is a necessary reliance on a handful of older references to inform carbon dioxide estimates for the Base Year.

For natural gas, the Gas Distribution Network (GDN) operators conduct routine analysis of the natural gas composition, and hence the UK Inventory Agency can derive a weighted-average carbon content of natural gas supplied to end users with high confidence. In this submission, specific improvement research has led to the development of separate fossil- and biogenic-carbon content of UK gas supplies, differentiating between the gas supplied to high-energy industrial users direct from the UK National Transmission System (with minimal biogenic gas content) and those sectors supplied via the lower-pressure distribution networks (with ~1-2% biogenic gas content). (See **Section 3.2.6** below for more details.)

As noted in the IPCC guidelines, the fuels that exhibits the widest range of carbon content are solid fuels, primarily coal, where different economic sectors will typically access different quality of coal. This is reflected in the data gathered by the DESNZ energy statistics team and reported within DUKES, which presents a range of net calorific values for coal supplied to different parts of the UK economy (e.g. power vs industry vs residential).

The range and volume of evidence per fuel type has informed a series of periodic research projects to conduct detailed analysis for the fuel types that are most variable within the UK economy. For example, as noted in Annex 5, the 2004 Carbon Factors Review (Baggott et al) brought together the evidence from the inventory Base Year to the advent of the ETS and derived the lowest uncertainty options for CEFs for a range of specific fuels.

More recently, DESNZ has published the latest UK research project into CEFs, which again targeted those sources and fuel types that were identified as contributing the most uncertainty to the UK GHGI. The December 2023 “*Review of Carbon Factors for Fuels*” (German et al, 2023) included sampling and analysis of UK fuels to derive up to date evidence for the CEFs of petrol, diesel, gas oil, LPG, ATF and solid fuels.

There are several minor fuels that have been used within the UK economy, often for short periods of time, where the available evidence for fuel composition is scarce and hence we are reliant on a small evidence base, often of historic references and/or limited quantitative analysis. For example:

- Orimulsion is a fuel reported as used in UK power generation up to 1997, for which the evidence base for the carbon content is limited to a single manufacturer’s specification provided in 1995 (BITOR, 1995);
- Colliery methane fuel compositional analysis is available from a very small number of UK operators (<3 every year) within the ETS dataset, with sporadic reporting across the time series. These values are taken as representative for all users, as they reflect the largest consumers of this minor fuel in the economy;
- Sour gas was used at a single UK power station until its closure in 2009, and hence there is a limited dataset of the CEF for that site during 2005-2009, via the ETS;

3.2.6 Biomass

Combustion of biomass and other biofuels is included in the UK energy statistics and in the UK inventory. The inventory considers the possible use of such fuels in all subsectors of CRT 1A. The UK energy statistics reports biomass activity data that are complete for all UK consumption, and these are presented in the inventory reported across many source sectors.

Greenhouse gas emissions including CO₂ are estimated for these fuels and presented in the relevant sections of the CRT. The CO₂ emissions from biomass are, however, not included in the total UK emissions from fuel combustion and are instead recorded as a memo item.

Emissions of N₂O and CH₄ from biomass combustion are included within the UK inventory totals although in the case of emissions from use of biofuels in road transport, the emissions are not reported separately, and are instead included in the emissions reported for the primary fuel these are blended with (such as petrol for bioethanol).

For fuels that contain both fossil carbon and biogenic carbon, the CO₂ emissions are reported to reflect the split between these components. The details for the relevant fuels are set out below.

- Scrap tyres: CO₂ emissions are split between *other fossil fuels* and *biomass*. CH₄ and N₂O, and the total activity data, are reported as *other fossil fuels*.
- Fossil component of liquid biofuels: there is a fossil-carbon component of some liquid biofuels (e.g., the methyl group in FAME is derived from fossil feedstock). The activity data, and CO₂ from biomass are reported under *biomass* and the fossil CO₂ emission is reported under *other fossil fuels*.

For the combustion of renewable and non-renewable waste, activity data and emissions are separately reported within the other fossil fuels category for non-renewable waste, and biomass for renewable waste.

For natural gas, the UK energy statistics include biogas injected into the gas grid as a transfer from biogas to natural gas, meaning that downstream deliveries of natural gas in energy statistics represents deliveries of blended natural gas and biogas. The Inventory Agency separates the biogas component to allow separate reporting of the emissions from these components. As almost all biogas is injected into the distribution grid, the Inventory Agency assumes that: (i) all biogas is consumed uniformly by users on the gas distribution network, and that (ii) users supplied directly from the gas transmission network (such as power plants) and consumption upstream of the transmission network (such as terminals) use only natural gas, i.e. with zero biogas component. This introduces a difference between the inventory natural gas balance and the energy statistics, as the Inventory Agency only include the natural gas as supplied, whereas the energy statistics report total blended gas as consumed. This deviation is also discussed in **Annex 5.2**.

The impact of biomass use on carbon stocks in the UK is recorded in the LULUCF sector; biomass imported into the UK will affect the LULUCF sector in the country from which the biomass is imported. Our understanding is that all major countries that export Harvested Wood Products to the UK report national inventory totals applying the 'production approach' to accounting for biomass, meaning that between countries carbon accounting should be complete and consistent.

3.2.7 Unoxidised Carbon

When fuels are combusted, a small proportion of the carbon in the fuel is not fully oxidized. For example, unburnt carbon can remain in the ash left after combustion of coal. Emission estimates for CO₂ need to take account of any carbon in fuels that remains long-term in this unoxidized form.

In the UK Inventory, it is assumed that unoxidized carbon is only significant for solid fuels. For gaseous and liquid fuels, although some carbon might not be oxidized fully during combustion (for example emitted as VOC or particulate matter), based on discussions with fuel suppliers, it is assumed that any indefinite storage of unoxidized carbon will be sufficiently trivial to be ignored. For solid fuels, UK-specific assumptions are employed, either based on expert judgements provided by UK industry, or based on UK ETS returns. **Table 3.2** summarises the assumptions used.

It should be noted that since 2006, UK and EU ETS data includes reporting of ash from coal power plants being re-fired (sometimes at a different plant to where the ash was generated), mostly reporting 100% oxidation of the re-fired ash. The UK includes emissions from re-fired ash from coal power plants in our estimate of emissions for coal use in power plants, meaning that the final implied rate of unoxidised carbon from coal power plants is much lower than the values relating to the initial coal combustion presented in **Table 3.2**.

Table 3.2 Levels of unoxidized carbon assumed for the UK GHGI

Fuel Type	Fuel sub-type	Source Sector	Years	Unoxidised carbon in the UK GHGI ^c	IPCC default for unoxidized carbon
Gaseous	All fuels	All sectors	All	0%	0%
Liquid	All fuels (incl. petroleum coke)	All sectors	All	0%	0%
Solid	Coal	1A1a	1990-2004	2% ^a	0%
Solid	Coal	1A1a	2005	1.8% ^b	0%
Solid	Coal	1A1a	2006	2.0% ^b	0%
Solid	Coal	1A1a	2007	1.7% ^b	0%
Solid	Coal	1A1a	2008	2.0% ^b	0%
Solid	Coal	1A1a	2009	1.9% ^b	0%
Solid	Coal	1A1a	2010	1.9% ^b	0%
Solid	Coal	1A1a	2011	1.8% ^b	0%
Solid	Coal	1A1a	2012	1.7% ^b	0%
Solid	Coal	1A1a	2013	1.8% ^b	0%
Solid	Coal	1A1a	2014	1.8% ^b	0%
Solid	Coal	1A1a	2015	1.8% ^b	0%
Solid	Coal	1A1a	2016	1.8% ^b	0%
Solid	Coal	1A1a	2017	1.6% ^b	0%
Solid	Coal	1A1a	2018	1.5% ^b	0%
Solid	Coal	1A1a	2019	1.7% ^b	0%
Solid	Coal	1A1a	2020	1.5% ^b	0%
Solid	Coal	1A1a	2021	1.7% ^b	0%
Solid	Coal	1A1a	2022	1.5% ^b	0%
Solid	Coal	1A1a	2023	1.7% ^b	0%
Solid	Coal	1A1a	2024	C ^d	0%
Solid	Coal	1A2f	All	0%	0%
Solid	Coal	1A4b	All	0%	0%
Solid	Coal	All others	All	0%	0%
Solid	Anthracite	1A4b	All	0%	0%
Solid	Coke, solid smokeless fuel	1A4b	All	0%	0%
Solid	Coke, solid smokeless fuel	All others	All	0%	0%

^a Expert judgements provided by UK fuel producers and fuel users (see Baggott *et al*, 2004).

^b Calculated from site-specific UK and EU ETS returns for all UK coal-fired power stations except in 2005 and 2016 where no information is available for one site. Note that the values presented above are weighted aggregates from ETS and reflect the

unoxidized fraction of the *initial firing* of coal, before any consideration of the refiring of ash. The UK GHGI estimates *do include* the emissions from the refiring of ash, within the emissions reported from coal combustion,

^c From the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, unless otherwise stated.

^d There is only one coal power plant reporting carbon oxidation rates in the UK in 2024 through UK ETS, making this information commercial in confidence. The data can be provided to a UN review team upon request.

3.3 CO₂ TRANSPORT AND STORAGE

Currently in the UK, engineered CO₂ capture and storage is not occurring. This source is not occurring for the UK.

It should be noted however, that CO₂ capture and use is occurring at a sodium bicarbonate production site using CO₂ captured from fuel use on site. This CO₂ is neither transported, nor geologically stored, so is not reported against CO₂ transport and storage. The UK's approach for accounting for this activity is discussed in **Section 4.12**. Similarly, there have been some trials of CO₂ capture at large power stations in the UK, but again, this CO₂ is neither transported, nor geologically stored, so is not reported against CO₂ transport and storage.

3.4 METHOD STATEMENTS

The rest of the energy chapter is structured using a series of inventory compilation method statements in order to group together categories where the source data and methods are similar, minimising unnecessary repetition of method descriptions and improving the clarity of the NID. The method statements are numbered, are cross referenced with the summary table for the sector (**Table 3.3**) and have been grouped broadly to combine method statements for stationary combustion, mobile combustion and fugitive sources.

Table 3.3 Method Statement Scope: CRT and Source Categories

MS number	CRT categories	Source categories
Stationary combustion		
MS 1	1A1ai, 1A1iii, 1A1b, 1A1cii	Power stations, Public heat production, refineries (<i>including emissions from flaring at refineries</i>) and other energy industries (collieries, gas production, nuclear fuel production).
MS 2	1A1cii	Upstream oil and gas production - combustion
MS 3	1A2	Manufacturing industries and construction (excluding iron and steel use of derived fuels, and off-road machinery)
MS 4	1A1ci, 1A2a, 1B1b, 2C1	Iron and steel, and coke manufacture
MS 5	1A4ai, 1A4bi, 1A4ci	Other stationary combustion
Mobile combustion		
MS 6	1A2giii, 1A2gv, 1A2gvii, 1A3eii, 1A4aii, 1A4bii, 1A4cii	Off-road machinery
MS 7	1A3a, 1D1a	Aviation, International aviation
MS 8	1A3b	Road Transport
MS 9	1A3c	Railways
MS 10	1A3d, 1A4ciii	National navigation and fishing
MS 11	1A3d	Inland Waterways
MS 12	1D1b	International shipping
MS 13	1A5b	Naval Shipping
MS 14	1A5b	Military aircraft

MS number	CRT categories	Source categories
Fugitive sources (Except 1B1b – see MS 3)		
MS 15	1B1ai, 1B1aii, 1B1aii1	Coal mining and handling (excluding closed coal mines)
MS 16	1B1ai3	Closed coal mines
MS 17	1B2	1B2 excluding: Natural gas distribution (1B2biv to v). <i>Note that emissions from Natural Gas Production (1B2b2) are reported as 'IE', and aggregated in reporting under Natural Gas Processing (1B2b3). Note also that emissions from refinery flaring are included under 1A1b, see MS1.</i> <i>Note that emissions for 1B2c1iii and 1B2c2iii, venting or flaring for oil and gas combined are reported as 'IE' and aggregated in reporting in oil or gas venting or flaring (1B2c1i, 1B2c1ii, 1B2c2i, 1B2c2ii).</i>
MS 18	1B2biv, 1B2bv	Natural Gas leakage – transmission, distribution, point of use
MS 19	1A1ci, 1B1b	Other solid fuel transformation
MS 20	1A1ai, 1A2, 1A4	Biofuel combustion

MS 1 Power stations, refineries, and other energy industries**Relevant Categories, source names**

1A1ai: Power stations

1A1aiii: Public heat plants

1A1b: Petroleum refining

1A1ciii: Other energy industries fuel use - Collieries, gas production and nuclear fuel production

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Burning oil, Coal, Colliery methane, Fuel oil, Gas oil, Liquefied petroleum gas (LPG), Naphtha, Natural gas, Other petroleum gases (OPG), Orimulsion, Petrol, Petroleum coke, Refinery miscellaneous, Sour gas and Waste oils

Note that emissions reported under 1A1b include those from flaring at refineries. The operator-reported emissions from refineries include both combustion and flaring sources; it is not possible to disaggregate the data accurately for all installations and years. Hence the UK does not include any emissions from refinery flaring under 1B2c.

*[Note that this MS excludes: coke production, smokeless solid fuel production (both **MS 4**) and upstream oil and gas production (**MS 2**). Emissions from the combustion of biofuels, or fuels containing biofuels, are described under **MS 20***

Background

This Method Statement (MS) includes information about UK power stations, public heat production, refineries, and other energy industries.

Table 3.4 shows the number of power stations in the UK, by the type of fuel burnt. The main fossil fuel used by the UK electricity supply industry is natural gas. The number of coal stations has decreased markedly across the time series, and the number of gas fired stations peaked in 2012 but has decreased slightly since then. The share of total UK electricity generated in 2024 was 0.9% from coal and 35% from gas. Nuclear stations and thermal renewables each generated a further 20% and 18%, respectively. The wind, wave and solar stations generated 19%. The remainder accounted for a small proportion of other thermal sources (5%), petroleum (1%) and hydro (1%) (Ricardo's analysis based on DUKES Tables 5.3-5.6).

Biomass is being burnt at an increasing number of power generation sites to help electricity generators meet Government targets for renewable energy production. These sites use poultry litter, straw, or wood as the main fuel. In the UK, the last coal-fired power station closed in September 2024; over recent years, the remaining coal-fired power stations increasingly used co-firing of biofuels such as short-rotation coppice to supplement the use of fossil fuels. Electricity is also generated in a large number of engines running on biogas at landfill sites and sewage treatment works. CO₂ emissions associated with biofuel combustion are estimated and reported as a memo item to the UK inventory; these emissions are not reported in the Energy sector, but they will be reflected in the LULUCF carbon stocks of the country producing the biofuel. Emissions of other greenhouse gases from biofuel use are estimated and included in the national inventory totals, in accordance with IPCC guidance on the treatment of biofuel-derived emissions.

Electricity is also generated at an increasing number of Energy from Waste (EfW) installations in the UK. Formerly classed as municipal solid waste (MSW) incinerators, all such installations have since the late 1990s been required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under CRT source category 1A1 (electricity generation), rather than 5C (Waste Incineration). Prior to 1997 at least some MSW was burnt in older installations without energy recovery.

Table 3.4 Power stations in the UK by type

Year	Coal	Fuel oil	Gas oil	Gas	Waste	Biomass	Biogas	Nuclear Fission
1990	44	8	12	1	2	0	Unknown ^a	19
1995	23	8	13	18	4	2	Unknown ^a	16
2000	21	5	11	37	15	4	267	15
2005	16	4	14	50	20	19	461	13
2010	16	3	14	59	24	21	554	10
2012	15	3	14	63	26	19	565	10
2013	14	3	14	57	28	22	621	10
2014	12	2	14	57	34	24	628	10
2015	12	1	14	57	35	25	633	9
2016	12	0	14	58	39	26	642	9
2017	9	0	14	57	40	26	658	9
2018	8	0	14	56	45	27	654	9
2019	7	0	14	56	49	33	650	8
2020	6	0	13	50	53	30	650 ^b	8
2021	4	0	19	48	55	33	650 ^b	7
2022	2	0	19	43	59	31	650 ^b	5
2023	1	0	17	49	61	31	650 ^b	6
2024	1	0	17	48	63	31	650 ^b	5

^a Number of power stations for early years is unknown although emissions are reported, biogas consumption is obtained from DUKES.

^b Figures from 2020 not published in DUKES, estimated equal to previous years

Table 3.5 shows how the numbers of refineries vary over the period covered by the inventory. The UK had 8 operating refineries during 2024, of which 2 were small specialist refineries employing simple processes such as distillation to produce solvents or bitumen only. The remaining 6 complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants,

and petroleum coke. The crude oils processed, refining techniques, and product mix will differ from one refinery to another, influencing the energy use and emissions from the sector. A seventh large crude oil refinery ceased operation in November 2014, and four other major refineries in operation in 1990 closed between 1997 and 2010.

Table 3.5 Refineries in the UK by type

Year	Crude oil refineries	Specialist refineries
1990-1996	11	4
1997-1998	10	4
1999	9	4
2000-2009	9	3
2010-2012	8	3
2013	7	3
2014	7	2
2015-2024	6	2

Some of the crude oil and natural gas input to the refineries comes from a large number of offshore installations in UK waters, together with a small number of onshore production facilities. Emissions estimates from these activities are described in **MS 2** and **MS 17**. Coal is extracted in the UK from deep mines and open-cast sites. The production of coal has been in rapid decline in the UK and levels of UK activity are far lower in recent years than in 1990. The last large UK deep mine closed in 2015 and so production of deep-mined coal was negligible in 2016-2024. Emissions from combustion at UK collieries are covered in this MS. Fugitive emission estimates from these mining and extraction activities are included in **MS 14** and **MS 17**.

Nuclear fuel production is a very minor user of fossil fuel in the UK, and is included in this MS.

Key Data sources

Activity data: DUKES (DESNZ, 2025a), UK and EU ETS (DESNZ, 2025b)

Emission Factors: Carbon factors are predominantly derived from UK and EU ETS data (2005 onwards), from refinery sector reporting (Fuels Industry UK, 2025a) and from the 2004 Carbon Factors Review (Baggott et al., 2004), with some solid fuel factors derived from UK research (Fynes and Sage, 1994); non-CO₂ EFs are predominantly IPCC defaults (IPCC, 2006).

*An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. The justification for use of several references, such as UK and EU ETS, the 2004 Carbon Factors Review and Fynes and Sage, are presented in **Annex 5.1.1.3**.*

Table 1.4 gives additional information for common activity data sources.

⁵⁶ This can be found as one of the additional documents to the NID https://naei.beis.gov.uk/reports/reports?report_id=1108

. Note that there can be a delay between the NID being published on the NAEI website after official submission.

Method approach

The calculation of direct greenhouse gases for the sources covered by this MS is:

$$\text{UK Emissions} = \text{EF} \times \text{AD}$$

The sources of emission factors (EF) and activity data (AD) are summarised under “key data sources” above, with a full list of emission factors set out in “*Energy_background_data_uk_2026.xlsx*”. The activity data are taken from DUKES, noting the exceptions set out under Assumptions & observations, below. **Annex 5.2** describes the energy balance for the UK and how this is used for the inventory, and any deviations from these data.

Assumptions & observations

- **Power stations - gas oil / fuel oil / burning oil activity data:** DUKES reports less fuel oil burnt by power producers than is reported by operators either directly to the Inventory Agency or via the UK Emissions Trading System (UK ETS). For some years this is also true of gas oil, and in the case of burning oil, DUKES does not give any figures for any year. For each oil therefore, we take the larger of either the DUKES figure or the operator data each year. Where we choose to use the operator data, fuel is reallocated from industry (1A2) to power stations to maintain consistency with the overall UK fuel consumption data in DUKES;
- **Coal-fired power stations – oxidation factors (OF):** All UK coal-fired power stations report to UK ETS and present installation-specific data on coal composition (carbon content), and almost all also report the fuel oxidation factor (OF). The weighted-average figure is reported in **Table 3.2** above. The range of OFs at UK coal-fired stations is typically 95-99%, with the UK average typically around 98-99%. The factors presented in “*Energy_background_data_uk_2026.xlsx*” are the factors including consideration of the oxidation factor. The data for recent years is taken from installation-specific analysis through EU and UK ETS, and from the underlying data we can derive the weighted average oxidation factor across UK coal-fired power stations. The data for earlier years is all taken from the Carbon Factors review in 2004. The data may be low compared to the IPCC default, but they are based on country-specific analysis and the carbon emission factor (CEF) is consistently low across the time series. For 1990-2004, the assumed oxidation factor for power station coal is 98%. For 2005 onwards, country specific (CS) oxidation factors are derived from the EU/UK ETS data. These EU/UK ETS data indicate that 98% is a defensible estimate.
- **Power stations – MSW:** The UK inventory reports non-biodegradable (fossil) and biodegradable wastes separately and we apply IPCC default carbon factors for each type of waste.
- **Refineries - OPG activity data:** Discrepancies in activity data are evident between UK ETS and DUKES. Based on data from UK ETS and the refinery trade association, Fuels Industry UK, potential under-reports were identified in the UK energy balance data for the refinery sector from 2004 onwards, although not in all years. The Inventory Agency takes the conservative approach of using the higher fuel consumption data for each year. The estimates for 2004 in the UK GHGI are therefore based on data supplied directly to the Inventory Agency by the Fuels Industry UK data, whilst the data for 2006-to 2024 are based on EU/UK ETS data. Data from DUKES are used for 2005. Prior to 2004 the UK GHGI emission estimates based on DUKES energy data are closely consistent with Fuels Industry UK sector estimates, and are therefore retained; and,
- **Refineries - Petroleum coke activity data:** Similar to the issue noted above for OPG, comparison of the AD presented in DUKES versus the AD reported via the EU/UK ETS

indicates for several years that the DUKES AD are under-reported. The UK GHGI estimates from refinery petroleum coke use are therefore based on the higher value of DUKES or EU/UK ETS and applying the EF for petroleum coke provided by Fuels Industry UK; EU/UK ETS data are higher (and therefore used in the GHGI, deviating from DUKES) for all years 2005 to 2010 and again in 2013, 2015-2019 and 2024. In 2011, 2012, 2014, and 2020-23 the DUKES data are higher than EU/UK ETS and are therefore retained; we note, however that this is a possible over-report and leads to UK GHGI emission estimates for the sector as a whole being higher than ETS totals in those years. The Inventory Agency retains this approach in order to use ETS emission estimates as a de-minimis, and taking a conservative approach to deriving the time series of refinery emissions. Note that the UK GHGI estimates for the refinery sector are also higher than the EU ETS figures for 2005: this is because DUKES reports higher consumption of other fuels (including fuel oil and natural gas) than given in EU ETS, rather than due to differences for OPG and petroleum coke as in other years.

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Recalculations

Activity data revisions include:

- Revisions to DUKES data, notably for natural gas and MSW for power stations.
- For refineries, there are reallocations to fuel oil and natural gas allocations in DUKES, however overall emissions do not change as these are based on ETS data (with the difference allocated to OPG).

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For emission factors:

- No notable revisions for direct GHGs.

Quantitative information on recalculations is included in **Chapter 10**.

Improvements (completed and planned)

Completed: Recalculations and updates completed as described above.

Planned/Ongoing: Emission factors and activity data remain under annual review.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- The Inventory Agency conducts extensive quality checks on the operator-reported UK ETS data covering: emissions, AD, EFs, net calorific values (NCVs). The QC assesses the fuel quality data, time-series consistency of reported data by installation, detailed source-specific UK ETS data against the installation-wide total emissions reported to the EU Transaction Log and UK Compliance Reports, and comparisons between DUKES and EU ETS AD to identify and resolve any potential mis-allocations or under-reports in the DUKES dataset. Findings are discussed with the DESNZ energy statistics team and (where necessary) the UK ETS regulators and/or operators. This process has led to many significant improvements in UK GHGI accuracy;
- The comparison of the reference/sectoral approach;
- A bilateral exchange with Denmark in 2015, providing peer review and quality assurance in updating to 2006 Guidelines; and
- A bilateral exchange with Germany in 2014, providing peer review and quality assurance of the energy sector and refinery estimates. (Ricardo-AEA, 2014a).

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Code of Practice for Statistics*⁵⁷. The UK ETS data, is subject to its own QA process, defined and managed by the competent authority and compliant with UK rules.

Time series consistency

Activity data for petroleum coke and OPG consumption in refineries are based on DUKES data for certain years, and data directly from UK ETS or trade association (Fuels Industry UK) for other years in the time series. This is described in the method approach section above. The differing data sources have been used to ensure a consistent complete coverage of emissions from refineries, addressing under-reports in DUKES and ensuring the time series consistency is maintained.

For some sources and fuels, carbon emission factors are taken from Baggott et al., for the period 1990-2003, and from UK and EU ETS for 2005 onwards (2004 is interpolated). This makes best use of available data and the time series trend of EFs shows a smooth transition between data sources. We note that the key data providers that informed the 2004 Carbon Factors Review are the same operators of high-emitting plants (i.e. power stations, refineries, cement kilns, iron, and steel works) that subsequently provide data to the UK ETS. Therefore, whilst the UK ETS data provides a larger dataset of more detailed, installation-specific fuel composition and hence carbon emission factors for recent years, the underlying source data available prior to EU ETS comes from the same operators. This means that, despite use of a smaller dataset prior to the availability of EU ETS data, the time series consistency of this approach is good.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately. Non-CO₂ emissions are dependent on a greater number of parameters and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

⁵⁷ Available from <https://www.statisticsauthority.gov.uk/code-of-practice>

MS 2 Upstream oil and gas production – fuel combustion**Relevant Categories, source names**

- Upstream oil production: fuel combustion
- Oil terminal: fuel combustion
- Upstream gas production: fuel combustion
- Gas terminal: fuel combustion

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Gas oil, Fuel gas⁵⁸ ('Natural Gas')

Background

This source category comprises emissions from the combustion of all fuels (excluding fuel used for vessel propulsion), including producers' own fuel gas and purchased fuels such as diesel, through all phases of exploration, development, production and decommissioning for all upstream oil and gas installations on the UK Continental Shelf (UKCS) and onshore, i.e. including at offshore assets (platforms, Floating Production Storage and Offloading vessels - FPSOs, and Mobile Offshore Drilling Units - MODUs), at onshore terminals and at onshore production sites.

The UK has been producing oil and gas, predominantly offshore in the North Sea, for decades, and there are several hundred oil and gas platforms that have been operating across the time series. As they have high power demands to run the exploration and production operations, most platforms include large gas turbines that are run off a proportion of the fuel gas produced on-site, with smaller supplementary engines, heaters and other units that may burn fuel gas and/or diesel.

UK GHGI methods are implemented to derive separate estimates for:

- onshore terminals;
- onshore production facilities; and
- offshore production facilities, including platforms, FPSOs and MODUs.

The different methods per installation type reflects the difference in source datasets between onshore and offshore facilities due to different regulatory systems in the UK for the respective installations. Each installation is allocated to either *upstream oil* or *upstream gas* production according to the North Sea Transition Authority (NSTA) definitions of the fields/terminals producing/treating the oil or gas.

⁵⁸ In UK upstream facilities where fuel gas is used, the gas is predominantly methane and similar in composition to natural gas but also typically contains more higher-chain hydrocarbons (e.g. ethane, propane, butane, C5 and above) and often also higher levels of CO₂ and sulphur compounds compared to natural gas that is provided to downstream users via the National Transmission System (NTS) after processing at gas terminals.

Key Data sources

- Activity Data:** Gas oil data are primarily taken from DUKES (DESNZ, 2025a); fuel gas ('natural gas') data are derived from operator reporting to the UK ETS (2005-) (DESNZ, 2025b) and EEMS (1998-) (DESNZ OPRED, 2025) reporting systems and quality checked against UK energy statistics in DUKES (DESNZ 2025a). Fuel use estimates for pre-EEMS years, i.e. 1990-1997, are derived from sector data submitted to UK Government based on operator reporting (UKOOA, 2005).
- Emission Factors:** Carbon factors for fuel gas ('natural gas') are derived from operator reporting to UK ETS (DESNZ, 2025b) and EEMS (DESNZ OPRED, 2025), supplemented by operator data for the earlier years in the time-series (UKOOA, 2005); the carbon factor for gas oil is derived from the 2004 Carbon Factors Review (Baggott et al, 2004). Methane and nitrous oxide EFs are based on operator reporting via EEMS from 1998 onwards; these EFs are also extrapolated back to 1990.

*An accompanying spreadsheet "Energy_background_data_uk_2026.xlsx" lists all emission factors used in the energy sector, including a full list of references⁵⁹. **Table 1.4** gives additional information for common activity data sources.*

Method approach

The Inventory Agency has researched and analysed all available activity and emissions data for the UK upstream oil and gas sector across the time series during a recent inventory improvement project (Thistlethwaite et al, 2022). The inventory method for 1A1cii draws upon the best available data from the sector, through a range of reporting mechanisms that have been developed by UK regulatory agencies across the time series.

*A more detailed summary of the oil and gas sector analysis is presented in **Annex 5.1.1.6**. The methods developed impact both fuel combustion emissions in 1A1cii and all upstream oil and gas fugitive emission sources reported in 1B2 (see **MS 17**).*

Across all years of the time series, the fuel use estimates presented in DUKES are incomplete and operator-reported data are used to deliver a complete and accurate inventory estimate. (For further details see the section below: 'Assumptions and Observations'.)

The key activity and emissions datasets used across the time series are:

- **1990-1997:** Inventory Agency estimate derived from the UKOOA 2005 aggregated estimates of GHG emissions presented for all offshore and onshore production emissions. AD estimated from the emissions data, assuming that the sector-wide EFs from 1998 are representative for earlier years for all fuels (diesel, fuel gas);
- **1998-2003:** EEMS operator-reported fuel combustion emission and activity estimates per installation, from all offshore mobile and fixed installations and all onshore terminals, supplemented by analysis of the UK ETS National Allocation Plan (NAP) data;
- **2004:** EEMS operator-reported fuel combustion emission and activity estimates per installation, offshore and onshore;

⁵⁹ This can be found as one of the additional documents to the NID https://naei.beis.gov.uk/reports/reports?report_id=1108

Note that there can be a delay between the NID being published on the NAEI website after official submission.

- **2005-2010:** UK ETS (CO₂) and EEMS (all GHGs) operator-reported fuel combustion emission and activity estimates per fixed installation, offshore and onshore. EEMS data for all mobile offshore units;
- **2010-Current:** UK ETS (CO₂) and EEMS operator-reported fuel combustion emission and activity estimates per fixed offshore installation; EEMS data for all mobile offshore units; UK ETS (CO₂) operator-reported fuel combustion emission and activity estimates per onshore terminal.

Since 1998 there are installation-level data reported to UK Government, including fuel combustion estimates that are based predominantly on installation-specific carbon emission factors for fuel gas; this is therefore a Tier 3 method using the aggregate of reported data across all UK installations, and based on a large dataset of fuel compositional analysis and operator reported emission estimates.

Prior to 1998 the source data reported to Government are more aggregated, based on sector surveys and (in some years) the use of proxy data (oil and gas production statistics) to estimate the activity data. An industry submission to Government in 2005 (UKOOA, 2005) provided a comprehensive estimate of sector emissions from 1990 to 2003 based on aggregated UK operator reporting, and hence this is a Tier 2 method.

Since 2005, the activity and emissions data for combustion are primarily derived from EU/UK ETS (DESNZ, 2025b) reporting for those installations that report to EU/UK ETS, and from EEMS (DESNZ OPRED, 2025) data for the sites that fall below the reporting threshold for EU/UK ETS. Analysis has shown that there is a small systematic under-report for fuel gas use by the oil and gas sector for recent years of the time series in the UK energy statistics, DUKES (DESNZ, 2025a). Where the fuel combustion emissions are reported for an installation via both EEMS and EU/UK ETS, the EU/UK ETS data are regarded as better quality as they are subject to Third Party verification, as part of the requirements of the trading scheme. However, the scope of reporting under EU/UK ETS is not as complete as EEMS. For example, mobile offshore units (e.g. drilling units) do not fall within EU/UK ETS scope and a number of smaller offshore platforms also report only to EEMS as they do not meet the EU/UK ETS threshold for combustion unit capacity.

Onshore oil and gas terminal operators reported fuel combustion estimates via EEMS from 1998 to 2010. Since 2010, terminal operators are not mandated to report to EEMS and most have ceased to do so, as they are already required to report installation-wide annual emission estimates under the IED/PPC reporting systems to onshore regulators. The EU/UK ETS data provide complete estimates for fuel use at all onshore oil and gas terminals from 2005 onwards.

The EU/UK ETS CO₂ data for high emitting source streams are based on source-stream-specific fuel analysis (i.e. compositional analysis to derive carbon content, NCV) and the assumption that the fuel is 100% oxidised; for example, on most oil and gas platforms the estimates of emissions from fuel gas use within turbines, engines, heaters and other units are based on sampling and analysis of the carbon content of the fuel gas. As such the EU/UK ETS data are considered highly accurate; they provide a rich and detailed dataset that exhibits a range of variability in the fuel gas across installations and across the time series.

For 1998 to 2004 inclusive, the combustion activity and emissions were reported by all upstream oil and gas installations, offshore and onshore, via EEMS. The oil and gas operators subsequently conducted more detailed analysis, to review activity data and carbon emission

factors, in the course of developing the National Allocation Plans (Phase I NAP, Defra 2005)⁶⁰, in the years leading up to the EU ETS. The accuracy of the 1998-2003 data was improved through this process to ensure accurate emission allocations per installation in the first phase of EU ETS which ran from 2005 to 2007. To derive the UK GHGI estimates for combustion in 1998 to 2004, the Inventory Agency has reviewed the EEMS and NAPs data during the recent oil and gas improvement project and used the best available data per installation.

For 1990 to 1997 there are more aggregated data available from industry reporting (UKOOA 2005) that are used to inform the UK GHGI estimates. The 1990 and 1991 CO₂ estimates are based on company reported data, with CH₄ and N₂O estimates derived by the Inventory Agency, applying EFs from operator reporting in later years (under EEMS). Data for 1995 to 1997 were compiled from operator reporting under a system with a similar reporting structure to EEMS, but data are only available from across the whole industry, rather than per installation, and hence are somewhat less transparent. The sector estimates for 1992 to 1994 are based on modelling by the oil and gas trade association, using oil and gas production data as a proxy, scaling emissions between the reported data in 1991 and 1995.

The fuel combustion in the sector is a minor source of emissions of methane and nitrous oxide. Operators report estimates to EEMS, predominantly applying defaults from operator guidance for fuel gas combustion or gas oil combustion. The inventory estimates are based on the operator-reported estimates from EEMS for 1998 onwards; the estimates in 1990-1997 are based on EFs rolled back from EEMS 1998 data.

Assumptions & observations

The DUKES commodity balance tables are regarded as high quality and complete for most fuels and sectors, where the fuel allocations are based on fuel sales data (from tax records, from annual and periodic surveys), surveys of fuel suppliers and producers, import and export data. However, for the upstream oil and gas sector a high proportion of fuel use (and hence combustion emissions) arise from operators' own use of fuels (mainly fuel gas, a mixture of methane and other hydrocarbons) that are generated and used on site and are therefore not 'bought and sold' (unlike most fuel use across the UK economy), nor are they metered or delivered through a system (e.g. pipeline network) where inputs and outputs are routinely monitored to track fuel use / sales to recharge the suppliers.

The DUKES long-term trends in producers' own fuel gas use by the upstream sector⁶¹ exhibit a ~20% single year step-change from the year 2000 to 2001 that the UK Government (then DECC) energy statistics team confirmed was due to the more complete data capture after the Petroleum Production Reporting System (PPRS) was implemented (DECC, 2012. Personal communication) and was not a 'real' change in fuel use. Prior to PPRS the data capture mechanisms in place under-reported the sector fuel use, with data gaps indicated by UK Government energy statisticians for fuel gas use at gas terminals and at oil terminals. This has informed our method choice to deviate from UK energy statistics and to use the industry reported data for emission estimates in the 1990s (i.e. the UKOOA 2005 dataset) in preference as they are the more accurate, complete dataset.

The UK inventory also deviates from UK energy statistics in the years since PPRS was introduced (2001-present). DUKES includes only fuel gas use at sites reporting via PPRS (DESNZ, 2024d), while the UK inventory also includes any additional sites that report via

⁶⁰ EU Emissions Trading Scheme, Approved Phase I National Allocation Plan 2005-2007, Defra (2005) https://webarchive.nationalarchives.gov.uk/ukgwa/20121024153024/http://www.decc.gov.uk/en/content/cms/emissions/eu_ets/phase_1/phasei_nap/phasei_nap.aspx

⁶¹ UK energy statistics, DUKES Table 4.2 Natural Gas Production and Supply. Producers own use is reported in GWh for 1999-2000-2001-2002 thus: 64,634 – 65,555 – 78,457 – 79,364. The step change 2000 to 2001 is a 19.7% apparent increase, but reflect better data capture (Personal communication: DECC, 2012)

EEMS and UK ETS. The resulting difference in fuel gas use is minor since the additional sites included in the UK inventory method are small, for example sites servicing interconnector pipelines.

DUKES (DESNZ, 2025a) reports gas oil use for the upstream oil and gas sector since 2005 but not for earlier years in the time series; the operator data from EEMS (1998-2004) and from UKOOA (1990-1997) shows that gas oil has been used by the sector throughout the time series. Therefore, the UK GHGI uses the operator-reported estimates directly for 1990-2004 and the DUKES data for 2005 onwards, which are based on operator returns to EEMS.

We note that when the operators' own **fuel gas** is the primary fuel for generating heat and power in upstream facilities, it is formed predominantly of methane and has a similar composition to **natural gas** processed at gas terminals and provided to downstream users in the UK via the National Transmission System (NTS). However, fuel gas frequently has a greater proportion of higher-chain hydrocarbons (e.g. ethane, propane, butane, C5 and above) than natural gas, as well as higher levels of CO₂ and sulphur compounds. Tables in **Annex 5.1.1.6** set out the fuel compositional data for the fuel gas, illustrating the variability of CEFs, densities and NCVs of the fuel gas across the UK upstream oil and gas sector. All of the emissions are reported under 'natural gas' use in 1A1cii, reflecting the allocation of the fuel gas to the natural gas commodity balance in DUKES.

Emissions from OTs and CDs are 'Not Estimated' for this source. There is no oil or gas production in any of the OTs and CDs and only limited well drilling and initial exploration activity (i.e. well testing) in waters around the Falklands Islands in 1998, in 2010, 2012 and 2015. There are no fuel use estimates specific to those exploration activities; it is assumed that any fuel use is accounted for within the Falklands energy balance data.

Emission factors for N₂O for 1A1cii are higher than the IPCC default range, and this issue has been noted by previous UNFCCC expert review teams. The factors applied in the UK inventory are based on operator-reported data from predominantly offshore oil & gas facilities using fuel gas, which is mainly natural gas or associated gas from oil production. These operator data are considered to be more representative of combustion emissions at UK installations than the IPCC defaults.

Recalculations

2023 emissions of CO₂ have been increased by 5.7%. This is due to corrections to estimates of emissions from fuel gas use at onshore terminals and several offshore platforms to use operator data from UK ETS in preference to data from EEMS.

Improvements (completed and planned)

The oil and gas sector improvement project (Thistlethwaite *et al*, 2022) has assessed all available UK data to improve the quality of the UK GHGI submission across 1A1cii and 1B2 and is described in more detail in **Annex 5.1.1.6**.

Emission factors and activity data remain under review.

Further improvements may be achieved if it becomes possible to obtain more resolved data on fuel gas quality per installation, to improve the assumptions for NCVs and density of fuel gas. The current method applies the best available data from PPRS but this is a separate data reporting mechanism to the EEMS and UK ETS datasets. If a more comprehensive NCV dataset, e.g. directly from the UK ETS data reporting, were to become available, this may help to improve data quality. However, we note that this would not alter the emission totals, but it would slightly improve the accuracy of the AD and EFs.

We note that the recent oil and gas improvement project has fully explored all available data for the early part of the time series and we see no practicable opportunity to improve the estimates for the 1990s.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- The comparison of the reference/sectoral approach;
- Comparison of EEMS, EU/UK ETS and DUKES activity data for fuel (natural) gas combustion. The data underpinning DUKES estimates are gathered via the PPRS which presents facility-level activity data that are compared against EEMS and UK ETS to identify and reconcile any data inconsistencies;
- Comparisons between EEMS and EU/UK ETS, to review installation-specific activity data and emissions data (and hence implied IEFs for each site and source) to identify any possible gaps in the EEMS dataset, using EU/UK ETS as a de-minimis. The UK ETS data typically covers a smaller scope of activities on a given installation, but the data quality (AD, EFs) are third-party verified, whereas the EEMS dataset should be a comprehensive record of all combustion activities on upstream oil and gas installations but the data are subject to less rigorous QC;
- Comparisons of total emissions data reported by each onshore oil and gas installation via the Regulatory Inventories (RIs) to assess time-series consistency and completeness of reporting, comparing CO₂ emissions data against those presented in EU/UK ETS (and EEMS if the terminal reports to EEMS also).

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Code of Practice for Statistics*. EU/UK ETS data is subject to its own QA process.

Time-series consistency

The method is compromised by the lack of source-specific data for the 1990-1997 period, where only aggregate emissions data across all sources in 1A1cii and 1B2 are available from the industry submissions to UK Government; this coincides with a period where consultation with the DESNZ energy statistics team has confirmed that the UK energy statistics were not gathering complete data for all oil and gas terminals. Wherever possible the Inventory Agency has filled data gaps with operator-reported estimates and applied IPCC good practice gap-filling methods to ensure that the time series consistency is as good as practicable given the available data; this is possible as there are a defined number of installations that are active in this sector and their activities (and emissions) are generally well documented with gaps in data being relatively minor.

Further, the Inventory Agency has conducted time series consistency checks between the aggregated emissions reported in the 1990-2003 data submission (UKOOA 2005) and the installation-level EEMS and NAPs data (BEIS OPRED, 2021), across the overlap years of 1998 to 2003. This analysis shows close consistency, indicating that the scope of reporting in the UKOOA 2005 dataset is consistent with the later installation-level EEMS data. *Further details are presented in Annex 5.1.1.6.*

In order to validate the data estimates, the Inventory Agency has derived estimates of *fuel gas use per unit production* for oil production and gas production back to 1990. There is a general trend to higher fuel gas use per unit production across the time series, reflecting the higher energy demands to extract materials from increasingly depleted oil and gas fields, although this trend is not always continuous year to year as some fields cease production and others come on stream. The total fuel gas use is 1.54 TJ net per kt crude oil production and 0.841 TJ net per Mm³ gas production in 1990 whereas by the end of the in 2000 the figures are 1.56 and 0.842, with increases evident to over 1.60 and around 1.00 by 2002. These figures can

only be regarded as indicative given the variability in emissions intensity production evident across the UKCS and limited data resolution in the early 1990s, but they do indicate that the derived estimates of fuel use for 1990 are lower than data for later years and of a similar order of magnitude, which is as expected.

We further note that whilst the emission estimates specific to fuel combustion in 1990-1997 are uncertain, that the total emissions across all upstream oil and gas sources ($\Sigma 1A1cii, 1B2$) in the UK GHGI are aligned with the industry submission to UK Government (UKOOA, 2005) and hence are regarded as the most accurate data available.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement, informed by the understanding of the available data, the level of uncertainty that is accepted within the reporting systems (e.g. UK ETS) and the likelihood of error compensation across the UK installations.

The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values.

Uncertainties in fuel use statistics are typically low. However, we note (as outlined above) that there are known data gaps in official statistics across the time-series and less detailed emissions data available for the 1990-1997 period, and hence uncertainties for the estimates in 1990 are higher than for recent years where much more detailed and complete operator-reporting of activity and emissions are evident. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately. Non-CO₂ emissions are dependent on a greater number of parameters and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 3 Manufacturing industries and construction (excluding iron and steel use of derived fuels, and off-road machinery)**Relevant Categories, source names**

1A2a – Iron and Steel (combustion)

1A2b - Non-Ferrous Metal (combustion)

1A2c - Chemicals (combustion)

1A2d - Pulp, Paper and Print (combustion)

1A2e - Food & drink, tobacco (combustion)

1A2f - Cement production – combustion, Lime production - non decarbonising,

1A2gviii - Other industrial combustion, Autogeneration - exported to grid, Autogenerators

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Biomethane, Burning oil, Coal, Coke, Coke oven gas, Colliery methane, Fuel oil, Gas oil, Liquefied Petroleum Gas (LPG), Lubricants, Natural gas, Other Petroleum Gas (OPG), Petroleum coke, Solid smokeless fuel (SSF), Waste, Waste oils, Waste solvent.

Background

This MS covers the use of fossil and biogenic fuels for heat and power production in industry. Estimates cover fuel used throughout industry and including from both large and small installations. Larger installations are included in the UK ETS (2021 onwards) and EU ETS (2008 – 2020), but there are large numbers of small industrial plants which are not. Sectoral emissions for iron and steel, non-ferrous metal, chemical, paper, food and drink, and mineral industries are reported under 1A2a to 1A2f. Emissions for fuel use that cannot be allocated to these industries are reported under 1A2g.

According to the 2006 IPCC Guidelines (GLs), electricity generation by companies primarily for their own use is autogeneration, and the emissions produced should be reported under the industry concerned. However, most National Energy Statistics (including those of the UK) report fuels used by industry for electricity generation as a separate category. The UK statistics for autogeneration covers all industry sectors in a single figure for each fuel. The UK inventory attempts to report this as far as possible according to the IPCC methodology by placing emission estimates in 1A2g.

The sectoral estimates reported under 1A2a to 1A2g include fuels reported in the national energy statistics for 'heat generation'. These are fuels that are used by sites that generate heat for other users e.g. many UK paper mills, and chemical manufacturers are supplied with steam from a separate combustion plant run on a neighbouring site by a different operator. The re-allocation from the heat generation category to industry sectors is made using estimates provided as an Annex to DUKES (DESNZ, 2025a).

Key Data sources

- Activity Data: DUKES (DESNZ, 2025a), cement sector fuel use estimates (MPA, 2025) and installation-specific activity data from UK ETS e.g. for lime kilns (EA, SEPA, NRW, NIEA, all 2025).
- Emission Factors: Where available, operator-reported EFs from UK ETS are used for high-emitting source sectors. Other UK CS CEFs are taken from the 2004 Carbon Factors Review (Baggott et al., 2004). Defaults for non-CO₂ gases are derived from IPCC (IPCC 2006).

*An accompanying document “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references. **Table 1.4** gives additional information for common activity data sources.*

Method approach

For most source estimates, the inventory method uses national energy statistics and applies country-specific factors for CO₂ (Tier 2), and default factors (typically from IPCC) for other gases (Tier 1).

DUKES provides most of the energy activity statistics, including a breakdown between industrial combustion categories (although the level of granularity across the time series is not consistent). A number of approaches are used to fine tune the allocation of energy use under the different subcategories to maximise consistency with other datasets such as UK ETS, industrial data (e.g. from trade associations) and other estimates in the GHG inventory (e.g. the off-road machinery model). These approaches are listed below:

- Fuel use in cement kilns (1A2f) is collected from process operators, via the Mineral Products Association (MPA). These data are not complete for the earlier part of the time series, so some assumptions have to be made to fill these gaps (see assumptions). Reallocations are sometimes made between cement and other subcategories compared with DUKES, to account for known fuel uses;
- Fuel use in lime kilns (1A2f) is estimated based on EU and UK ETS data. All lime kilns are included in the scope of EU ETS from 2008 – 2020, and in the UK ETS from 2021, so there is a full set of fuel data for 2008-2024, with incomplete data for the years 2005-2007. For the earlier part of the time-series, fuel use is estimated by extrapolation from the EU ETS data using lime production estimates;
- Balancing of energy consumption data between 1A2 and other source categories, to accommodate source-specific AD from other data sources (e.g. operator data, UK and EU ETS) in preference to DUKES data. Key examples of fuel re-allocations in 1A2 are: AD for natural gas for gas network operators (i.e. gas use re-allocation between 1A2 and 1A1c); AD for oils for power stations (i.e. gas and fuel oil re-allocations between 1A2 and 1A1a);
- Analysis of UK and EU ETS data indicates that there are several installations which use petroleum coke as a fuel, where there is no such allocation of petroleum coke as a fuel for that source in DUKES. The Inventory Agency therefore re-allocates some petroleum coke from the non-energy use estimate in DUKES to address this reporting discrepancy and align emission estimates in 1A2f and 1A2g with UK and EU ETS. This re-allocation increases the overall reporting of petroleum coke as an emissive energy use, deviating from DUKES;
- Analysis of UK and EU ETS data has identified several chemical and petrochemical manufacturers that utilise carbon-containing process off-gases and residues as fuel sources. Consultation with industry and with the DESNZ energy statistics team has clarified that in DUKES the delivery of feedstock materials to chemical and

petrochemical sites are reported as non-energy use, with no subsequent reporting in DUKES of the use of process off-gases as an energy source in these industries. The ETS data are therefore used to derive inventory estimates to account for this use of feedstock-derived process gases, which are reported as “other petroleum gas” use within the inventory, in addition to DUKES allocations to fuel use in these sectors. However, in accordance with the 2006 GLs, these emissions are reported under source category 2B8 (see IPPU chapter) rather than 1A2; and,

- Separation of gas oil used for stationary and mobile machinery is based on data on populations of mobile equipment, or train or ship movements etc. The approach developed for allocating gas oil between different source categories is described in **Annex 5.2**.

Emission factors for carbon are almost exclusively derived from country specific data. Site-specific data, (including both UK / EU ETS data, and data provided by process operators directly or via industrial trade associations) is aggregated up to generate factors for a small number of sectors. Sector-wide factors are derived in other cases based usually on the methods described in Baggott *et al*, 2004.

In the case of coal-fired autogeneration, EU ETS-based factors are available for 2005-2011. This sector was dominated by a single plant that supplied electricity to a large aluminium smelter until 2012. Originally, the UK inventory used a combination of EU ETS factors for 2005 onwards, and factors from Baggott *et al*, 2004 for earlier years but this resulted in a large step change in the emission factor between 2003 and 2005. The Inventory Agency reviewed the EU ETS data for the one installation (Lynemouth smelter), which exhibits a very stable CEF across all reported years (2005 to 2011) and concluded that it was very unlikely that this plant would have used significantly different quality coal in 2003 from that used in 2005. Therefore, to improve the inventory time series consistency, the Inventory Agency now extrapolates CEFs from the EU ETS back to 1990 and applies the 2011 value for subsequent years.

Emission factors for waste oils are based on the analysis of 8 samples of waste oils collected from UK sites in 2003. The factors for coke and other manufactured fuels are based on carbon balance approaches (see **MS 4** for coke). Emission factors for methane and nitrous oxide are largely IPCC defaults. An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶

Assumptions & observations

There is no breakdown of fuel use for the cement sector available for 1991-1999, and therefore fuel use is estimated for these years by interpolation of data between 1990 and 2000, considering changes in cement clinker production in each year. Combined Heat and Power (CHP) systems where all of the electricity is fed into the public supply are classified as power stations and excluded from estimates described here.

Allocation of industrial electricity generation:

- The UK’s statistical data for autogenerators relate to fuels used for electricity generation by companies primarily for their own consumption. This includes CHP systems where electricity is used by the generator. The UK methodology allocates all autogeneration to 1A2g (as no other sub-categorisation is available). Coal use by autogenerators was previously allocated to 1A2b since until 2013, almost all of the coal is known to have been used in a power station operated by an aluminium producer, which supplied electricity to their smelter operation. The smelter closed in 2012 and since then the power station has supplied electricity to the national grid and coal used at that site is now allocated to 1A1a. This autogenerator coal use is now allocated to 1A2g, for consistency with reporting for other fuels.

- The large change in the quantity of coal burnt by autogenerators between 2012 (when consumption was over 1,000,000 tonnes) to 2013 (33,000 tonnes) and then 2014 onwards (less than 20,000 tonnes) has a marked impact on the time-series for the CH₄ IEF reported for 1A2gviii in the CRT. Since the factors applied for autogeneration and non-autogeneration use of coal are quite different, there are large step changes in the time-series over the 2012-2015 period as a result.

Recalculations

Revisions to DUKES impact emissions in 1A2, notably there have been revisions to natural gas allocations across all categories.

The improvements described below have led to time series changes for gas oil and transparency changes for 'natural gas'.

Improvements (completed and planned)

Key improvements impacting sources within this category are:

Time series improvements to the category allocations for gas oil. Improvements have been made to the time series consistency of gas oil allocations throughout the inventory. This was to address known time-series inconsistencies in DUKES between 1997 and 1998, and between 2008 and 2009 where methodology changes in DUKES were not applied to older years' data.

The DUKES team have made significant improvements to the gas oil allocations to end use sectors for 2009 onwards. For example, the unclassified (i.e. fuel that the energy statistics team cannot identify an end user for) gas oil use falls from 33% to 9% between 2008 and 2009. So, the Inventory Agency has assumed that the 2009 onwards trends are a robust basis to determine while older data are time-series consistent. Each sector has been reviewed to determine the likely consistent and inconsistent trends, and gap-filled using a mixture of interpolation and extrapolation methods to maximise the use of data judged to be time-series consistent.

Note that the time series adjustments are done before inputting data into the gas oil reconciliation process (described in **Annex 5.2**).

Separate reporting of emissions from biogas combustion, where the biogas has been supplied via injection into the natural gas grid. The treatment of biogas injected into the natural gas grid has been revised to improve the transparency of reporting. The approach used for this allocation is described in **Section 3.2.6**. The overall impact of this change to total emissions is minimal.

Planned/Ongoing: Emission factors and activity data remain under annual review.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- the comparison of the reference/sectoral approach; and,
- comparison of UK and EU ETS data with DUKES and data direct from industry

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Code of Practice for Statistics*⁵⁷.

The UK ETS data, is subject to its own QA process, defined and managed by the competent authority.

Time series consistency

Differences in data sources across the time series are noted in the method approach section above. The Inventory Agency seeks to identify and address any inconsistencies in the inventory time series, such as those arising from revisions to the energy balance data that may be implemented within DUKES for recent years only, through meetings with the key data providers. The use of carbon EFs derived from the UK and EU ETS, which are available only from 2005 onwards, is considered the best available data for recent years in many source categories; the carbon EF data prior to 2005 were also derived from analysis of UK fuels, either from data submissions from fuel users or fuel suppliers, and so the method is consistent across all years noting that the level of detail, frequency of reporting and QA/QC underpinning the data prior to EU ETS is generally lower than from 2005 onwards, and hence the uncertainty of estimates in the earlier years is higher than for recent years.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately. Non-CO₂ emissions are dependent on a greater number of parameters and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 4 Iron and steel, and coke manufacture**Relevant Categories, source names**

1A1ci: Coke production

1A2a: Iron, and steel - combustion plant coke oven coke only

1B1b: Coke production

Iron and steel - flaring

2C1a: Basic oxygen furnaces

2C1b: Iron and steel – flaring

2C1b: Blast furnaces,

Iron and steel - combustion plant (coke oven gas and blast furnace gas only)

2C1d: Sinter production

Relevant GasesCO₂, CH₄, N₂O**Relevant fuels, activities**

Blast furnace gas, Coal, Coke, Coke oven gas, Coke produced, Colliery methane, Dolomite, Fuel oil, Gas oil, Limestone, Liquefied Petroleum Gas (LPG), Natural gas

Background

This MS covers the carbon balance approach used for integrated steelworks and independent coke manufacture. Integrated steelworks use the blast furnace/basic oxygen furnace route to produce steel from iron ore. It should, however, be noted that due to the recent closures of the coke ovens and the resulting statistical uncertainties with regards to the submitted data to different datasets used for the compilation of the inventory, an alternative approach to the carbon balance has been implemented to account for the flow of material and carbon across the steelworks in the recent years (i.e. 2022-2024).

Most UK coke has historically been produced at coke ovens associated with the UK's integrated steelworks, although one independent coke manufacturer also existed until closure at the end of 2014. The Teesside steelworks was closed in September 2015 and the two coke ovens at Scunthorpe steelworks were closed in early 2016 and mid-2023. At the end of 2024, there were no coke ovens left operating in the UK. The last operational coke oven in the UK was shut in early 2024. Four other coke ovens were in existence in 1990 but closed in the years up to 2005 due to the closure of two integrated steelworks and other coke consumers, such as the UK's only lead/zinc smelter in 1999. **Table 3.6** shows how the numbers of coke ovens and steelworks vary over the period covered by the inventory. Coke production emissions are reported under 1A1ci (combustion) and 1B1b (fugitive).

Table 3.6 Number of coke ovens and steelworks in the UK operating within the years specified

Year	Coke ovens	Integrated steelworks	Electric arc steelworks
1990-1992	10	5	21

Year	Coke ovens	Integrated steelworks	Electric arc steelworks
1993-1995	9	4	21
1996	9	4	20
1997-1998	9	4	18
1999-2001	9	4	17
2002	9	3	17
2003	7	3	14
2004-2005	6	3	12
2006	6	3	11
2007	6	3	10
2008	6	3	7
2009-2010	6	3	6
2011	6	2	6
2012-2014	6	3	5
2015	3	2	5
2016-2020	2	2	5
2021-2022	2	2	4
2023	1	2	4
2024	1	2	4

The carbon balance method described in this method statement covers the use of coke oven coke, blast furnace gas and coke oven gas as fuels throughout the iron and steel industry, whereas the use of primary fossil fuels in boilers and heat treatment or melting furnaces is described in the method statement for 1A2. All fuels used in coke ovens, sinter plant, and blast furnaces are included in the carbon balance. This describes the method used up until 2021.

As highlighted above, the recent closure of the remaining operational coke ovens in the UK has led to statistical uncertainties in the complementing datasets that were historically used as the basis for implementing the carbon balance approach. These statistical uncertainties resulted in emission factors for production of coke breeze, coke oven gas, blast furnace gas and basic oxygen furnace gas for years 2022-2024 that were unrealistic and significantly different from those of the historical trends and IPCC default factors. Therefore, carbon factors for the aforementioned parameters were extrapolated instead from the historical trends with sufficient stability and representativeness. This has resulted in a deviation from the carbon balance approach for years 2022-2024.

The key processes and related emission activities covered by this method statement are summarised below.

1. Coke oven coke is produced by heating coking coal in ovens in order to drive off volatiles which are collected as gases (coke oven gas, used as a fuel to heat the ovens) or liquids (coal tars and benzole, recovered for use in chemicals manufacture and other processes). The solid residue is coke oven coke, which is used as a fuel for sintering, as a reductant in blast furnaces, or sold for use in other industrial processes. Emissions of greenhouse gases resulting from combustion to heat the coke ovens are reported in 1A1c, whereas fugitive emissions of methane from the coke ovens are reported in 1B1b.
2. Integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. Emissions from integrated steelworks are estimated for these three processes, as well as other minor processes such as slag processing.
3. Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter. Emissions from sintering are reported in 2C1d.
4. Blast furnaces are used to reduce the iron oxides in iron ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke, fuel oil and coal. Hot air is blown into the lower part of the furnace and reacts with the reducing agent, producing carbon monoxide, which reduces the iron ore to iron.
5. Gas leaving the top of the blast furnace has a high heat value because of the residual CO content and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. The most significant greenhouse gas emissions to occur directly from the blast furnace process are the combustion gases from the 'hot stoves' used to heat the blast air.
6. These generally use blast furnace gas, together with coke oven gas and/or natural gas as fuels. These emissions are now reported under CRT category 2C1b, in line with reviewer recommendations. Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is lost, and the carbon content of this gas is also reported under CRT category 2C1.
7. Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, some losses occur, and these losses are reported with blast furnace gas losses under CRT category 2C1. In DUKES, basic oxygen furnace gas is combined with blast furnace gas and so separate figures for production and use of the two gases are not given.
8. The fuels derived in coke ovens and integrated steelworks are used in boilers and in heat treatment or melting furnaces and CO₂ emissions from these energy uses are calculated using emission factors derived using the carbon balance.

Key Data sources

Activity Data: Main sources of activity data (fuel use, production data) are DUKES (DESNZ, 2025a), ISSB annual statistics (ISSB, 2025), installation-specific activity data from EU/UK ETS (EA, NRW, both 2025), operator information for integrated steelworks (Tata Steel and British Steel, both 2025)

Emission Factors: Input parameters for the carbon balance method are derived from EU/UK ETS data or operators of integrated steelworks (reference as for AD). Other UK CS CEFs are derived from the 2004 Carbon Factors Review (Baggott et al., 2004). EFs for non-CO₂ gases are predominantly IPCC defaults (IPCC 2006).

*An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. **Table 1.4** gives additional information for common activity data sources.*

Method approach

The carbon balance for the combined coke ovens and integrated steelmaking processes is based on tracking the carbon through four successive stages – coke making, sintering, pig iron production, and basic oxygen steel production. This method has been applied up to year 2021 where the statistical uncertainties of the model were low enough to allow for the application of this method. From 2022 onwards the emission factors for the production of coke breeze, coke oven gas, blast furnace gas and basic oxygen furnace gas were extrapolated from an average value of years 2017-2021 instead of being directly calculated from the carbon balance approach.

At each stage carbon is input as fuels and/or feedstocks; carbon leaves in products; is emitted to air or removed as waste products. The carbon flow description and **Figure 3.1** below presents a simplified version of the model listing main inputs and outputs:

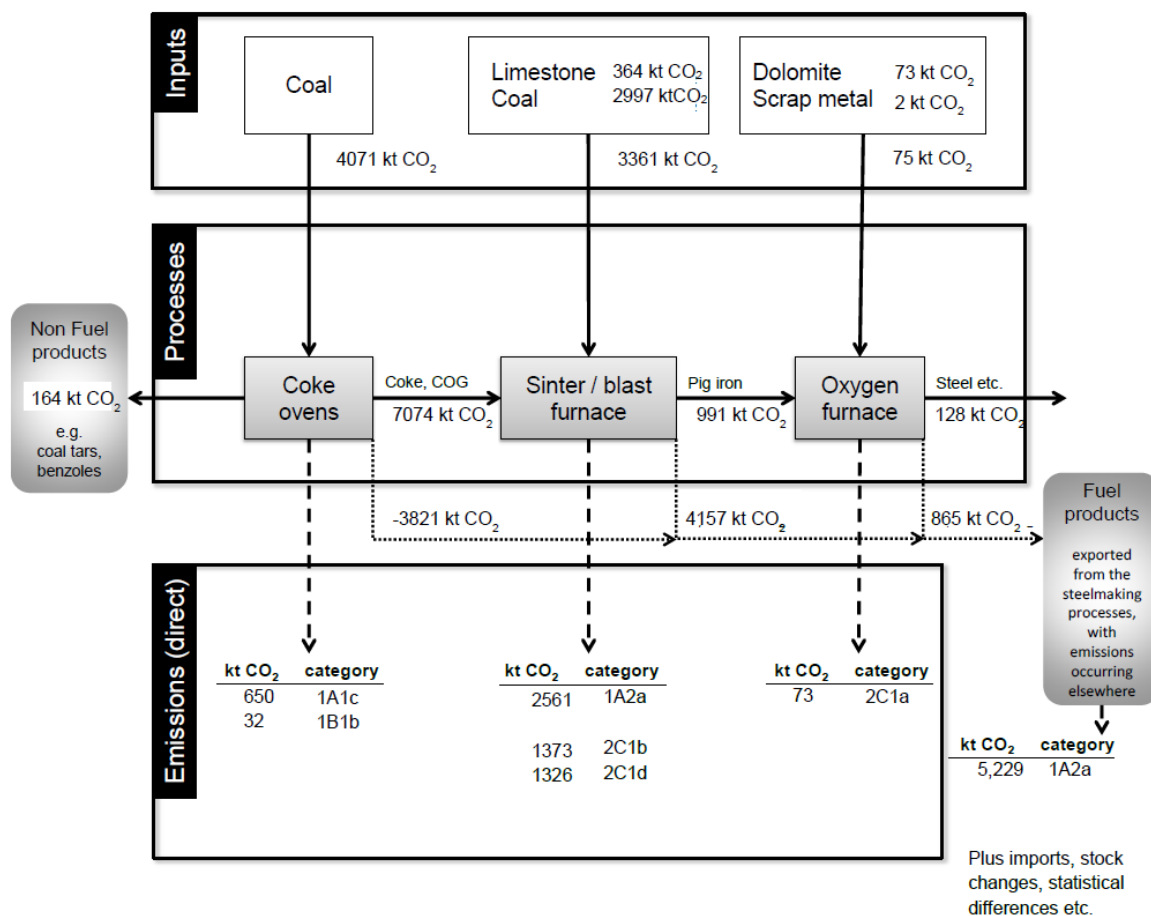
Carbon Flow Description

coal → coke + coke oven gas + benzole & tars + fugitive carbon emission
coke + limestone + iron ore → sinter + carbon emission
sinter + coke + other reducing agents → pig iron + blast furnace gas
pig iron + scrap + dolomite → steel + slag + basic oxygen furnace gas

The outputs that are allowed to vary, and therefore used to ensure that the overall carbon balances, are coke, blast furnace gas and basic oxygen furnace gas.

The carbon balance model used is shown in a simplified form in **Figure 3.1**, with inputs and outputs of carbon (expressed as CO₂) given for the latest year that this method has been fully applied with no deviations in 2021. Note that the negative value in the diagram is because the figures account for imports, exports, and stock changes. For some years, DUKES does not have sufficient coke oven coke to account for all known uses and so the GHGI has to deviate from DUKES by assuming a higher demand for this fuel.

Figure 3.1 Carbon balance model for 2021^a



^a Other adjustments includes statistical differences (+6 kt CO₂), imports (-3414 kt CO₂), exports (0 kt CO₂), stock changes (-620 kt CO₂), fugitive emissions from coke ovens reported as methane (15 kt CO₂), adjustments for natural gas added to coke oven gas (-53 kt CO₂), carbon stored in dusts (+23 kt CO₂).

Emission estimates for limestone and dolomite added to sinter plants, blast furnaces, and oxygen furnaces are based on industry consumption data (Iron & Steel Statistics Bureau, 2025) and carbon contents from the operators (Tata Steel, British Steel, both 2025 and SSI Steel 2015), and based on their UK and EU ETS reporting (EA, NRW, both 2025).

Emissions of CH₄ and N₂O are estimated using IPCC 2006 default emission factors.

Assumptions & observations

A detailed description of the carbon balance methodology has been given in Ricardo-AEA, GHG Inventory Research: Use of EU ETS Data - Iron & Steel Sector, Chemical Industry Feedstock Use, April 2014 (available for download on the NAEI website⁶²) and so only a brief summary of assumptions is given here.

The carbon balance method requires the carbon content in input fuels and feedstocks to be estimated using consumption data and carbon contents for each fuel or feedstock. The balance is then used to distribute that carbon amongst the various derived fuels, products and wastes from the coke ovens and steelmaking processes. The total emission of CO₂ is therefore dependent upon the assumptions made about the quantity of carbon in inputs, and in the main input – coking coal – in particular. The carbon content of coking coal and blast furnace coal

⁶² https://uk-air.defra.gov.uk/assets/documents/reports/cat19/1405081135_GHG_Inventory_Research_Report_EUETS_final.pdf

has, in recent years, been measured by operators as a result of their need to collect data for EU/UK ETS reporting purposes, and operators have also been able to supply high quality measurement-based data for the carbon contents of derived fuels, coal tars, benzole, limestone, dolomite, steel scrap, and steel product. The EU/UK ETS data indicate that the carbon contents of fuels do not vary greatly from one year to another and therefore, for earlier years, where EU/UK ETS data are not available, carbon factors are assumed to be the same as for those years where EU/UK ETS data are available. For each fuel, the average carbon content is calculated for years with EU/UK ETS reporting, and these values then used for the earlier years.

The operators also supply data on the consumption and production of fuels and these data should be consistent with UK energy statistics. This is largely so, but in a couple of instances where the UK statistics seem to underestimate consumption of a particular fuel in a particular year, we have used the operators' data instead. For example, operator data for the consumption of coking coal in coke ovens is mostly lower than the figures given in DUKES, and the operator data are used in preference. The coal consumption figures for other industrial use are also modified by an equal and opposite amount so that overall coal consumption in the GHGI is the same as in DUKES. DUKES also excludes a small quantity of coke oven gas generated at one steelworks which is then supplied as a fuel to a co-located process, and so we have used operator data on this fuel in the inventory. In this case, it would not be appropriate to maintain consistency with overall UK demand figures in DUKES (since this fuel is missing from DUKES, not classified to a different sector). Finally, some small deviations are made for 2009, where operator data on consumption of coal and coke oven coke in blast furnaces are somewhat higher. The changes to coal are treated as misallocations in DUKES (so UK totals for coal consumption are adhered to), whereas for coke oven coke, it is necessary to increase UK consumption to above the level given in DUKES, since coke consumption by known users exceeds the DUKES figure.

Recalculations

There have been minor changes to the underlying energy statistics (DUKES) data that have resulted in minor recalculations for this sector.

There have been changes to the methodology for this version of the inventory that have resulted in recalculations for years 2022-2023. This change particularly concerns parts of the carbon balance approach that resulted in unrealistic emission factors for the production of coke breeze, coke oven gas, blast furnace gas and basic oxygen furnace gas. The methodology has therefore been changed to use on the historical trends for these parameters instead, resulting in a deviation from the carbon balance approach. All input data and assumptions, including the underlying data for the aforementioned parameters, are kept under review for next year.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- the comparison of the reference/sectoral approach;
- comparison of inventory estimates based on the carbon balance, with EU/UK ETS data and detailed emission estimates provided by the operators;
- comparison of DUKES data with industry-reported activity data (e.g. from ISSB);
- comparison of carbon emission factors derived from the carbon balance, with IPCC default emission factors; and,
- checks on the time-series consistency of carbon emission factors generated by the carbon balance method.

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Code of Practice for Statistics*⁵⁷. EU ETS data is subject to its own QA process. A bilateral exchange was undertaken in May 2015 with the Inventory Agency from Germany, which included a review of the revisions to the iron and steel sector method in the 2014 submission.

Time series consistency

All activity data used are available for the full time series of the estimates. Carbon factors for key inputs such as coking coal and blast furnace coal are available from operators only for some recent years (2005-2014 and more recently from 2021-2024 in the case of coking coal, 2007-2014 for other fuels) so the same values must be assumed to be appropriate in earlier years. Data are not available for 2015 to 2020, partly due to the Teesside works closing in September 2015, and the sale of the Scunthorpe works to a new operator in early 2016, so 2014 values for some parameters have been assumed to be correct for 2015-2020 as well. While this does introduce some additional uncertainty for parts of the time-series, the assumed factors for coking coal and blast furnace coal, and the derived factors for coke oven coke, coke oven gas and blast furnace gas for these years are all within the ranges suggested in the IPCC 2006 Guidelines. The approach for the years 2022 – 2024 deviates from the carbon balance approach, using the historical trends for key parameters because issues with the input data meant that the existing methodology is no longer appropriate. The revised method leads to outputs that are more time series consistent with the earlier years, since the anomalies resulting from the issues with the statistics are removed.

Note that the implied emission factor for 1B1b is very sensitive to the weighting of emissions between coke manufacture and other solid fuel transformation; this is discussed further in **MS 19**.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately.

MS 5 Other stationary combustion

Relevant Categories, source names

1A4ai: Miscellaneous industrial/commercial combustion

Public sector combustion

Railways - stationary combustion

1A4bi: Domestic combustion

1A4ci: Agriculture - stationary combustion

Miscellaneous industrial/commercial combustion

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Anthracite, Burning oil, Coal, Coke, Fuel oil, Gas oil, LPG, Natural gas, Peat, Petroleum coke, SSF

Background

This method statement covers emissions from fuel combustion by non-industrial sectors including commercial, agricultural, public and residential sectors. Most stationary plants are small-scale, apart from a few large installations providing energy for large commercial or public sector buildings (e.g. banks, hospitals, schools, sport centres). Emissions from stationary railway sources are reported under 1A4a where the fuel is used in stationary combustion of burning oil and fuel oil to heat buildings, as well as natural gas combustion. This gas usage may include fuel used for electricity generation for own use by the railway sector. The 'miscellaneous' source includes energy use by a range of other users including the sewage and refuse disposal sector, and fuels used by television and radio broadcasters.

Key Data sources

Activity: DUKES (DESNZ, 2025a)

Emission factors: Baggott et al., 2004, IPCC, 2006

An accompanying spreadsheet "Energy_background_data_uk_2026.xlsx" lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

Emissions for this category are calculated based on multiplying activity data by an emission factor. Activity data are taken directly from DUKES, with a few exceptions (see assumptions and observations). A full list of emission factors is included in **Annex 5.1**. Carbon emission factors are largely UK specific, whereas non-CO₂ emissions use default emission factors.

To improve the accuracy of emissions estimates for air quality pollutants, fuel use in domestic appliances is modelled to account for the ages and types of appliances used. However, for greenhouse gases, a single emission factor is applied across all appliance types, and the total modelled fuel use is normalised to DUKES. As such the method applied to model the fuel use

by appliance type is not detailed here but is described in the UK's Informative Inventory Report (Elliott et al., 2026).

Assumptions & observations

The source representing public sector combustion includes emissions from stationary combustion at military installations, which should ideally be reported under 1A5a Stationary. However, we do not currently have separate data for the military fuel component.

Bottom-up estimates are made for a number of categories using gas oil (railways, off-road machinery etc.). In order to reconcile the gas oil used in these categories with the total in DUKES, reallocations (subtractions) are made from other categories, including AD used for the estimates of emissions from stationary combustion in 1A4. These deviations from DUKES are presented in **Annex 5.2**.

Activity data estimates for domestic sector use of fuels derived from petroleum coke are based on estimates provided by industry experts (CPL, 2025).

Estimated emissions from the combustion of peat are calculated based on peat extraction estimates, formerly taken from the UK Minerals Yearbook (BGS, 2015) up to 2014. From 2015 onwards, estimates are made for Scotland based on information provided by Scottish Government (Pers. Comm, 2024). Estimates for Northern Ireland are from Tomlinson (2010), and are for hand cutting only. Peat is not included as a fuel in DUKES.

Recalculations

Revisions to DUKES and other input data have been incorporated into the inventory.

There are recalculations to peat, gas oil, and natural gas as a result of the improvements described below.

The impact of changes is set out in **Chapter 10**.

Improvements (completed and planned)

The method for calculating emissions from peat combustion has been reviewed and updated. A literature review of peat assumptions was conducted for 5 main peat types (e.g. air dried, fuel-grade, and dry matter), considering:

- a) Moisture content
- b) Carbon content (on a calorific, volume, and mass basis)
- c) Density
- d) Calorific value
- e) If data are UK-specific or international values

As a result, we have:

- Adopted a much higher calorific value than the IPCC default (which appears to be representative of air-dried peat, but not fuel peat), increasing activity data when expressed in TJ (net), and therefore almost doubling emissions for many pollutants (*the emission factors for which are per unit TJ (net); emission factors that are per unit mass burned will have an equal and opposite unit conversion to the activity data and therefore no impact on emissions*).
- Aligned much more closely to the UKCEH estimates of carbon content in fuel peat extracted from Northern Ireland, leading to a 20% increase in CO₂ emissions from this peat.

Categories included in this MS are also impacted by time series improvements for gas oil (described in **MS 3**), and improvements to the reporting of biogas in the natural gas grid, where the approach used for this allocation is described in **Section 3.2.6**.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Fuel combustion estimates are verified through the comparison of the reference and sectoral approaches.

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Official Statistics Code of Practice*⁵⁷.

For gas oil, bottom-up estimates are made for various sources, which leads to changes in the sectoral allocations within DUKES. There are no official top-down statistics to verify the bottom-up statistics, however, the totals are reconciled with DUKES. Petroleum coke and peat data are outside of DUKES but are small emission sources included for completeness.

Time series consistency

Emission factors and activity data are taken from consistent data sets; there are no time series consistency issues to note.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. There are no additional official statistics to compare the category specific fuel use for 1A4 with, as such it is difficult to verify the activity data allocations in DUKES. As such the uncertainty for the sources included in this MS will be higher than for power stations, for example. Uncertainties in total fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately. Non-CO₂ emissions are dependent on a greater number of parameters and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 6 Off-road machinery**Relevant Categories, source names**

1A2giii : Mining and Quarrying

1A2gv : Construction machinery

1A2gvii: Generators, Waste, and Other Industrial machinery

1A3eii : Aircraft - support vehicles, Refrigerated Transport, Sea Ports

1A4aii : Forklifts

1A4bii : House and garden machinery

1A4cii : Agriculture/Forestry/Fishing - mobile machinery

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

DERV, Gas oil, Petrol, LPG

Background

In 2022 Defra commissioned Ricardo to conduct a detailed Government-supported machinery population and usage survey with industry stakeholders, including evaluating the findings for their use in the inventory. Following review, agreed implementation of the data into an updated version of the off-road machinery model has been conducted, containing revised activity and population data. **As such, there are now two models**, the previous approach covering house and garden machinery and forestry machinery, and the current model for all other off-road machinery.

Emissions are estimated for different types of portable or mobile equipment powered by diesel, gas oil, LPG, or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers and aircraft support equipment. In the inventory they are grouped into the following main categories:

- Mining and quarrying – reported under 1A2giii;
- Aircraft support machinery, Sea Port machinery, and Refrigerated Transport – reported under 1A3eii;
- Construction – reported under 1A2gv;
- Generators, Waste, and Other Industry – reported under 1A2gvii
- Forklifts– reported under 1A4aii;
- Domestic house & garden – reported under 1A4b; and
- Agricultural machinery (includes forestry) – reported under 1A4c.

Key Data sources

Activity: Netcen, 2004, ONS, DfT, Eurostat, UKMY, OHEEG (2021), AEA, BEIS Projections (personal communication), CAA, Forestry Research

Emission factors: Baggott et al., 2004, EMEP/ EEA Guidebook, EU Non-Road Mobile Machinery Directive.

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. **Table 1.4** gives additional information for common activity data sources.

Method approach - House and Garden Machinery and Forestry Machinery (1A4bii, 1A4cii)

A Tier 3 methodology is used for calculating emissions from individual types of house and garden machinery and forestry machinery. Default machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from EMEP/ EEA Guidebook. For methane, emission factors for more modern machinery based on engine or machinery-specific emission limits for total hydrocarbons established in EU Non-Road Mobile Machinery Directive are also included where available. The measures introduced to reduce total hydrocarbon emissions are assumed to affect methane emissions. Activity data are based on bottom-up estimates of machinery numbers and hours of use in 2004 (Netcen, 2004). Various proxy statistics are used as activity drivers for different groups of machinery types to estimate fuel consumption across the full time-series. UK households statistics (ONS, 2025) are used as drivers for activity of house and garden machinery, and forestry statistics (Forest Research, 2025) are used as activity drivers for forestry machinery.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery. The emission estimates are calculated using a modification of the methodology given in EMEP/ EEA Guidebook (2009).

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by the Inventory Agency on behalf of the Department for Transport (Netcen, 2004). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel and petrol powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used. The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. **Table 3.7** below details the drivers used for domestic house and garden machinery and forestry machinery.

Table 3.7 Activity drivers used for domestic house and garden, and forestry off-road machinery

Category	Driver source	Machinery types
Domestic house and garden	Office for National Statistics - Labour Force Survey (LFS) Table 5: number of households by size	All types of garden equipment, e.g. lawn mowers, garden tractors, leaf blowers, chain saws, trimmers
Forestry	Forest Research statistics – UK Wood production	Specialised equipment designed for forestry operations (typically larger engines and professional-grade machinery), e.g. fellers, bunchers, chain saws, shredders

A simple turnover model is used to characterise the population of house and garden machinery and forestry machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP/ EEA (2009) though a few of the more obscure classes

were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004). For the air pollutants and for those equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in terms of how they apply to different machinery types. Each of the different machinery types was mapped to the relevant regulation in terms of implementation date and limit value. The trends in total hydrocarbon (THC) emissions across the emission regulation stages were applied to the trends in methane emissions as it is assumed that measures to control THC emissions will also impact methane emissions.

Method approach – all other Off-Road Machinery (Industrial, Airports, Agriculture (1A2gvii, 1A4cii, 1A3eii))

Databases and information for the current model were provided by industry trade associations and stakeholder groups including the Off Highway Engine and Equipment Group (OHEEG) the Agricultural Engineers Association (AEA), Department for Transport (DfT) and the Construction and Agriculture Equipment Security and Registration (CESAR) database, and though these data were not designed for use in inventories, they provided valuable information.

Machinery or engine-specific fuel consumption and emission factors (g/kWh) in the new model are based on stakeholder consultation and the 2019 EMEP/EEA Guidebook. The AEA were able to provide fuel consumption rates for different agricultural machinery types in litres per hour based on telemetry data. Exception were agricultural telehandlers which were adjusted to align with fuel consumption rate implied by Guidebook factors.

The current model was designed in 'R', an open-source software to accommodate the new activity data and used to calculate an estimate of emissions. Using activity data collated from OHEEG, AEA, DfT licensing statistics supplemented by various assumptions from expert judgement from discussions with AEA where data are missing, the model was constructed and used to calculate trends in fuel consumption and emissions, initially from agricultural machinery and then extended to other off-road machinery (excluding house and garden).

Inventories for these machinery were grouped into portable generators, construction machinery, forklifts, machinery used in mining & quarrying, waste services, airport support and seaport support machinery and Transport Refrigeration Units (TRUs). Nearly all types of machinery use gas oil, but for some machinery types, a further breakdown in consumption and emissions is provided for machines running on petrol and LPG, where relevant.

In the case of portable generators, cement mixers, cranes and various lifting equipment used in construction and industry, data from Eurostat PRODCOM statistics on sales/production of these equipment were used. ONS construction statistics and DESNZ energy statistics for other types of construction and industry machinery continue to be used.

- Confidential data provided by the British Industrial Truck Association (BITA) have been adopted for trends in sales of forklifts.
- For airport machinery, statistics on number of terminal passengers at UK airports continue to be used.
- DfT port freight statistics have been used as proxies for trends in activities for machinery used in sea ports.
- Trends in TRU activities were based on DfT statistics on licensed "insulated vans" vehicle category.

In the current model, emissions from off-road agricultural machinery are calculated using the Tier 3 method in the EMEP/EEA Emissions Inventory Guidebook 2019 (The latest 2023 Guidebook does not contain any relevant changes, thus the model method remains unchanged). The equation to calculate the emissions is given below:

$$E = N \times HRS \times P \times LF \times (1 + DFA) \times LFA \times EFB_{base}$$

where:

E = mass of emissions of pollutant during inventory period (g),

N = number of engines (units),

HRS = annual hours of use,

P = engine size (kW),

LF = load factor,

DFA = deterioration factor adjustment,

LFA = load factor adjustment,

EFBase = Base emission factor (g/kWh).

The emission factors are taken from the 2019 Guidebook, as provided for different legislative stages and engine power ratings. The exception to this was for the smallest and largest machinery in the power bands <19 kW or greater than 560 kW for the other machinery types. For these machines, OHEEG noted that although off-road in these power classes were unregulated in Europe prior to Stage V (which was incorporated into the new model), nevertheless it was common for machines in these size classes to be fitted with engines suitable for the US market, with the exception of >560 kW gensets. Thus, a significant proportion will have lower emissions than might be assumed for 'unregulated' engines as provided in the Guidebook. Thus, emission factors were changed to reflect US Tier 2 or Tier 4 regulations prior to Stage V. Tier 2 machines were phased into the market from 2006 for machinery for >560kW. Tier 4 is phased in from 2008 for those machines <19kW.

In contrast to the previous approach, in the current off-road model, machinery can be grouped into more than one of eight sector types (excluding house & garden which remains in the previous approach), based on stakeholder feedback. Each machinery type can be placed into eight power bands from P < 8 to P > 560, where P is power in kW. **Table 3.8** summarises the machinery types and sectors in the new off-road model.

Table 3.8 Machinery types and sectors in off-road model

Machinery Type	Sector							
	Construction	Waste	Mining Quarrying	Airport	Port	Other	Refrigeration	Agriculture
Trencher / mini excavator	√							
Excavator	√							
Forklifts	√	√	√		√	√		
Telehandlers	√	√	√		√			

	Sector							
Machinery Type	Construction	Waste	Mining Quarrying	Airport	Port	Other	Refrigeration	Agriculture
Rough terrain forklifts	√		√					
Dumpers / tenders	√		√			√		
Rollers	√							
Cement & mortar mixers	√							
Cranes	√				√			
Rubber tyred gantry cranes					√			
Pumps	√							
Air compressors	√							
Gas compressors						√		
Bore / drill rigs	√		√					
Plate compactors	√							
Landfill compactors		√						
Loaders	√	√	√					
Bulldozers	√	√	√					
Asphalt / concrete pavers	√							
Generators	√					√		
Scrapers	√							
Graders	√							
Crushing / processing equipment	√		√					
Aerial Lifts	√		√			√		

	Sector							
Machinery Type	Construction	Waste	Mining Quarrying	Airport	Port	Other	Refrigeration	Agriculture
Sweepers / scrubbers	√	√						
Welding equip	√		√			√		
Concrete / industrial saws	√							
Pressure washers	√					√		
Tampers / rammers	√							
Aircraft support equip				√				
Terminal tractors				√				
Reachstackers					√			
Shuttle carrier / Straddle carrier					√			
Terminal tractors - port					√			
Industrial tractors, burden and personnel carriers						√		
Other material handling equip						√		
Bitumen Applicator						√		
Aggregate Applicator						√		
TRUs							√	
Other general industrial equip						√		
Paving equip	√							

	Sector							
Machinery Type	Construction	Waste	Mining Quarrying	Airport	Port	Other	Refrigeration	Agriculture
Surfacing equip	√							
Concrete pumps	√							
Agricultural machine								√
Agricultural tractor								√
Agricultural telescopic handler								√
Combine harvester								√
Forage harvester								√
Root crop harvester								√
Sprayer								√
Windrower								√

^[1]<https://www.ons.gov.uk/businessindustryandtrade/manufacturingandproductionindustry/bulletins/ukmanufacturerssalesbyproductprodcom/2021results>

^[2] <https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/datasets/outputintheconstructionindustry>

^[3] <https://www.caa.co.uk/data-and-analysis/uk-aviation-market/airports/uk-airport-data/>

^[4] <https://www.gov.uk/government/collections/maritime-and-shipping-statistics>

^[5] Private communication

Assumptions & observations

The assumptions made to estimate emissions from this source are described in the methods and approach section above. The drivers chosen are considered by expert judgement to be most appropriate among all the statistical data that are available. A fuel reconciliation procedure is followed for gas oil which takes account of consumption from all sources, as described in **Annex 5.2**.

Recalculations

The main recalculations in the off-road machinery sector are as a result of gas oil recalculations across the time series of 2009-2023, due to improvements in the time series assumptions and allocations. This impacts the time series as a consequence of the complex fuel reconciliation for gas oil.

Time series recalculations in forestry machinery is due to the update of a proxy driver for forestry.

Improvements (completed)

Defra have commissioned Ricardo to conduct a detailed Government-supported machinery population and usage survey with industry stakeholders and evaluating the findings for their use in the inventory.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

An expert judgement quality check has been done to verify that the amount of gas oil used by off-road machinery estimated from the bottom-up approach is neither excessively high nor low as a proportion of total UK gas oil available for consumption as given in DUKES.

Time-series consistency

Although the bottom-up data for machinery population and usage is only available for one year, the proxy statistics used to generate the time-series are consistent across the time-series.

Uncertainties

Fuel consumption by these off-road machinery sources is not provided in DUKES and so is estimated for each machinery type from a bottom-up Tier 3 approach to derive machinery population and usage rates. An overall fuel balance taking account of consumption by other uses of gas oil, diesel and petrol ensures consistency with total consumption figures in DUKES. Various proxy data are used to establish a consistent time-series in activity rates, as explained in this section.

The highest uncertainties are considered to be in the estimates for general industrial machinery as these cover a wide range of machinery types with multiple use applications, e.g. portable generators. Uncertainties in the trends for the other off-road sources (domestic house and garden, airport machinery and agricultural machinery) are considered to be smaller and less biased by the choice of proxy data.

MS 7 Aviation**Relevant Categories, source names**

1A3a: Aviation

1D1a: International bunkers - Aviation

Relevant GasesCO₂, CH₄, N₂O**Relevant fuels, activities**

Aviation turbine fuel (jet kerosene), Aviation spirit (aviation gasoline), Sustainable Aviation Fuel (SAF)

Background

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation are recorded as a memo item and are not included in national totals. Emissions from both the Landing and Take-Off (LTO) phase and the Cruise phase (including climb and descent) are estimated. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. The method reflects differences between airports and the aircraft that use them. In addition to aircraft main engines exhaust, emissions from aircraft auxiliary power units are also included. A full description is given in Watterson *et al.* (2004). The method used to estimate emissions from military aviation can be found in **MS 14**.

Key Data sources

Activity data: CAA (2025a); CAA (2025b); DESNZ (2025a); DfT (2025)

Emission Factors: Baggott et al. (2004); EMEP/EEA (2019); IPCC (1997); IPCC (2006)

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. In addition, Annex 5.1 includes a table to map all aircraft types evident in UK activity data from the CAA to the EMEP/EEA Guidebook aircraft categories.

Table 1.4 gives additional information for common activity data sources.

Method approach

Estimates are based on IPCC Tier 3 method and use the number of aircraft movements broken down by aircraft type at each UK airport together with UK energy statistics.

Activity data

The methods used to estimate emissions from aviation require the following activity data:

- Aircraft movements and distances travelled**

Detailed activity data has been provided by the UK Civil Aviation Authority (CAA). These data include aircraft movements broken down by: airport; aircraft type; whether the flight is international or domestic; and the next/last POC (port of call) from which sector lengths (great circle) have been calculated. The data covered all Air Transport Movements (ATMs)

excluding air-taxi. The CAA also compiles summary statistics at reporting airports, which include air-taxi and non-ATMs.

- **Inland Deliveries of Aviation Turbine Fuel, Aviation Spirit, and Sustainable Aviation Fuel (SAF)**

Total inland deliveries of aviation spirit, aviation turbine fuel and Sustainable Aviation Fuel (SAF) to air transport are given in DUKES (DESNZ, 2025a). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of Aviation Turbine Fuel and Aviation Spirit by the Military**

These data are supplied by the Ministry of Defence (MoD). Military aviation estimates are included in **MS 14**. The data for total fuel use for military aviation is used in the normalisation to the DUKES total.

Calendar year activity data are derived from the data sources described above.

Table 3.9 Aircraft Movement Data: LTOs and Cruise distances for Domestic and International Flights from UK Airports, 1990-2024

Year	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	460.1	377.3	652.0	116.4
1995	530.9	365.3	849.0	118.3
2000	704.3	407.2	1190.7	145.2
2005	800.5	488.2	1447.6	178.7
2010	734.0	393.9	1395.1	146.3
2015	821.7	356.0	1565.8	135.0
2016	874.6	349.5	1675.5	133.7
2017	903.2	349.3	1751.7	135.2
2018	911.6	340.9	1803.9	130.8
2019	911.9	326.9	1818.4	126.5
2020	367.3	135.8	731.7	48.7
2021	322.5	149.0	673.4	56.9
2022	708.3	221.8	1457.5	87.7
2023	813.0	243.9	1729.1	98.5
2024	860.0	246.0	1853.9	100.0

Gm: Giga metres, or 10⁹ metres

Estimated emissions from aviation are based on data provided by the CAA and, for overseas territories, the DfT.

Gm flown calculated from total flight distances for departures from UK and overseas territories airports.

Emission factors used

A combination of national airport specific LTO factors (derived from local airport studies) and EMEP/EEA Eurocontrol cruise factors for generic aircraft are used.

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including aviation, and associated references. Carbon emission factors are country specific, whereas defaults are used for other gases.

Method

The basic approach to estimating emissions from the LTO cycle is as follows. The contribution to aircraft exhaust emissions (in kg) arising from a given mode of aircraft operation (see list below) is given by the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second) and the emission factor for the pollutant of interest (kg pollutant per kg fuel).

The annual emissions total for each mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year. The time in each mode of operation for each type of airport and aircraft has been taken from individual airport studies. The time in mode is multiplied by an emission rate (the product of fuel flow rate and emission factor) at the appropriate engine thrust setting in order to estimate emissions for phase of the aircraft flight. The sum of the emissions from all the modes provides the total emissions for a particular aircraft journey. The modes considered are:

- Taxi-out;
- Hold;
- Take-off Roll (start of roll to wheels-off);
- Initial-climb (wheels-off to 450 m altitude);
- Climb-out (450 m to 1000 m altitude);
- Approach (from 1000 m altitude);
- Landing-roll;
- Taxi-in;
- Auxiliary Power Unit (APU) use after arrival; and
- APU use prior to departure.

Departure movements comprise the following LTO modes: taxi-out, hold, take-off roll, initial-climb, climb-out and APU use prior to departure.

Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

Aircraft often take-off at reduced thrust (i.e. less than 100% thrust). Thrust setting for Take-off roll, Initial-climb, and Climb-out depend on airport and aircraft type and are derived from local airport studies. Thrust setting during Approach are 15% for the initial phase (above 600 ft) and 30% for the final phase (below 600 ft). Depending on airport and aircraft type, the Landing-roll often includes periods of reverse thrust at either at idle or 30%, the remainder of the time is at idle thrust setting. Other modes (Taxi and Hold) are at idle thrust. Idle thrust is nominally 7%, however an adjustment is made to the idle fuel flow to account for engine specific variations.

The approaches to estimating emissions in the cruise are summarised below. Cruise emissions are only calculated for aircraft departures from UK airports (emissions therefore associated with the departure airport), which gives a total fuel consumption compatible with recorded deliveries of aviation fuel to the UK. This procedure prevents double counting of emissions allocated to international aviation.

The EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2019) provides fuel consumption and emission data for non-GHGs (NO_x, HC and CO) for a number of aircraft

cruise modes (climb cruise and descent). The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP/EEA Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data has been assigned to a generic type in the Guidebook. Details of this mapping are given in **Table A 5.1.2** in **Annex 5.1.1.4**.

Piecewise linear regression has been applied to these data to give fuel consumption as a function of distance:

$$FC\_Cruise_{d,g,p} = m_{g,p} \times d + c_{g,p}$$

Where:

$FC\_Cruise_{d,g,p}$	is the fuel consumption in cruise of pollutant p for generic aircraft type g and flight distance d (kg)
g	is the generic aircraft type
p	is the pollutant (or fuel consumption)
$m_{g,p}$	is the slope of regression for generic aircraft type g and pollutant p (kg / km)
$c_{g,p}$	is the intercept of regression for generic aircraft type g and pollutant p (kg)

Estimates of CO₂ were derived from estimates of fuel consumed in the cruise (see equation above) and the carbon contents of the aviation fuels. Methane emissions are believed to be negligible at cruise altitudes (IPCC, 2006).

Estimates of N₂O have been derived from an emission factor recommended by the IPCC (IPCC, 1997)⁶³ and the estimates of fuel consumed in the cruise (see equation above).

The estimates of aviation fuels consumed in the commodity balance table in the DESNZ publication DUKES are the official statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. Air-taxi and non-ATM fuel consumption estimates are not documented by Watterson *et al.* (2004), as this revision to methodology occurred after publication of the report. The aviation fuel consumptions presented in DESNZ DUKES include the use of both civil and military fuel, and the military fuel use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil aviation fuel consumption has been used in the fuel reconciliation. Emissions from flights originating from the overseas territories have been excluded from the fuel reconciliation process as the fuel associated with these flights is not included in DUKES. Emissions will be re-normalised each time the aircraft movement data are modified or data for another year added.

⁶³ T1 cruise factors in the 2006 IPCC Guidelines are not in units consistent with our methodology, and T2 LTO factors in the 2006 IPCC Guidelines are based on IPCC 1997 values anyway.

For aviation turbine fuel reconciliation is quite close; pre-normalised fuel estimates generally agree with DUKES within 5%. However, the reconciliation for aviation spirit is poor due to limited coverage of smaller flights by the CAA dataset.

Assumptions & observations

The following modifications are made to the CAA data in order to ensure complete geographical coverage of the inventory and full compliance with the IPCC definitions of domestic and international:

- Flights between the UK and overseas territories are reclassified from international to domestic;
- International flights with an intermediate stop at a domestic airport are considered international in the CAA aircraft movement data. These are reclassified as having a domestic leg and an international leg in response to a recommendation from the UNFCCC centralised review in 2013; and
- The CAA data have been supplemented with data on flight schedules from overseas territories, supplied by DfT.

Recalculations

There were revisions due to the adoption of cruise factors from the 2023 EMEP/EEA Guidebook, affecting most aircraft types and all years. These revisions also had an impact on the LTO emissions via the mass balance.

There were minor revisions to the SAF data reported in DUKES in 2023. Data were also available from the 2023 Heathrow inventory, replacing previously rolled data from 2022.

Improvements (completed and planned)

A number of improvements have been made to the model over recent years, to include findings from UK specific research. The 2024 inventory submission included improvements resulting from the adoption of taxi times from the 2023 EMEP/EEA Guidebook, and the introduction of SAF (Sustainable Aviation Fuel) as a new fuel type to reflect the addition of aviation biofuel use data in DUKES.

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time series consistency

Consistent data sets and methods are used across the full time series to ensure time series consistency. There was a dramatic reduction in aviation activity in 2020 and 2021 as a result of the COVID-19 pandemic.

It should be noted that since emissions of methane from engines consuming aviation spirit vary significantly, and that total use of this fuel in aviation is low, the time-series of implied emission factors of methane is subject to large year-on-year variations, including a notable change in methane IEF between 2009-2010.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The carbon emission factors are based on UK specific data. Since there is a direct link between the carbon emitted and the carbon content of the fuel, it is possible to estimate CO₂ emissions accurately. Non-CO₂ emissions are dependent on a greater number of parameters and are largely based on defaults. As such, the uncertainties are higher, but since the emissions are smaller, this does not have a significant impact on the overall uncertainty of total GHG emissions.

MS 8 Road Transport**Relevant Categories, source names**

- 1A3bi : Road transport - cars - cold start
 Road transport - cars - motorway driving
 Road transport - cars - rural driving
 Road transport - cars - urban driving
- 1A3bii : Road transport - LGVs - cold start
 Road transport - LGVs - motorway driving
 Road transport - LGVs - rural driving
 Road transport - LGVs - urban driving
- 1A3biii : Road transport - buses and coaches - motorway driving
 Road transport - buses and coaches - rural driving
 Road transport - buses and coaches - urban driving
 Road transport – HGV articulated – motorway driving
 Road transport – HGV articulated – rural driving
 Road transport – HGV articulated – urban driving
 Road transport – HGV rigid – motorway driving
 Road transport – HGV rigid – rural driving
 Road transport – HGV rigid – urban driving
- 1A3biv: Road transport - mopeds (<50cc 2st) - urban driving
 Road transport - mopeds (<50cc 2st) – lubricants use
 Road transport - motorcycle (>50cc 2st) - rural driving
 Road transport - motorcycle (>50cc 2st) - urban driving
 Road transport - motorcycle (>50cc 4st) - motorway driving
 Road transport - motorcycle (>50cc 4st) - rural driving
 Road transport - motorcycle (>50cc 4st) - urban driving
- 1A3bv: Road transport - all vehicles LPG use

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Petrol (gasoline), Diesel (DERV), Liquefied Petroleum Gas (LPG), Natural Gas (NG)

Background

This MS includes all fuel related emissions from road transport. Emissions from Urea consumption are reported under IPPU and detailed in **Chapter 4**.

Key Data sources

Activity data: DfT (traffic data, vehicle licensing statistics, ANPR data, MOT data). Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics (DUKES) published by DESNZ and corrected for consumption by off-road vehicles and the fuel consumed by the Crown Dependencies included in DUKES.

Emission factors: COPERT 5.8, EMEP/EEA 2023 Emission Inventory Guidebook.

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

A Tier 3 methodology is used for calculating exhaust emissions from passenger cars (1A3bi), light goods vehicles (1A3bii), heavy goods vehicles, buses and coaches (1A3biii) and motorcycles (1A3biv).

Petrol and diesel vehicle fuel consumption and emissions are estimated for individual vehicle types from a bottom-up approach using an array of traffic statistics and exhaust emission and fuel consumption factors representing the real-world performance of vehicles. These estimates are reconciled to national energy consumption statistics from DUKES. This approach provides estimates that are consistent with the IPCC 2006 Guidelines and includes inherent QA/QC in the comparison of bottom-up traffic activity related estimates and top-down fuel sales data.

Emissions from vehicles running on LPG are estimated on the basis of national figures derived from DUKES, detailing the consumption of this fuel in road transport. The CO₂ emissions from LPG consumption cannot be broken down by vehicle type because there are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is only a small percentage (0.42%) of the total amount of fuels consumed by road transport and vehicle licensing data suggest a similar percentage of all light duty vehicles run on LPG.

Few vehicles in the UK run on natural gas. Figures from DUKES provide natural gas consumed by road transport in energy units, which are converted into estimated vehicle kilometres travelled using COPERT 5.8 energy consumption factors. Based on this method, natural gas accounted for around 0.13% of the total vehicle kilometres in the UK in 2024.

Traffic-based emission calculations: an overview

A Tier 3 method is used to calculate fuel consumption and emissions from different types of petrol and diesel vehicles using detailed traffic and fleet information before a final fuel reconciliation is done. Details of the methodology are given in a separate report “*Methodology for the UK’s Road Transport Emissions Inventory*” (Brown et al., 2018) which will be updated periodically covering any new methodological changes for both greenhouse gases and air pollutants. This describes the very detailed information available on road transport activities in the UK and how these are used in estimating the road transport inventory. Only a brief overview of the approach used and the activity data and emission factors specific to the greenhouse gases in the current inventory are provided in this report.

Fuel consumption and emissions of CH₄ and N₂O, as well as the GHG precursors and air pollutants, NMVOCs, NO_x, CO and SO₂, from individual vehicle types are calculated from measured emission factors expressed in g/km and road traffic and fleet composition statistics

from the Department for Transport. The emission factors are from the COPERT 5.8 (Emisia, 2024) and EMEP/EEA Guidebook 2023 – Update 2024 expressed as equations relating emission factor to average vehicle speed or road type for different vehicle types compliant with different legislative emission standards (Euro standards).

The type of emissions include:

- **Hot exhaust emissions:** emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature.
- **Cold start emissions:** the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature.

For NMVOCs, evaporative emissions of fuel vapour from petrol-fuelled vehicles are also included.

Emissions are calculated for vehicles of the following types:

- Petrol cars;
- Diesel cars;
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW) $\leq$ 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) $\leq$ 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW $\geq$ 3.5 tonnes);
- Articulated Heavy Goods Vehicles (GVW $\geq$ 3.5 tonnes);
- Buses and coaches; and
- Motorcycles.

Total emission rates (as well as fuel consumption) are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads. This procedure is followed to derive the initial bottom-up estimate of fuel consumption and implied fuel-based emission factors for CH₄ and N₂O by vehicle category before the normalisation to fuel sales is carried out.

Activity data for traffic-based emission calculations:

Hot exhaust emission factors are dependent on average vehicle speed and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on rural roads, higher speed motorways/dual carriageways and different types of urban roads with different average speeds. The emission results are combined to yield emissions on each of these main road types:

- Urban;
- Rural single carriageway; and
- Motorway/dual carriageway.

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as motorways, trunk, principal and minor roads in urban and rural areas (DfT, 2025a). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2024 inventory, taking into account any revisions to historic data. The vkm data are derived by DfT from analysis of national traffic census data involving automatic and roadside traffic counts. Additional information discussed later (e.g. Automatic Number Plate Recognition data) (DfT, 2025) are used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development, Northern Ireland, Road Services (DRDNI, 2016). This gave a timeseries of vehicle km data from 2008 to 2014. To create a timeseries of vehicle km data for 1990 to 2007, the vehicle km data from DRDNI (2013) was used. The data were

scaled up or down based on the ratio of the data for 2008 between DRDNI (2016) and DRDNI (2013) for the given vehicle type and road type considered. Data for 2015-2024 were not available for the current inventory compilation and thus they were extrapolated from 2014 vehicle km data for Northern Ireland based on the traffic growth rates between 2014 and 2024 in Great Britain. Motorcycle vehicle km data were not available for Northern Ireland so they were derived based on the ratio of motorcycles registered in Northern Ireland relative to Great Britain each year. The ratios were then applied to the motorcycle vehicle km activity data for Great Britain. Information about the petrol/diesel split for cars and LGVs in the traffic flow are based on licensing data for Northern Ireland as provided by DfT (2025d).

The Northern Ireland data has been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2024. **Table 3.10** shows the time-series of total UK vehicle kilometres by vehicle and road type for selected years from 1990 to 2024.

Table 3.10 UK Vehicle km by Type of Road Vehicle, 1990-2024

Billion vkm		1990 ⁶⁴	2000	2005	2010	2015	2022	2023	2024
Petrol cars	urban	142.2	134.8	118.1	98	89.4	86.9	90.3	92.8
	rural	140.9	134.1	127.6	110.4	95.6	97.1	102.7	106.9
	m-way	49.3	53	48.8	41.8	34.5	40.3	43.1	44.5
Diesel cars	urban	5.8	26	40.2	52.7	64.9	56.2	52.9	49.3
	rural	6.1	28.3	47.8	66.5	90.1	81	78	73.9
	m-way	2.8	14.7	25.3	33.4	45.8	34	32.2	29.5
Electric cars	urban	0	0	0.1	0.1	0.2	5.8	9.2	13.3
	rural	0	0	0.1	0.2	0.3	6.4	10	14.5
	m-way	0	0	0	0.1	0.1	2.7	4.2	6.1
Petrol LGVs	urban	11.2	4.5	2.1	1.4	0.6	0.6	0.6	0.6
	rural	11.6	5.4	2.6	1.7	0.8	1	1	1
	m-way	4	2.1	1.1	0.6	0.3	0.4	0.4	0.4
Diesel LGVs	urban	5.7	15.1	20.2	21.8	25.4	26.5	26.1	26
	rural	5.9	18.3	25.2	29.5	35.3	43.6	43.4	43.5
	m-way	2	7.2	10	11.2	14.7	19.8	19.9	19.9
Electric LGVs	urban	0	0	0	0	0	0.4	0.6	0.8
	rural	0	0	0	0	0	0.7	1	1.4
	m-way	0	0	0	0	0	0.3	0.4	0.6
LPG LGVs	urban	0	0.1	0.5	0.4	0.3	0.2	0.3	0.4
	rural	0	0.1	0.7	0.6	0.5	0.4	0.6	0.8

⁶⁴ Prior to 1993, a different definition was used for urban and rural areas; areas were defined as 'built-up'/'non-built-up'. 'Non-built-up' roads were those with a speed limit of more than 40mph, and 'built-up' roads were those with a speed limit of 40mph or less.

Billion vkm		1990 ⁶⁴	2000	2005	2010	2015	2022	2023	2024
	m-way	0	0	0.3	0.2	0.2	0.2	0.3	0.4
Rigid HGVs	urban	4.5	3.9	4	3.2	3	2.5	2.4	2.3
	rural	7.1	7.2	7.5	6.7	6.4	5.9	5.6	5.5
	m-way	3.7	4.2	4.2	4.1	3.9	3.9	3.8	3.7
Articulated HGVs	urban	1.1	1.1	1.1	0.8	0.9	1	1	1
	rural	4.4	5.2	5.4	5.1	5.3	6.2	6	6
	m-way	4.7	7.4	7.9	7.5	8.4	9.4	9.2	9.1
Buses	urban	2.4	3	3.1	3	2.7	1.9	1.8	1.9
	rural	1.7	1.7	1.5	1.6	1.4	1.1	1.1	1.1
	m-way	0.6	0.5	0.5	0.5	0.4	0.2	0.3	0.3
M/cycle	urban	3.3	2.3	2.9	2.5	2.2	2.6	2.6	2.8
	rural	2	2	2.2	1.8	1.9	1.8	1.8	1.8
	m-way	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3
Total		423.3	482.7	511.2	507.9	535.9	541.1	553.1	562.1

The road classification and traffic speed assignments have been developed to improve the representation of total road transport emissions and their spatial distribution. Speed limit classification data has been assigned to OS Openroads geometry based on the length weighted median speed limit for each road link. The underlying speed limit dataset has been provided by Basemaps for Great Britain (Basemap, 2021). The vehicle speeds assigned to each category were derived from an analysis of GPS vehicle speed observations (Teletrac Navman, 2021) for England provided by DfT. The observed average speeds for England were applied across the UK. The vehicle speeds are used to derive the emission factors for each vehicle and road type from the emission factor-speed relationships available for different pollutants.

Vehicle kilometre data based on traffic surveys does not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age.

The inventory uses the Automatic Number Plate Recognition (ANPR) data provided by DfT (2025) to define petrol and diesel mix in the car fleet on different road types (urban, rural and motorway), leading to the vehicle km data for petrol and diesel cars on different road types in the UK shown in **Table 3.10**. The ANPR data has been collected annually from 2007-2011 and then biennially since 2011 at over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. They cover various vehicle and road characteristics such as fuel type, age of vehicle, engine size, vehicle weight and road types.

The road transport fleet turnover model is developed to calculate the composition of the UK vehicle fleet and road transport emissions over a time-series from 1990 to 2024. The model is based on a comprehensive set of vehicle licensing (DfT, 2025d) and annual mileage data from MOT (Ministry of Transport) records provided by DfT (2025e), covering years between 2007 and 2024 (licensing data back to 1994 and MOT data also available for 2024). These have been supplemented with additional DfT data from the Road Freight Domestic Survey and National Travel Survey and used to develop revised vehicle survival rate and mileage with age profiles that vary by year and have been used to update the NAEI's fleet turnover model. The model is used to calculate a consistent time-series in the composition of the fleet in terms of

the proportion of vehicle kilometres travelled by vehicles of different Euro emission standards from 2005 to 2024.

Vehicle licensing statistics and mileage data are used to define trends in:

- The breakdown in vkm of cars, mopeds and motorcycles by engine size category.
- The breakdown in vkm by rigid HGVs, articulated HGVs, buses and coaches by vehicle weight category.

The year-of-first registration of a vehicle determines the type of emission regulation that the vehicle complies with. These have entailed the successive introduction of tighter emission control technologies. Although emission standards do not apply to CH₄ and N₂O, technologies designed to control the regulated pollutants such as hydrocarbons and NO_x affect these GHG emissions.

Detailed information on the fleet composition in London was provided by Transport for London (TfL, 2023). The inventory pays particular attention to the unique features of the bus, taxi, HGV and LGV fleets in London. This is primarily so as to be able to account for measures taken to reduce emissions and improve air quality in London through the introduction of the London Low Emission Zone and Ultra Low Emission Zone both introduced in stages. The expanded area of the ULEZ up to, but not including the North and South Circular Roads, was introduced in 2021, is also taken into account. The inventory also takes account of the early introduction of certain emission standards and additional voluntary measures, such as incentives for HGVs to upgrade engines and retrofit with particle traps, to reduce emissions from road vehicles in the UK fleet. This was based on advice from officials in DfT.

Fuel Consumption Factors for Vehicle Types:

Fuel consumption is calculated for each vehicle type using the fuel consumption-speed relationships given in COPERT 5.8 and the EMEP/EEA Emissions Inventory Guidebook (2023). This includes a method for passenger cars which applies a year-dependent 'real-world' correction to the average type-approval CO₂ factor weighted by new car sales in the UK from 2005 to 2024. The new car average type-approval CO₂ factors for cars in different engine size bands were provided by the Society of Motor Manufacturers and Traders (SMMT, 2025). The real-world uplift uses empirically-derived equations in the Guidebook that take account of average engine capacity and vehicle mass. As mentioned previously, the bottom-up fuel consumption is reconciled to DUKES fuel consumption.

Using the Guidebook factors with fleet composition data and average speeds on different road types, fleet average fuel consumption factors for each main vehicle category are shown in **Table 3.11** for a selection of years between 1990 and 2024.

Table 3.11 UK Fleet-averaged fuel consumption factors for road vehicles (in g fuel/km)

Source	1990	2000	2005	2010	2015	2022	2023	2024
Petrol cars	79.9	71.7	68.1	65.9	62.3	55.8	55.0	54.0
Diesel cars	60.5	59.2	59.8	60.8	58.5	57.6	57.4	57.4
LGVs	99.0	81.9	75.7	74.4	73.3	72.3	71.8	71.5
HGVs	234.6	218.1	230.2	230.3	230.1	231.6	230.5	230.2
Mopeds and motorcycles	57.9	57.3	50.5	46.0	43.7	38.0	37.3	36.7
Buses and coaches	316.7	288.0	282.0	275.1	271.3	269.5	268.1	265.9

Carbon Factors

CO₂ can be calculated from the carbon content of the fuel and the fuel used (calculated as above). Carbon emission factors for petrol, diesel and LPG are set out in “Energy_background_data_uk_2026.xlsx”.

CH₄ and N₂O Emission Factors for Vehicle Types

The emission factors for N₂O and CH₄ for all vehicle types in g/km are based on the recommendation of the Emissions Inventory Guidebook (EMEP, 2023) derived from COPERT 5.8. Tables showing the emission factors for different vehicle types, Euro standards and road types are provided in Annex A in the road transport inventory report by Brown et al (2018). This also shows the cold start emission factors for N₂O emissions from petrol cars and LGVs included in the calculations.

Nitrous oxide emissions were a problem with early generation petrol cars fitted with three-way catalysts, being formed as a by-product on the catalyst surface during the NO_x reduction process. Emission factors have been declining with successive Euro standards since the first generation of catalysts for Euro 1, presumably due to better catalyst formulations as well as reductions in fuel sulphur content which also reduces N₂O emissions. The fuel sulphur content of road fuels has been steadily declining since 2000 with the requirements of the European Fuel Quality Directive and is now less than 10ppm since January 2009 according to the Directive 2009/30/EC. Factors for HGVs and buses have been increasing with more recent Euro standards (Euro IV-VI). This is most likely due to the fitting of selective catalytic reduction (SCR) systems on the exhaust system for controlling NO_x emissions.

Road transport is a relatively unimportant emitter of CH₄, only being produced as a consequence of incomplete combustion, but largely controlled by catalysts on petrol vehicles. Tighter regulations on hydrocarbon emissions from petrol and diesel vehicles have led to reductions in CH₄ emissions with the introduction of successive Euro standards.

Table 3.12 summarises the N₂O and CH₄ implied emission factors for each vehicle type in mg/km. These factors are weightings according to the distances travelled by the mix of Euro classes in the fleet each year as well as the proportions of kilometres travelled at different speeds and therefore with different emission factors. These factors also include the contribution from cold start emissions.

Table 3.12 N₂O and CH₄ Implied Emission Factors for Road Transport (in mg/km). Includes cold start emissions

Gas	Source	1990	2000	2005	2010	2015	2022	2023	2024
CH ₄	Petrol cars	111.8	57	32.7	17.1	12.2	9.3	9.1	8.9
	DERV cars	19.7	8.4	4.4	2.1	0.9	0.3	0.3	0.2
	LGVs	80.7	26	9	3.7	1.2	0.4	0.3	0.3
	HGVs	86.2	70.1	66.3	37.4	13.6	5.6	5.2	5.1
	Buses and coaches	149	116.6	94.1	54.8	27	7.4	6.4	5.6
	Mopeds and motorcycles	207.9	182	140.9	91	66.8	40.8	35.8	31.6
N ₂ O	Petrol cars	8.2	11.1	7.7	2.7	1.6	1.2	1.2	1.2
	DERV cars	-	3.9	5.8	6.3	6.0	6.1	5.7	5.6
	LGVs	5.5	5.2	6.1	6.2	6.0	5.7	5.4	5.2
	HGVs	35.2	16.9	10.0	18.0	35.7	43.2	41.5	41.3
	Buses and coaches	35.2	18.2	10.3	13.5	22.6	33.1	32.2	32.4

Gas	Source	1990	2000	2005	2010	2015	2022	2023	2024
	Mopeds and motorcycles	1.9	1.9	1.8	1.7	1.7	1.7	1.8	1.8

Using the CH₄ and N₂O emissions and fuel consumption calculated from the traffic data, it is possible to derive implied fuel-based emission factors of CH₄ and N₂O (in g/kg fuel) for each vehicle type in each year which is used in conjunction with the normalised fuel consumption (see below) to estimate their emissions. This ensures all pollutant emissions are consistent with fuel sales.

Fuel reconciliation with official statistics and normalisation

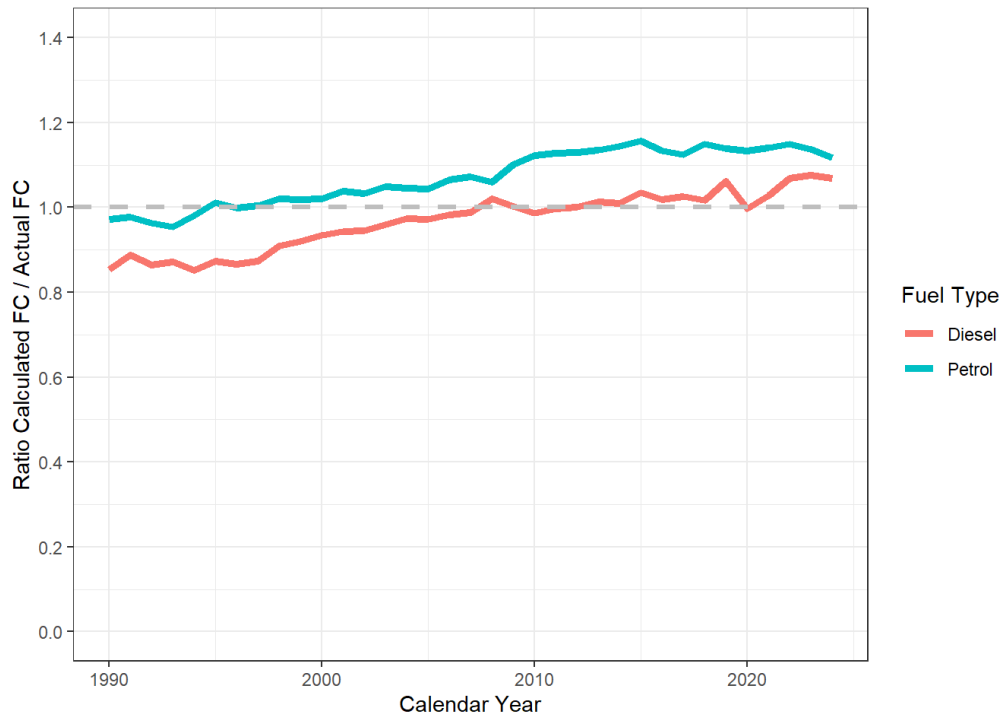
The 'bottom-up' calculated estimates of petrol and diesel consumption described above are compared with DESNZ figures for total fuel consumption in the UK published in DUKES. The total amounts in DUKES are adjusted to remove the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies, and are combined with the estimated lubricant oil consumption. For a valid comparison with DUKES which covers only fossil fuel petrol and diesel, the amount of petrol and diesel displaced by biofuel consumption, based on data from the Renewable Transport Fuel Obligation (RTFO), has been used to correct the calculated consumption of petrol and diesel. Natural gas is not included in this reconciliation process, however it is a very small proportion of total road transport fuel use. A small proportion of LGV consumption of diesel in the bottom-up model is displaced by LPG as well, which is described on the following page.

This comparison shows a small difference between the bottom-up estimated fuel consumption and DUKES-based figures. In order to be consistent with the IPCC methodologies and ensure that the fuel consumption data matches official statistics, it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total calculated consumption of petrol and diesel equals the DUKES-based figures.

Figure 3.2 shows the ratio of model calculated fuel consumption (corrected for biofuel consumption) to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. In the earlier part of the time-series, there was a greater deviation from the DUKES figures with the maximum deviation being at 16% (for Petrol, in 2015). When the ratio tends to be towards 1, it indicates a better agreement with fuel sales data. The bottom-up method for petrol consumption in 2024 was 111.8% and for diesel in 2024 was 106.9% of the value from DUKES.

The normalisation process introduces uncertainties into the fuel consumption estimates for individual vehicle classes even though the totals for road transport are known with high accuracy. Petrol fuel consumption calculated for each vehicle type was scaled up by the same proportions to make the total consumption align with DUKES. The same procedure was used to scale up diesel consumption by each vehicle type. Passenger cars consume the vast majority of petrol, so one would expect that DUKES provides a relatively accurate description of the trends in fuel consumption by petrol cars. This suggests the gap in the early part of the inventory time-series between DUKES and bottom-up estimates is due to inaccuracies in the estimation of fuel consumption by passenger cars during the 1990s.

The fuel consumption, normalised to DUKES in the manner described above, is used to calculate CO₂ emissions for each vehicle type. For CH₄ and N₂O, the year-dependent implied fuel-based emission factors derived from the traffic data are combined with the normalised fuel consumed by each vehicle type with the amount of displaced biofuel added to the DUKES total. This is so that these non-CO₂ emissions cover all the fuel consumed by the road vehicles, including the biofuel, and not just the fossil-fuel amounts included in DUKES.

Figure 3.2 Ratio of calculated consumption of petrol and diesel fuel

Note: Calculated petrol and diesel fuel consumption are based on traffic movement and fuel consumption factors summed for different vehicle types. DUKES figures for these fuels are based on fuel sales in the UK.

Emission factors for CH₄ and N₂O emissions from LPG consumption

Carbon emissions from LPG consumption are calculated from the total LPG consumption given in DUKES and fuel-based factors set out in “*Energy_background_data_uk_2026.xlsx*”.

Consumption of LPG is relatively small in the UK (0.42% of all road fuels in 2024) and there are no reliable data on the number or types of vehicles running on LPG. Vehicle licencing statistics suggests that 0.07% of all light goods vehicles ran on LPG in 2024.

Assuming all the LPG consumed in the UK is by Light Goods Vehicles, the amount of LPG consumed was used to estimate the number of vehicle km travelled by LGVs using LPG. Emissions of CH₄ and N₂O from consumption of LPG were then calculated from the vehicle km data and emission factors (expressed as g of pollutant per km) available from the EMEP/EEA Emissions Inventory Guidebook (2023) covering all types of light duty vehicles. Further details are given in Brown et al (2018).

Emission from lubricants

Lubricant consumption by the unintended combustion in vehicle engines is estimated using the method from the EMEP/EEA Emissions Inventory Guidebook (2023). These consumption estimates were used to calculate CO₂ emissions from lubricant combustion in road vehicle engines and are reported in CRT sector 2D1 (**Section 4.22**) except for lubricants use by 2-stroke mopeds, which is deemed to be intentional fuel use and hence reported in CRT sector 1A3biv.

Emissions of CH₄ and N₂O also arise from lubricant combustion in engines. However, the exhaust emission factors for these gases will include the contribution of lubricants as well as the main fuel to the pollutant emissions when the vehicles were tested. Hence, the emissions of CH₄ and N₂O (and other air pollutants) from lubricants are included implicitly in the hot

exhaust emissions calculated for each vehicle and fuel type. Treating emissions of these pollutants separately would lead to a double count.

Overseas Territories and Crown Dependencies

Fuel consumption data for 1A3b were obtained from official statistics for all Overseas Territories and Crown Dependencies. This was disaggregated into fuel consumption by vehicle type by assuming a UK fleet breakdown and assuming the relative mileage of each vehicle type is the same as non-London urban UK. UK-specific emission factors were applied to the disaggregated fuel consumption.

Assumptions & observations

There are many assumptions made, using expert judgement, in the Tier 3 approach and these are referred to in the detailed road transport inventory methodology report by Brown et al (2018).

Emissions of direct greenhouse gases are calculated on the basis of fuel sold (and not vkm travelled) and are consistent with UK energy statistics.

For CO₂, the assumptions have little effect on total road transport emissions as this is based on fuel sales figures in DUKES, but the assumptions used during the normalisation process affect the distribution of emissions between vehicle types. In particular, the procedure used to normalise the diesel consumption calculated for each vehicle type with the total DUKES figure is important as all vehicle types have a similar share of diesel consumption.

For CH₄ and N₂O emissions, the diesel normalisation method assumed has a direct effect on emission estimates as emissions per unit of fuel consumed vary for each vehicle type.

A sensitive parameter in the emission calculations of CH₄ and N₂O for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008 only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. From 2009, a change in the repair rate is taken into account for Euro 3 and above petrol LDVs assuming all failed vehicles are rectified properly due to the introduction of EU Regulations Controlling Sale and Installation of Replacement Catalytic Converters. Further details are given in Brown et al (2018).

Other key assumptions that affect CH₄ and N₂O emissions include:

- Application of vehicle speeds measured on a sample of roads to cover the whole road network;
- Distances covered by petrol car engines not fully warmed up in the calculation of cold start emissions; and
- All LPG is consumed by light goods vehicles.
- All natural gas is consumed by Heavy Goods Vehicles.

Recalculations

Time series revisions are relatively minor across all pollutants. For example, CO₂ emissions from cars in 2023 have been revised downward by around 1%, and CO₂ emissions from LGVs in 2023 have been revised upward by around 2%. These revisions are due to reallocations of fuel by vehicle type due to updated activity data from DfT, the use of actual ANPR data for 2023, and a higher proportion of diesel LGVs relative to petrol LGVs than previously assumed.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

An internationally established Tier 3 method is used consistent with IPCC Guidelines and EMEP/EEA Emissions Inventory Guidebook approaches. The Method Approach section has described a comparison between the bottom-up, traffic-based approach for calculating fuel consumption and the total fuel sales figures provided in DUKES; the agreement is within 16% across the time-series.

The traffic data (vkm) and fleet composition data are provided by DfT and have been assessed by the UK Statistics Authority and confirmed as Official Statistics. DfT statistics are accompanied by a Statement on Statistical Quality⁶⁵.

Emission factors and fuel consumption factors are from standard IPCC and EMEP/EEA Inventory Guidebooks and COPERT. These are peer-reviewed sources.

Time-series consistency

There are no time-series issues. Time-series consistency is ensured by the use of DUKES fuel consumption and use of continuous, consistent vkm traffic data from DfT.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The reconciliation between bottom-up and top-down approaches gives a high level of confidence in the calculated emissions for road transport. There is greater uncertainty in the division in CO₂ emissions between vehicle types.

There are greater uncertainties in the emission factors for CH₄ and N₂O because of limited emission factor measurements, in particular for more recent vehicle technologies and emission standards entering service. The main sources of uncertainties in the activity data affecting the CH₄ and N₂O inventories are in the division of diesel fuel consumption between vehicle types and the uncertainty in the fuel consumption factors that determine how much CH₄ and N₂O emissions are scaled to be consistent with national fuel consumption. There are also uncertainties affecting the emission estimates for CH₄ and N₂O in the on-road fleet composition, catalyst failure rates, trip lengths (for estimating cold start emissions).

⁶⁵ Standards for official statistics published by the Department for Transport, available at: [Statement on statistical quality - GOV.UK](#)

MS 9 Railways**Relevant Categories, source names**

1A3c : Rail - coal

Railways: freight – gas oil

Railways: intercity – gas oil

Railways: regional – gas oil

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Gas oil, coal

Background

This MS includes emissions from gas oil used to power trains and from the consumption of coal used to power steam trains. The methodology for gas oil is based around three categories of railway locomotive: freight, intercity and regional. Stationary combustion in the rail sector is included in **MS 5**. Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity.

Key Data sources

Activity: DUKES, Office of Rail and Road (ORR) National Rail Trends Yearbook (NRTY), ORR data portal and Network Rail Open Data Platform

Emission factors: Baggott et al. (2004), 2006 IPCC Guidelines, EMEP/EEA 2023, DfT's Rail Emissions Model (REM; DfT 2016), AP-42 (USEPA), Rail Safety and Standards Board (RSSB; 2020)

*An accompanying spreadsheet "Energy_background_data_uk_2025.xlsx" lists all emission factors used in the energy sector, including a full list of references⁵⁶. **Table 1.4** gives additional information for common activity data sources.*

Method approach

Emissions are calculated based on AD x EF.

Coal consumption data has been obtained from DUKES. Estimates have been made for 2005 onwards and are believed to be due to consumption by heritage trains. No coal use is allocated to railways in DUKES for earlier years, it is assumed that this is included within other reporting categories.

The UK GHGI reports emissions from trains that run on gas oil in three categories: freight, intercity and regional. Emissions from these are reported under the CRT category 1A3c Railways.

Apart from the relevant activity data updates for 2024, the main aspects of the methodology remain consistent with 2023 inventory. In the 2019 inventory, emission estimates were improved based on recent work for the UK's Rail Safety Standards Board (RSSB) to develop new emission factors that better reflect actual operation of the diesel engine) and account for

the non-linear relationships between engine power output and emissions of pollutants (RSSB 2020).

For Great Britain, vehicle kilometre data for intercity and regional trains has been obtained from REM for 2009 to 2011, 2014 and 2018 and from recent RSSB emission mapping work for 2023, and then estimated for other years (including 2024) from the Office of Rail and Road (ORR) historic National Rail Trends Yearbook (NRTY) and current data portal (ORR, 2025). Adjustments to the diesel vehicle kilometres for 2019-2022 were made to account for the introduction of new bi-mode passenger trains. Actual train kilometre data for diesel freight train movements in 2019 is available and this has been scaled back to 2005 and forward to 2022 using the trend in net tonne km from the ORR NRTY and data portal. Train kilometre data for freight trains is also available for 2004 and 2023, and, similarly, data is scaled back to the start or end of the time series (i.e. to 2024), respectively, using information on the trend in net tonne km of freight moved.

Gas oil consumption by passenger and freight trains is obtained from the 2011 NRTY for the period 2005-2009 and from ORR's data portal for the years 2011-2023. No data is available for the years 1970-2004 and 2010, and data for 2024 had not yet been released at time of compilation. Therefore, fuel consumption for these years was estimated based on the trend in diesel passenger train kilometres or net tonne km of freight moved.

For Northern Ireland, train kilometre data and fuel consumption data are provided by Translink (2025), the operator of rail services in the region.

Carbon and nitrous oxide emissions are calculated using fuel-based emission factors and the total fuel consumed. The CEF for coal is derived from the 2006 IPCC guidelines whilst the CEF for gas oil is taken from Baggott et al. (2004). The N₂O emission factor was updated in the 2020 inventory to utilise the new value provided in the 2019 EMEP / EEA Guidebook for the rail sector (and which has not changed in the 2023 EMEP / EEA Guidebook).

Emissions of other pollutants are based on the vehicle / train kilometre estimates, and emission factors for different train classes.

For coal-fired steam trains, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate non-CO₂ emissions. These are considered most appropriate for the type of coal-fired boilers on heritage trains.

Assumptions & observations

In recent years diesel passenger train kilometres have steadily increased from 220 million km in 2000 to almost 256 million km in 2019. In 2020 diesel passenger train kilometres declined to 186 million km, primarily as a result of reduced services due to the Covid-19 pandemic. Diesel passenger train kilometres then increased in 2021 to 208 million km but remained lower than years prior to 2020 due to the continuing effects of the pandemic. From 2022 to 2024, activity levels are estimated to have remained similar to 2021 due in part to industrial action across the UK (in 2022 and 2023) and also due to a switch to more electric passenger trains on the network. The amount of freight moved has declined steadily since 2013 as a result of a substantial decline in the amount of coal hauled and then due to the Covid-19 pandemic. The amount of freight moved in 2020 was around 68% of the amount estimated for 2013 but increased to around 75% of the 2013 value in 2021 before reducing to around 70% of the 2013 value in both 2022 and 2023. In contrast, in 2024 the amount of freight moved increased by 4.5% compared to the 2023 value

Recalculations

Recalculations of emissions were the result of one or a combination of the following:

- Revision of the ORR fuel consumption figures for freight for 2021 and for passenger and freight for 2022
- Use of the ORR fuel consumption figures for 2023 now that data is available
- Use of observed activity data and fleet distributions for 2023

Improvements (completed and planned)

Various emissions-related projects are currently being undertaken by the rail industry in the UK which may lead to further improvements in the NAEI rail emission estimates in future years.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time series consistency

Coal use in heritage railways is not reported in DUKES for all years. For the years in which no activity data are reported, emissions are reported as “IE.” Consultation with the DUKES team has indicated a high level of confidence in total coal use for the UK. As such although no data are available to allocate emissions to rail for earlier years in the time series, this does not represent an under report in the UK inventory.

Gas oil consumed by the rail sector is estimated based on the change in train / vehicle kilometres prior to 2005 and for 2010 and 2023. However, the total amount of gas oil consumed in the UK is thought to be reliable and therefore this does not represent an under / over report in the UK inventory as a whole.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. The main uncertainties for the rail sector relate to the quality of emission factor data across all sources and the lack of detailed train kilometre data by train class for most years.

MS 10 National navigation and fishing**Relevant Categories, source names**

1A3d: Shipping – coastal

Shipping between UK and Gibraltar

Shipping between UK and OTs (excl. Gibraltar)

1A4ciii: Fishing vessels

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Gas oil, fuel oil, Liquefied Natural Gas (LNG)

Background

This MS includes emissions from UK domestic and crown dependency coastal shipping, fishing, including fishing outside UK territorial waters, and shipping between the UK and OTs (classified as domestic). Emissions from inland waterways are covered in MS 11.

Key Data sources

Activity: DUKES (DESNZ 2025a), UK Maritime and Coastguard Agency, DfT Maritime Statistics (2025c), MMO Fishing statistics (MMO, 2025), the DfT Maritime Emissions Model (DfT, 2025f).

Emission factors: DfT (2025), IMO (2020).

An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 3.11 gives additional information for common activity data sources.

Method approach

The DfT Maritime Emissions Model (MEM) applied uses 2019 high resolution satellite and terrestrial Automatic Identification System (AIS) vessel movement data supplied by the UK Joint Maritime Security Centre matched to a fleet database of vessel characteristic provided by Sea/ by Maritech (DfT, 2025f). This meets and exceeds the requirements of a Tier 3 methodology. The methodology carries out an emission calculation specific to each vessel and for each point of the vessel’s voyage around the UK coast that is tracked with terrestrial AIS receivers on the UK shore and AIS receivers’ onboard satellites in space.

The DfT MEM covers larger vessels carrying AIS that are 100 Gross Tonnes or greater. It covers voyages such as movements to and from offshore oil and gas rigs, and voyages to/from crown dependencies and overseas territories and voyages from the UK to international ports. The approach also uses a detailed set of port statistics for different vessel categories as proxies for estimating activities in years back to 1990 and forward to 2024 from the 2019 base year.

A significant step in the process is identifying whether a vessel movement is a UK domestic movement, and reported under 1A3dii, or part of an international voyage calling in the UK reported as a Memo item under 1A3di.

The bottom-up estimates of fuel consumption calculated in the DfT MEM are reconciled to national energy consumption statistics from DUKES. This approach provides estimates that are consistent with the IPCC 2006 Guidelines.

Details of the methodology are given in the report by DfT (2025) and only a summary is given here.

Activity data for 2019 vessel movement-based emission calculations

The model methodology estimates the Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO) and Liquefied Natural Gas (LNG) fuel consumption for each AIS position message down-sampled to 5-minute temporal resolution. The calculation takes into account where available the individual vessel characteristics of main engine power, engine speed and load, and makes bottom-up assumptions for auxiliary engines. The fuel and emissions are estimated for each AIS message to cover the time period until the next AIS message, which is often 5 minutes. Many assumptions for the modelling have been drawn from the International Maritime Organization's (IMO) Fourth Greenhouse Gas Study (IMO, 2020).

The emissions are calculated separately for each vessel and for each AIS data point assuming that the vessel continues to combust fuel and emit pollution at the same rate until the subsequent AIS message. The fuel consumption and emission factors are tailored to the specific vessel that is identified in the AIS dataset. The factors account for:

- The fuel type assumed to be used by the vessel, the known engine type and engine speed (rpm).
- The rated power of the engines, which are either known from a third-party vessel characteristics database, or estimated based on other known or reported vessel characteristics (e.g. vessel length).
- The actual power demands on the main engines for each AIS message, expressed as a function of reported and designed vessel speed, and reported and designed vessel draught.
- The location and type of the vessel, i.e. whether the vessel is in a Sulphur Emission Control Area (SECA), whether the vessel is at berth, and whether the vessel is a passenger vessel.

The detailed Tier 3 approach used in DfT (2025) is able to distinguish fuel consumption and emissions between domestic movements from one UK port to another and UK international movements between a UK port and a port overseas. This enables the correct activities and emissions to be allocated to the NFR14 category 1A3dii Domestic Water-borne Navigation.

The inventory developed from the DfT MEM excluded emissions and fuel consumption from military vessel movements which are not fully captured in the AIS movements database. Naval shipping emissions are reported separately using fuel consumption data supplied by the Ministry of Defence (MoD). Emissions from these vessels are covered in **MS 13**.

The DfT MEM (DfT, 2025f) did not cover small tugs and service craft used in estuaries, private leisure craft and vessels used in UK rivers, lakes and canals as these were not captured in the AIS data. These were captured in the estimates for inland waterways described in **MS 11**.

Commercial fishing vessels were captured by AIS data, including those that eventually leave the UK to fish in overseas waters, before returning later, so emissions could be calculated in the same way as for other domestic navigation and reported separately under 1A4ciii.

Time-series trends in activity data for vessel movement-based emission calculations

The approach to estimate emissions for historical years before 2019 and years after 2019 largely uses DfT port statistics as proxies for activity levels. Overall, there are 18 vessel

categories that are each mapped to a DfT port statistic, or other proxy (Marine Mangement Organisation (MMO), or DUKES). This includes separating cargo or freight commodity types. The statistical time-series cover all years back from 2019 to 1990 and forward to the most recent year of statistics (currently 2024). In many cases, multiple statistical series need to be used if no complete series is available to cover the entire period to 1990. The specific statistical series used for each vessel category is indicated in Table 3.13. The main DfT statistics used are (DfT, 2025c):

- PORT0201 Domestic UK major port freight traffic by cargo type and direction, annually: 2000 – 2024
- SPAS0101 UK international sea passenger movements, by port and port area: from 1950
- SPAS0201 UK domestic sea passenger movements by type of route: from 2003

Table 3.13 Summary of activity indices

Vessel category	Activity index used	Separate Domestic index
Bulk carrier	2000-2024: Table PORT0201 - 'All dry bulk traffic' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Chemical tanker	2000-2024: Table PORT0201 - 'Other liquid bulk products' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Container	2000-2024: Table PORT0201 - 'All container traffic' 1990-1999: Table PORT0104 - 'All Traffic'	Yes
General cargo	2000-2024: Table PORT0201 - 'All other general cargo traffic' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Liquefied gas tanker	2000-2024: Table PORT0201 - 'liquefied gas' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Oil tanker	2000-2024: Table PORT0201 - 'total of Crude Oil and Oil Products' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Ferry -Ro-Pax	2000-2024: Table PORT0201 - 'Roll-on/roll-off traffic' 1990-1999: Table PORT0104 - 'UK Port Freight Tonnage'	Yes
Ferry-pax only	1994-2024: UK domestic sea passenger movements by type of route - Table SPAS0201. 1990-1993 linearly extrapolated based on trend for 1994-2000.	Yes
Cruise	Same approach as used for the Ferry-pax only vessel category	Yes
Refrigerated bulk	2000-2024: Table PORT0201 - 'Other dry bulk' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Ro-Ro	2000-2024: Table PORT0201 - 'Roll-on/roll-off traffic' 1990-1999: Table PORT0104 - 'All Traffic'	Yes

Vessel category	Activity index used	Separate Domestic index
Service - tug	2000-2024: Table PORT0201 - 'total domestic traffic' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Vehicle	2000-2024: Table PORT0201 - 'total domestic traffic' 1990-1999: Table PORT0104 - 'All Traffic'	Yes
Miscellaneous - fishing	1990-2024: MMO UK Sea Fisheries Annual Statistics - Chapter 3 Landings.	No
Offshore	Domestic: Gross UK Oil and NGL Production in kt (DUKES table 3.1.1 Crude oil and petroleum products: production, imports and exports; Indigenous production of crude oil) International: U.S. Energy Information Administration (EIA) crude oil production across the world.	Yes
Service – other	2000-2024: Table PORT0201 - 'total domestic traffic' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes
Miscellaneous - other	2000-2024: Table PORT0201 - 'total domestic traffic' 1990-1999: Table PORT0102 - 'UK Port Freight Tonnage'	Yes

Time series trends for freight vessels between the UK and overseas territories are taken from unpublished data sourced from the DfT port freight statistics database. The data is available for the years 2000 to 2024 and the total UK international freight tonnage trend is used to complete the index for the years 1990 to 1999. It is not practical to calculate different activity indices for each vessel type due to data quality. Cargo codes needed for several vessel types are not included in the 2019 data or are missing for other years. Instead, an index based on total tonnage is used for all the freight vessel type indices, with UK to Crown Dependencies tonnage used for UK to Crown Dependencies routes and UK to Overseas Territories (UK-CD) tonnage for UK to Overseas Territories (UK-OT) routes.

Time series trends for Cruise vessels on routes UK-OT and UK-CD are based on international cruise activity.

Trends for passenger ferries ('Ferry pax only') were developed from UK-CD passenger figures for 2003-2024 taken from the 'All Channel Islands' and 'All Isle of Man' totals from table SPAS0201 of UK domestic sea passenger movements by type of route. UK-CD passenger figures for 1994-2002 are taken from the 'Total GB to Isle of Man' and 'Total GB to Channel Islands' total from a previous iteration of table SPAS0201. UK-CD passenger figures for 1990-1993 are estimated using a linear trend based on passenger numbers for 1994-2000. According to DfT, no vessels make UK-OT voyages.

The model assumes that there is a fuel switch from HFO to MDO as a result of the tightening in 2015 of the SECA fuel sulphur limit from 0.5% to 0.1%. This assumption is made on the basis of evidence that low sulphur heavy fuel oil was available to comply with the SECA fuel sulphur limits of 1.5% to 2010 and 1% from 2010 (IMO, 2010).

The requirement that vessels at berth from 2010 use fuel which complies with a sulphur limit of 0.1% implies the need for MDO. Therefore, in the back casted inventory prior to 2010, any

vessels that would have used HFO, save for the at berth requirement of 0.1% S fuel, are assumed prior to 2010 to use HFO.

Fuel reconciliation with official statistics

The DfT MEM provides bottom-up estimates of fuel consumed by domestic from AIS vessel movement data. Data on fuel sold for national navigation are taken from DUKES published by DESNZ (DESNZ, 2025a). The bottom-up estimates of emissions from domestic shipping are normalised to align with the DUKES fuel sold figures for national navigation.

Fuel consumption from inland waterways, port machinery and naval shipping are included in the DUKES figures for fuel sold for national navigation. To avoid double counting and be consistent with DUKES and MoD fuel sold estimates, bottom-up estimates of fuel consumptions from naval shipping are subtracted from the DUKES figures prior to normalisation. The fuel consumption from inland waterways and port machinery are normalised together with the domestic navigation to DUKES national navigation fuel sold.

Fuel use for other sources have not been revised as a result of this method change, as any reconciliations of fuel balances for in-land fuel use was previously (and continues to be done) excluding DUKES allocations to national navigation.

Both the previous and new international shipping method normalises to DUKES international bunkers for international journeys. However, the new estimates of fuel use at berth are being reported as domestic shipping, including vessels at berth about to embark on an international journey, which means that some fuel is reallocated from marine bunkers to domestic transport. Bottom-up estimates of fuel used on journeys from UK to OTs are aligned with DUKES figures for international bunkers and are included with international shipping in the normalisation to DUKES figures for international bunkers.

Emission factors

The source of the raw emission factors used for CO₂, CH₄ and N₂O is given in DfT (2025f). Fuel-based emission factors in kg/tonne fuel are used and may differ by engine type and/or fuel type.

The fuel-based CO₂ emissions factors for main and auxiliary engines are the same as assumed in IMO (2015) and IMO (2020) and are based on MEPC 63/23, Annex 8:

- HFO: 3,114 kg CO₂/tonne fuel
- MDO: 3,206 kg CO₂/ tonne fuel
- LNG 2,750 kg CO₂ /tonne fuel

Methane emission factors for diesel and LNG fuelled engines are taken from a literature review commissioned by DfT and are 0.14-0.31 kg/tonne (DfT, 2025f). Methane emission factors for steam boilers and gas turbines are the same as used in IMO (2020).

The N₂O emission factors for diesel-fuelled engines are taken from a literature review commissioned by DfT and are 0.08-0.12 kg/tonne (DfT, 2025f). N₂O emission factors for gas and steam turbines are the same as those used in IMO (2020).

Emission factors for NO_x, PM and SO₂ are taken from the 2023 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2023). The PM and SO₂ emission factors were adjusted to account for the sulphur content of marine fuels in the UK using data from the UK Petroleum Industry association, where available, (UKPIA, 2021b) and other sources to complete the time series (Entec, 2010; IMO, 2020). Emission factors for other pollutants are given in DfT (2025f).

Emission factors remain constant over the time-series. However, vessels using HFO in a SECA are assumed to switch to using MDO from 2015 onwards, with an SO₂ emission factor reduction of 90% (from 1% S HFO to 0.1% MDO) accordingly.

Fuel consumption is calculated for each vessel based on the characteristics of the vessel, engine type, movement and draught for the 2019 activity dataset received.

Previously, a fuel efficiency formula was applied due to the assumption that the efficiency of sea transport improved by 1% per year from 2014 to 2035. This accounted for reduced fuel consumption per unit transported and the transition to more fuel-efficient vessels compared to older ones. This fuel efficiency formula is no longer applied over the historic time-series, due to the assumption that improvements in fuel efficiency have unlikely to have been as significant as previously assumed.

Assumptions & observations

The activity data for domestic shipping is now reconciled to the national energy statistics in DUKES for domestic navigation and reflects emissions from UK national marine fuel sales. DUKES estimates marine fuel consumption through monthly surveys targeting 20 major oil companies, refineries, and importers handling over 50 kilo tonnes of oil annually. Sales reports from wholesalers and bunkering firms help classify fuel use, while the Downstream Oil Reporting System (DORS) consolidates data on oil stocks, fuel transfers, and refinery activities. Engagement with the DUKES team at DESNZ showed that it is estimates that DUKES covers over 97% of UK oil supply, but that 80% of fuel is resold through wholesalers, making it hard to track actual usage between coastal shipping, inland waterways, fishing and international shipping. Despite these uncertainties, the DUKES figures cover a high proportion of fuel sales and the UK now reports emissions on a 'fuel sold' basis, consistent with the IPCC 2006 Guidelines.

In some years, the fuel consumption for national navigation and inland waterways (1A3dii) and fishing (1A4ciii) based on the bottom-up estimates from the DfT MEM exceed the total given in DUKES for national navigation plus marine bunkers. Notwithstanding uncertainties in the modelling approach discussed in DfT (2025), one possible reason for this difference is that a significant proportion of domestic voyages in the UK are taken by vessels that are fuelled overseas. This amount of "fuel tankering" is not known.

The previous inventory versions assumed that if a vessel is stationary at berth for more than 24 hours, then the engine is switched off. The new DfT MEM assumed that as long as AIS messages are transmitted a vessels auxiliary engine remains switched on, irrespective of the time that the vessel is stationary at berth. This assumption is applied to all boats except shipping vessels where the 24-hour cutoff is still applied. The evidence from contacting port authorities showed that the revised method for calculation of 'at berth' emissions should be incorporated into the emission inventory. Therefore, the new emission estimates are in line with DfT MEM assumption that as long as there is an AIS message transmitted from the vessels, they do not switch off their auxiliary engines while 'at berth', even if they are stationary for more than 24 hours (except fishing vessels). Furthermore, estimates of fuel use at berth for ships engaged in international journeys are reallocated from marine bunkers and reported as domestic shipping. This increases the proportion of fuel used for domestic navigation from activity at berth.

Recalculations

Within navigation, there were major changes to the methodology to estimate emissions:

- There is a new model (the DfT maritime emissions model) which calculates emissions for a new baseline year of 2019 (previously the baseline year was 2014)
- The proxies for the time series have been reviewed and revised in line with the DfT MEM and DUKES fuel sold statistics.
- New emission factors have been implemented as part of the model.

- Assumptions for fuel consumption and emissions at berth have been reviewed and revised. It is now assumed that as long as AIS messages are transmitted, vessels at berth do not switch off their auxiliary engines, where it was previously assumed that vessels switch off their engines after 24 hours at berth.

There are substantive reductions to fuel use for national navigation due to transition from a 'fuel used' approach (modelled fuel use based on shipping movements in NAEI23) to a 'fuel sold' approach (normalising modelled shipping fuel use to national energy statistics from DUKES).

Improvements (completed and planned)

A major methodology change was undertaken for the 2026. A watching brief is kept on developments in emission factors, revisions to the DfT MEM and improvement to the DUKES statistics.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. The new approach that has been adopted is described in detail in DfT (2025). Ricardo undertook an independent review of the DfT MEM methodology under the DESNZ funded Greenhouse Gas Improvement Program to assess the methodology and provide assurance that it meets inventory reporting requirements.

Time-series consistency

Time-series consistency is ensured by using fuel consumption data for national navigation taken directly from the latest version of DUKES in all years. Fluctuations reflect any fluctuations in the national navigation figures in DUKES.

Uncertainties

The uncertainty analysis is set out in **Annex 2**.

Uncertainties with using DUKES fuel consumption data in national navigation for domestic shipping are:

- Includes Inland waterways and fishing, which cannot be separated from domestic shipping.
- Suppliers under the annual 50kt oil reporting threshold might not have reported their sales data.
- Some fuel sold in Crown Dependencies and Overseas Territories might not be included in the UK's national navigation, instead they might be recorded under marine bunkers or separately.
- Some vessels might be fuelled overseas or at sea even though they depart from and arrive at UK ports.

The uncertainty in the carbon emission factor is considered low, whereas the uncertainties for non-CO₂ gases are higher. Another source of uncertainty in NO₂ and CH₄ emissions is the allocation of activity between different vessel engine types based on the allocations in the DfT MEM. Further consideration of uncertainties and evidence of validation of emissions estimates in the DfT MEM are presented in DfT (2025).

MS 11 Inland Waterways**Relevant Categories, source names****1A3d Inland goods-carrying vessels**

Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)

Personal watercraft e.g. jet ski

Sailing boats with auxiliary engines

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

DERV, Gas oil, Petrol

Background

The category 1A3dii Waterborne Navigation includes emissions from fuel used for small passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. Methods for estimating emissions for these small vessels are presented separately here as they are calculated using different approaches to other marine emissions in the UK inventory.

Key Data sources

Activity: Walker et al (2011), ONS Social Trends, Visit England (2025), OECD Stat, DfT Maritime Statistics (elaborated under Method approach, below).

Emission factors: EMEP/EEA 2009, IMO 2015

An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts. The UK has no separate national fuel consumption statistics on the amount of fuel used by inland waterways in DUKES. However, they are included in the overall marine fuel statistics. A Tier 3 bottom-up approach based on estimates of population and usage of different types of inland waterway vessels is used to estimate their emissions. In the UK, all emissions from inland waterways are included in domestic shipping totals.

The methodology applied to derive emissions from the inland waterways sector uses an approach consistent with the 2023 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2023).

Emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EF_i$$

where:

E = mass of emissions of pollutant i or fuel consumed during inventory period,
 N = source population (units),
 HRS = annual hours of use,
 HP = average rated horsepower,
 LF = typical load factor,
 EF_i = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat; and
- g/kWh fuel consumption factors and fuel-based emission factors.

The inland waterways class is divided into four categories and sub-categories (Walker et al, 2011):

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
 - recreational craft operating on inland waterways;
 - recreational craft operating on coastal waterways;
 - workboats;
- Personal watercraft i.e. jet ski; and
- Inland goods carrying vessels.

Activity data for 2008

A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland, as described in Walker et al. (2011).

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time-series:

- Private leisure craft – ONS Social Trends (2010). No data were available for this dataset after 2009, therefore a second dataset was used to estimate the activity from 2010: OECD stat (2025).
- Commercial passenger/tourist craft – Visit England (2025).
- Freight – DfT - Waterborne transport in the UK: goods lifted and moved by traffic type, Table PORT0701 (Goods lifted - UK inland waters traffic - Non-seagoing traffic – Internal⁶⁶).

⁶⁶ <https://www.gov.uk/government/statistical-data-sets/port-and-domestic-waterborne-freight-statistics-port>

One of these three proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate to all other years in the inventory.

Emission factors

The fuel-based emission factors used for all inland waterway vessels for CH₄ were taken from the EMEP/EEA 2009. Emission factors for carbon are from Baggott et al, 2004. For N₂O, the emission factor for fuel oil is taken from EMEP/EEA 2009. For N₂O from diesel and gas oil, the emission factor used is 0.15 g /kg fuel from IMO (2015) .

Assumptions & observations

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker et al., 2011). Some smaller vessels also run on petrol engines.

Walker et al. (2011) and Murrells et al. (2011) had previously drawn attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap. This potential overlap was reconsidered in light of improvements to the methodology for domestic shipping develop emission estimates using AIS activity data (Scarborough et al. (2017) and DfT (2025)). Certain types of vessels operating at sea close to shore that were previously included in the inland waterways sector of the inventory were now captured in the AIS data. Hence their emissions are included under coastal shipping described above and by DfT (2025f). These vessels were considered to be passenger vessels with >12 passengers and 3 or more engines operating in estuaries, tugs, cranes, and chartered and commercial fishing vessels. To avoid a double count, the activities for these vessels were therefore removed from the inland waterways database.

Recalculations

Inland waterways gas oil consumption has been revised downwards as it was incorporated into the fuel reconciliation for domestic navigation (see **MS 10**). Revised ONS data led to revisions to bottom up-estimates of activity for private leisure craft from 2020, with the largest revision in 2022 (+4.3%).

Improvements (completed and planned)

Emission factors and activity data are kept under review. Improvements may be considered in the scope of wider improvements to shipping planned for the 2026 inventory submission.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time-series consistency

The bottom up analysis for this source category was carried out for one year, and the time-series is generated using proxy statistics, as set out in the method approach section, above. Consistent time-series of proxy statistics, where available, have been used to estimate the inland waterways activities time-series. For private watercraft, two data sets have been combined. Where the two data sets overlap, there is a correlation in the trend. The combination of these data sets does not introduce any time consistency issues.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. There are no official statistics for the population of vessels, the total fuel consumption or the annual usage of the vessels. There may also be some overlap in definitions between small coastal shipping and inland waterways.

MS 12 International shipping**Relevant Categories, source names**

1D1b: Marine bunkers: Shipping - international IPCC definition

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Gas oil, fuel oil, LNG

Background

This method statement covers estimates of international marine bunkers which are reported as a Memo item and not included in the UK totals.

Key Data sources

Activity: UK Maritime and Coastguard Agency, DfT Maritime Statistics (2025c), MMO Fishing statistics (MMO, 2025), DUKES (DESNZ 2025a), the DfT Maritime Emissions Model (DfT, 2025f).

Emission factors: DfT (2025), IMO (2020).

An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

Fuel consumption and emissions for international shipping are estimated following an approach that meets and exceeds the requirements of a Tier 3 methodology. The DfT Maritime Emissions Model, used to estimate emissions for national navigation and fishing (**MS 10**) has global coverage and is also used to estimate emissions for international shipping.

The model uses 2019 high resolution satellite and terrestrial Automatic Identification System (AIS) vessel movement data supplied by the UK Joint Maritime Security Centre and carries out an emission calculation specific to each vessel and for each point of the vessel’s voyage around the globe. Port calls are used to identify a voyage as a UK domestic movement, and reported under 1A3dii, or part of an international voyage calling in the UK reported as a Memo item under 1A3di.

The bottom-up estimates of fuel consumption calculated in the DfT MEM are reconciled to national energy consumption statistics from DUKES. This approach provides estimates that are consistent with the IPCC 2006 Guidelines.

Details of the methodology are given in the report by DfT (2025f) and in **MS 10**, and only a summary is given here.

Activity data for 2019 vessel movement-based emission calculations

The approach taken to estimate Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO), and Liquefied Natural Gas (LNG) fuel consumption is the same as described for national navigation and fishing (**MS 10**). The detailed Tier 3 approach used in the DfT Maritime Emissions Model (MEM) identifies fuel consumption and emissions from international movements from a UK port to a non-UK overseas port.

Time-series trends in activity data for vessel movement-based emission calculations

The approach to estimate emissions for historical years before 2019 and years after 2019 uses DfT MEM port statistics for each vessel category as proxies for activity levels.

Overall, there are 18 separate vessel categories considered. The statistical time series cover all years back from 2019 to 1990 and forward to the most recent year of statistics (currently 2024). In many cases, multiple statistical series need to be used if no complete series are available to cover the entire period to 1990. The approach to estimate trends in international shipping activity follows the same approach as that set out for Domestic shipping. The specific statistical series used for each vessel category is indicated in Table 3.13. For international shipping, trends are developed largely from DfT port statistics for international activity. The main DfT statistics used is PORT0201 international UK major port freight traffic by cargo type and direction, annually: 2000 - 2024 (DfT, 2024d).

Fuel reconciliation with official statistics

The DfT MEM provides bottom-up estimates of fuel consumed by domestic and international from AIS vessel movement data. Data on fuel sold for national navigation are taken from DUKES published by DESNZ (DESNZ, 2025a). The bottom-up estimates of emissions from international shipping are normalised to align with the DUKES fuel sold figures for marine bunkers.

Both the previous and new international shipping method normalises to DUKES international bunkers for international journeys. However, the new estimates of fuel use at berth are being reported as domestic shipping, including vessels at berth about to embark on an international journey, which means that some fuel is reallocated from marine bunkers to domestic transport.

Table 3.4 summarises the time-series in gas oil and fuel oil consumption for domestic coastal and military shipping, fishing, inland waterways, international shipping and voyages from the UK to the OTs for selected years since 1990. Fuel consumed in the OTs and for voyages from the OTs to the UK are not included in this table.

Table 3.14 Fuel consumption (Mtonnes) for UK marine derived from inventory method

Year	Domestic coastal and military Gas oil	Fishing Gas oil	Inland waterway Gas oil	International bunkers Gas oil	Domestic coastal and military Fuel oil	Fishing Fuel oil	Voyages from UK to OTs Fuel oil	International bunkers Fuel oil
1990	1.42	0.07	0.02	0.61	0.043	0.010	0.051	1.33
2000	1.20	0.04	0.01	0.66	0.036	0.004	0.033	0.90
2005	1.04	0.04	0.01	0.54	0.334	0.025	0.030	1.12
2010	0.97	0.04	0.01	0.58	0.092	0.011	0.071	1.77
2015	1.18	0.06	0.03	1.16	0.000	0.000	0.043	0.79
2016	1.23	0.07	0.03	1.22	0.000	0.000	0.029	0.85
2017	1.22	0.07	0.03	1.15	0.000	0.000	0.024	0.75
2018	1.22	0.07	0.03	1.13	0.000	0.000	0.022	0.79

Year	Domestic coastal and military Gas oil	Fishing Gas oil	Inland waterway Gas oil	International bunkers Gas oil	Domestic coastal and military Fuel oil	Fishing Fuel oil	Voyages from UK to OTs Fuel oil	International bunkers Fuel oil
2019	1.18	0.06	0.03	1.08	0.008	0.000	0.018	0.67
2020	0.84	0.04	0.01	0.91	0.003	0.000	0.027	0.52
2021	0.94	0.04	0.01	0.91	0.000	0.000	0.020	0.57
2022	0.91	0.04	0.01	0.87	0.012	0.000	0.057	0.60
2023	0.96	0.05	0.02	0.92	0.000	0.000	0.016	0.57
2024	0.97	0.06	0.02	0.91	0.003	0.000	0.011	0.58

Emission factors

The source of the raw emission factors used for CO₂, CH₄ and N₂O is given in DfT (2025). Fuel-based emission factors in kg/tonne fuel are used and may differ by engine type and/or fuel type. Emission factors for international shipping (1A3di) were consistent with the factors for national navigation described in **MS 10**.

Assumptions & observations

Emissions of direct greenhouse gases for the international navigation Memo item 1A3di in this inventory are reported on the basis of fuel sold figures in DUKES for international fuel bunkers. However, in the new methodology introduced for this submission estimates of fuel use at berth are being reported as domestic shipping and this means that some fuel is reallocated from marine bunkers to domestic navigation.

Recalculations

Within navigation, there were major changes to the methodology to estimate emissions for this submission. There are reductions to fuel use for international shipping due to the reallocation of estimates of fuel use at berth by vessels about to embark on an international journey from marine bunkers to domestic shipping.

Improvements (completed and planned)

A major methodology change was undertaken for the 2026 submission. A watching brief is kept on developments in emission factors, revisions to the DfT MEM and improvement to the DUKES statistics.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time-series consistency

Time-series consistency is ensured by using fuel consumption data for international fuel bunkers taken from the latest version of DUKES in all years. Fluctuations reflect any fluctuations in the bunker fuel figures in DUKES.

Uncertainties

The uncertainty analysis is set out in **Annex 2**. Uncertainty for international bunkers is not estimated.

MS 13 Naval shipping

Relevant Categories, source names

1A5b: Shipping - naval

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Gas oil

Background

Emissions from military shipping are reported separately under CRT Category 1A5b.

Key Data sources

Activity: MoD, 2025

Emission factors: DfT (2025f), IMO (2020)

An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Sustainable Development team of the MoD (MoD, 2025). Data are provided on a financial year basis and are amended to derive figures on a calendar year basis.

Emission factors for military shipping were calculated based on the DfT MEM emissions for naval vessels divided by the activity for naval vessels (DfT, 2025f). Although the DfT MEM does not cover all military shipping activity, the factors were assumed to apply to military vessels.

Assumptions & observations

The DfT MEM provides partial coverage of emissions from naval vessels, which are not required to switch on AIS at all times. It is assumed that emission factors for naval vessels covered by the DfT MEM apply to military vessels.

Recalculations

Time-series emissions revisions are mainly a result of the update to use emission factors for military shipping based on emissions and activity for naval vessels from the DfT MEM.

Improvements (completed and planned)

Improvements to the emission factors for naval shipping were made under the scope of the wider improvements to national navigation completed for this submission. Emission factors and activity data are kept under review.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time-series consistency

The time-series is generated from consistent data sets for all years, there are no known issues to raise.

Uncertainties

The uncertainty in the fuel use estimates is low since these are taken directly from the MoD. The carbon factors of fuel used by naval vessels would be known with low uncertainty, but default factors for CH₄ and N₂O taken from military vessels covered by the DfT MEM, and their relevance to naval vessel engines are more uncertain.

MS 14 Military aircraft**Relevant Categories, source names**

1A5b : Aircraft - military

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Aviation spirit, aviation turbine fuel

Background

Emissions from military aviation are reported separately under CRT Category 1A5b.

Key Data sources

Activity: MoD, 2015, 2025

Emission factors: Baggott et al., 2004, IPCC, 1997.

An accompanying spreadsheet "Energy_background_data_uk_2026.xlsx" lists all emission factors used in the energy sector, including a full list of references⁶⁷. Table 1.4 gives additional information for common activity data sources.

Method approach

LTO data are not available for military aircraft movements, so a simple, Tier 1 approach is used to estimate emissions from military aviation. The estimate of military emissions is made using military fuel consumption data (MoD, 2025) and IPCC (1997)⁶⁷. The military fuel data include fuel consumption by all military services in the UK. An earlier data set (MoD, 2015) also includes fuel shipped to overseas garrisons and casual uplift at civilian airports; these data have been extrapolated assuming constant consumption at the level the latest data indicates to generate a complete time-series.

Assumptions & observations

Most fuel use for military aviation is included in the DUKES totals. Military aircraft consumption data provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2025) is subtracted from DUKES to ensure there is no double counting (see **Annex 5.2**). Fuel use for casual uplift is considered to be outside of DUKES.

Recalculations

No recalculations.

Improvements (completed and planned)

No improvements to this method are currently planned. Emission factors and activity data are kept under review.

⁶⁷ T1 cruise factors in the 2006 IPCC Guidelines are not in units consistent with our methodology, and T2 LTO factors in the 2006 IPCC Guidelines are based on IPCC 1997 values anyway.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time-series consistency

The time-series is generated from consistent data sets for all years, there are no known issues to raise.

Uncertainties

The uncertainty in the fuel use estimates is low since these are taken from a reliable source. Carbon emission factors are based on country specific data, whereas the non-CO₂ gases are reliant on defaults, which can lead to higher uncertainties.

MS 15 Coal mining and handling

Relevant Categories, source names

- 1B1ai1: Deep-mined coal
- 1B1ai2: Coal storage and transport
- 1B1aii1: Open-cast coal

Relevant Gases

CH₄

Relevant fuels, activities

Coal produced

Background

In 2024 there were only eight small deep-mining collieries licensed to operate in the UK. The UK coal industry has been in decline for many years and during 2015 the last large deep coal mines closed, and this is reflected in an over 99% reduction in UK deep-mined coal production since 2015, according to UK energy statistics (DESNZ, 2025a). None of the remaining mines are large enough to warrant investment in methane drainage and recovery systems used to collect and burn mine gas to raise power; until 2015 there were still operational deep mines in the UK that did capture and utilise methane. There were no open cast coal mines operating in the UK in 2024 after the closure of the last large surface mine, Ffos-y-Fran in November 2023. This is compared with 188 deep mining collieries and 126 open-cast mines operating in 1990⁶⁸.

Key Data sources

- Activity Data: All activity data on coal production at open cast and deep mines is from DUKES (DESNZ, 2025a), except for production at licensed mines during 1990-1995 (only) which are from an industry reference (Barty, 1995). The operator of the one remaining significant deep coal mine, at Aberpergwm, which produces highly anthracitic coal product used in water treatment and as a reductant in the I&S sector, has provided estimates of annual production in recent years (Energybuild, personal communication, 2024).
- Emission Factors: Operator reported data on methane emissions from deep mines are available for many years of the inventory time-series (1998-2014), and are used to derive CS EFs (UK Coal, 2015; Coal Authority, 2015), in conjunction with UK energy statistics from DUKES (DESNZ, 2025a). Following the closure of all UK large deep mines there is only operator-reported emissions data for one site, Aberpergym, which has reported annual methane emissions from 2021 onwards. Up to and including 2014, many UK deep mines were operating and, for a high proportion of those deep mines, data are available at the mine-specific level on coal production, methane drainage, methane used in gas engines and methane emitted to atmosphere. From these data, mine-specific methane emission factors are derived for (i) total methane released from the mining activity (i.e. including the methane that is available for use in gas

⁶⁸ http://webarchive.nationalarchives.gov.uk/20140721140515/http://coal.decc.gov.uk/assets/coal/DyGgJafg_pdf_part.pdf

engines), and (ii) the total methane emitted to atmosphere (i.e. after having subtracted the amount of methane used in gas engines). In deriving inventory estimates for 2015, the mine-specific emission factors from 2014 (UK Coal, 2015) were applied to 2015 data on mine-specific production (Coal Authority, 2016), taking account of where those deep mines were still utilising methane in engines. For 2016 onwards, with UK deep-mined coal production only at a handful of small mines with no methane capture and utilisation, the inventory estimates are derived based on the UK weighted-average emission factor from 2014 (UK Coal, 2015) *excluding any mitigation of methane in gas engines*, applied to the 2016 to 2024 UK activity data on coal production in deep mines (DESNZ, 2025a), except in the case of Aberpergym mine, where the reported emissions and production data from 2021 are used to estimate emissions, with 2018-2020 emission estimates based on annual production data and the IEF from 2021-2023 inclusive. Methane EFs from mining operations from UK research are used to estimate emissions from open-cast mines and licensed mines (both from Williams, 1993), and emissions from coal storage and transport (Bennett et al, 1995).

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

Emissions are calculated from saleable coal production statistics for open-cast and deep-mined coal, taken from DUKES (DESNZ, 2025a). For all sources, UK-specific emission factors are applied, which in the early part of the time-series are derived from periodic industry publications, and for later years (1998 onwards) are primarily derived from company-specific or mine-specific reporting of methane emissions by mine operators. Industry-wide colliery methane utilisation data are taken from DUKES (DESNZ, 2025a).

From 1990-1995, a small number of privately-owned mines classified as “deep mines” operating in the UK were shallower and smaller than Government-owned deep mines. These mines were licensed by the UK Government and in all years produced less than 3% of total UK deep-mined coal, whilst the majority of deep mines were Government-owned and operated. The Watt Committee Report #28 (Williams, 1993) indicates that these smaller licensed mines emitted less methane than the nationalised deeper mines, and therefore the aggregate emission factor for the early part of the time-series is slightly lower. Activity data for production at licensed mines is taken from Barty (1995), with the activity data for non-licensed mines calculated by difference from the UK deep-mine coal production total in UK energy statistics.

Emission factors for methane from **deep-mined coal** production are taken from:

1990-1992 Bennett et al (1995) was a study on deep mines which produced estimates of emissions for the period 1990-93. This was a period over which significant numbers of mines were being closed, hence the range in emission factors from 10 to 13.1 kg CH₄ per tonne coal extracted.

1990-1995 The methane emission factor of 1.36 kg CH₄/tonne coal produced at licensed, shallow mines is from Williams (1993).

1993-1997 No time-series of emissions data or industry research for deep-mined mines are available for 1993-97, and therefore the 1998 factor from operator reporting at deep mines (see below) is used. The combination of this 1998 factor for deep-mined coal and the lower

factor for licensed, shallow mines operating to 1995 leads to a variable aggregate factor during 1993-1995.

1998-2014 The emission factors for UK mines in 1998-2014 are based on operator measurements of the methane extracted by the mine ventilation systems for all collieries operated by UK Coal (UK Coal, 2015) and for collieries owned by other operators that report methane utilisation and venting data (Coal Authority, 2015). Not all UK collieries provide data on methane utilisation and venting. The emission factor derived from the sites that provide data is applied across all UK production at deep-mined sites. The proportion of UK production that is covered by the reporting collieries ranges from 77% in 1998 to 96% in 2004 and 2007, and was around 90% from 2008 to 2012, but following closures fell back to 78% in 2014 and no mine-specific data from operators are available for 2015, 2016 nor 2017.

In **2015**, only data on the production of coal at the UK's large deep mines was available (Coal Authority, 2016). In order to maintain time-series consistency of the method, the Inventory Agency used the mine-specific production data from 2015 and applied the emission factors derived from the 2014 dataset for each of the large deep mines.

From 2016 onwards, as all of the UK's major deep mines had already closed, total UK coal production declined to its lowest level across the time-series. To maintain time-series consistency, the Inventory Agency applies the 2014 emission factor derived for all UK coal deep-mined extraction but *discounting any methane mitigation* as none of the remaining small mines have any systems to capture and use the eluted methane in gas engines. This is reflected in the increase in the IEF from 2016 onwards. As noted above, the Aberpergym mine closed in 2015 and then re-opened in 2018 and produces a highly anthracitic coal product for use in water treatment and as reductant in the I&S sector, rather than as a fuel. Production has increased, leading to methane emissions being measured and reported to the regulator inventory from 2021 onwards. The reported emissions are included in the UK GHGI and emissions from the mine during 2018 to 2020 are estimated using site-level production data and the IEF derived from production and emissions reported during 2021 to 2023.

Methane extracted at deep mines is either emitted into the atmosphere or utilised for energy production; the gas is not flared for safety reasons. Data provided by colliery operators provides mine-specific annual data on the mass of methane:

- vented to atmosphere, fan drift (A);
- drainage to surface (B); and
- utilisation of methane in electricity generation I.

The total methane vented to atmosphere from these sites that report the methane vented drained and utilised is therefore calculated as "A + B – C".

For the non-reporting sites that are typically smaller with no methane utilisation, the EF is derived from the sites that do report (from the vented and drained methane). Annual data (methane generation, methane utilisation, coal production) are obtained from mine operators. In 2005 there were 7 mines that reported methane emissions, then 6 in 2006, 5 in 2007 to 2010, 4 in 2011-12 and only three in 2013 and 2014. For these mines the aggregate emissions of methane (before any utilisation in gas engines) has been used together with the annual production data to derive an "unabated" methane IEF that is regarded as the most representative factor to apply to the production data from the smaller non-reporting (of emissions) UK deep coal mines.

Therefore, total methane emission estimates for deep-mined coal in the UK from 1998 onwards are calculated as follows:

$$\text{UK Emissions} = D + (E * F)$$

Where:

D = the sum of methane emissions reported (after any utilisation in gas engines) by the (typically larger) UK deep coal mines that can provide annual methane emission estimates;

E = UK total deep-mined coal production from DUKES – Annual coal production at all sites included in D; and

F = IEF for unabated methane emissions, based on reported methane emissions data from sites included in D (i.e. methane elution before any utilisation) / production at the sites included in D.

The decline in methane emissions in recent years in the UK reflects both the decline in UK deep-mined coal production and the increase in uptake of technology to utilise coal mine methane to generate electricity.

The emission factor for methane from coal storage and transport factor of 1.16 kg CH₄ per tonne of coal produced is only applied to deep mined coal production and is taken from industry research, Bennett et al (1995).

The emission factor for methane emissions from open-cast coal production of 0.34 kg CH₄ per tonne of coal production is taken from industry research, Williams (1993). The total production of saleable coal is derived from the DUKES statistics. Where coal is upgraded to saleable form, some coal is rejected in the form of coarse discards containing high mineral matter and also in the form of unrecoverable fines. Typically, around 20% of the weight of the raw coal feed is lost through these preparation processes, as per the 2006 IPCC guidelines. Raw coal production is therefore estimated by increasing the amount of 'saleable coal' by the fraction lost through washing. The total emissions from open-cast mining are based on measurements of the total methane content of freshly sampled coal cores from open-cast sites from the three main producing regions in the UK. These data are used to generate the total emission factor for all open-cast coal production, regardless of the stage at which this emission takes place.

Assumptions & observations

- Open cast coal emission factor:** As noted in the method section, the CS EF for CH₄ emissions from open cast coal production are based on analysis of the total methane content of freshly sampled coal cores and these EFs reflect the total methane emissions for all open-cast coal produced, regardless of the stage at which this emission takes place. i.e. it is assumed in the UK GHGI that all of the measured methane content of the coal is released prior to combustion, and these emissions are all allocated within 1B1ai2 open-cast coal mining (Mining activities). This is consistent with the 1996 IPCC GLs method where country-specific data are used, in section 1.7.2.4, Equation 5 and the text on page 1.11: "*In most cases, if the Tier 2 approach is used to estimate methane emissions from surface mines, post-mining emissions from surface-mined coals are assumed to be zero.*" Furthermore, the UK approach is consistent with the general equation for estimating fugitive emissions from surface coal mining presented in section 4.1.4 of the 2006 GLs, as the UK EF comprises all methane in the coal produced that could be released at any stage post-mining. As a result, the UK estimate for open-cast coal mining activities is likely to be an over-estimate, as some methane will be retained within the coal up to the point of combustion, especially for lump coal used in domestic grates, where desorption of the methane is much slower than for fine coal processed for use in other sources such as power stations. The basis for this open-cast coal production factor also explains why the EF on methane from coal storage and transport (see paragraph above) is only applied to the activity of deep-mined coal in the UK, rather than to the total UK coal production data; to apply it to open-cast production also would introduce a double-count;

- **Other coal:** In the UK energy balance, there is an additional line for coal production which is for “other” sources of coal into the UK economy, which are typically very small numbers (95 kt in 2013 and zero since 2014) and represent coal obtained from slurries, ponds and rivers. We therefore include the activity data from other sources of coal within the UK energy balance, as part of the overall supply of coal as reported in the CRT table 1. Ab, but we do not derive any estimates of fugitive emissions from this production source, as it is not coal that has been abstracted from open-cast or deep mines.
- **Decline in emissions from deep-mined coal.** The 61% reduction in emissions reported in 1B1ai1 since 2015 reflects the closure of all large UK deep-mines, with just a handful of smaller deep mines, with no methane mitigation, still in operation.

Recalculations

There have been no significant recalculations to this sector in the 2026 submission.

QA/QC

Activity data for coal production in deep-mined and open-cast mines in the UK are quality-checked through comparison of data reported within DUKES and data reported directly by the UK Coal Authority, which provides regional and UK totals of coal production. The information provided directly by colliery operators regarding their methane recovery systems are also checked against the data published by DESNZ on coal mine methane projects in the UK (which encompasses both operating and closed / abandoned mines with coal mine methane recovery systems).

The Inventory Agency has consulted directly with the operators of the Aberpergym mine to validate the reported annual methane emission estimates. The operators have provided an indication of the total material extracted from the mine in order to generate their highly anthracitic (non-fuel) product, as well as the measurements taken of methane concentrations in the mine gases vented to atmosphere, and of the mass flow rates. The high level of reported methane emissions per unit ‘coal’ product reflects: (i) the high gassy content of the anthracitic coal seams, (ii) the high level of material extraction per unit product, which is roughly double the mass of the ‘coal’ product reported by the mine, and (iii) that there is no mine gas collection and utilisation or flaring to mitigate the methane emissions.

Time-series consistency

The factors for coal mining are all based on UK industry research. Emission factors from coal storage and transport, licensed mines and from open-cast mines do not vary through the time series; in each case the same factor is applied to the UK activity in every year. For deep-mined coal emissions there is a variable emission factor across the time series, derived from operator reporting and reflecting the changing methane management practices within UK collieries, especially to increase methane capture and oxidation for power-raising in recent years, leading to a gradually declining methane emission factor per unit coal produced since the early 2000s. The variability in the factor also reflects the changes in production from different mines that have different methane management practices, as for some UK collieries the capture and use of methane has not proved cost-effective and therefore the technology is not uniformly implemented. The variability of the time series of emission factors represents changes in UK coal mining, and not time series consistency issues. As described in the methodology section above, for the latest years of reporting (since 2015) the Inventory Agency has extrapolated the EFs from 2014 to estimate emissions from all deep mines where there is no emissions reporting to UK regulators, in order to maintain time-series consistency of the method.

Uncertainties

The uncertainty in the coal production statistics is low, since these are based on official statistics. The emission factors applied are country specific, and in some cases based on mine specific data, and therefore the uncertainty is lower than using default literature values. Additional uncertainty is introduced through the application of emission factors based on a sub-set of mines to represent full UK coal production, but we note that the total UK deep mined production where a methane elution factor is applied based on data from other sites is typically smaller sites that together produce (for many years in the time series) only around 10% of UK coal. However, we also note that the proportion of UK production at non-reporting deep mines has grown due to recent closures to 28%, 22% and 15% in 2013, 2014, and 2015 respectively and now 100% in 2016 to 2024. Therefore, the overall uncertainty of deep-mined coal methane emissions is higher for these years, but it this is set against the context that deep mined coal emissions only account for less than 0.66% of total methane emissions in the UK in 2024, whilst open-cast coal mining only accounts for 0.01% of total UK methane emissions.

MS 16 Closed coal mines**Relevant Categories, source names**

1B1ai3: Closed Coal Mines

Relevant Gases

CH₄

Relevant fuels, activities

Modelled emissions of releases of residual methane within coal seams from abandoned coal mines, including from the flooding of mine seams following closure.

Background

Methane emissions from **closed coal mines** are accounted for within category 1B1ai3 of the UK inventory. Emission estimates are based on a study funded by DECC (WSP, 2011) which updated research from 2005 (White Young Green, 2005) to:

- reflect the UK trend in mine closures and re-openings driven by fluctuations in energy prices since the 2005 research; and
- improve the representation of methane recovery and utilisation at closed collieries (Colliery methane combustion emissions are reported in the energy sector, 1A).

Methane emissions from closed mines reach the surface through many possible flow paths: vents, old mine entries, diffuse emission through fractured and permeable strata. Direct measurement of the total quantity of gas released from abandoned mines is not practical.

Data for 32 mines closed between 1990 and 2015, and 121 mines closed before 1990 are included in the model. The model also includes projections, which can be changed to account for mine closures occurring earlier or later than predicted. Note that all major UK deep coal mines were closed by the end of 2015, leaving a very small number of operating small mines. The abandoned mines model was updated to reflect this for the 2017 submission, and there has been no further update to the model in the 2026 submission. Methane utilisation has increased significantly across the time-series, up to a maximum of 94% in 2004.

Key Data sources

WSP, 2011 and Kershaw, 2005

*An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. **Table 1.4** gives additional information for common activity data sources.*

Method approach

The UK model was developed in 2005 (Kershaw, 2005) and revised in 2011 (WSP, 2011). The 2011 study used the same method, updating data for mine closures during 2005-2010.

The model generates both historic and projected methane emission estimates from closed UK coal mines, combining two separate sets of calculations to estimate emissions from:

- coal mines that were closed before 2005 and included in the 2005 update; and
- mines that were not included in the 2005 update, including mines closing or predicted to close between 2004 and 2028.

The model uses a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines.

The model calculates methane reserves for all UK coalfields that are not totally flooded from 1990 with projections to 2050. The gas reserves are calculated by totalling all the gas quantities in individual coal seams likely to have been disturbed by mining activity. To enable calculation of the reserves over time, the rise in water levels in the abandoned mines due to water inflow has been calculated based on industry consultation, with a date estimated for each of the mines to be fully flooded; as mine workings become flooded they cease to release significant amounts of methane to the surface.

The development of the model has drawn on industry monitoring to measure methane emission from vents and more diffuse sources, including measurement of the flow rate and methane concentrations of vented mine gases. The industry knowledge of these methane sources has increased greatly in the UK over the last 10 years as the technology to capture and utilise the methane for power generation has developed alongside new economic incentives to utilise the mine methane in this way. Monitoring of more diffuse sources involves the collection of long-term gas samples to measure any increases in background atmospheric methane level in the locality.

Methane flows measured by both methods showed a general increase with the size of the underlying gas reserve. The data indicate an emission of 0.74% of the reserve per year as a suitable factor to apply to the methane reserve data in order to derive methane emission estimates for abandoned UK coalfields for 1990 to 2050, and this factor is applied within the model to derive the UK emission estimates.

Estimates have been made for both deep-mined and open-cast coal.

Assumptions & observations

WSP (2011) derived estimates for historic methane emissions from closed coal mines and also generated projections to 2050, based on forecasts for UK coal mining activity and industry information on the quantity of underlying methane gas and expected rates of flooding of each mine following closure. The 2024 emission estimates in the 2026 UK GHGI submission were therefore taken from the projections of emissions within the 2011 WSP report, with the emission profiles through time for all major UK deep mines recently closed (i.e. since the study in 2011) brought forward to the actual date of closure, as all such mines were closed by the end of 2015. Each large deep mine within the model has a profile of projected flooding and emissions of methane upon closure; the closure dates in the model have now been fixed to the actual dates rather than projected dates, and the emissions of methane following closure are therefore now occurring for every deep mine and will diminish over time. Following the rapid decline of the UK deep-mined coal industry, this source is now the most significant emission source in 1B1, and accounts for 0.8% of total UK methane emissions in 2024.

The emissions from all abandoned mines are included within the 1B1ai3 source category.

All large deep mines in the UK have now closed, and therefore this source category will decline in significance in future years.

Recalculations

There were no recalculations or method changes to the closed coal mines source category in this submission. All remaining large deep coal mines closed by the end of 2015, and the model was modified to reflect the closures in deriving estimates for the 2017 submission; no further updates to the model have been made for subsequent submissions, as the modelled future profile of emissions across the sector is unchanged.

Improvements (completed and planned)

No improvements to this method are currently planned. The model is periodically reviewed and updated. However, as all large deep mines in the UK that contribute significantly to this emission source are now closed, the emissions trend is diminishing through time and in 2024 only accounts for 0.8% of the UK methane inventory total, this source is considered a low priority for future improvement work.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. WSP (2011) was subject to review by a steering committee, and final sign off by DECC. The research also includes benchmarking of UK specific estimates with other inventories to ensure that the method used remains appropriate for the UK.

Time-series consistency

No time-series consistency issues have been identified.

Uncertainties

The uncertainty in the emissions from this source was assessed as part of WSP (2011). The uncertainty assessment indicated a range of $\pm 17\%$ to $\pm 41\%$ over the period 1990-2050. This level of uncertainty is in line with IPCC guidance on Tier 2 and Tier 3 methodologies. This considered the uncertainty in the future mine closure dates, gas reserve estimates, the annual methane emissions rate as % of gas reserve, the open cast mine methane emissions factor and the methane utilisation factor.

MS 17 1B2 excluding: Oil refining, storage and distribution (1B2aiv to v) and natural gas distribution (1B2biii to v)**Relevant Categories, source names**

1B2ai:	Onshore, offshore oil well exploration; Oil production: offshore well testing
1B2aii:	Upstream oil production: fugitives, direct processes; Onshore oil production (conventional); Oil terminal: other fugitives, direct processes
1B2aiii:	Upstream oil production: onshore, offshore oil loading; Oil transport fugitives: pipelines, road/rail tankers
1B2aiv:	Oil terminal storage
1B2avi:	Abandoned oil wells: onshore, offshore
1B2bi:	Unconventional gas well exploration; Onshore, offshore gas well exploration; Gas production: offshore well testing
1B2bii:	Onshore natural gas production (conventional); Onshore natural gas gathering
1B2biii:	Upstream gas production: fugitives, direct processes; Gas terminal: other fugitives, direct processes
1B2biv:	Gas terminal storage
1B2bvi:	Abandoned gas wells: onshore, offshore
1B2c1i:	Upstream oil production: venting; Oil terminal: venting
1B2c1ii:	Upstream gas production: venting; Gas terminal: venting
1B2c1iii:	<i>(Reported as IE)</i>
1B2c2i:	Upstream oil production: flaring; Oil terminal: flaring
1B2c2ii:	Upstream gas production: flaring; Gas terminal: flaring
1B2c2iii:	<i>(Reported as IE)</i>

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

All fugitive releases from oil and gas production, excluding leakage from gas transmission and distribution. Distribution of oil products is not described since there are no direct GHG emissions.

The activity data for well exploration and also for wells abandoned are the number of wells (drilled or abandoned, accordingly) per year.

The activity data for well testing is the mass of flared gas arising from the well tests, whilst the activity data for all other gas flaring is also the mass of gas flared.

The activity for the oil transport source categories is the annual mass of crude oil transported per source per year.

The activity data for source categories in 1B2b2 is the annual volume of natural gas produced/gathered.

For other source categories the methods are based on the sum of reported emissions and there are no associated activity data.

Background

These source categories across 1B2 cover fugitive emissions arising from the exploration, production, transportation, processing and storage of liquid and gaseous fuels. It excludes fuel combustion emissions associated with upstream oil and gas exploration and production which are reported within 1A1cii Oil and Gas Extraction, the method for which is presented in **MS2**.

The UK has been producing oil and gas, predominantly offshore in the North Sea, for decades, and there are several hundred oil and gas platforms that have been operating across the time series. Oil and gas exploration activities (well drilling, completions, well testing) lead to fugitive and flaring emissions; similarly at the end of the production life of each well there may be emissions from abandoned wells, whether they are plugged or not, and from purging of infrastructure during decommissioning. Process treatments (e.g. acid gas treatment) and fugitive releases give rise to GHG emissions during the production phase at offshore facilities and in subsequent material processing at onshore terminals to prepare oil and gas products for onward distribution.

*[Emissions from leakage during gas transmission and distribution, and the point of use are included in **MS 18**.]*

Offshore oil and gas is transported to onshore terminals via pipelines and marine tankers. Emissions of CH₄ and NMVOC occur during loading of oil into the ship's tanks and subsequent unloading. Similarly, CH₄ and NMVOC occur when storage tanks are loaded or unloaded, whether these be at oil terminals or a different onshore location.

There are also a small number of onshore oil and gas wells in the UK. This is a very small component of the upstream sector. Fugitive emissions do arise from well drilling, the production of oil and gas, flaring of waste gases, from well abandonment and from the transfers of oil product to rail and road tankers for deliver to oil terminals and refineries.

Shale gas reserves have been identified and some preliminary testing to explore the prospects for shale gas production has occurred during the inventory time series, but there is no active exploration or production of shale gas currently in the UK.

Key Data sources

Activity data:	EEMS (DESNZ OPRED, 2025), DUKES (DESNZ, 2025a), IED/PRTR-reported data (EA, NRW and SEPA, 2025) UK ETS data (DESNZ, 2025b), UKOOA (2005), Fuels Industry UK (2025), PPRS data (DESNZ, 2025c), DTI Brown Book (DTI, 2004), WONS data (NSTA, 2025).
Emission factors:	EEMS (DESNZ OPRED, 2025), UK ETS (DESNZ, 2025b), UKOOA (2005), IPCC 2006 Guidelines (IPCC, 2006), 2019 Refinement to the 2006 GLs (IPCC, 2019)

*An accompanying spreadsheet "Energy_background_data_uk_2026.xlsx" lists all emission factors used in the energy sector, including a full list of references⁶⁹. **Table 1.4** gives additional information for common activity data sources.*

⁶⁹ This can be found as one of the additional documents to the NID https://naei.beis.gov.uk/reports/reports?report_id=1108. Note that there can be a delay between the NID being published on the NAEI website after official submission.

Method approach

The Inventory Agency has researched and analysed all available activity and emissions data for the UK upstream oil and gas sector across the time series during a recent inventory improvement project (Thistlethwaite et al, 2022). The inventory methods for sources across 1B2 draw upon the best available data from the sector, through a range of reporting mechanisms that have been developed by UK regulatory agencies across the time series.

*A more detailed summary of the oil and gas sector improvement project is presented in **Annex 5.1.1.6**. The methods developed impact both fuel combustion emissions reported in 1A1cii (see **MS 2**) and all upstream oil and gas fugitive emission sources reported in 1B2.*

An overview of the data sources and methods used to derive estimates for the categories included in this MS is below.

Note that in the UK there are different regulatory mechanisms that govern the activities of: (i) offshore oil & gas exploration and production, (ii) onshore conventional oil & gas exploration and production, and (iii) onshore unconventional shale gas exploration (of which, there is no current production). These different regulatory systems dictate data availability for upstream oil and gas activities, which impacts on the best available method for each sector of the inventory; for example, the data available for offshore rigs is more detailed (source-specific) than for onshore terminals (where only some resolution of emissions by source is feasible).

It is important to note however that despite these different methods and data availability, the UK Inventory Agency does report in a time series consistent manner for each source, and that the UK inventory is complete for all emission sources, with the exception that there are no data available currently to estimate emissions from oil and gas well blowouts other than for the 2012 blow-out at the Elgin platform, as outlined below.

Table 3.15 Overview of UK GHGI methods per source category

IPCC	Source Category	Method Description
1B2a1	Oil Exploration	Onshore wells, all years: IPCC Tier 1 (2019 Refinement) method. Emission = #wells drilled x IPCC default EF (per conventional oil well) Offshore well testing, 1990-1997: UKOOA 2005 (Tier 2). Assumptions to derive time series using well drilling time series. Offshore well testing, 1998 – Latest year: $\sum$ operator emissions per facility, based on EEMS (DESNZ OPRED, 2025), which includes well testing emissions per facility, per year. Tier 2/3 as EFs are from EEMS operator guidance (CS).
1B2a2	Oil Production	Onshore oil production: Hybrid Tier 2 method. $\sum$ Large + small sites. Larger sites, Emissions = $\sum$ operator emissions per wellsite (EA, 2025) Smaller sites, Emissions = Production AD (PPRS) x EF derived from larger sites, IEF from (PI emissions / PPRS production data) Offshore oil production, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends; residual category for CH₄. Offshore oil production, 1998- Latest year: $\sum$ operator emissions per facility, based on EEMS (DESNZ OPRED, 2025). Tier 3 as emissions for process emissions are derived from operator reporting; fugitives derived from EEMS guidance EFs.

IPCC	Source Category	Method Description
		Oil terminals, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends; residual category for CH₄. Oil terminals, 1998- Latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI, SPRI (EA, SEPA, 2025). Tier 3 as process emissions are based on operator reporting; fugitives derived from EEMS guidance EFs. 2011- only RI data, so estimates modelled on previous years share of RI total; source is also used to report residual CH₄.
1B2a3	Oil Transport	Offshore oil loading, all years: IPCC Tier 1 (2019 Refinement). Emission = OTL production (PPRS/BB) x IPCC default EF (<i>assumes no VRU</i>) Onshore oil loading, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Onshore oil loading, 1998-latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 2/3 as emissions for oil loading are derived from operator reporting and use of EEMS guidance EFs (CS). 2011- only RI data, so estimates modelled on previous years share of RI total; Seal Sands data from operator consultation. Onshore oil transport (pipelines), all years: IPCC Tier 1 (2019 Refinement). Emission = Wytch Farm production (PPRS/BB) x IPCC default EF Onshore oil transport (road/rail), all years: IPCC Tier 1 (2019 Refinement). Emission = Onshore production <i>less Wytch Farm</i> (PPRS/BB) x IPCC default EF
1B2a4	Oil Refining / Storage	Oil terminal storage, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Oil terminal storage, 1998 – latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 2/3 as emissions for oil storage are derived from operator reporting and use of EEMS guidance EFs (CS). 2011- only RI data, so estimates modelled on previous years share of RI total.
1B2a6	Oil - Other	Oil wells abandoned, all years: IPCC Tier 1 (2019 Refinement) method. Emission = #wells abandoned per year (cumulative) x IPCC default EF (<i>per well abandoned where it is unknown if plugged or not</i>) The AD are taken from the NSTA wellbore database search facility. The AD comprise all historic oil and gas wells, so the estimates include abandoned gas wells. IPCC Refinement states that leaks from abandoned offshore wells are assumed to be 2% of those onshore, as 98% of the gases are dissolved in the water column. This assumption is applied in the method for offshore wells abandoned.
1B2b1	Natural Gas Exploration	Onshore conventional gas wells, all years: IE, reported within 1B2a1, as there are no AD specific to gas wells drilled, only oil and gas combined.

IPCC	Source Category	Method Description
		Onshore unconventional gas well drilling: Activity only evident in 2011, 2012, 2014, 2018 and 2019. Σoperator emissions per facility, based on operator and regulator information. Offshore well testing, 1990-1997: UKOOA 2005 (Tier 2). Time series based on #wells drilled per year, from NSTA. Offshore well testing, 1998 – Latest year: Σoperator emissions per facility, based on EEMS (DESNZ OPRED, 2025), which includes well testing emissions per facility, per year. Tier 2/3 as EFs are from EEMS operator guidance (CS).
1B2b2	Natural Gas Production	Onshore gas production, all years: IPCC Tier 1 (2019 Refinement) method. Emission = natural gas produced (Mm³) x IPCC default EF (for onshore activities with higher-emitting technologies and practices) Onshore gas gathering, all years: IPCC Tier 1 (2019 Refinement) method. Emission = natural gas produced (Mm³) x IPCC default EF (for onshore activities with higher-emitting technologies and practices)
1B2b3	Natural Gas Processing	Offshore gas production, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends; installation-level direct process emissions from key sites (i.e. Elgin, Rough) based on their gas production trends. Residual category for CH₄ and NMVOC. Offshore gas production, 1998- Latest year: Σoperator emissions per facility, based on EEMS (DESNZ OPRED, 2025). Tier 3 as process emissions are based on operator reporting; fugitives derived from EEMS guidance EFs. Also includes one-off estimate of emissions from Elgin blow-out, 2012, based on <i>Lee et al</i> publication from aircraft monitoring of methane, NMVOC plume. Gas terminals, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends; installation-level estimates of process emissions from key sites (i.e. SAGE, CATS) based on gas throughput. Residual category for CH₄. Gas terminals, 1998- Latest year: Σoperator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 3 as process emissions are based on operator reporting; fugitives derived from EEMS guidance EFs. 2011- only RI data, so estimates modelled on previous years share of RI total.
1B2b4	Natural Gas Transmission & Storage	Gas terminal storage, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends. Gas terminal storage, 1998 – latest year: Σoperator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 2/3 as emissions for gas storage are derived from operator monitoring and use of EEMS guidance EFs (CS). 2011- only RI data, so estimates modelled on previous years share of RI total.
1B2b6	Natural Gas - Other	Gas wells abandoned, all years: Included Elsewhere. Reported within 1B2a6, as there are no AD specific to gas wells abandoned, only oil and gas wells combined.

IPCC	Source Category	Method Description
1B2c1i	Venting & Flaring: Oil venting	Offshore oil venting, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Offshore oil venting, 1998- Latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025). Tier 3: venting emissions are based on operator monitoring. Oil terminals venting, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Oil terminals venting, 1998- Latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 3: venting emissions are based on operator monitoring. 2011- only RI data, so estimates modelled on previous years share of RI total.
1B2c1ii	Venting & Flaring: Gas venting	Offshore gas venting, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends. Offshore gas venting, 1998- Latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025). Tier 3: venting emissions are based on operator monitoring. Gas terminals venting, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends. Gas terminals venting, 1998- Latest year: $\sum$operator emissions per facility, based on EEMS (DESNZ OPRED, 2025) and PI/SPRI (EA, SEPA, 2025). Tier 3: venting emissions are based on operator monitoring. 2011- only RI data, so estimates modelled on previous years share of RI total.
1B2c2i	Venting & Flaring: Oil flaring	Offshore oil flaring, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Offshore oil flaring, 1998- Latest year: $\sum$operator emissions per facility, based on EU/UK ETS (DESNZ, 2025b), EEMS (DESNZ OPRED, 2025). Tier 3: flaring emissions are based on operator reporting. CEFs from flare gas sampling, analysis, 98% oxidation factor. Oil terminals flaring, 1990-1997: UKOOA 2005 (Tier 2). Time series based on crude oil production trends. Oil terminals flaring, 1998- Latest year: $\sum$operator emissions per facility, based on EU/UK ETS (DESNZ, 2025b), EEMS (DESNZ OPRED, 2025). Tier 3: flaring emissions are based on operator reporting. CEFs from flare gas sampling, analysis, 98% oxidation factor.
1B2c2ii	Venting & Flaring: Gas flaring	Offshore gas flaring, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends. Offshore gas flaring, 1998- Latest year: $\sum$operator emissions per facility, based on EU/UK ETS (DESNZ, 2025b), EEMS (DESNZ OPRED, 2025). Tier 3: flaring emissions are based on operator reporting. CEFs from flare gas sampling, analysis, 98% oxidation factor. Gas terminals flaring, 1990-1997: UKOOA 2005 (Tier 2). Time series based on natural gas production trends.

IPCC	Source Category	Method Description
		Gas terminals flaring, 1998- Latest year: $\sum$ operator emissions per facility, based on EU/UK ETS (DESNZ, 2025b), EEMS (DESNZ OPRED, 2025). Tier 3: flaring emissions are based on operator reporting. CEFs from flare gas sampling, analysis, 98% oxidation factor.

[Where BB = DTI Brown Book “*Development of the Oil and Gas Resources of the UK*”]

Key data sources for the 1B2 inventory methods include:

- Oil and gas operators submit annual source-specific emission estimates to the **Environmental and Emissions Reporting System (EEMS)**, regulated by DESNZ Offshore Petroleum Regulator for Environment and Decommissioning (DESNZ OPRED).
- Industry survey data from 1990 onwards were used to derive a time-series of sector estimates from 1990 to 2003, reported to UK Government studies by the trade association (**UKOOA, 2005**). Whilst the data resolution per source is limited in this dataset, it is the best available information to inform estimates prior to the EEMS system, i.e. during 1990-1997
- **Well testing** emissions estimates on an installation-specific basis are also included within the EEMS datasets from 1998 onwards at all sites of offshore exploration activities within UK’s territorial waters, including data on both activity and emission factors of excess gas that is flared or released to the atmosphere. Emissions released at the seabed are not included in estimates; it is assumed that any such releases will dissolve in the water column without subsequent release to the atmosphere.
- **Onshore well drilling** for oil and gas exploration leads to fugitive emissions. These are estimated using a Tier 1 method from the 2019 IPCC Refinement, with the number of wells drilled per year obtained from the North Sea Transition Authority’s Well Operations Notification System (WONS). **Abandoned wells** also release fugitive methane and NMVOC, and again a 2019 IPCC Refinement Tier 1 method is applied, using NSTA wellbore database information on the number of wells abandoned.
- Annual reporting of emissions by pollutant aggregated across all emission sources under the **IED/PRTR reporting system** to the UK environmental regulatory agencies (i.e. EA, NRW, SEPA) are available for onshore sites only (i.e. including oil and gas terminals but excluding all offshore oil and gas installations). These data are available from 1998 in England and Wales and for 2002 and 2004 onwards in Scotland and include emission estimates for a suite of GHG and air quality pollutants including CO₂, CH₄ and N₂O. Whilst there is a high level of complete reporting from onshore oil and gas terminals, operators only report to these Regulatory Inventories (RIs) where the annual pollutant emission is above a reporting threshold; hence there is very little RI data reported by operators of onshore well sites in the UK, where emissions are low.
- For 1995 to 2009, all terminals reported source-specific emission estimates to the **EEMS system**. For combustion and flaring sources, the EEMS dataset for this period includes mass-based activity data, and emission estimates for GHG and air quality pollutants. Since 2010 onshore terminals report voluntarily to EEMS, but the reporting is incomplete across UK terminals; reporting to EEMS was deemed a duplication of the reporting requirements under IED/PRTR and hence was no longer a mandatory duty on terminal operators. Hence from 2010 onwards the EEMS dataset is not a comprehensive record of emissions from onshore terminals. The UK GHGI estimates are based on the IED/PRTR data in conjunction with EU/UK ETS data, which provides emissions of CO₂ from combustion and flaring sources.

- Under the Energy Act and Petroleum Act, upstream oil and gas operators are mandated to report on their economic activities to the North Sea Transition Authority (NSTA). Whilst these data are not specific to environmental reporting, they do provide a full time series of useful activity data such as UK oil production and gas production; detailed data per oil and gas field are now reported via the **Petroleum Producers Reporting System** (PPRS), which began in 2000. Prior to PPRS, the same data were published in annual statistical releases such as the historic DTI publication “*The Development of the Oil and Gas Resources of the UK*”, known as the **Brown Book**, which ceased to be published in 2004. Together these resources provide a full, time-series consistent dataset on activity for the sector, as well as a wealth of installation-level detail. They are used in inventory method development primarily to support the use of IPCC good practice gap-filling techniques, as they provide a useful proxy dataset of activity to help address reporting gaps per source, per installation and/or at the sector level.
- The Inventory Agency continues to investigate ways in which methane and NMVOC emissions from **oil and gas well blow outs** can be estimated, although there is no IPCC methodology for such events, and only limited data are available in the UK with which to estimate emissions. The Inventory Agency has researched the UK Health and Safety Executive (HSE) hydrocarbon release database, and there is only one major blow-out event recorded by upstream operators and reported to the HSE across the time series, which was the Elgin blow-out of 25th March to 16th May 2012. In this case, the Inventory Agency has estimated the total methane and NMVOC released by the blowout and added it to the fugitive emission estimates for the year 2012. The UK emission estimate is based on reported daily methane flow-rate observations taken on 5 days during the blow-out period (30th March, 3rd April, 17th April, 24th April and 4th May 2012). These estimated flow rates of methane are derived from air sampling and analysis by research aircraft flights, as reported by **Lee et al. (2018)**⁷⁰. The Inventory Agency will continue to research data from UK academic and industry researchers, regulators and operators, in order to develop emission estimates for any similar historic events.
- All UK onshore production to date is from *conventional* oil and gas wells. These installations are all regulated under the IED/PRTR by UK environmental regulators (EA, SEPA) and the operators report on annual methane emissions and these estimates are aggregated and included within the UK GHGI under 1B2a2. However, the Inventory Agency has sought to estimate **methane emissions from onshore shale gas exploration** activities, though to date there has been no production of natural gas from unconventional shale gas resources in the UK. Since 2010 there have been twelve shale gas wells spudded in the UK. None of these sites are actively producing gas and none of the shale gas sites are yet under IED/PRTR regulation by the EA or SEPA, and there are no annual reported emission estimates by operators from their initial well spudding and completion activities. Also, as there has been no production of natural gas at any of these sites, there is no activity data available to apply a Tier 1 factor as provided in Table 4.2.4 in Section 4.2.2.3 of the Fugitives chapter of the IPCC 2006 Guidelines. Therefore, the Inventory Agency has consulted with the regulatory agencies (NSTA, EA) and obtained one-off reports, where available, from each unconventional gas well site.
 - The EA has confirmed that 12 wells were spudded during the period of August 2010 to January 2019 in England and that no extraction of products has occurred. It has been confirmed with the Regulator that all shale wells are now

⁷⁰ Atmos. Meas. Tech., 11, 1725-1739, 2018.

abandoned, and permits surrendered or suspended, with no foreseeable exploration and production activity⁷¹.

- One report to the EA provides methane emission estimates during a nitrogen gas lift operation at one of the larger shale gas well sites; review of the other sites identified that several wells did not strike any hydrocarbon deposits.
- Based on the limited data available, a conservative estimate of emissions for methane from the well exploration activities has been made and added to the UK GHGI; methane emissions are estimated to peak at 60t CH₄ in 2010 and 2011, with well drilling emissions in 2014 of 20t CH₄, and 25t CH₄ in 2019.
- Further information can be made available to an ERT, to access the NAEI research report which contains commercial in confidence details on a site-by-site basis (Thistlethwaite, Gorji and Passant, 2021).

Assumptions & observations

The source resolution in the UKOOA 2005 data reference is limited across the 1990-1997 period, and a series of proxy datasets have been used to derive time-series estimates per source back to 1990. These are described in more detail in **Annex 5.1.1.6**.

The resolution of data by source type within the EEMS dataset is such that fugitive emission sources are typically reported aggregated for each installation, without any further information on the specific source/unit. Further, the emissions reported from gas terminals are aggregated across all sources under the IED/PRTR reporting system. These national circumstances of data availability mean that the UK inventory data cannot be disaggregated to separate fugitive emissions from gas processing units, from other fugitives, such as tie-ins to transmission systems, acid gas removal units, other connectors, flanges and pipeline infrastructure. Hence the emissions from all of these sources are reported together under 1B2biii.

The 2019 Refinement method has been applied as the better resolution of fugitive EFs in the 2019 Refinement enables the UK to address the emissions from the onshore gas production and gathering sector. UK production is a very small part of the upstream industry and predominantly takes place at small gas well sites that do not typically report emissions (e.g., of hydrocarbons) to UK regulatory mechanisms (e.g., to the Pollution Inventory of the Environment Agency). Therefore, applying the 2019 Refinement method to the total UK onshore gas production AD ensures that the inventory is complete. Implementing mitigation practices / technologies is unlikely to be cost-effective at small gas well sites and so the Inventory Agency has applied the 2019 Refinement EFs for "activities occurring with higher-emitting technologies and practices". Noting that the 2019 Refinement is based on the latest scientific research, this is considered to be the most representative approach for estimating UK inventory emissions.

We note that the emissions reported in 1B2b3 (natural gas processing) do not include any pollutant emissions that are also reported in 1B2b2, i.e., there is no double-counting of emissions. The 1B2b2 emissions are all associated with onshore production at well sites and the associated gathering systems. The 1B2b3 emissions are based on separate data streams of production and treatment at (i) offshore dry gas and associated gas platforms/FPSOs, and (ii) UK onshore gas terminals that process the gas from offshore sources and inject the gas to the National Transmission System.

Recalculations

Onshore well testing activity data has been updated for recent years by the NSTA, leading to minor increases in emissions from 1B2ai; in addition, updates to drilling activity by MODUs via

⁷¹ Personal communication with the Environment Agency, March 2021

the EEMS dataset has led to increased emission estimates for offshore well testing in recent years, in the same CRT source category. Overall in 2023 this accounted for a total ~12 ktCO₂e increase compared to the previous submission.

Revised allocations of methane emissions to onshore oil loading and oil terminal storage within the OPTIS model have led to a combined reduction of 0.7 ktCO₂e across CRT source categories 1B2aiii and iv in 2023.

Revisions to the installation-level reporting allocation for oil and gas terminal combustion emissions (see MS2 recalculations for details) through use of UK ETS data in preference to EEMS and PI/SPRI data has led to revised fugitive estimates in the OPTIS model, which reconciles total installation emissions across combustion and fugitive sources to the operator-reported totals. This leads to lower reported fugitive emissions in 2023 for upstream oil fugitives in 1B2aii (down 246 ktCO₂e) and upstream gas fugitives in 1B2biii (down 114 ktCO₂e).

Improved processing of UK ETS data also increased 2023 CO₂ emission estimates from flaring at terminals, though revised EEMS data for offshore flaring partially counteracted this. As a result, overall flaring emissions rose by 18 ktCO₂e for oil production (1B2c2i) and 12 ktCO₂e for gas production (1B2c2ii).

Additional revisions to activity between 2021–2023 arise from improvement work to make use of density data from PPRS when converting fuel-gas activity from Nm³ to tonnes.

Improvements (completed and planned)

Following the oil and gas sector improvement project (Thistlethwaite *et al*, 2022), which assessed all available UK data to improve the quality of the UK GHGI submission across 1A1cii and 1B2, and is described in more detail in **Annex 5.1.1.6**, emission factors and activity data remain under review.

The Inventory Agency will maintain dialogue with regulators and industry experts in order to seek any new data on emissions from oil and gas well blowouts, and to follow-up on the reporting of well testing within the new EEMS system.

The Inventory Agency will also maintain a watching brief on the development of the shale gas industry, in order to ensure that if the industry does start to produce gas in the UK, that the Inventory Agency will have access to information to allow emission estimates to be derived for future inventory submissions.

QA/QC

The EEMS dataset quality system is managed by the regulatory agency (DESNZ OPRED) and developed in conjunction with the trade association, Offshore Energies UK (OEUK). EEMS uses an online reporting system with controls over data entry, together with guidance notes provided to operators to provide estimation methodology options and emission factors for specific processes. The IED/PRTR system is similar to EEMS, but regulated by the onshore environment agencies (EA, NRW, SEPA); it also has operator guidance on emission estimation and reporting, and a system of annual checks on data submitted by operators, by a Site Inspector / Process Engineer assigned by the regulator to manage the performance and compliance assessments for each installation. The data reported under IED/PRTR however are installation-wide, rather than source-specific.

The UK ETS dataset quality system is managed by the regulatory agency (DESNZ OPRED). The reporting standards of the ETS currently operating in the UK are consistent with the EU ETS, with estimation methods that operators may use defined within their permit. The data are third party verified and submitted to the regulator.

The Inventory Agency combines UK energy statistics, the EEMS data, EU/UK ETS and IED/PRTR data to derive the oil and gas sector estimates, then conducts time series consistency checks using other sector activity data from PPRS and the Brown Book to identify and address any potential data reporting gaps or outliers. Where the EU/UK ETS or IED/PRTR data are inconsistent with the EEMS data, the Inventory Agency works with DESNZ OPRED and facility operators to help determine the best available data for each source to ensure that the reported data are complete for each installation. The Inventory Agency also conducts time-series consistency checks to identify missing sites or sources, and for those sources where the EEMS data includes emissions and activity data the Inventory Agency reviews the time-series of implied emission factors to identify outliers. Any sites or sources where the quality checks identify gaps, outliers or inconsistent reporting between different regulatory systems are resolved in consultation with regulators and operators, as required.

Time-series consistency

The emission estimates for the offshore industry are based predominantly on the EEMS dataset for 1998 onwards, whilst emission estimates for 1990-1997 are based on sector data submitted to UK Government (UKOOA, 2005).

The method is compromised by the lack of source-specific data for the 1990-1997 period, where only aggregate emissions data across all sources in 1A1cii and 1B2 are available from the industry submissions to UK Government; this coincides with a period where consultation with the BEIS (now DESNZ) energy statistics team has confirmed that the UK energy statistics were not gathering complete data for all oil and gas terminals. Wherever possible the Inventory Agency has filled data gaps with operator-reported estimates and applied IPCC good practice gap-filling methods to ensure that the time series consistency is as good as practicable given the available data; this is possible as there are a defined number of installations that are active in this sector and their activities (and emissions) are generally well documented with gaps in data being relatively minor.

Further, the Inventory Agency has conducted time series consistency checks between the aggregated emissions reported in the 1990-2003 data submission (UKOOA 2005) and the installation-level EEMS and NAPs data (BEIS OPRED, 2022), across the overlap years of 1998 to 2003. This analysis shows close consistency, indicating that the scope of reporting in the UKOOA 2005 dataset is consistent with the later installation-level EEMS data. *Further details are presented in Annex 5.1.1.6.*

We further note that whilst the emission estimates specific to fuel combustion in 1990-1997 are uncertain, that the total emissions across all upstream oil and gas sources (Σ 1A1cii, 1B2) in the UK GHGI are aligned with the industry submission to UK Government (UKOOA, 2005) and hence are regarded as the most accurate data available.

The EEMS dataset (DESNZ OPRED, 2025) provides a consistent time-series of emission estimates for many facilities and sources, but since 2010 the reporting by onshore terminals is voluntary. Furthermore, whilst the EEMS data quality appears to be improving over recent years, the completeness of EEMS data for specific facilities and sources is still subject to uncertainty; reporting gaps appear to be systematic for some facilities, such as frequent non-reporting of oil loading / unloading emissions at some terminals. For this reason, the Inventory Agency has moved away from using EEMS data for the estimates of oil loading and instead uses the PPRS activity data on oil production at OTLs, in conjunction with industry EFs, as this method delivers a more complete and time series consistent estimate.

The Inventory Agency continues to work with the regulatory agency, DESNZ, in the continued development of emission estimates from this sector.

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement, informed by the understanding of the available data, the level of uncertainty that is accepted within the reporting systems (e.g. UK ETS) and the likelihood of error compensation across the UK installations.

The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values.

Emissions data taken from the EEMS reporting system 1998 onwards are considered to be high quality, emissions data for other years are subject to greater uncertainties. As noted above, while the uncertainty per source may be high due to the limited source resolution in the UKOOA 2005 dataset, the overall uncertainty in the sum of emissions across 1A1cii and 1B2 is much lower and is based on the best available data for that period.

MS 18 Gas leakage

Relevant Categories, source names

- 1B2biv: Natural Gas (transmission leakage)
- 1B2bv: Natural Gas (distribution leakage)
 - Natural Gas (leakage at point of use)

Relevant Gases

CO₂, CH₄

Relevant fuels, activities

Leakage from gas transmission and distribution, leakage at the point of use

Background

The UK GHG inventory includes estimates of methane and carbon dioxide emissions from natural gas leakage from the downstream gas supply network, including releases from: high pressure transmission network; distribution network; gas leaks at point of use. Annual activity data and gas compositional analysis are provided by National Gas, four companies (formed in 2005) that operate the low-pressure gas distribution networks within Great Britain, and three gas suppliers in Northern Ireland.

Key Data sources

- Activity data: Natural gas leakage data in energy and mass units, from the UK gas network operators including National Gas Transmission (operators of the National Transmission System), and Gas Distribution Network (GDN) operators and gas suppliers: Cadent Gas, SGN, Northern Gas Networks, Wales & West, and Phoenix Gas and Firmus Energy.
- AD for gas use in domestic and commercial sectors from DUKES (DESNZ, 2025a) are used to generate leakage at point of use estimates.
- Emission factors: Natural gas compositional data (mass % data for: nitrogen, carbon dioxide, methane, ethane, propane, i-butane, n-butane, neo-pentane, i-pentane, n-pentane, hexanes+) supplied by the GB gas network operators as listed above. UK estimates of natural gas consumption within each Local Distribution Zone (LDZ) are used to generate a weighted-average UK compositional analysis of natural gas consumed annually. From 2007 these data are available from Long Term Development Plans published by each of the gas network operators; earlier data by LDZ are based on Local Authority-level consumption estimates aggregated into LDZs (CLARE database, 2012).
- EFs for the gas leakage at point of use are derived from UK data on gas fitting performance and assumptions regarding unit operational cycles, ignition times.

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶.

Method approach

The leakage estimates are calculated using separate methodologies to cover:

1. Natural gas leaks from the high-pressure National Transmission System (NTS) operated by National Gas Transmission (NGT); (reported under **1B2b4 Transmission**)
2. Natural gas leaks from the low-pressure distribution network, medium pressure gas mains, Above Ground Installations (AGIs), AGI working losses and interference (Cadent Gas, SGN, Northern Gas Networks, Wales & West, Phoenix Gas, Firmus Energy); (Reported under **1B2b5 Distribution**)
3. Other losses of natural gas at the point of use (DESNZ DUKES, UK research); (Reported under **1B2b5 Distribution**)

For methods 1 and 2 above, from 2004 onwards the gas network operators provide annual gas leakage estimates on a mass basis, providing a breakdown of emissions across all 14 regional gas networks in the UK, which are called Local Distribution Zones (LDZs). National Gas Transmission operates the high-pressure NTS; Cadent Gas operates 5 of the LDZs; Northern Gas Networks operates 2 LDZs; SGN operates 3 LDZs; Wales and West Utilities operates 3 LDZs; Phoenix Gas, SGN and Firmus Energy together supply gas within the Northern Ireland network. In addition, each of the GDN operators provides annual natural gas compositional analysis for their networks. Prior to 2004, the data on gas leakage (activity data and compositional analysis) was all provided by British Gas, which operated all of the UK networks before the industry was privatised.

The information on methane losses from the high pressure transmission system (1B2b4) are estimated by National Gas Transmission (NGT) based on (i) periodic fugitive emission surveys for the National Transmission System (NTS), compressor stations and LNG terminals, (ii) NG records of intentional venting actions on the network, (iii) estimation of fugitive emissions from AGIs using Marcogaz model and (iv) estimation of emissions as the result of incomplete combustion using compressor station turbine specification and site running hours. These data have not been available for every year across the time-series, with only two data points in the 1990s, annual data from 2000-2004, and for 2011-2024, with data for other years estimated using interpolation (2005-2010) and extrapolation (early time-series).

The UK GHG inventory estimates for 1B2b5 (distribution leakage) are based on the aggregate of mass of gas leaked across all networks (low pressure mains and other losses), with the methane content of the natural gas based on compositional analysis from all of the gas network operators.

The activity data reported in the CRT for these sources are the final UK annual gas demand data. These data are not used within the GHG inventory estimation method, but are presented to enable IEFs to be derived, to aid comparability of the UK estimates with those of other countries.

UK Gas Network Leakage Model

The UK gas network operators use a common industry leakage model to derive their annual estimates of gas leakage from the low and medium pressure distribution systems. The UK gas network leakage model was developed by British Gas and uses factors and assumptions on leakage rates for different types of gas mains and installations, based on measurements and surveys conducted in 1992 and 2002, with annual updates to maintain the representation of the UK gas network infrastructure (such as length and type of pipelines and other units) and reflect the rolling programme of network replacement. Historical data for the leakage from the low-pressure distribution network and other losses is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993).

Natural Gas Compositional Data

Data on the methane and NMVOC content of natural gas have been provided by contacts within British Gas Research for 1990-1996 and by UK Transco from 1997 to 2005 (Personal Communication: Dave Lander, 2008), and from the gas network operators from 2006 onwards. NMVOC content for 2001-2003 has been estimated by interpolation due to a lack of data; CO₂ compositional data from 2004 onwards are derived from annual compositional analysis by gas network operators, whilst the 1990-2003 data have been extrapolated back from the 2004 figure.

Each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition.

The calculation of the reported Great Britain (GB) average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs. No gas composition data have been provided by any operator in Northern Ireland, and in the absence of data, the average composition of the gas available in GB's network is assumed to be applicable in Northern Ireland. The estimates of gas consumption within each LDZ are based, from 2007 onwards, on LDZ throughput data presented within Long Term Development Statements by each of the gas network operators; prior to 2007 these data are unavailable, and the best available data to inform the UK weighted average composition are sub-national gas use statistics at local authority level (then aggregated to LDZs) which are published by DESNZ annually and processed for UK Local Authority CO₂ emission estimates via the CLARE database.

Northern Ireland Gas Network

The gas infrastructure in Northern Ireland is much newer than in the rest of the UK, as the gas pipeline (from Scotland) was only commissioned in 1999. Since then, the gas network has continued to develop across Northern Ireland. Annual estimates of gas leakage from 2005 onwards have been provided by the main gas operator (Phoenix Gas, 2025; SGN, 2025; Firmus Energy, 2025), and the data for 1999 to 2004 have been extrapolated back from the 2005 figure.

Gas Leakage at the Point of Use

The third inventory estimation methodology is used to determine estimates of natural gas leakage at the point of use, and these estimates are also reported in 1B2b5. Leakages are estimated for a range of different appliances that use gas, combined with official statistics on natural gas consumption in the domestic and commercial sectors (DESNZ, 2025).

Industrial Heating Boilers

Methane releases are assumed to be “**Not Occurring**” from these appliances, based on consultation with technical experts that advise the UK Government for the CHP QA scheme (Personal Communication: R Stewart, 2011). Larger boilers typically operate almost permanently once ignited (particularly if used for steam-raising) with little or no cycling from on to off states. Furthermore, releases of un-burnt natural gas are strictly controlled in industrial locations for safety reasons.

Domestic Heating, Water Heating Boilers and cooking

Methane emissions from pre-ignition losses of gas appliances domestic properties are based on activity data from Energy Consumption in the UK (DESNZ, 2025) which provides a time-series of gas use for heating, water heating and cooking in the domestic sector, using a series of assumptions regarding the size of units, number of units, age of units, gas flow rates, air

flow rates, delays to ignition, operation times from used to determine the percentage of gas that is not burned. The estimates of UK appliance stock, by capacity and design and estimated average gas consumption per appliance per day are all derived from Ecodesign studies (energy efficiency analysis) through the UK Government Market Transformation Programme (Ecodesign Lot 22 and Lot 23, 2011). The estimates of appliance cycle operation times and estimated delays to ignition for different appliances are based on expert judgement of UK combustion technology experts (Personal communication, Stewart, 2012).

Commercial Gas Appliances: Catering and other uses

Methane emissions from pre-ignition losses of gas appliances used in commercial catering and other uses are based on activity data from ECUK (DESNZ, 2025) which provides a time series of gas use for catering and other uses in the commercial sector to 2024. The method then applies a series of assumptions regarding the operational cycles and delays to ignition, to derive a simple percentage non-combusted estimate for each gas appliance type using references and expert judgements as noted above for domestic appliances.

An overview of the time series of gas leak at point of use estimates in the UK, together with overall gas use by economic sector and appliance type is presented in **Annex 5.1**.

Assumptions & observations

Assumptions used to estimate the leakage at point of use for domestic heating and water heating boilers are as follows:

- average boiler size in the UK of 30kW;
- a burn chamber size, natural gas flow rate taken from a typical combination boiler;
- estimated delay to ignition: 0.25 seconds for automatic ignition, 2 seconds for manual ignition;
- an air flow rate based on 25% excess oxygen in the combustion chamber when compared to stoichiometric ratio;
- an equation for a mixed reactor ($1-e^x$) that when integrated will provide an estimate of the concentration of un-burnt air/fuel mixture released; and
- assumptions relating to the boiler yearly operation and cycling frequency, between heating and water heating applications
 - On average in the UK domestic properties have heating systems operating for half of the year and on average the heating is on for 5 hours per day. It is also assumed that during each hour that the boiler providing heating cycles on and off 4 times.
 - All UK domestic properties that have hot water heating systems also have gas heated hot water.
 - Average water heating is on for 4 hours per day every day of the year.
 - During each hour that a boiler is heating water, the boiler cycles on and off 5 times.

The number of boilers across the time series is thought to have increased (ca. 22 million in 2008) due to the increasing use of gas central heating for space heating, and the increase in the number of houses. However, it is assumed that pre-ignition gas loss in boilers installed in houses in 1990 were greater than in the current boilers installed, as technology has improved. Therefore, it is assumed that the proportion of gas leaked (i.e. % of the total gas use) from domestic heating and water heating appliances per annum is steady across the time series, with the rationale that the sum of greater pre-ignition losses from fewer older-technology boilers in the early part of the time series will be roughly equivalent to the sum of lower pre ignition losses per unit from the greater number of newer-technology boilers in recent years.

Assumptions used to estimate the leakage at point of use for domestic cooking appliances (manual and automatic ignition) and gas fires are as follows:

- gas fires use an estimated 2.5% of total gas used for space heating in the domestic sector, with the remainder used in (automatic ignition) boilers;
- gas use in cooking hobs is estimated to be 73.6% of the total domestic gas use in cooking, with the remainder in gas ovens. This is based on data of average annual gas oven fuel use in kWh/yr and average domestic gas hob fuel use in kWh/yr, combined with data on UK stock of gas ovens and hobs, taken from a series of 2011 European Commission Eco-design studies (Bio IS / ERA Technology, 2011);
- for manual ignition devices, a conservative estimate of the delay prior to ignition of 2 seconds has been assumed (expert judgement), whilst the average operational cycle times for different types of appliance have been estimated at 900 seconds for a domestic hob (expert judgement) and 5400 seconds for a gas fire (EC Eco-design Lot 20 Task 5, gas stove base case, 2011); and
- for automatic ignition appliances, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle times of domestic ovens has been estimated at 900 seconds (expert judgement).

Assumptions used to estimate the leakage at point of use for commercial gas appliances (catering and other uses) are as follows:

- for commercial catering gas use, a conservative estimate of the delay prior to ignition of 0.5 seconds has been assumed (expert judgement, to reflect a mixture of hobs and oven use), whilst the average operational cycle has been estimated at 900 seconds (expert judgement); and
- for other commercial gas appliances, assumed to be predominantly gas-fired boilers of automatic ignition design, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle time has been estimated at 1800 seconds (expert judgement).

Recalculations

There are minor recalculations throughout the timeseries, reflecting revisions to DUKES, updates to the leakage data from the distributors and national transmission system, natural gas compositional updates and other minor method changes.

Emissions at the point of use (1B2bvi1) in 2023 were around 1.7% lower than previously estimated; this was due to the combined impact of (i) UK energy statistics recalculations (+1%) to the amount of gas used in the residential and commercial sectors, and (ii) revision to the weighted-aggregate UK natural gas compositional analysis data, reducing the estimated methane content by around 3% in 2023.

Emissions from the distribution network (1B2v) in recent years have also been impacted (down ~3%) by the revision to weighted-aggregate UK natural gas compositional analysis.

Other minor recalculations have been made in recent years, including a small increase in estimated gas leakage in the downstream network in Northern Ireland, and the addition to NTS estimates of new minor sources of gas leakage from incidents on the network and pipeline venting during non-routine operations.

Improvements (completed and planned)

An improvement project has been carried out studying the impact of fugitive emissions from post-meter settings such as natural gas fuelled vehicles, appliances in commercial and residential sector and leakage at industrial plants and power stations.

The UK is currently pursuing development of an improved methodology or protocol that captures fugitive emissions from significant incidents that the current underlying methods do not currently capture. Such incidents could include rupture of natural gas downstream distribution pipelines and facility level infrastructure failures. Remotely sensed measurement estimates, such as mobile, drone and satellite measurements, could be used to supplement emissions estimates derived from data from regulators and operators.

QA/QC

The sector estimates are subject to the same Tier 1 QA/QC routines as all other source categories in the UK GHGI.

Checks on data reported by gas network operators are conducted to check consistency across the time-series and also between operators.

As recommended during the September 2014 centralised review of the UK inventory, the UK Inventory Agency has also conducted verification checks on the UK GHGI estimates, by deriving separate emission estimates for methane using the Tier 1 default methods outlined in both the 1996 GLs and the 2006 GLs. The method in the 1996 GLs uses max and min default factors based on the pipeline length of the transmission and distribution network, whilst the 2006 GLs Tier 1 method uses max and min default factors based on the total volume of delivered natural gas. The results are summarised below for 1990 and 2013 data:

1990 UK GHGI total (transmission plus distribution) = 372 kt CH₄

Using IPCC 1996 GLs Tier 1 method, the range for emissions is derived as 155 to 215 kt CH₄

Using IPCC 2006 GLs Tier 1 method, the range for emissions is derived as 67 to 105 kt CH₄

Therefore, compared to both Tier 1 methods, the 1990 UK GHGI estimate is higher than the range of values.

2013 UK GHGI total (transmission plus distribution) = 166 kt CH₄

Using IPCC 1996 GLs Tier 1 method, the range for emissions is derived as 155 to 215 kt CH₄

Using IPCC 2006 GLs Tier 1 method, the range for emissions is derived as 95 to 148 kt CH₄

Therefore, compared to the Tier 1 methods, the 2013 UK GHGI estimate is within the range of values for the 1996 GLs method and higher than the range of values for the 2006 GLs method.

The comparison against the IPCC Tier 1 methods indicates that the UK GHGI estimates are of a similar order of magnitude as the Tier 1 defaults. The 1990 UK GHGI value appears to be high, as it is above the range of values derived from the IPCC Tier 1 methods, whilst the 2013 UK GHGI value is also higher than the range for the 2006 GLs Tier 1 method. However, the UK estimates are derived from a country-specific method and we note that the uncertainty estimates provided in the 2006 GLs for the default EFs provided for gas network distribution (which is by far the greatest contributor to overall methane leakage) are cited as -20 % to +500% for factors for developed countries. Therefore, given the large uncertainty range, the UK data are consistent with the IPCC Tier 1 estimates.

Time series consistency

As far as possible, consistent source data and methods are used across the time series. However, we note the following limitations of the current methods:

- The available data on methane leakage from the high-pressure gas transmission system is limited. Data are not available for all years of the time series and therefore gap-filling techniques (extrapolation and interpolation) are used;
- The calibration of the UK gas leakage model used by all natural gas network operators is based on two in-depth studies of the leakage rates from different constituent elements of the UK gas network – one in 1992, another in 2002. These studies have been used to establish estimated leakage rates in the UK model that are then applied to activity data gathered annually through surveys and from gas network renewal projects; and
- The derivation of the UK average natural gas composition uses the best available data for every year of the time series, as the factors are critical for the UK GHGI estimates as a whole (not just for the leakage estimates, but also for natural gas combustion estimates). Since 2007 the weighted average has been calculated using actual data available on gas throughput for each LDZ; prior to 2007 these data are not available and the LDZ gas throughput estimates used in the calculation of the UK average gas composition use Local Authority level gas use estimates, aggregated up to LDZs. These earlier data at Local Authority level were regarded as “experimental statistics” by DECC until the 2005 dataset were published as official statistics, and as such are regarded as more uncertain than the more recent data.

Uncertainties

Uncertainties are presented in **Annex 2**. Uncertainties in the emission estimates from leakage from the gas transmission and distribution network stem predominantly from the assumptions within the industry model that derives mass leakage estimates based on input data such as network pipe replacement (plastic replacing old metal pipelines) and activities/incidents at Above Ground Installations; for these sources the methane content of the gas released is known to a high degree of accuracy, but the mass emitted is based on industry calculations.

As noted in the section above, the uncertainties for the estimates of gas leakage at point of use are high due to the lack of source data, an IPCC method and the need to use a series of assumptions and expert judgement to estimate the leakage from different gas appliance types. The Inventory Agency considers that the assumptions provide a conservative estimate of gas leakage at point of use across the time series.

MS 19 Other solid fuel transformation**Relevant Categories, source names**

1A1ci: Solid smokeless fuel production

1B1bi: Solid smokeless fuel production

Charcoal production

Relevant GasesCO₂, CH₄, N₂O**Relevant fuels, activities**

Coke oven coke, petroleum coke, solid smokeless fuel production, charcoal production

Background

Solid smokeless fuels (SSF) are products which are designed to be suitable for use in smoke control areas.

There have been a number of SSF production processes used in the UK. Currently, only one large-scale manufacturing site remains in operation – a briquetting works in Eastern England following the closure of another briquetting works in South Wales in 2022. The remaining briquetting process is understood to only use mild heating to cure the binder used in briquettes made of naturally smokeless materials such as anthracite. The Welsh briquetting site was using similar processes before it closed. Historically, there were also at least three sites that used carbonisation of coal to remove volatiles in order to generate a smokeless fuel. These carbonisation processes were similar to the process used to create coke and had the potential for more significant emissions than the briquetting processes. These three processes, located in Abercwmboi, Grimethorpe and Bolsover, closed in 1991, 1994 and 2004 respectively. One other briquetting works has been identified that closed in 1996.

Charcoal production and some SSF production involves processes similar to those of coke oven coke production.

Key Data sources

Activity: DUKES (DESNZ, 2025), FAOSTAT Forestry Production and Trade Statistics (FAO, 2025)

Emission factors: Inventory Agency mass balance calculations, EIPPCB, 2001, IPCC, 1997.

An accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” lists all emission factors used in the energy sector, including a full list of references⁵⁶. Table 1.4 gives additional information for common activity data sources.

Method approach

Emissions of carbon from SSF production are based on a carbon balance approach. This carbon balance approach is very suitable for the carbonisation processes that were previously used in the UK but is less relevant for the briquetting processes that are now the only type of SSF manufacturing in the UK. In these briquetting processes there should be little or no release of carbon contained in the smokeless fuels as they are being briquetted, and all of that carbon should instead remain in the smokeless fuel until that is burnt. However we retain the

method since it ensures that all of the carbon contained in the raw materials is accounted for in the UK inventory, albeit split between being reported as emitted during manufacture and reported as emitted during use as a domestic fuel. It is likely that this approach means that emissions are now over-reported during manufacture and under-reported during fuel use but we do not have the data to develop an alternative methodology.

For other pollutants, estimates are either made based on a mass balance approach (for sulphur dioxide) or on SSF production data and emission factors as provided in **Table A 3.2.9**.

Given the range of SSF manufacturing processes in use in the UK over the 1990-2024 period and the limited data available, emission estimates will be somewhat uncertain. Historically, some emissions from SSF manufacture may have arisen from the combustion of off-gases produced during carbonization-type SSF manufacturing processes e.g., gases evolved from retorts used to manufacture some fuels such as anthracite or coal, similar to the use of coke oven gas as a fuel in the coke manufacturing process. However, combustion of this type is not reported in UK energy statistics and so all emissions from SSF manufacture are treated as being fugitive and reported under 1B1b.

In addition to coal, the manufacture of SSF involves the consumption of small quantities of coke oven coke in some years. This coke oven coke is treated as a fuel rather than a feedstock and the carbon within the coke is assumed emitted and reported under 1A1c.

Activity data for coal use in SSF manufacture are taken from UK energy statistics, DUKES (DESNZ, 2025), combining the sum of fuel used in SSF manufacture. The emission factor is derived from the carbon balance approach which calculates total carbon lost (i.e., emitted) during the SSF manufacturing process, by subtracting the carbon retained in the SSF product from the sum of carbon inputs.

Methane emissions are currently estimated using a factor of 0.0802 kt per Mt SSF produced, this factor being one that has been reported for coke manufacture rather than specifically for SSF manufacture. The use of a factor for coke manufacture is justified because of the similarity between coke production and production of SSF by the carbonisation processes used in the UK until 2005. However, this factor may be conservative i.e. overestimate for the briquetting processes that are the only type of SSF manufacture in the UK since 2005. The original factor is 27 g CH₄ / tonne of liquid steel, which is then combined with the assumptions that 1 tonne of liquid steel requires 940 kg of pig iron and 1 tonne of pig iron requires 358 kg of coke. All of these figures are taken from Table 6.2 of the December 2001 version of the EIPPCB, Best Available Techniques Reference Document on the Production of Iron & Steel (EIPPCB, 2001). We note that this reference document was subsequently revised and that the later 2012 edition only gave a range of factors (1-80 g CH₄ / tonne coke) so the UK inventory factor is marginally above the maximum of that later range.

Emissions from charcoal production are based on UK activity data on charcoal production from FAOSTAT Forestry Production and Trade Statistics (FAO, 2025). These data were available for the UK and the Falkland Islands but not for and other overseas territories or crown dependencies. The methane emission factor is derived from the default emission factors in table 1.14 of the IPCC 1996 Guidelines. Note that we did not identify suitable factors in the 2006 IPCC guidelines.

Assumptions & observations

Note that any fugitive emissions of CO₂ from charcoal production would be considered biogenic and therefore do not contribute to the GHGI national total.

Recalculations

There have been no major changes to estimates for these sources in the 2026 submission.

Improvements (completed and planned)

The UK is considering reviewing the mass balance methodology for SSF, in particular to better capture the wide range of SSF products with varied feedstocks, and an increasing range of biomass being used for SSF production.

QA/QC

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

Time-series consistency

The UK believes that the estimates are time-series consistent, although the data reported under sector 1B1b (including coke oven coke manufacture described in **MS 4**) are a diverse group of sources with highly variable implied emission factors, particularly when aggregated. For example, solid smokeless fuel production sources dominate emissions for 2015–2019 and are mainly responsible for some large inter-annual variation in the CO₂ IEF during this period. The IEF variation is driven by fluctuations in the ratio of coal to petroleum coke inputs and by the ratio of inputs to solid smokeless fuel outputs. The activity data and emission factors for these sources can be found in the accompanying spreadsheet “Energy_background_data_uk_2025.xlsx” help explain the underlying data for these fluctuations.

Uncertainties

Due to the nature of the mass balance approach used for SSF manufacture, uncertainty in both the estimated carbon content of input products and the carbon content of SSF delivered to market both contribute to a substantial uncertainty in the difference (i.e., the carbon assumed to be emitted during manufacture). This uncertainty is further increased by the range of SSF products, including SSF products which include biomass inputs, introducing an uncertainty on the proportion of the carbon which might be biogenic.

Non-CO₂ emissions for this category only contribute a small proportion of the total emissions, and therefore do not make a major contribution to overall uncertainty

MS 20 Biofuel combustion**Relevant Categories, source names**

1A1ai: Power stations
 1A2a: Iron and steel - combustion plant
 1A2c: Chemicals (combustion)
 1A2d: Pulp, Paper and Print (combustion)
 1A2e: Food & drink, tobacco (combustion)
 1A2f: Other industrial combustion
 1A2f: Cement production - combustion
 1A2gviii: Autogenerators
 1A2gviii: Other industrial combustion
 1A4ai: Miscellaneous industrial/commercial combustion
 1A4bi: Residential combustion
 1A4ai: Public sector combustion
 1A4ci: Agriculture - stationary combustion

Relevant Gases

CO₂, CH₄, N₂O

Relevant fuels, activities

Straw, Wood, Landfill gas, Sewage gas, Scrap tyres, Liquid bio-fuels, Municipal solid waste: biomass fraction, Municipal solid waste: non-biomass fraction, Animal Biomass, Non-municipal solid waste: biomass fraction, Non-municipal solid waste: non-biomass fraction, Biogas, Plant Biomass, Waste, Charcoal, Wood – dry, Wood – seasoned, Wood – wet, Wood briquettes, Coffee logs, Wood pellets, Woodchip.

[Note that this MS excludes: fuel used in aviation (Sustainable Aviation Fuel (SAF) - bio based) MS 7, biofuels used in road transport (Biodiesel, Bio-MTBE, Bioethanol, Hydrotreated Vegetable Oil (HVO), Bio-Methanol) MS 8, and biogas in the gas grid Section 3.2.5]

Background

This Method Statement (MS) includes information the estimation of GHG emissions from biofuel combustion in stationary sources within the energy sector. CO₂ emissions associated with combustion of material of biogenic origin are estimated and reported as memo items, but not included in the energy sector; these emissions will be reflected in the LULUCF carbon stocks of the country producing the fuel. This is further discussed in section 1.8.2.3. Emissions of other greenhouse gases from biofuel use are estimated and included in the national inventory totals, in accordance with IPCC guidance on the treatment of biofuel-derived emissions.

DUKES (DESNZ 2025a) is the key data source for allocation of activity data for biofuel categories in the UK inventory. The mapping between DUKES and NAEI naming conventions is provided for transparency in **Table 3.16**.

Table 3.16 DUKES / NAEI fuel mapping

DUKES fuel name	NAEI fuel name
Waste wood	Wood (excluding wood used in 1A1ai, and 1A4bi)
Wood	Wood – dry, Wood – seasoned, Wood – wet (1A4bi only), Woodchip, Wood briquettes, Wood pellets
Plant biomass	Wood (1A1ai only), Straw, Plant biomass
Animal biomass	Animal biomass
Anaerobic digestion	Biogas
Sewage gas	Sewage gas
Landfill gas	Landfill gas
Renewable waste	Municipal solid waste: biomass fraction (1A1ai only), Non-municipal solid waste: biomass fraction, Scrap tyres
Non-renewable waste	Municipal solid waste: non-biomass fraction (1A1ai only), Non-municipal solid waste: non-biomass fraction, Scrap tyres
Liquid biofuels	Liquid biofuels
N/A	Charcoal, Coffee logs

Key Data sources

Activity data: DUKES (DESNZ, 2025a), UK and EU ETS (DESNZ, 2025b) Waste Management Information (Environment Agency, 2025), MPA, Power plant operators, FAOStat.

Emission Factors: All EFs are predominantly IPCC defaults (IPCC, 2006).

An accompanying spreadsheet “Energy_background_data_uk_2026.xlsx” lists all emission factors used in the energy sector, including a full list of references⁷².

Table 1.4 gives additional information for common activity data sources.

Method approach

The calculation of direct greenhouse gases for the sources covered by this MS is:

$$\text{UK Emissions} = \text{EF} \times \text{AD}$$

The sources of emission factors (EF) and activity data (AD) are summarised under “key data sources” above, with a full list of emission factors set out in “Energy_background_data_uk_2026.xlsx”. The activity data are taken from DUKES, noting

⁷² This can be found as one of the additional documents to the NID https://naei.beis.gov.uk/reports/reports?report_id=1108

. Note that there can be a delay between the NID being published on the NAEI website after official submission.

the exceptions set out under Assumptions & observations, below. **Annex 5.2** describes the energy balance for the UK and how this is used for the inventory, and any deviations from these data.

Assumptions & observations

Key assumptions and deviations from the DUKES data are set out below.

Table 3.17 Assumptions related to DUKES data

Fuel type	Assumptions
Plant biomass, animal biomass and biogas	Where these categories are aggregated as solid biomass, and data for electricity generation is drawn from DUKES Table 6.1, this is all allocated to Major Power Producers; The DUKES categories of Major Power Producers and Autogenerators are summed together to allow reconciliation with data on power stations from other sources, so this does not have an impact on final results
Plant biomass	From inspection of the data and communication with the RESTATs team, it is known that the fuel categorised as solid biomass, pre-2004, which is consumed in agriculture is plant biomass (straw) so this is all allocated to this category. As this value matches the total heat use of plant biomass in these years, use of plant biomass in all other end use sectors pre 2004 is set to zero. As the agriculture line has been adjusted the TOTAL other line is replaced with a sum rather than directly reading the Table 6.1 value.
Animal biomass	From inspection of the data and communication with the RESTATs team, it is known that the pre 2015 biogas was included with animal biomass in DUKES Table 6.1, appearing in electricity generation, in heat use in agriculture and in transfers. The biogas for electricity generation and heat generation and use pre 2015 from DUKES Table 6.4 are therefore subtracted from the values for electricity generation and for agriculture from Table 6.1 to give a time series that is solely for animal biomass. The animal biomass transfer is known to be biogas injected to the grid and is therefore subtracted from animal biomass in agriculture as well. As the agriculture line has been adjusted the TOTAL other line is replaced with a sum rather than directly reading the DUKES Table 6.1 value.
Waste wood	From discussion with the DUKES team this fuel category refers only to wood used for heat production in non-domestic sectors. From inspection of the data, wood use in period 1998 to 2014 is almost exclusively allocated to unclassified industry. For the pre-1998 period, waste wood used for heat from DUKES Table 6.4 is therefore assigned to the unclassified industry category.
Liquid biofuels	Data series in DUKES Table 6.1 begins in 2005 but non-zero entries only begin in 2019. Table 6.1 shows no use for heat or electricity generation in period 1990 to 2005.

Fuel type	Assumptions
Biogas	Data from DUKES Table 6.1 are only available from 2015, Biogas used for electricity generation pre 2015 is taken from DUKES Table 6.4 and is allocated to autogenerators rather than major power producers, both because biogas generation plant are typically small, and because the data series from 2015 suggests this is the case. Pre 2015 data on heat use is available from Table 6.4, this is adjusted to remove heat supplied via injection to the grid.
Landfill gas	Data from DUKES Table 6.1 available from 1998. Data from 1990 to 1998 taken from Table 6.4; heat use distributed according to pattern of use in 1998.
Sewage gas	Data from DUKES Table 6.1 available from 1998. Data from 1990 to 1998 taken from Table 6.4; heat use distributed according to pattern of use in 1998.
Renewable waste	Data from DUKES Table 6.1 available from 1998. Data from 1990 to 1998 taken from Table 6.4; heat use distributed according to pattern of use in 1998.
Non-renewable waste	Data from DUKES Table 6.1 available from 1998. Data from 1990 to 1998 taken from Table 6.4; heat use distributed according to pattern of use in 1998.

Additional considerations for more detailed fuel categories and specific inventory sources are set out below.

- Power stations: bottom-up data from UK and EU ETS, individual operators, and the Environment Agency are used to estimate activity data for power stations. These are balanced with the DUKES electricity generation total and industry totals. Bio-carbon emission factors for straw, and animal biomass, are also based on the operator reported data.
- Scrap tyres: the use of scrap tyres within cement and lime kilns, and as part of the power generation sector are included within the cement, lime and power station models. Scrap tyres form part of the renewable and non-renewable waste fuels in DUKES (and the assumptions for the reconciliation within the non-renewable and renewable waste fractions differ across the time series). Scrap tyre use from the cement, lime and power stations models are imported into the bioenergy model so that these data can be removed from the renewable and non-renewable waste fuel totals to avoid a double count.
- Paper / plastic / profuel: This is a fuel category reported by the MPA and is modelled as part of the cement mastersheet. Consultation with the RESTATS team has confirmed that this is captured in the plant biomass category of DUKES. This fuel use is imported into the bioenergy model to be removed from the plant biomass category of DUKES, to avoid a double count.
- Domestic wood combustion: Domestic combustion is modelled based on appliance type, population and age profile, and then normalised to the DUKES totals. Outputs from the Domestic combustion model are combined with the residential wood total from DUKES so that the percentage breakdown by appliance type can be applied.
- Charcoal use: Charcoal is not reported within DUKES, and so the UK inventory estimates production and use based on import, production and export statistics from the FAO. All

charcoal use is included in the residential sector, using default emission factors from the IPCC Guidelines.

- Coffee logs: use of coffee logs in the domestic sector is modelled as part of the domestic combustion model. Total coffee log use is estimated based on the Defra burning survey. This fuel is assumed to be additional to data reported in DUKES.

Recalculations

In the 2026 submission the most sizable recalculations are due to revisions to DUKES data in recent years.

Additionally, some minor sources have been aggregated to align with the level of detail for other fuels. Specifically, mineral products (other), mechanical engineering, electrical engineering, vehicle manufacture, textiles and leather, and construction combustion sources have been grouped into other industrial combustion. This has no impact on overall emission and is simply a reallocation.

Improvements (completed and planned)

Completed: The methodology for assigning additional wood use in years since the Defra Domestic Burning Survey has been improved to use a more detailed breakdown of the underlying DUKES activity data. This allowed the changes to be distinguished between the annual variation in heating degree days and the result of new solid fuel appliance installations. The impact of this is limited to 2023 and 2024.

Planned/Ongoing: Emission factors and activity data remain under annual review. Defra has commissioned a study to improve the understanding of waste composition which may yield improvements to the CO₂ emission factor.

QA/QC

Specific QA/QC and validation exercises relevant to these source categories include:

- The Inventory Agency conducts extensive quality checks on the operator-reported UK ETS data covering: emissions, AD, EFs, NCVs. The QC assesses the fuel quality data, time-series consistency of reported data by installation, detailed source-specific UK ETS data against the installation-wide total emissions reported to the EU Transaction Log and UK Compliance Reports, and comparisons between DUKES and EU ETS AD to identify and resolve any potential mis-allocations or under-reports in the DUKES dataset. Findings are discussed with the DESNZ energy statistics team and (where necessary) the UK ETS regulators and/or operators. This process has led to many significant improvements in UK GHGI accuracy;
- The comparison of the reference/sectoral approach, and mass balance checks between the data in the inventory database and the DUKES totals;
- The bioenergy model was developed under the GHGIIP, as part of this the model was developed to be compliant with the DESNZ QA guidance for models, and the model scope and specification, and final report, underwent peer review.
- As part of the GHGIIP work programme, extensive consultation with data providers was carried out to check on the understanding and use of the data

The energy AD used in these estimates that come from DUKES are subject to the UK Statistics Authority's *Code of Practice for Statistics*⁷³. The UK ETS data, is subject to its own QA process, defined and managed by the competent authority and compliant with UK regulations.

⁷³ Available from <https://www.statisticsauthority.gov.uk/code-of-practice>

Time series consistency

DUKES data are typically only updated for the latter 3-5 years of the time series, and there is greater granularity of reporting in the latter part of the time series. Where revisions and step changes to the categorisation of the fuels is evident, and there is sufficient fuel to enable it, some extrapolations to earlier years have been used, where possible.

Bioenergy use in DUKES is reported in two tables:

- Table 6.1: Renewables and Waste: commodity balances (1998 to current year)
- Table 6.4: Renewable sources used to generate electricity and heat and for transport fuels (1990 to current year)

DUKES Table 6.1 details use of each fuel for energy transformation and final consumption in industry sectors, transport, and other sectors (domestic, public administration, commercial, agriculture and miscellaneous). It also includes data on transfers of gaseous biofuels to the national gas grid. Electricity generation is further subdivided into major power producers (electricity generation sites belonging to companies with a portfolio of over 100 MW of generation) and autogenerators (companies who produce electricity, but whose main business is not electricity generation).

The level of disaggregation provided in DUKES Table 6.1 has increased significantly over the years - the level of detail provided in more recent years is not present in earlier years. The level of disaggregation by fuel type over time is listed in **Table 3.18**. In terms of disaggregation by sector, pre 2015 all use in the industry sector is allocated to a single sector 'unclassified', and a split by industry sector is only included between 2015 and current day. It should be noted that there are some obvious discontinuities in the time series, where it appears that fuel use has been reallocated from one sector to another, but the change has not been applied over the whole time series⁷⁴.

In contrast, DUKES Table 6.4 includes data over the whole required time period (from 1990 to current day) but only splits fuels between use for electricity, use for heat (which includes the heat generation category in DUKES Table 6.1 and all final consumption sectors) and use for transport. Fuels listed in DUKES Table 6.4 include all of those in DUKES Table 6.1 but also an additional category – co-firing with fossil fuels – where the type of biomass is not specified (Table 3.19).

Table 3.18 Coverage of biomass fuel types in DUKES Table 6.1

Fuel type	1990 to 1998	1998 to 2003	2004 to 2014	2015 to 2018	2018 to current
Solid biomass	No	Yes	No	No	No
Plant biomass	No	No - included as solid biomass	Yes	Yes	Yes
Animal biomass	No	No - included as solid biomass	No - includes Anaerobic digestion	Yes	Yes
Liquid biofuels	No	No	No	No	Yes
Renewable waste	No	Yes	Yes	Yes	Yes

⁷⁴ Typical practice in DUKES when changes are implemented is to only implement the change for a few historic years.

Fuel type	1990 to 1998	1998 to 2003	2004 to 2014	2015 to 2018	2018 to current
Non-renewable waste	No	Yes	Yes	Yes	Yes
Anaerobic digestion (biogas)	No	No - included as solid biomass	No - included with animal biomass	Yes	Yes
Landfill gas	No	Yes	Yes	Yes	Yes
Sewage gas	No	Yes	Yes	Yes	Yes
Waste wood (industry and other non-domestic sectors)	No	Yes	Yes	Yes	Yes
Wood (domestic sector only)	No	Yes	Yes	Yes	Yes

Table 3.19 Coverage of biomass fuel types for electricity and heat in DUKES Table 6.4

Fuel type	Used for electricity generation	Used for heat generation
Plant biomass	Yes	Yes
Animal biomass	Yes	Yes
Landfill gas	Yes	Yes
Sewage gas	Yes	Yes
Anaerobic digestion	Yes	Yes
Bioliquids	Yes	Yes
Biodegradable energy from waste	Yes	Yes
Non-biodegradable wastes	Yes	Yes
Co-firing with fossil fuels	Yes	No
Waste wood	No	Yes
Wood	No	Yes

Through inspection of the data, comparisons between the two data sets, and discussions with the DUKES and RESTATS it was possible to create a time series that is considered to represent the most disaggregated and consistent time series available given limitations of the data. The actions which are taken within the model to achieve this are listed in Table 3.17

Uncertainties

Uncertainties for both activity and emission factors are based on expert judgement. The uncertainty analysis set out in **Annex 2** provides details of these uncertainty values. Uncertainties in fuel use statistics are typically low. The detailed consideration of the available activity data has improved the understanding of the data, however it has not been possible to further reduce the uncertainty in the emission factors as these are largely based on IPCC Defaults.

4 Industrial Processes and Product Use (IPPU; CRT Sector 2)

4.1 OVERVIEW OF SECTOR

The table below gives an overview of the industrial processes and product use (IPPU) sector. The Key Categories indicated are based on both the Approach 1 and Approach 2 analyses. The uncertainty estimate has been taken from Monte Carlo analysis.

Emission trends are presented for 1990-2024 and 2023-2024. A description of the trends and the main drivers behind these can be found in **Chapter 2**

Table 4.1 Industrial Processes and Product Use Overview

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Key Categories	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)	Method	EF	Notes
Total industrial processes			20.65	-75%	-15%	-7%	3%					
A. Mineral industry			5.03	-51%	-3%	0%	0%					
1. Cement production	CO ₂ (L1)	3%	3.47	-52%	-1%	0%	0%	CO ₂	4.2	T2	CS	
2. Lime production		5%	0.98	-26%	-2%	0%	0%	CO ₂	4.3	T1 (1990-1993) T3 (1994 – latest year)	D	
3. Glass production		5%	0.30	-27%	-7%	0%	0%	CO ₂	4.4	T2	CS	

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Key Categories	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)	Method	EF	Notes
4. Other process uses of carbonates		4%	0.28	-77%	-22%	-2%	0%	CO ₂ , CH ₄	4.5	CS	CS (bricks), D (FGD)	CH ₄ from this source reported under 2H3i in the CRT tables.
B. Chemical industry	CO₂, N₂O, HFCs (L2, T2)		1.57	-96%	-13%	11%	7%					
1. Ammonia production		n/a	0.00	-100%	N/A	N/A	0%	CO ₂ , CH ₄ , N ₂ O	4.6	T3 (CO ₂), T1 (CH ₄ , N ₂ O)	CS (CO ₂), D (CH ₄ , N ₂ O)	
2. Nitric acid production	N ₂ O (T1)	10%	0.01	-100%	-28%	0%	0%	N ₂ O	4.7	T2	CS	
3. Adipic acid production	N ₂ O (L1, T1)	N/A	0.00	-100%	N/A	N/A	0%	N ₂ O	4.8	T2	CS	
4. Caprolactam, glyoxal and glyoxylic acid production		N/A	0.00	N/A	N/A	N/A	N/A	N/A	4.9	N/A	N/A	
5. Carbide production		N/A	0.00	N/A	N/A	N/A	N/A	N/A	4.10	N/A	N/A	
6. Titanium dioxide production		10%	0.13	23%	8%	0%	0%	CO ₂	4.11	CS	CS	
7. Soda ash production		6%	0.10	-57%	-2%	0%	0%	CO ₂	4.12	CS	CS	
8. Petrochemical and carbon black production	CO ₂ (L1)	30%	1.24	-74%	-15%	12%	0%	CO ₂ , CH ₄ , N ₂ O	4.13	CS, T1	CS, D	N ₂ O from this source reported under 2B10 in the CRT tables

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Key Categories	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)	Method	EF	Notes
9. Fluorochemical production	HFCs, PFCs, SF ₆ and NF ₃ (L1, T1)	9%	0.09	-99%	-20%	28%	0%	HFCs, PFCs	4.14	T2	PS	
10. Other (as specified in table 2(I).A-H)		29%	0.01	-97%	-7%	-11%	0%	CH ₄	4.15	CS	CS	
C. Metal industry		9%	6.06	-77%	-30%	-19%	-4%					
1. Iron and steel production	CO ₂ (L1)		6.01	-75%	-31%	-19%	0%	CO ₂ , CH ₄ , N ₂ O	4.16	T2 (CO ₂), T1, T3 (CH ₄)	CS (CO ₂), CR, CD, D (CH ₄)	N ₂ O from this source reported under 2C7 in the CRT tables.
2. Ferroalloys production			0.00	N/A	N/A	N/A	N/A	N/A	4.17	N/A	N/A	
3. Aluminium production			0.05	-94%	-2%	0%	12%	CO ₂ , PFCs	4.18	T1 (CO ₂), T2 (PFCs)	CS (CO ₂), PS (PFCs)	
4. Magnesium production			0.00	-99%	0%	0%	0%	HFCs, SF ₆	4.19	T2	PS	
5. Lead production			0.00	N/A	N/A	N/A	N/A	N/A	4.20	N/A	N/A	
6. Zinc production			0.00	-100%	N/A	N/A	0%	CO ₂	4.21	CS	CS	
7. Other (as specified in table 2(I).A-H)			0.00	N/A	N/A	N/A	N/A	N/A		T1	CR	N ₂ O from iron and steel production reported here in the CRT tables
D. Non-energy products from fuels and solvent use		53%	0.39	-30%	-10%	-7%	0%					

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Key Categories	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)	Method	EF	Notes
1. Lubricant use			0.32	-38%	-8%	1%	0%	CO ₂	4.22	T1	CS	
2. Paraffin wax use			0.02	-51%	-2%	3%	0%	CO ₂	4.23	T1	D	
3. Other			0.05	N/A	-22%	-34%	N/A	CO ₂	4.24	T2 (non energy use of petroleum coke), T3 (urea use)	D (non energy use of petroleum coke), CR (urea use)	
E. Electronics industry		46%	0.00	-55%	-12%	0%	0%					
1. Integrated circuit or semiconductor			0.00	-55%	-12%	0%	0%	HFCs, NF ₃	4.25	T2	D	
2. TFT flat panel display			0.00	N/A	N/A	N/A	N/A	N/A	4.26	N/A	N/A	
3. Photovoltaics			0.00	N/A	N/A	N/A	N/A	N/A	4.27	N/A	N/A	
4. Heat transfer fluid			0.00	N/A	N/A	N/A	N/A	N/A	4.28	N/A	N/A	
5. Other (as specified in table 2(II))			0.00	N/A	N/A	N/A	N/A	N/A		N/A	N/A	
F. Product uses as substitutes for ODS⁽²⁾	HFCs (L2, T2)	6%	6.45	858%	-7%	0%	0%					
1. Refrigeration and air conditioning	HFCs, PFCs, SF ₆ and NF ₃ (L1, T1)		5.22	7126%	-7%	0%	0%	HFCs	4.29	T2	CS	
2. Foam blowing agents			0.28	65%	-2%	0%	0%	HFCs	4.30, 4.31	T2	CS	
3. Fire protection			0.08	5038%	-44%	-2%	0%	HFCs, PFCs	4.32	T2	CS	

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Key Categories	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)	Method	EF	Notes
4. Aerosols	HFCs, PFCs, SF ₆ and NF ₃ (T1)		0.85	107%	-5%	0%	0%	HFCs	4.33	T2	CS	
5. Solvents			0.01	N/A	1%	1%	N/A	HFCs	4.34	T1a	OTH	
6. Other applications			0.02	-7%	-11%	0%	0%	HFCs	4.35	CS	CS	
G. Other product manufacture and use	N ₂ O (L2, T2)	65%	1.14	-40%	-3%	0%	14%					
1. Electrical equipment			0.24	-71%	-15%	7%	0%	SF ₆	4.36	T3	CS	
2. SF ₆ and PFCs from other product use			0.08	-57%	-11%	0%	0%	PFCs, SF ₆	4.37, 4.38, 4.39	T2 (Accelerators), T2, T3 (Electronics and shoes), OTH (Tracer gas), T1 (military)	D (Accelerators), CS, D, (Electronics and shoes), CS (Tracer gas), D (military)	
3. N ₂ O from product uses			0.69	N/A	N/A	-3%	0%	N ₂ O	4.40, 4.41	OTH (Medical), CS (propellants)	CS (Medical), OTH (Propellants)	
4. Other			0.12	N/A	N/A	-4%	154%	N ₂ O,	4.42	CS	CS	
H. Other (as specified in tables 2(I).A-H and 2(II))⁽³⁾			0.00	N/A	N/A	N/A	N/A			CS	CS	CH ₄ from 2A4 reported here in CRT tables

* CH₄ emissions from flint brick production are reported under 2H in the CRT tables, as not possible to report in 2A4 alongside CO₂ emissions from this source.

** N₂O emissions from 2B8 are reported under 2B10 in the CRT tables

***N₂O emissions from 2C1 are reported under 2C7 in the CRT tables

The industrial processes and other product use sector (CRT Sector 2) contributes 5.46% to total greenhouse gas emissions. Emissions from this sector include non-energy related emissions from mineral products, chemical industry and metal production and product use, including emissions of F-gases. Since 1990, this category has seen a 74% decline in emissions, mostly due to changes in the emissions from the chemical production and halocarbon and SF₆ production industries. The step-change in emissions between 1998 and 1999 evident in **Figure 4.2** is due predominantly to the fitting of nitrous oxide abatement equipment at the UK's only adipic acid production plant (this plant has since closed).

The figures in Figure 2.14 - Figure 2.16 show that the numbers of industrial processes in the UK have been declining since 1990. While this is partly due to the closure of some smaller sites, perhaps with growth in capacity at remaining sites, it is predominantly a reflection of decreasing production of many industrial materials in the UK. A large number of closures in the period 2007-2009 were due to decreased demand for many products as a result of the general economic situation in the UK and elsewhere, with falling demand for steel, cement, bricks and aluminium, for example, leading to plant closures.

Figure 4.1 Breakdown of total GHG emissions in Industrial Processes sector for the latest inventory year

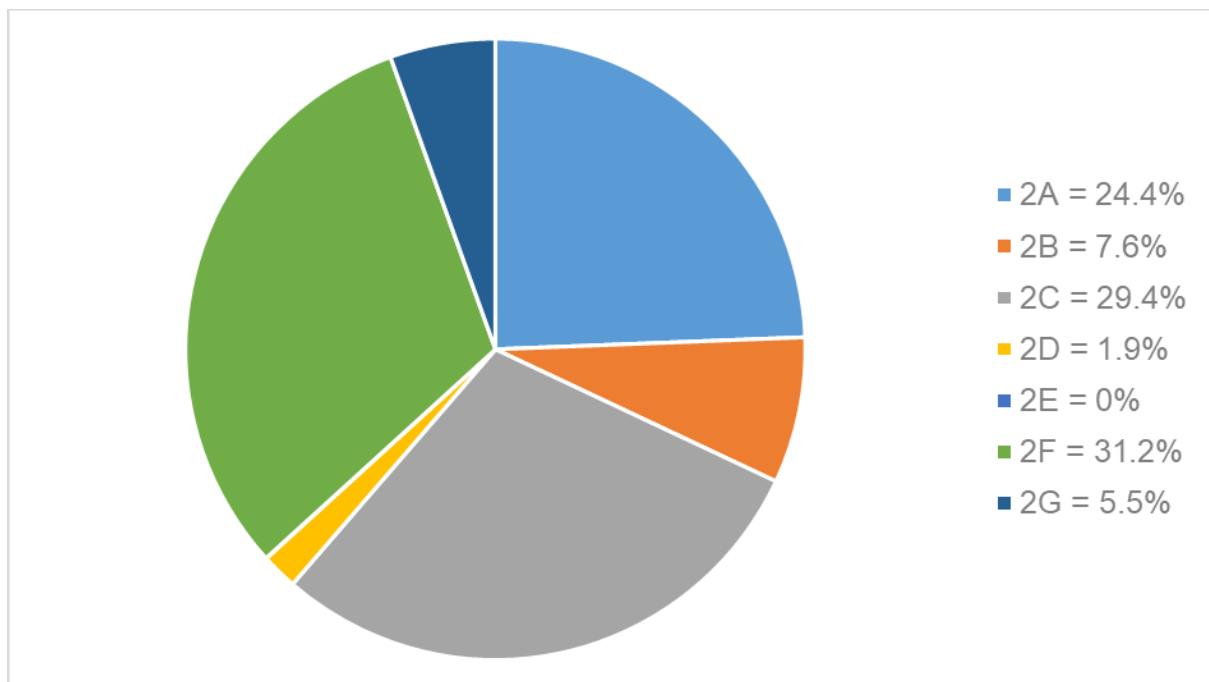
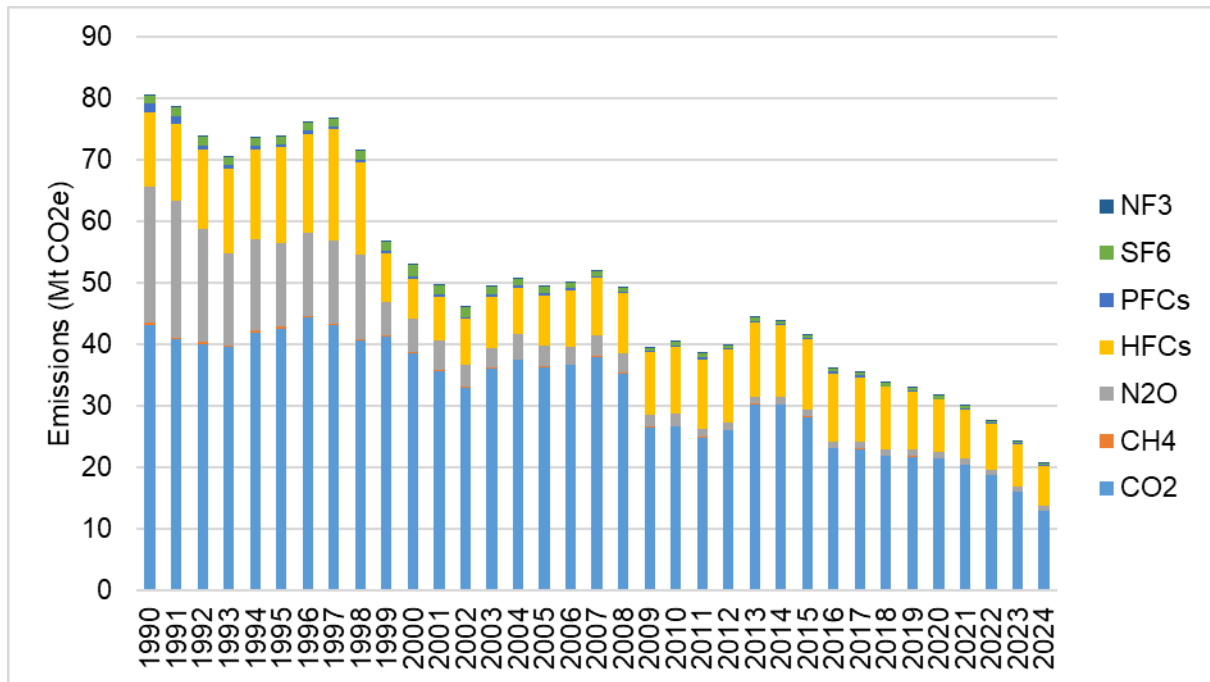


Figure 4.2 Trend in total GHG emissions in Industrial Processes sector


4.2 SOURCE CATEGORY 2A1 – CEMENT PRODUCTION

4.2.1 Source Category Description

Emissions of CO₂ from fuels burnt in cement kilns are reported under CRT category 1A2f, whilst emissions from calcination of non-fuel feedstocks are reported under category 2A1.

Fuel combustion also gives rise to emissions of nitrous oxide, reported under 1A2f. Emissions of methane also occur, both due to fuel combustion but also due to the evaporation of organic components present in the raw materials. The current GHGI methodology for estimating emissions of methane does not allow emissions from fuels and from raw materials to be quantified separately so all emissions are reported under 1A2f.

4.2.2 Methodological Issues

Emission estimates for 2005 onwards are available from the annual UK production of clinker and emission factors provided by the Mineral Products Association (MPA, 2025), formerly the British Cement Association (BCA). These AD and EFs are based on site-specific data generated by UK cement clinker producers for the purposes of reporting to the UK/EU Emission Trading Scheme (ETS), and therefore the methodology is effectively Tier 3. Data from the MPA are cross-checked against the UK/EU ETS data set supplied directly by regulators for use in the inventory. The UK/EU ETS data are incomplete for 2005-2006 as several kilns were reporting within a different trading system, and therefore UK/EU ETS-MPA data comparisons for those two years are not useful. From 2007 onwards, the scopes of the two datasets are the same, and the emission totals are closely consistent, particularly from 2008 onwards where there is an average difference of 0.08%. In each year, the inventory estimates are based on the higher of the two figures, i.e. MPA data for 2007, 2010, 2015-2017, and 2023-2024, and UK/EU ETS for 2005-2006, 2008-2009, 2011-2014 and 2018-2022. The UK/EU ETS and MPA/BCA data both include emissions associated with cement kiln dust.

UK/EU ETS and MPA data are available for 2005 onwards only, but are regarded as the best available data to represent the emissions performance of UK cement kilns before 2005.

Therefore, the emission factor value for 2005 has been extrapolated to all earlier years, as it is the most representative figure of the full range of UK kilns operating back to 1990. Several kilns closed during the economic down-turn of the late 2000s, meaning that emission factors for 2007 onwards are less representative of the period before 2005.

The methodology used for estimating CO₂ from calcination is summarised in **Table 4.2**.

Table 4.2 Methods used to estimate cement production emissions of CO₂

Period	Activity data	Emission factor, kt C / kt carbonate	Method
1990-2000	British Geological Survey – UK Minerals Yearbook, clinker production data for the UK	Use of the 2005 emission factor derived from emissions from all UK cement plant, from the British Cement Association	Emission = AD x EF
2001-2004	British Cement Association, clinker production data for UK		
2007, 2010, 2015-2017, and 2023-2024	Mineral Products Association, clinker production data for UK	Factor derived from annual, site-specific data compiled from UK/EU ETS data by Mineral Products Association (since higher than UK/EU ETS-based CEF for that year)	Emission = AD x EF (UK wide EF and AD for 1990-2004, and on a site and material basis from 2005 onwards)
2005-2006, 2008-2009, 2011-2014 and 2018-2022		Factor derived from site-specific UK/EU ETS returns for all UK sites (since higher than MPA-based CEF for that year).	

4.2.3 Uncertainties and Time Series Consistency

The time-series consistency of the activity data used in the UK GHGI emission calculations is very good across all years, as the Inventory Agency has a complete, consistent dataset from the UK trade association (BCA then MPA) from 2001 onwards, and routine statistical datasets for the earlier years from BGS. Furthermore, since 2005 there is a comprehensive sector-wide dataset for emissions and the EFs applied for carbonisation emissions. Cross-checks with UK/EU ETS data received directly from UK regulators indicate only very small differences. The extrapolation of the EF from 2005 back to 1990 is the best available data to use for the UK cement sector but does lead to higher uncertainties for the emissions total in the base year.

It is important to note that there is a distinction to be made between: (i) the data used to estimate emissions in the UK methodology; and (ii) the data that can be released into the public domain for the purposes of reporting the national inventory. The data used to estimate emissions are a complete dataset (of emissions and production) from all UK cement kilns. *These data can be provided to a UNFCCC Expert Review team on request.*

The data reported in the CRT and NID, however, are limited by commercial confidentiality. UK Government statistical publications of cement clinker production for 2001-2014 are for Great Britain only, i.e. excluding production in Northern Ireland. Throughout this part of the time series either one or two cement kilns operated in Northern Ireland. Their emissions and production data are provided to the Inventory Agency and used in the inventory calculations. However, to release the complete UK clinker production statistics would be disclosive for the

sites in Northern Ireland. Therefore, in the table below and the CRT dataset, only GB production data are presented for the years from 2005 to 2014. This is the reason for the step-change upwards in IEF over the time series between 2000 and 2005 and the step-change downwards in the IEF between 2014 and 2015. The underlying calculations do not exhibit any such step-changes.

A large drop in clinker production after 1990 can be explained by a sharp drop in construction activity. This initial drop and a less pronounced downward trend in production over the period 1994-2007 may, in part, also be due to increased use of slag cement, production of which is likely to have risen sharply over the same period; the Inventory Agency estimates that capacity for slag cement production increased from 0.75 Mtonnes in 1990 to 2 Mtonnes by 2007. A sharp decrease in clinker production between 2007 and 2009 is linked to the recession, which caused a decline in construction and therefore demand for cement. A number of kilns were closed or mothballed during those years, and none have subsequently been re-opened. However, there has been a slow and uneven increase in clinker production since 2009, and production in Great Britain in 2016 was at the highest level since 2008, before falling back slightly in subsequent years.

Table 4.3 summarises activity data and implied emission factors over the time series. The activity data for 2005 to 2014 are for Great Britain only. The CO₂ emissions data in the table are for the whole of the UK. The CO₂ emission factors are therefore a mixture of those based entirely on UK data (for 1990-2000 & 2015-2024) and those that mix UK emissions and GB activity data (2005 to 2014), but are shown to give an indication of the trend in the factor over time.

Table 4.3 Activity data and carbon EF for cement production, 1990 - 2024

Year	Cement Clinker production (kt) ^a	CO ₂ emitted (kt)	CO ₂ emission factor, (t / t clinker)
1990	13,199	7,295	0.553
1995	11,371	6,285	0.553
2000	11,456	6,332	0.553
2005	<i>10,074</i>	5,941	0.590
2006	<i>10,066</i>	5,893	0.585
2007	<i>10,228</i>	6,117	0.598
2008	<i>8,701</i>	5,205	0.598
2009	<i>6,421</i>	3,721	0.580
2010	<i>6,598</i>	3,792	0.575
2011	<i>7,096</i>	4,097	0.577
2012	<i>6,555</i>	3,724	0.568
2013	<i>6,712</i>	4,029	0.600
2014	<i>7,197</i>	4,215	0.586
2015	7,804	4,393	0.563
2016	8,029	4,553	0.567
2017	7,821	4,410	0.564
2018	7,748	4,364	0.563
2019	7,903	4,448	0.563
2020	6,929	3,900	0.563
2021	7,419	4,215	0.568
2022	7,224	4,045	0.560
2023	6,339	3,515	0.554
2024	6,328	3,469	0.548

^a Figures in italics (for 2005-2014) exclude production in Northern Ireland

The UK-specific emission factor for cement clinker production is constant for 1990-2000 because no year-specific data are available, and a UK factor from the UK/EU ETS reporting period is extrapolated back to UK production data. Factors presented above for the period 2005-2014 are all higher than the factor for 1990-2000 because of the change in the Government statistics from UK to GB in 2001, as explained above. Since the 2005-2014

activity data exclude production at a small number of sites in Northern Ireland, the activity data are lower, and the implied emission factors for CO₂ are therefore higher. The emission factors in the period from 2005 to 2014 vary from year to year, with a minimum value of 0.568 t CO₂ / t in 2012 and a maximum value of 0.600 t CO₂ / t in 2013. Since 2015, when IEFs are based instead on UK-level activity data, the minimum and maximum factors are 0.548 t CO₂ / t in 2024 and 0.568 t CO₂ / t in 2021. The average IEF for the years where GB-level activity data are available is 4% higher than the average IEF in the years where UK-level activity data are available. That average level of difference is broadly consistent with the known capacity of kilns in Northern Ireland relative to the rest of the UK.

4.2.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**. Emissions reported to the Inventory Agency by the Mineral Products Association are cross checked with plant specific data reported in the UK/EU ETS to ensure complete coverage of all emissions.

4.2.5 Source Specific Recalculations

No recalculations have been made to emissions from this category.

4.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.3 SOURCE CATEGORY 2A2 – LIME PRODUCTION

4.3.1 Source Category Description

Lime (CaO) is manufactured by the calcination of limestone (CaCO₃) and dolomite (CaMg(CO₃)₂) in kilns fired mainly by coal, coke or gas, though some wastes and other fossil fuels are also used. The calcination results in the evolution of carbon dioxide. However, it is necessary to distinguish between merchant lime processes where the purpose is to produce lime for use off-site and where carbon dioxide is an unwanted by-product emitted to atmosphere, and those captive lime processes where lime is produced so that both the carbon dioxide and lime can be used on-site in the process. In these latter processes, which include sugar refining, none of the carbon dioxide is emitted to atmosphere, apart from the exception listed in the next section. Emissions from lime kilns used in the manufacture of sodium carbonate are, in line with IPCC Guidelines, reported in 2B7.

4.3.2 Methodological Issues

The UK method uses EU and UK ETS data to determine emissions from 2005 onwards, Pollution Inventory (PI) data from 1994 to 2004 and British Geological Survey (BGS) data from 1990 to 1993. The EU/UK ETS data consist of CO₂ emission estimates (including emissions associated with lime kiln dust) and activity data. The activity data takes various forms e.g. feedstock or product, depending upon site, and so it is not possible to generate UK activity data simply by summing the activity data in EU/UK ETS. Therefore, the emissions data have been adopted, with the lime activity data then being back-calculated using a default emission factor of 121.5 t carbon/kt limestone or dolomite. This emission factor is derived by assuming that 85% of UK lime production is from limestone and the remaining 15% is from dolomite (based on a recommendation from the EU's UNFCCC review). For limestone, an emission factor of 120 t carbon/kt limestone is then assumed, based on the stoichiometry of the chemical reaction, and for dolomite, a corresponding emission factor of 130 t carbon/kt dolomite is used. EU/UK ETS returns do provide some indication of site-specific activity data

although this is a mixture of data on carbonate inputs and lime outputs. Nevertheless, it would be possible to generate an approximate time-series of lime production for merchant lime producers from EU/UK ETS returns for the period from 2008 onwards and while these cannot be published due to the confidential nature of the data, the figures could be provided on request to a UNFCCC Expert Review Team. There are no suitable data in EU/UK ETS for captive lime processes so we are unable to provide any similar lime production estimates for those sites.

Prior to 2005 there are no UK/EU ETS data at all, and data are incomplete for 2005-2007 because of UK exemptions from the EU ETS for some sites in those years. Therefore, between 1994 and 2004, CO₂ emission estimates for lime production are based on emissions data published for each site in the Pollution Inventory (PI), and these data are also used for those sites that were exempt from EU ETS before 2008. The PI data are mostly for total CO₂ i.e. include emissions from both decarbonisation and fuel combustion on a site, but estimates of the CO₂ from decarbonisation only are made using EU ETS data and PI data for 2006-2008, both of which give fuel combustion emissions separately from decarbonisation. For the period 1994-1997, there is less reporting of CO₂ in the PI and so site-specific CO₂ emissions are estimated based on other site-specific data such as emissions data for particulate matter from those sites in the relevant years. The PI data are assumed to cover the same scope as the later EU ETS data i.e. to include emissions from lime kiln dust as well as lime product. There are no PI data for the period 1990-1993 so BGS activity data are the only data available to calculate emissions. As emissions estimates based on BGS data are consistently lower than emissions from PI and UK/EU ETS sources for the period from 1994 onwards, it is assumed that BGS data for 1990-1993 would also underestimate emissions and the Inventory Agency has therefore applied a 'correction' factor of 1.08 to the BGS data for those years. This correction factor is based on the average difference between BGS-based estimates and PI-based estimates for the period from 1995 to 2001. From 2002, there is a step-change in the BGS data and in the BSG:PI ratio, and we therefore exclude any later data from the calculation of the correction factor on the assumption that the period 1990-1994 was more likely to be similar to 1995-2001 (when BGS & PI give broadly similar results) than 2002 onwards (when BGS gives much lower results). The methods used for each part of the time series are summarised below.

Table 4.4 Methods used to estimate emissions from merchant lime plants

Period	Activity data	Emission factor, t C / kt carbonate	Emission
1990-1993	BGS x 1.08	121.5	AD x EF
1994-1997	(back-calculated)	121.5	PI CO ₂ + estimates extrapolated from later PI data on basis of other data such as emissions data for other pollutants
1998-2004	(back-calculated)	121.5	PI CO ₂
2005-2007	(back-calculated)	121.5	EU ETS & PI CO ₂
2008-2020	(back-calculated)	121.5	EU ETS
2021-2024	(back-calculated)	121.5	UK ETS

The calculated emissions and activity data exclude carbonates calcined in the chemical industry since this is all used in the Solvay process, for which emissions are reported in 2B7.

The EU/UK ETS data for UK sugar producers do not include any emissions from calcination, and consultation with the industry in the past confirmed that the industry considers there to be no CO₂ emissions from this source - all of the lime used in the carbonation process (whereby lime and carbon dioxide are used to remove impurities in sugar solutions) is considered to be converted back to calcium carbonate at the end of the process, meaning no net emission in CO₂. However, the UNFCCC centralised review of the 2013 submission of the UK GHG Inventory recommended that CO₂ emission estimates were needed and that it should be assumed that some unreacted lime was present in waste sludges at the end of the carbonation process. Emission estimates are therefore included using a default percentage (24%) of unreacted lime as advised by the Expert Review Team (ERT). This ERT default is based on data from other countries since UK-specific data indicate zero emissions. Due to the confidentiality of the lime production data at the sugar production sites, further details of the methodology are not presented here, but can be provided to a UNFCCC Expert Review Team.

The calcium carbonate produced by the sugar industry is marketed as a soil liming agent and is assumed to be wholly used by UK agriculture. Emissions associated with this usage are included in the estimates for agriculture as described in **Section 5**.

4.3.3 Uncertainties and Time Series Consistency

Uncertainty in the emission estimates for merchant lime plants is low for recent years but higher for earlier years in the time series. EU and UK ETS provide a full dataset for UK facilities from 2008 onwards, and the uncertainties associated with these verified data are low. UK/EU ETS data for 2005-2007 provide partial coverage of the sector and are used in conjunction with other data sources to derive inventory estimates, and hence these estimates are also regarded as subject to low uncertainty. Uncertainty is higher for the estimates before 2005, because of the need for assumptions to be made in deriving the estimates (for example, assumptions regarding the split between combustion and process emissions in the PI data used between 1994 and 2004). Estimates for the years 1990 to 1993 are the most uncertain, because no reported CO₂ emissions data are available, and emissions have therefore to be based on the BGS data that are known to be inaccurate for later years. An adjustment is made to the BGS data to try to deal with the expected underestimating of activity by BGS, but a comparison of BGS and other data for later years indicates that the BGS underestimates are not consistent and so the scale of any underestimation in 1990-1993 is difficult to predict with any confidence.

The estimates for lime kilns used in sugar production are highly uncertain since UK/EU ETS data for those sites suggest no CO₂ is emitted. In addition, a study for the European Commission on UK/EU ETS emission allowances for the lime sector (Ecofys, 2009b) states that it can be assumed that “there are no process-dependent CO₂ emissions released from the limestone that is used”. The UK producer has also indicated that they consider the conversion of lime back to calcium carbonate as being complete (Personal Communication: British Sugar, 2013).

4.3.4 Source-specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**. Cross comparison of the BGS data with the UK/EU ETS data as a means of verification has indicated a potential under report in the BGS data. This has led to a change in the methodology to ensure completeness of the inventory reporting.

4.3.5 Source Specific Recalculations

No recalculations have been made to emissions from this category.

4.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review. In response to the ERT recommendation (2017 ARR, item I.14) to collect lime production data to enable the UK to derive and report a production-based IEF, the UK Inventory Agency has consulted with the Office of National Statistics (ONS) to seek any data that are available from the industry on production of lime, via the Prodcom surveys and database. The Inventory Agency research has found that there is no complete, consistent time series of annual production data from UK producers from ONS. This is due to the nature of the periodic surveys conducted by ONS, the combination of production data from several mineral sectors (e.g. cement with lime aggregated) and the commercial sensitivity of reported production data. The Inventory Agency notes that the UK/EU ETS emissions reporting is known to cover all existing UK lime works and therefore is complete and accurate for recent years, and that to gather any further activity data from the industry is not practicable given the competing priorities for inventory improvement resources. As discussed in **Section 4.3.2**, it would be possible to provide an ERT with an approximate timeseries of lime production estimates for 2008 onwards for merchant lime sites only, which could then be used to generate an approximate IEF for those sites only.

4.4 SOURCE CATEGORY 2A3 – GLASS PRODUCTION

4.4.1 Source Category Description

Emissions from glass manufacture include emissions of carbon dioxide resulting from the use of limestone, dolomite and soda ash as sources of CaO, MgO and Na₂O respectively in soda-lime and other glasses. Emissions from fuels used in glass furnaces are reported in 1A2g.

The UK had 22 large sites making glass at the end of 2024, producing container glass (12 sites), flat glass (3 sites), continuous filament glass fibre (1 site), glass wool (4 sites), and stone wool (2 sites). Two sites producing flat glass by the float process closed in November 2013 and February 2024. There is also a small site producing ceramic fibres. Ballotini are produced at three sites, but production is small - output is estimated to be less than 1% of UK glass production. Special and non-lead domestic glasses are no longer manufactured in the UK, and production of lead glass is only on a very small scale. The last producer of frits closed in 2014. It is assumed that limestone and dolomite are used in the production of container, flat, and special glass, and in glass and stone wool. Any use of carbonates in frits and lead glass is assumed to be trivial because of the small-scale production of these in the UK (together, both sectors account for about 0.1% of UK glass production). UK/EU ETS data for the sole UK site making ceramic fibres indicate that this process does not involve the use of the three carbonate minerals. The ballotini processes are not covered by UK/EU ETS but are based almost exclusively on the use of recycled glass (cullet) and so carbonates are not used in significant quantities. Since the production of ballotini is a trivial fraction of UK glass production and the use of carbonates for ballotini is also trivial, emissions are not estimated.

Due to the very small number of sites involved, and the confidential nature of the UK/EU ETS data used to generate the emissions data, reporting the stone wool sector separately would be problematic. The UK therefore combines the data with emissions for other glass industry sites.

Process emissions of N₂O are not estimated for glass production because suitable methods or data have not been found. Operators of UK plants regulated under the Environmental Permitting Regulations (EPR) 2016 (England and Wales) and The Pollution Prevention and Control (PPC) Regulations for Scotland and Northern Ireland do not report any emissions data to the regulators and so any releases of N₂O from these sites (including N₂O from combustion

of fuels) must be below the reporting threshold of 10 tonnes and therefore any process emissions will be very low for the UK as a whole.

4.4.2 Methodological Issues

Emissions from the use of carbonates in glass production are calculated using data from two sources:

- A detailed, site by site survey of raw material usage in the glass industry, carried out in 2006 (GTS, 2008). This report covered the flat, container, and fibre sectors;
- Data reporting under the UK/EU Emissions Trading System (UK/EU ETS) from 2008 onwards.

In the case of the survey of raw material usage, data are available on the quantities of each type of carbonate used by each sub-sector of the industry during 2006. Emissions must be estimated, and this is done based on the stoichiometric relationship between carbon and the related carbonate, and assumes all of the carbon is released to atmosphere i.e.

120 t carbon/kt limestone;
130 t carbon/kt dolomite;
113 t carbon/kt soda ash.

The UK/EU ETS data are for CO₂ emissions, disaggregated by the source of the emission e.g. use of natural gas, use of limestone etc. The data have to be analysed so that emissions can be separated into those that occur due to use of fuels, and those that are due to use of the three carbonates. Data are available for the period 2008-2024 for all sites manufacturing flat glass, container glass, continuous filament glass fibre, glass wool and stone wool. Carbonate use is back-calculated using the stoichiometric relationships given above. Since ETS data are available on a site-by-site basis, the emissions data and the derived activity data can be agglomerated to give estimates for each sub-sector of the glass industry.

The two data sources can be used to derive estimates of carbonate use / CO₂ emissions for each sub-sector of the glass industry as follows:

2008-2024: flat, container, glass fibre, glass wool, stone wool;
2006: flat, container, glass fibre/glass wool (combined in the survey).

These data indicate some changes over time in rates of carbonate use for flat, container and glass wool, and partial UK/EU ETS data for 2005-2007 also support this. Therefore the 2006 survey, rather than the later UK/EU ETS data, is assumed to be more reliable as a guide to the rates of carbonate usage in the three sectors in the years 1990-2005 and usage for that period is therefore extrapolated from the 2006 figures on the basis of production in each sub-sector in each year. For stone wool, data are only available from the UK/EU ETS for 2008-2024, so the average consumption rate calculated for those years is then applied to the period 1990-2007 using stone wool production estimates for each year. The data indicate that some glass industry sub-sectors in the UK do not use all three carbonate minerals, or only use small quantities of some. Neither of the two data sources contains information on special or domestic glasses because the only UK sites producing either type of glass closed before the end of 2006. Therefore, carbonate usage for both types of glass have been assumed to be equal to the average rate for container, flat and glass wool in 2006, as given in the raw material usage study.

Glass production data are available on an annual basis for container glass only (British Glass, 2025), and a full time-series of production for other types of glass has therefore to be estimated based on the partial time series of production data covering a limited years (e.g. data for late 1990s from EIPPCB, 2000; flat glass data for 2003 onwards from British Glass). These are then extrapolated to other years on the basis of estimated plant capacity. In the case of flat and container glass, the glass production data used to estimate carbonate usage are corrected

for the amount of cullet used in each year, so the estimates do take into account changes over time in recycling rates and use of cullet. This is not possible for other types of glass, and so the calculation of carbonate usage for these glass types is based on total production. Therefore, the estimates for glass wool, special glasses and domestic glass implicitly assume that the rate of recycling in these sectors remains constant over the time series.

Table 4.5 Summary details for the UK glass industry and the scope of estimates for CO₂ emissions from carbonate use

Glass Sector	1990 production, kt	2024 production, kt	Emission estimates included for use of Limestone	Emission estimates included for use of Dolomite	Emission estimates included for use of Soda Ash
Container	a	a	Yes	Yes	Yes
Flat	a	a	Yes	Yes	Yes
Special	226	-	Yes	Yes	Yes
Domestic, including lead	76	0.2	Yes	Yes	Yes
Continuous filament glass fibre	82	62.6	Yes	Yes	Yes
Glass wool	104	302.4	Yes	Yes	Yes
Stone wool	85	69.3	No	Yes	Yes
Ceramic fibres	14	14.0	No	No	No
Frits	13	0	No	No	No
Ballotini	20	34.6	No	No	No

a – confidential

The UK/EU ETS data also includes extremely small CO₂ emissions (<1 tonne) occurring due to use of barium or potassium carbonate by the glass sector, and somewhat larger though still relatively trivial emissions from other process sources. The largest of these is emissions that occur when waste wool at one site is recycled through the process, and it is assumed that the carbon results from oxidation of organic coatings that were applied to the wool as part of the finishing process. The waste is generated during cutting of the wool following the coating process, and it is this waste that is then recycled back to the glass kilns.

4.4.3 Uncertainties and Time Series Consistency

For the years 2008-2024, the methodology is based on the use of highly accurate emissions data reported under the EU and UK ETS for all significant UK glass producers.

The emission estimates for 2006 are based on activity data given in a detailed industry study. These emission estimates should be assumed to be slightly more uncertain than the EU and UK ETS data of 2008-2024 since the source gives carbonate usage figures only, and emissions have to be calculated assuming that these figures refer to pure carbonates and that all carbon in the minerals is released to atmosphere. While the emissions data are therefore conservative, the uncertainty is still considered to be low since fairly pure carbonate minerals are readily available.

For the remaining years in the time-series, the methodology relies upon the extrapolation of highly accurate activity/emissions data for one year to all other years based on glass production. The glass production data are, however, a mixture of actual production data from the glass industry, and Ricardo estimates, which are far more uncertain. The emission estimates for 2A3 are therefore subject to far greater uncertainty for the earlier part of the time-series than for recent years, because of the greater reliance on extrapolation, and the lower quality of the glass production estimates for these years.

4.4.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.4.5 Source Specific Recalculations

Minor recalculations due to model updates, revisions to the ONS activity data and incorporation of the latest British Glass activity data for the container sector.

4.4.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.5 SOURCE CATEGORY 2A4 – OTHER PROCESS USES OF CARBONATES

4.5.1 Source Category Description

The UK has a large number of sites involved in the production of heavy clay goods such as bricks, roofing tiles, and similar items. These sites range from the smallest operations where bricks are hand-made, to bigger sites where bricks are manufactured on a large scale, using automated production methods. The brick industry can also be divided into fletton and non-fletton types. Fletton bricks are manufactured using the Lower Oxford Clay found in South-East England. This clay has an exceptionally high content of carbonaceous material which acts as an additional fuel when the bricks are fired but also produces a characteristic appearance in the finished bricks. Non-fletton bricks are made from other clays and shales and these have much lower carbon contents. For all bricks, firing leads to emissions of CO₂ from the carbonaceous material in the clay. Limestone, dolomite, and barium carbonate can also be used in brickmaking, leading to further releases of CO₂ during firing. Finally, many brick manufacturers add crushed coke ("colourant") to some bricks to change the final appearance of the bricks. Coke oven coke is known to have been used in this manner, and it is assumed that petroleum coke is as well. Colourant is added at rates of up to 15% of the raw material weight. A high proportion of the carbon in the colourant is known not to be oxidised during firing and remains in the brick: for Emissions Trading Scheme (ETS) reporting purposes, all UK brick makers use a figure of 50% oxidation. Although 2A4 explicitly covers use of carbonates, the UK inventory estimates include carbon emissions from the use of colourants in bricks here as well, in the absence of anywhere more appropriate to report them. Also included are emission estimates for the use of clays to produce ceramics other than bricks.

The 2006 GLs draws attention to other sources of CO₂ emissions from use of soda ash and other carbonates. These other uses include Flue Gas Desulphurisation (FGD), magnesia production, and use of soda ash in soaps & detergents, and other applications.

The UK inventory includes CO₂ emissions that occur during the manufacture of soda ash and from the use of soda ash by the glass sector and detailed descriptions of those source categories are provided in **Sections 4.12 & 4.4** respectively. The inventory also includes

emission estimates for the use of soda ash in applications other than glass production, and these emissions are reported in 2A4b. These estimates are based on a review (Passant *et al*, 2019) which found that soda ash is used in the UK for a wide range of applications but that most is used for one of three purposes – manufacture of glass, manufacture of chemicals (including sodium bicarbonate) and manufacture of detergents and soaps. Not all uses of soda ash are likely to result in CO₂ emissions and so this review also considered the potential for emissions. Emissions also occur from the subsequent use of sodium bicarbonate and these emissions are reported in 2A4d.

Limestone was used in FGD systems for abatement of SO₂ emissions at various UK coal-fired power stations and emissions are reported under 2A4. The power stations at Drax and Ratcliffe were the first to get FGD (in 1994), followed by West Burton A in 2004, Eggborough and Cottam in 2005, then Ferrybridge C, Fiddlers Ferry, and Rugeley B in 2008/2009. The Ferrybridge C and Rugeley B stations were both closed during 2016, Eggborough closed in September 2018, Cottam in September 2019, and Fiddlers Ferry in March 2020, while the last coal-fired units at Drax closed in March 2021 (FGD was no longer required for the remaining biomass units). West Burton A closed in March 2023 so the sole remaining coal station with FGD at the end of 2023 was Ratcliffe, which subsequently closed in September 2024. Various small, predominantly waste and/or biomass-fired stations also report CO₂ emissions from limestone scrubbing in the ETS. In all of these processes, limestone reacts with the SO₂ present in flue gases, being converted to gypsum, with CO₂ being evolved. Uskmouth B has a dry lime-injection system, so there is no potential for CO₂ emissions at this site, and in any case this site was mothballed in 2017. Seawater scrubbing systems were used at Aberthaw (closed March 2020), Kilroot (closed September 2023) and Longannet (closed March 2016). However, CO₂ emission estimates are not included in the GHGI for this type of FGD system: there is no estimation method for this process. Some MSW incinerators are believed to use the dry lime injection process to remove SO₂ emissions: as with Uskmouth B, there will be no CO₂ emissions from this type of FGD technology.

Magnesia production in the UK is thought to be limited to a single plant that closed in 2005. This site produced magnesia from seawater, with magnesium salts in the seawater precipitated as magnesium hydroxide, followed by conversion to magnesia in kilns. No process emissions of CO₂ occurred at this site.

4.5.2 Methodological Issues

CO₂ emissions from production of bricks and tiles are based on data reported in the UK and EU ETS. ETS provides site by site emissions, with data in most cases broken down by source (e.g., from clays, fuels, colourants etc.). The ETS data from the producers of bricks and tiles are representative of the sector from 2008 onwards, when all significant manufacturing sites were included in ETS. The ETS dataset is documented and reported at a level of resolution such that the Inventory Agency can readily apportion the emissions data between fuel combustion and non-fuel sources (i.e., process emissions). However, it is more difficult to divide the non-fuel data into sub-types such as emissions from clays, colourants, or 'pure' carbonates like limestone, dolomite, and barium carbonate since some of the information on the source of the CO₂ is presented as aggregated data and not resolved per specific material input to the process. The information presented by UK operators confirms that the emissions from the colourant (coke oven or petroleum coke) are included within the aggregated process emissions, but it is not practicable to obtain a precise figure for the colourant alone.

The ETS data are calculated by each brick and tile producer using site-specific activity data, and industry-wide emission factors, compiled by the industry trade association (British Ceramic Confederation, 2014). These include factors for simple carbonates based on the stoichiometric relationship of carbon to the carbonate, as well as measured emission factors for different types of clay e.g., Keuper Marl, Weald Clay, and Lower Oxford Clay. A high

proportion of the carbon in the colourant is known not to be oxidised during firing and remains in the brick: for ETS reporting purposes, all UK brick makers use a figure of 50% oxidation (British Ceramic Confederation, 2013).

Consultation with the brick industry indicates that the ETS data for 2008-2012 covered 93% of sector production. A single further site joined ETS in 2013, bringing coverage to 95%. The remaining 5% of production is at small sites that are outside the scope of ETS. The ETS emissions data for 2008 onwards are therefore increased using these figures to reflect non-reporting brickworks, assuming that emission rates at non-reporting sites will be the same as on average at reporting sites. With the exception of the large site that joined in 2013, the non-reporting sites over the period since 2008 are much smaller producers and it is not known how representative the industry factors will be for these atypical sites. In the absence of better data, it is assumed that emission rates are the same.

ETS data are incomplete before 2008 and therefore are not used to derive a national total. Instead, annual brick production data are used, available in Government Statistics (Monthly Statistics of Building Materials and Components, August 2025, available from www.gov.uk) to extrapolate back from the ETS data. These data are for total numbers of bricks produced, and it is necessary to consider what proportion of these bricks are of the fletton type, since this type of brick is associated with higher process emissions. Fletton bricks have had a declining share of the UK brick market for many years and are no longer used in the construction of new buildings. Information on the market share is however limited: Ove Arup (1990) puts it at 25%, Blythe (1995) states it is 20%, and by 2011, following the announcement that the last but one fletton brickworks was being closed, local media reports all stated that fletton bricks now accounted for less than 10% of the UK market. The inventory method therefore assumes a 25% share in 1990, falling to 20% in 1995, then falling to 10% by 2010. ETS data for the fletton works suggest production has fallen further since 2010 and so is used to estimate the trend for fletton bricks since 2010. Using these data and assumptions, it is possible to then generate estimates of the numbers of fletton bricks and non-fletton bricks produced each year. For the period from 2015 onwards, it is estimated that, on average, 5% of UK bricks produced were of the fletton type.

A figure of 152 grams CO₂ per non-fletton brick can be calculated from the ETS-based emission estimates for 2008-2013, and then the estimates of non-fletton bricks produced can be used to generate emission estimates for the period 1990-2007 using this emission factor.

In the case of fletton bricks, the PI provides additional data to supplement the information in the ETS for 2008 onwards. Total CO₂ emissions are reported for the Stewartby and Saxon/Kings Dyke sites for each year between 1998 and 2007. The later ETS data at these sites is used to separate the PI data for 1998-2007 into a fuel component and a process component. This gives a time series of process emission estimates back to 1998, and this is further extrapolated back to 1990 on the basis of the estimates of fletton brick production.

Table 4.6 gives a timeline for the brick sector, summarising what is known about the sites operating and the data available for emission estimates over the time series.

Table 4.6 **Timeline for the brick sector in the UK: production sites and data availability**

Years	Number of sites and fuels	Availability of data
1990-1997	8 fletton works operating in 1990; only 5 still in operation by 1993. Those in 1993 burnt coal, or a mixture of coal and natural gas. Unknown number of non-fletton works.	No emissions data available, annual production (numbers) of all bricks available and fletton and non-fletton brick production estimated from this. Emission estimates require use of emission factors generated from later PI and ETS data.

Years	Number of sites and fuels	Availability of data
1998-2007	Two of the 5 fletton works in operation since 1993 close in 1998/1999. Both used only coal as a fuel so by the end of 1999, 3 works remain: Stewartby burns coal, the other two (Saxon/Kings Dyke), both in the same area in England, now burn natural gas only. Approximately 100 non-fletton brickworks in early 2000s.	Annual emissions of CO ₂ and methane available in the Pollution Inventory for each fletton site until 2004, when emissions for the two gas-burning sites, which are located about 1.5 km apart start to be reported as combined totals. Reported emissions have to be split between energy- and process-related emissions. Estimates for non-fletton bricks have to be generated using emission factors from later ETS data Annual production (numbers) of all bricks available: fletton and non-fletton brick production estimated.
2008	Closure of coal-burning fletton works at end of 2008, leaving only the 2 gas-burning works remaining. 63 non-fletton brickworks report in UK/EU ETS in 2008.	Annual emissions of CO ₂ and methane available in the Pollution Inventory for Stewartby, and for Saxon/Kings Dyke. ETS data for the same two fletton brickmaking units, and also for non-fletton brickworks. These data are detailed, allowing fuel-related and process-related emissions to be separated. Emission estimates can be based directly on ETS data.
2009 onwards	Saxon works closed in 2011, leaving only the Kings Dyke fletton brickworks in operation. Many closures of non-fletton brickworks, with 49 reporting in ETS by 2011. In 2013, final large site joins ETS, with total of 46 non-fletton sites then reporting.	Annual emission of CO ₂ and methane available in the Pollution Inventory for the Saxon/Kings Dyke works. ETS data for all significant fletton and non-fletton works for all years except for one site that joins ETS in 2013. Emission estimates can be based directly on ETS data.

Other types of ceramics are manufactured in the UK, including wall and floor tiles, refractories, sanitary ware, household ceramics etc. No suitable national data on the levels of production for these types of ceramic goods have been found. However, the UK Minerals Yearbook (BGS, 2024) gives production, imports, and exports for 4 types of clay (ball clay, china clay, fireclay, other clays & shales), and these data can be used to estimate total UK demand for each type of clay. These figures can then be compared with ETS data for clays used in brick production, and then the difference can be assumed to be clay usage for non-brick manufacture. ETS data only extend back to 2005 but clay usage for bricks in 1990-2004 can be estimated by extrapolating back from 2005 using the brick production data. Significant quantities of clays and shales are used in the manufacture of cement clinker, and emissions from this usage will already be reported in 2A1. BGS reports separate figures for this usage, so clay usage in other ceramics can then be calculated using the following equation:

$$\text{Clay}_{\text{Other ceramics}} = \text{Clay}_{\text{Total}} (\text{from BGS}) - \text{Clay}_{\text{Bricks}} (\text{from ETS}) - \text{Clay}_{\text{Cement}} (\text{from BGS})$$

There are likely to be other, possibly non-emissive uses of clay, for instance some china clay may be used in paper production. But we assume these other uses are either trivial or emissive. The calculations suggest that, on average over the 1990-2024 period, about two thirds of UK clay consumption is used for bricks, and the remaining third is used for the manufacture of other ceramics, cement clinker or other uses. The trends in the total clay and brick clay estimates are fairly similar in the 1990-2014 period, so that this pattern of approximately two thirds bricks to one third other uses is broadly true for all years within that period. But this pattern has changed since 2015, and the total clay figures for 2015, 2018 & 2019 are only slightly higher than the estimates for brick clay, suggesting that hardly any clay was used in those years for other uses. BGS data for clays used for cement confirm that consumption by this sector reduced by about 90% after 2014. It is therefore assumed likely that UK production of other ceramics has declined significantly in the last five years. BGS data

are never available for the latest year in each inventory submission, and therefore we have to assume the same total clay consumption in the latest year as the year prior. The figures for the latest year will be revised in the next submission once BGS data for the year become available.

No emission factors are available specifically for clays used in other ceramics, therefore we apply the emission factors used by brickworks to estimate their emissions in the ETS dataset. Separate factors are available for ball clay and fire clay, whereas emissions from china clay and 'other clays and shales' are estimated using the generic 'other clay' factor also used for ETS reporting by brick producers. A few non-brick ceramic processes do report in ETS and so the emissions data for these sites are used directly.

For non-glass use of soda ash, consultation with the only UK producer of soda ash identified the main uses of soda ash, as shown in **Table 4.7**. This table also notes whether each application has been assumed to be emissive i.e., leading to emissions of CO₂.

The UK emission estimates are based on UK demand estimates supplied by the sole UK producer for soda ash, who estimated consumption in 1990 and 2019 (Tata Chemicals Europe, 2019). Consumption in 1991-2018 was then estimated by the Inventory Agency, with one of three methods being used to estimate consumption in each sector:

- For most sectors, the overall demand for soda ash/sodium bicarbonate was similar in 1990 and 2019, so intervening years were estimated on the basis of a linear change.
- For the chemical sector, a linear change would not be realistic since consumption would have been dominated by a small number of sites, many of which are now closed. Therefore, the processes operating each year were identified, and annual consumption then estimated based on the likely consumption at each site. The overall consumption figures then reflected the closure of key sites and the commissioning of new processes:
 - Closure of the tripolyphosphate works in 1999
 - Closure of the Ultramarine Blue works in 2008
 - Closure of the sodium chromate works in 2009
 - Commissioning of the sodium percarbonate works in 2000 and closure in 2014
- A breakdown of the sodium bicarbonate market is only available for 2019 (for 1990 we have only the total market). Therefore, we have estimated the market split for sodium bicarbonate by extrapolation back from the 2019 figures. However, one of the key markets is flue gas treatment and we consider it unlikely that this market existed until fairly recently. This type of flue gas treatment is likely being used in recently commissioned Energy from Waste (EfW) plants, and since many have been built since 2010, we assume that consumption for flue gas treatment was zero up until 2009.

Figures for 2019 were extrapolated to 2020 onwards assuming no change in demand. We expect that some uses such as detergents might have been affected by the pandemic and demand in sectors could have also increased or decreased for other reasons. However, we believe that any year-on-year changes will be relatively small because of the nature of these uses. Future submissions may be able to incorporate new data if soda ash suppliers can provide this.

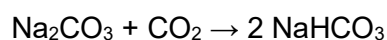
Table 4.7 Non-glass uses of soda ash and sodium bicarbonate

Sector	Uses	% Emissive
Soda ash: chemicals	Used in production of various chemicals or chemical processes:	
	• Sodium tripolyphosphate	100%
	• Sodium chromate	100%
	• Ultramarine Blue	100%
	• Sodium silicates	100%

Sector	Uses	% Emissive
	- Sodium percarbonate - Metal carbonates - Brine purification - Sodium bicarbonate	0% 0% 0% 0% ^a
Soda ash: detergents	Used as a builder to emulsify oil; to reduce the deposit of dirt during cleaning; to provide alkalinity, and to soften laundry water.	0%
Soda ash: other	Fertilizers, production of bentonites, organic and inorganic colourings, enamelling, petroleum industry, fats, glue and gelatin.	50%
Sodium bicarbonate: animal feed	Used in poultry & cattle feeds	0%
Sodium bicarbonate: detergents	Sodium bicarbonate used where a milder detergent is required. Used in hard surface cleaners where its limited water-solubility is advantageous.	0%
Sodium bicarbonate: flue gas treatment	Used for treatment of acidic flue gases.	100%
Sodium bicarbonate: food	Used as a raising agent for a wide range of bakery and confectionery products.	100%
Sodium bicarbonate: miscellaneous	Sodium bicarbonate can be used in foam blowing, soda blasting, explosion suppressants and fire extinguishing.	50%
Sodium bicarbonate: distributors	Sold to distributors (so end use is unknown)	75%

^a Rather than being emissive, conversion of soda ash to sodium bicarbonate requires CO₂ so the process consumes some of the CO₂ generated in the production of soda ash. This consumption of CO₂ to convert from soda ash to sodium bicarbonate is taken into account in the emissions reported in 2B7.

Emissions were then estimated assuming that uses were emissive or non-emissive as shown in **Table 4.7**, based on information from UK industry contacts, except for specific chemical processes, where the stoichiometry of the chemical reactions was used to inform the emission rate. For emissive processes, it is assumed that all of the carbon in the soda ash was converted to CO₂ which was then emitted. An emission factor of 0.41492 ktonne CO₂ / ktonne soda ash consumed was used for emissive applications (Table 2.1, Chapter 2, Volume 3 of the 2006 IPCC Guidelines). In the case of sodium bicarbonate use, the activity data used in the UK inventory are expressed as soda ash converted to bicarbonate. The conversion from soda ash requires reaction with CO₂:



So, it follows that for any emissive uses of sodium bicarbonate, an emission factor of 0.8302 kt CO₂ / kt soda ash is appropriate i.e., double that of soda ash used for other applications. Further detailed discussion of the methodology is included in the report by Passant et al (2019).

Emissions from Flue Gas Desulphurisation (FGD) are either calculated using an emission factor of 69 t carbon/kt gypsum produced or based on UK/EU ETS emissions data. The factor is based on the stoichiometric relationship between gypsum and carbon dioxide formed in the FGD plant. Data on gypsum produced in FGD plant are available from the UK Minerals Yearbook (British Geological Survey, 2016 and earlier versions), but these data are not always consistent with site-specific emissions data available from ETS, and so a composite series of

emissions data is used with BGS activity data, and the emission factor used for 1994-2004, and ETS emissions data for 2005-2024. Four small biomass-fired power stations were no longer in ETS after 2012, and so we have obtained CO₂ emissions data for the scrubbing systems at these sites from the operator. Emissions at these non-ETS sites have averaged about 2% of the total emission in recent years.

Table 4.8 summarises the activity data for different soda ash and sodium bicarbonate applications in the inventory for 1990-2024. The provided activity data correspond to the sectors provided in Table 4.7 and Table 4.9.

Table 4.8 Activity data for different soda ash and sodium bicarbonate applications (ktonnes).

Year	Non Energy Use: chemical feedstock, soda ash	Bread baking, sodium bicarbonate	Flue gas treatment, sodium bicarbonate	Other emissive applications of soda ash	Unknown applications of sodium bicarbonate	Other emissive applications of sodium bicarbonate
1990	170.4	10.8	0.0	59.2	5.7	3.8
1995	179.1	11.2	0.0	59.0	5.9	3.9
2000	146.5	11.6	0.0	58.8	6.1	4.1
2005	146.5	12.0	0.0	58.6	6.3	4.2
2008	146.5	12.2	0.0	58.5	6.5	4.3
2009	109.6	12.3	0.0	58.5	6.5	4.3
2010	78.0	12.4	2.8	58.4	6.6	4.4
2015	67.9	12.8	17.1	58.3	6.8	4.5
2020	67.9	13.1	28.5	58.1	6.9	4.6
2021	67.9	13.1	28.5	58.1	6.9	4.6
2022	67.9	13.1	28.5	58.1	6.9	4.6
2023	67.9	13.1	28.5	58.1	6.9	4.6
2024	67.9	13.1	28.5	58.1	6.9	4.6

Table 4.9 Source of activity data for soda ash and sodium bicarbonate in the inventory per sector.

Inventory source	Sector
Non-Energy Use: chemical feedstock, soda ash	Soda ash: chemicals
Bread baking, sodium bicarbonate	Sodium bicarbonate: food
Flue gas treatment, sodium bicarbonate	Sodium bicarbonate: flue gas treatment
Other emissive applications of soda ash	Soda ash: other
Unknown applications, sodium bicarbonate	Sodium bicarbonate: distributors
Other emissive applications, sodium bicarbonate	Sodium bicarbonate: miscellaneous

4.5.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

In the case of FGD plant there is a change in methodology between 2004 and 2005. However, BGS and UK/EU ETS-based emission estimates for 2005 are very close, and for 2006-2014 are within 6% of each other (with the UK/EU ETS numbers usually higher). No data are available from BGS for 2015-2024 and so no comparison can be made with the UK/EU ETS based figures.

Emission estimates for soda ash are relatively uncertain, for a number of reasons:

- The time-series of estimates rely on estimates for UK demand in 1990 and 2019 only and a linear interpolation is generally used to estimate demand in the years in-between. The UK manufacturer was unable to provide further data, so alternative sources would probably need to be identified in order to refine the time-series.
- No data could be obtained for 2020 onwards, so we assumed the same consumption as in 2019. In reality some uses such as detergents might have been affected by the Covid pandemic and demand in sectors could have also increased or decreased for other reasons, such as population change. However, we believe that any year-on-year changes will be relatively small because of the nature of many of the sectors that use soda ash and sodium bicarbonate, and so assuming no change in usage is unlikely to introduce large errors providing this is only done over a very short period. Future submissions will be able to incorporate new data if soda ash suppliers can provide this, alternatively it will be necessary to obtain alternative data to allow a better long-period timeseries (for example, estimates of consumption of bread and other baked products could be considered as a means to extrapolate forward the estimates for bicarbonate usage by the food industry).
- Estimates are also sensitive to assumptions regarding the operation of certain chemical processes. However, since these plant closed in the years from 1999 to 2014, this uncertainty does not affect the estimates for recent years.
- While it is certain that some uses of soda ash are emissive (e.g., glass and certain chemical processes), for other uses it is less so. Soda ash seems to be used for a wide range of minor applications, including both emissive and non-emissive ones. In the absence of any detailed breakdown of individual uses, we assume 50% emissive.

Estimates for bricks are considered to be highly reliable for the period 2008 onwards where ETS data are available for almost all sites. For earlier years, the emission estimates rely upon extrapolation of the 2008 emissions data using brick production estimates and this will introduce uncertainty within the earlier part of the time series. Emission estimates for methane from fletton brickworks are, similarly, based on reported data in later years and extrapolation using brick production for the early part of the time-series, so the uncertainty will again be greatest in the earlier part of the time series.

Emission estimates for other ceramics are derived using the difference between total UK consumption of clays, and consumption of clays by the brick and cement sectors. Emission factors specifically for other ceramic processes do not exist, therefore we use factors developed by the UK brick industry for the purpose of reporting to ETS. Emission estimates for other ceramics are more uncertain than those for bricks because of this. The figures for 1990-2004 are also more uncertain than later figures, because the estimates for clay usage for brickmaking are more uncertain.

4.5.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.5.5 Source Specific Recalculations

The methodology for extrapolating bricks activity data for 1990-97 has been refined to use an average of several years' reported data instead of only 1998 data. Minor recalculations occurred due to the change in precision of the soda ash default EF, per section 4.5.2. above.

4.5.6 Source Specific Planned Improvements

Emission factors and activity data for bricks, ceramics, soda ash use and FGD will be kept under review. We will continue to seek updated data on soda ash consumption from the manufacturers and suppliers.

One sodium bicarbonate site started using captured CO₂ from combustion as a feedstock for the process in mid-2022, and because of the way in which the ETS data for the site are presented, this can only currently be taken into account in the emissions data reported for 2B7. It is on the improvement programme to consider how best to estimate and report this carbon capture and utilisation process in future.

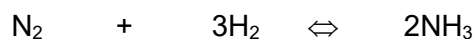
4.6 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION

4.6.1 Source Category Description

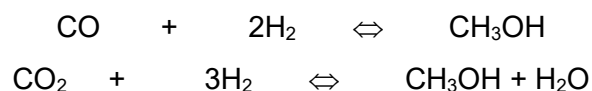
Ammonia is typically produced using the Haber process, which starts with the steam reforming of natural gas to make hydrogen. The simplified reactions are:



The hydrogen is then reacted with nitrogen to form ammonia.



If the by-products CO and CO₂ are not captured and used, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol manufacture for greater efficiency, since the carbon oxides can be used to manufacture methanol:



Over the time period covered by the UK greenhouse gas inventory, ammonia has been manufactured at four locations in the UK. CO₂ emissions are reported from three of those sites: at the remaining site (Hull), the ammonia is produced with hydrogen supplied as a by-product from another chemical process operated on a neighbouring site. At one of the remaining three sites where CO₂ is reported, some carbon from the steam reformer was, until 2001, exported for use in the manufacture of methanol.

At least one ammonia plant sold CO₂ to the food industry and nuclear industry. Because this CO₂ was ultimately emitted to atmosphere, it is included in the emissions reported here. This is considered more reliable than trying to identify carbon emissions at the point of final use since CO₂ will also be emitted from other processes within those sectors, for example from fermentation. Potential applications for exported CO₂ might include (but are not limited to):

- use in carbonating drinks (emitted on consumption of the drinks, which is not reported elsewhere in the inventory);
- use as a cover gas for the brewing industry (emitted during brewing or consumption of drinks, not reported elsewhere in the inventory);

- use as a refrigerant (emitted from leakage during the manufacture, use and disposal of the product, not reported elsewhere in the inventory, although it is modelled as part of wider refrigerant modelling);
- use as a feedstock for other chemical industries (emitted on oxidation of those chemicals, this is accounted for in the case of methanol; we do not currently hold data on the extent to which other chemical processes might use this feedstock); or
- by slaughterhouses to render animals unconscious (emitted during use, and not reported elsewhere in the inventory).

It is also worth noting there is cross-border activity for some CO₂-containing products, such as soft drinks. So, it is expected that some of the CO₂ is emitted outside the UK, and some CO₂ will be emitted in the UK which ultimately derives from by-product CO₂ generated outside the UK. For simplicity, we assume that by-product CO₂ generated in the UK is emitted in UK and that net imports of CO₂ in products are zero.

Methane emissions from the steam reforming processes and the associated ammonia production facilities are reported partly under 2B1 and partly under 2B10, with the latter including methane emissions from other chemical manufacturing sites as well. Nitrous oxide emissions from natural gas combustion are also estimated. UK ammonia manufacturers do not report any emissions of this pollutant and so any additional process emissions are assumed to be negligible or not occurring.

CF Fertilisers UK Ltd permanently closed its Ince manufacturing facility in 2022 and its ammonia plant at the Billingham Complex in 2023. This resulted in significant reduction in production of ammonia from 2023 onwards.

Urea production was occurring in the UK at one site as recently as 1986, but this facility closed soon after. No other urea production facilities have been commissioned in the UK, and throughout the records from UK environment regulation and permitting of production plant (whereby individual plants operate under agreed permits, which in England was implemented from 1993 onwards) there is no mention of urea production in any EPR/PPC permits. The main company that currently manufactures ammonia in the UK has three urea production facilities (one in each of France, Germany and Netherlands) that they use to supply the UK market. Therefore, the Inventory Agency is confident that there has been no production of urea in the UK since 1990, and the UK ammonia production estimates throughout the time series need not take any account of urea production.

4.6.2 Methodological Issues

Ammonia production processes require natural gas both as a feedstock and as a fuel to produce heat required by the steam reforming stage of the ammonia process. The emissions from both feedstock **and** fuel use of natural gas are both reported under 2B1, in line with the requirements of the 2006 Guidelines.

Emissions of CO₂ from both fuel and feedstock use of natural gas are calculated by combining reported data on CO₂ produced, emitted and sold by the various ammonia processes. Where data are not available, they have been calculated from other data such as plant capacity or total natural gas consumption. The ammonia plant utilising hydrogen by-product from chemical manufacture does not need to be included as there are no process emissions of CO₂.

Table 4.10 summarises the details of the UK ammonia plants and **Table 4.11** gives details of production and emissions etc. by the sector.

Table 4.10 Details of UK ammonia plants

Plant	Feedstock	Carbon emissions	Notes
Billingham	Natural gas	Yes	Some production of methanol using by-product carbon until 2001, ammonia production closed in 2023
Sevenside	Natural gas	Yes	Closed in 2007
Ince	Natural gas	Yes	Closed in 2022
Hull	Hydrogen	No	

Table 4.11 UK ammonia production and emission factors

Year	Ammonia production (kt)	CO ₂ emitted (kt)	CO ₂ emission factor, (t / t NH ₃) (all UK production plant)*
1990	1328	1895	1.43
1995	1388	1944	1.40
2000	1213	1886	1.56
2005	1172	1780	1.52
2006	949	1385	1.46
2007	1251	1865	1.49
2008	1082	1683	1.56
2009	889	1296	1.46
2010	1084	1488	1.37
2011	687	1043	1.52
2012	1017	1574	1.55
2013	957	1386	1.45
2014	987	1482	1.50
2015	1022	1602	1.57
2016	959	1442	1.50
2017	1129	1764	1.56
2018	876	1339	1.53
2019	960	1548	1.61
2020	1038	1645	1.58
2021	771	1179	1.53
2022	371	697	1.88
2023-2024 ⁺	-	-	-

*As reported within the CRT table 2(I).A-Gs1

⁺ Majority of ammonia production facilities were closed by 2023. Therefore, no data is provided here.

CRT table 2(I).A-Gs1 presents the ammonia production data for all UK sites (including Hull where there are no CO₂ emissions).

Due to the limited market for ammonia production in the UK, to present detailed technology-specific data on production and emissions would be disclosive. Full details of the installation-specific production, fuel use and emissions will be provided upon request to a UNFCCC Expert

Review Team. The data in the table above summarises the estimated overall UK production of ammonia (which is partly based on operator data and partly on Inventory Agency estimates based on plant capacity), total estimated 2B1 CO₂ emissions and ammonia IEF on a production basis, as presented in the CRT.

The operator of the Ince and Billingham UK ammonia plants has provided information on reasons underlying the year-on-year variation in emission factors. Firstly, plants are typically shut down for routine maintenance every two years, and start-up and shut-down procedures increase the emission factors overall. Secondly, plant production rates are varied by the operator during times of high gas prices or low demand, which reduce efficiency and increase emission factors. In addition to these operational variables, each plant will have a different intrinsic efficiency, which will in part reflect the age of the plant and the technology used.

The IPCC 2006 Guidelines suggests a Tier 1 default emission factor of 1.694 tonnes CO₂ / tonne NH₃ for a 'modern' European plant, but a higher Tier 1 default of 2.104 tonnes CO₂ / tonne NH₃ for a 'typical' plant i.e. based on a mix of modern and old plant. The overall UK IEF presented in the table above are below the IPCC default, but this is due to the production at the UK plant where there are no CO₂ emissions; Aggregate UK factors for the three sites with CO₂ emissions show an average of 1.51 tonnes CO₂ / tonne NH₃ for production across the whole 1990-2023 time-series, and averages for individual years would mainly be within the range suggested by the two IPCC defaults, the exceptions being 1990-1993 & 1998 when the factors were marginally below 1.694 tonnes CO₂ / tonne NH₃, and 2002 when the emission factor was slightly higher than 2.1 tonnes CO₂ / tonne NH₃. *[Note that fully detailed data are not presented in the table above due to commercial confidentiality, but full details are available to an ERT.]* All of the UK plants have been in operation since before 1990; the fact that the average UK factor lies between the 2006 IPCC Guideline defaults for modern plant and mixed modern/old plant indicates that the performance of the UK ammonia plants is broadly typical of European ammonia production facilities.

Methane and nitrous oxide emissions from natural gas burnt at ammonia plant to produce heat are estimated by applying IPCC default factors for industrial combustion of natural gas (1 kg methane / TJ & 0.1 kg N₂O / TJ), and these emissions are reported in 2B1. It is assumed that there are additional emissions of methane from the ammonia process itself, for example from fugitive leaks. Therefore, in the UK inventory, methane emissions from ammonia production also include estimates provided from plant operator reports to the UK regulators; these emissions are reported, together with process emissions from other chemical sites, in 2B10a. These operator-reported emissions may include estimates of methane from fuel combustion and hence there is potential for a small double-count in emissions reported across 2B1 and 2B10a. Because it is not at all certain that the methane reported by the operator would include methane from fuel combustion, we have retained the estimates in both 2B1 and 2B10a on the basis that a potential double-count is preferable to a potential gap, particularly since we believe that the latter is more likely were we to remove one of the estimates.

4.6.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type. The uncertainty associated with this source is low, since the carbon content of natural gas is well known and plant specific data are received from the operators annually.

A consistent time series of activity data has been reported from the manufacturers of ammonia, and this results in good time series consistency of emissions.

4.6.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4** and the source emissions data from plant operators is subject to the QA/QC procedures of the Environment Agency's Pollution Inventory.

4.6.5 Source Specific Recalculations

There have been no significant recalculations to this category.

4.6.6 Source Specific Planned Improvements

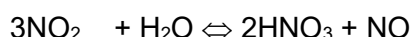
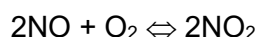
Emission factors and activity data will be kept under review.

4.7 SOURCE CATEGORY 2B2 – NITRIC ACID PRODUCTION

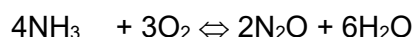
4.7.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B2: Nitric Acid Production	T3, T2	CS
Gases Reported	N ₂ O, NO _x		
Key Categories	2B2: Nitric acid production - N ₂ O (T1)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7 .		
Major improvements since last submission	No major improvements to the data and methods. Further information on the abatement technology applied at UK installations has been added below.		

Nitric acid is produced by the catalytic oxidation of ammonia:



Nitrous oxide is also formed by oxidation of ammonia:



Nitrous oxide is emitted from the process, as well as a small percentage of the NO_x that cannot be recovered for conversion into nitric acid. At the end of 2021, nitric acid was being manufactured at 2 UK sites with a total of 4 production plants. One of these sites were closed in 2022 with the three remaining lines at the other site being still operational at the end of 2024. The closed nitric acid production plant had NO_x/N₂O abatement fitted to all units since commissioning (pre-1990), whilst at the other UK production site, all three production lines have had nitrous oxide abatement retrospectively fitted during 2011 Quarter 1. This has led to

a notable reduction in the UK IEF for nitrous oxide emissions from nitric acid production in the UK between 2010 and 2011 (see **Table 4.13** below).

4.7.2 Methodological Issues

Across the 1990-2024 time-series the availability of emissions and production data for UK nitric acid plant is inconsistent, and so a range of methodologies have had to be used to provide estimates and derive emission factors. Where possible, emission estimates are based on site-specific data provided by process operators. Site-specific production estimates are largely based on production capacity reported directly by the plant operators. This approach may overestimate actual production. No data are available for three sites operating between 1990 and 1993, and production at these sites is calculated based on the difference between estimates of total production and the sum of production at the other sites.

Emission estimates for N₂O are derived for each nitric acid site using one of the following:

- Emissions data provided by the process operators directly or via the Pollution Inventory (1998 onwards for plant in England, 2001 onwards for plant in N Ireland);
- Site-specific emission factors derived from reported emissions data for the same site for another year (1990-1997 for some plant in England, 1994-1997 for other plant in England, 1990-2000 for plant in N Ireland); and
- A default emission factor of 7 kt N₂O /Mt 100% acid produced in cases where no emissions data are available for the site (some sites in England, Scotland, 1990-1993). This default factor is the default factor provided in the 2006 IPCC Guidelines (IPCC, 2006) for medium pressure plant.

Table 4.12 gives a summary of the approaches used across the time series to estimate production and N₂O emissions for the UK inventory and the methods used by operators to derive the emissions data they report to regulators and the inventory team. The emissions monitoring at the two sites still in operation was originally based on periodic (at least quarterly, if not more frequent) sampling, but from 2010 onwards has been continuous, using on-line infra-red monitoring systems. The continuous monitors at both sites are certified to MCERTS, installed and maintained to EN14181, and subject to UK ETS Permit. MCERTS (Monitoring Certification Scheme) was set up by the Environment Agency to ensure good quality environmental measurements. The scheme is based on international standards and provides for the product certification of instruments, the competency certification of personnel and the accreditation of laboratories. The European Standard EN14181 covers quality assurance for automated measuring systems. The details of monitoring at the closed sites are not known, but it is assumed to have been the same as the sites that remain in operation i.e. periodic prior to 2010. The closed sites were shut before the fitting of continuous monitoring devices was required for UK/EU ETS reporting purposes. The N₂O monitoring systems at the remaining sites comply with the requirements of UK/EU ETS reporting, and are subject to low uncertainty (5-10%). Therefore, the emissions data reported by operators are associated with low uncertainty, and are representative of the technology and abatement in the UK installations.

Table 4.12 Methods used to estimate emissions from this category (figures are numbers of sites)

Period	Estimated production data	Operator reported production data	Reported by operator Based on emission factors	Reported by operator Based on monitoring	Inventory Agency Estimate using Site-specific EF	Inventory Agency Estimate using IPCC EF
1990-1993	7	1			5	3
1994	5	1			6	

Period	Estimated production data	Operator reported production data	Reported by operator Based on emission factors	Reported by operator Based on monitoring	Inventory Agency Estimate using Site-specific EF	Inventory Agency Estimate using IPCC EF
1995-1997	4	2			6	
1998-1999		6	4	1	1	
2000	1	5	4	1	1	
2001		5	3	1	1	
2002-2004		4	3	1		
2005		4	2	2		
2006-2007		4	1	3		
2008		4	2 ^a	2		
2009-2022		2	-	2		
2023-2024		1	-	1		

^a One site closed at end of January 2008 which submitted emissions data for that month based on emission factors having used monitoring to quantify emissions the previous year.

Table 4.13 Summary of Nitric Acid Production in the UK, 1990-2024

Year	Number of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N ₂ O / Mt Acid)
1990	8	2.41	5.38
1995	6	2.40	3.82
2000	6	2.03	6.94
2005	4	1.71	3.80
2006	4	1.47	3.87
2007	4	1.61	3.54
2008	4	1.29	3.89
2009	2	0.93	3.89
2010	2	1.21	3.51
2011	2	1.08	0.616
2012	2	1.13	0.108
2013	2	1.01	0.142
2014	2	1.10	0.124
2015	2	1.13	0.087
2016	2	1.17	0.071
2017	2	1.22	0.103
2018	2	1.08	0.077
2019	2	1.19	0.108
2020	2	1.14	0.145
2021	2	0.90	0.117
2022	2	0.66	0.108
2023-2024	1	-	-

The larger of the two remaining UK plants fitted control equipment to reduce N₂O emissions in early 2011, and this has decreased NO_x emissions from that plant as well, leading to the large decreases in the aggregate EFs for both pollutants in 2011 compared with the previous year. A large increase in N₂O emissions between 1998 and 1999 resulted from a change in the NO_x abatement system at one plant from NSCR to SCR. NSCR reduces emissions of N₂O as well as NO_x, whereas SCR only abates NO_x and can actually increase N₂O emissions.

Since 2011 all of the UK nitric acid production facilities are fitted with EnviNO_x SCR abatement (Alexander, 2019) which includes heating of the tail gases from the production vessels,

followed by NO_x and N₂O destruction in a catalyst bed using ammonia gas and hydrocarbon inputs to mitigate the NO_x and N₂O. The technology is described in a reference document (Groves and Sasonow, 2010)⁷⁵. The UK installations apply the technology in process variant 2 design, which achieves N₂O mitigation performance of around 99.5%, and this is the reason for the very low IEF of the UK nitric acid production sector since 2011. The N₂O emissions from all UK plant are monitored (since 2009 for all plant) using Continuous Emission Monitoring systems, and the annual operator submissions to the Environment Agency (the environmental regulatory agency for both UK nitric acid facilities) are subject to quality checks by the Site Inspectors to validate that the annual data reported to the PI and used in the UK GHGI are accurate.

4.7.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Emissions from nitric acid production are estimated based on a combination of emission factors and reported emissions data. The methodology used to estimate N₂O for this sector does vary through the time-series depending upon the availability of data. The calculated N₂O EF for UK nitric acid production facilities vary quite significantly across the time series, which is a reflection of nitric acid production patterns across UK sites that utilise different process conditions. Successive closures have changed the average N₂O EF, as plants with generally above-average emission rates cease production. Abatement of N₂O using catalytic decomposition technology at the remaining UK production plants has also played a part in reducing the UK emission factors over time. The changes in EF may also partially reflect the lack of availability of a consistent time-series of emissions data. Emission estimates for recent years have been based partially (1998-2008) or wholly (2009-2024) on continuous monitoring, and therefore will be subject to low uncertainty. The monitoring systems used at the two sites are subject to an uncertainty of 5-10%. Earlier estimates relied on site-specific or IPCC default factors and so are more uncertain.

The nitric acid plant emissions data reported by operators since 1998 are considered to be complete and accurate, since they are subject to internal QA/QC checks by the plant operators and the Environment Agency before being reported in the Pollution Inventory.

4.7.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.7.5 Source Specific Recalculations

There have been no significant recalculations to this category.

4.7.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

⁷⁵ <https://doi.org/10.1080/19438151003621334> See Figure 3 for the process variant 2 design, as applied in UK installations, and Figure 5 for information on the N₂O abatement performance of the technology.

4.8 SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION

4.8.1 Source Category Description

Adipic acid is manufactured in a multi-stage process from cyclohexane via oxidation with nitric acid. Nitrous oxide is produced as a breakdown product from the nitric acid.

4.8.2 Methodological issues

There was only one company manufacturing adipic acid in the UK, but this closed in early 2009. Production data are not provided in the NID because of commercial confidentiality.

Production data and emission estimates have been provided by the process operator (Invista, 2010). The emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated. In 1998 an N₂O abatement system was fitted to the plant. The abatement system was a thermal oxidation unit and was reported by the operators to be 99.99% efficient at N₂O destruction. The abatement unit was not available 100% of the time, and typically achieved 90-95% availability during adipic acid production.

A small nitric acid plant was associated with the adipic acid plant, and both the adipic and nitric acid plants emitted NO_x. From 1994 until the plant's closure in 2009, the NO_x emission from the nitric acid production is reported under 2B2, but prior to 1994 it is included under adipic acid production because separate emissions data for the different processes on that site were not available for those years. Therefore, the N₂O emissions from nitric acid production and adipic acid production were reported together for 1990 – 1994 under category 2B3 (adipic acid production). This discrepancy in reporting will cause a variation in the reported effective emission factor for these years for 2B2 and 2B3 but overall emission estimates are not affected.

4.8.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Emissions data for N₂O from adipic acid production are provided by the process operator, but can be cross-checked against emissions reported in the Pollution Inventory. The level of uncertainty associated with reported emissions is not known, but the data are considered to be reliable as they are subject to QA/QC checks by the operator, and the related Pollution Inventory data are also checked by the regulator. A higher uncertainty is assumed for 1990 than for later years. Emissions no longer occur from this source since the plant has closed.

Fluctuations in the N₂O EF from this plant are apparent since the installation of the abatement plant. Following direct consultation with the plant operators, it has been determined that the variability of emissions is due to the varying level of availability of the abatement plant. A small change in the availability of the abatement system can have a very significant impact upon overall plant emissions and hence upon the annual IEF calculated.

4.8.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**. During summer 2005, consultation between Defra, AEA, plant operators and the UK Meteorological Office was conducted to discuss factors affecting emissions from the adipic acid plant, including: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic

fluctuations in reported emissions. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

4.8.5 Source Specific Recalculations

There have been no significant recalculations in this category.

4.8.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.9 SOURCE CATEGORY 2B4 – CAPROLACTAM, GLYOXAL AND GLYOXYLIC ACID PRODUCTION

Caprolactam was made at one site in the UK in the early 1970s. The site was destroyed in a serious explosion in 1974, and no other production sites have been built since. Glyoxal and glyoxylic acid have not been produced on an industrial scale in the UK at any time. A literature search of documents from the last 25 years on chemical production in Europe as well as consultation with the Chemical Industries Association has confirmed that these sources should be reported as not occurring.

4.10 SOURCE CATEGORY 2B5 – CARBIDE PRODUCTION

This source category includes silicon carbide and calcium carbide. Neither chemical is known to have been manufactured on an industrial scale in the UK since the 1960s, when calcium carbide plants at Kenfig and Runcorn closed. As above for 2B4, literature searches and consultations with UK chemical industry representatives have confirmed that this source should be reported as not occurring in the UK.

4.11 SOURCE CATEGORY 2B6 – TITANIUM DIOXIDE PRODUCTION

4.11.1 Source Category Description

Titanium dioxide has been produced in the UK by two methods: i) from ilmenite, using the sulphate process; and ii) from rutile, using the chloride process. Only the chloride process leads to process emissions of greenhouse gases. In 1990, there were two sites each using the chloride and the sulphate process, but the two sulphate processes closed in 1997 and 2009, so all titanium dioxide in the UK is now produced using the chloride process at the two sites at Stallingborough and Greatham. The chloride process involves the chlorination of rutile ore in a reducing atmosphere to produce titanium tetrachloride (TiCl_4), followed by oxidation of the TiCl_4 to titanium dioxide. The reducing atmosphere is produced by combustion of petroleum coke or coke oven coke.

4.11.2 Methodological Issues

The 2006 GLs recommend the use of either a Tier 1 method involving a default emission factor and national activity data, or a Tier 2 method using installation-specific data on reducing agent usage. For the UK, neither of these methods are feasible options due to limited data; there are no UK activity data (i.e. annual production statistics) for any individual chemical product, and the only site-specific data for the UK plant is in the form of CO_2 emissions data. These

emissions data are available from two regulatory reporting sources, however the scope of reporting has varied over the years:

- From the PI, a single figure covering CO₂ from reducing agents and fuel use in plant utilities. However, for three years (2006-2008), the process operators were required to report thermal CO₂ and chemical CO₂ separately, so the latter could be assumed to cover emissions from coke use only;
- From the ETS, detailed data covering fuel use for energy production in site boilers during phase II (2008-2012), extended to cover fuels burnt in furnaces, driers etc. as well as use of reducing agents (coke) for phase III (2013 onwards).

From these data it is possible to obtain the emissions from the chemical process for some years: 2006-2008 (using the PI data for chemical CO₂ emissions), and 2013 onwards (from the detailed ETS data). The fuel/process split in emissions for these years can be calculated, and the PI provides total CO₂ emissions at each site back to 1998. Prior to 1998, there is no data on either emissions or production, and therefore it is assumed that emissions in 1990-1997 are at the same level as in later years (the production capacity at all UK sites producing TiO₂ by the chloride route is the same for all years).

In order to avoid a potential double-count in emissions in the UK GHGI, it is necessary to ensure that the reductant used in the processes is not included as a fuel and emissions reported in 1.A. The method adopted by the inventory team addresses this issue by back-calculating the coke oven coke/petroleum coke used as a reductant from the emissions data using UK carbon emission factors for the feedstock, and discounting this amount from the Energy sector estimates.

4.11.3 Uncertainties and Time Series Consistency

The country-specific method used is regarded as the best available method for the UK, given the lack of any production activity data. The use of site-specific EU/UK ETS and PI data, even if not relating to input materials as required by the Tier 2 method in the GLs, ensures that emissions data are quite certain for the period from 1998 onwards. Estimates for 1990-1997 are more uncertain due to the need to extrapolate 1998 data backwards in the absence of any specific information on production, materials usage or emissions in those years.

4.11.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.11.5 Source Specific Recalculations

There have been no significant recalculations in this category.

4.11.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.12 SOURCE CATEGORY 2B7 – SODA ASH PRODUCTION

4.12.1 Source Category Description

Soda ash has been produced in the UK using the Solvay process at two sites operating since the start of the time period covered by the inventory. The Solvay process involves the conversion of limestone (calcium carbonate) and brine (sodium chloride) to soda ash (sodium carbonate) and calcium chloride. The initial stage in the process is the calcination of limestone

in a kiln to produce lime and CO₂ gas, both of which are used in the process. Coke oven coke is used to fire the lime kilns and CO₂ from the coke is included in the gases used in the soda ash plant. In theory, if limestone and brine are converted completely to soda ash and calcium chloride, then that part of the soda ash process is carbon-neutral and the CO₂ emitted should be equal just to those emissions occurring from the coke. In practice, the process is not 100% efficient so emissions of CO₂ are actually higher than would just be due to the coke use. Soda ash production at one of the two UK sites (Winnington) ceased in February 2014, although the site is still being used to make sodium bicarbonate from sodium carbonate solution & CO₂, which we assume is sourced from the neighbouring Lostock plant. The sodium bicarbonate process will consume CO₂ some of which is subsequently emitted since some uses of sodium bicarbonate are emissive. However, these emissions from sodium bicarbonate usage are reported elsewhere. UK/EU ETS data suggest that the sodium bicarbonate process does emit some CO₂ – presumably unreacted CO₂ that passes through the process and, since this CO₂ probably originates with the soda ash process at Lostock, it is included in the emission estimates for 2B7.

Emissions from soda ash (sodium carbonate, Na₂CO₃) used in the manufacture of soda-lime glasses is reported under source category 2A3 and emissions from other uses of soda ash and sodium bicarbonate are reported in 1B2d and 2A4d.

4.12.2 Methodological Issues

The 2006 GLs suggest that emissions should be based "on an overall balance of CO₂ around the whole chemical process". In the UK, soda ash has been produced at two sites and both began to report under the UK/EU ETS in 2013, although one is now closed. The UK/EU ETS emissions data for the two sites is calculated using a carbon balance approach with inputs in coke and limestone balanced against soda ash and waste products. The 2013-2021 EU and UK ETS data therefore meets the requirements for the method suggested in the GLs.

Prior to 2013, no data for the UK plant were reported in UK/EU ETS, but CO₂ emissions have been reported in the PI from 1998 onwards. Comparison of the PI and UK/EU ETS data for 2013-2020 shows that UK/EU ETS data were 34% higher than emissions in the PI in 2013 and, on average, 60% higher in the years from 2014-2020. The reason for this is not known, but since the PI data for 1998-2013 are fairly consistent, it is assumed that there is a systematic underestimate in the PI data across the entire time-series (possibly the PI data represent CO₂ releases from just part of the process, rather than the whole-process balance used in the UK/EU ETS). We have assumed that the level of underestimation in 1998-2012 is at the same level as in 2013 and we have therefore used the PI data for 1998-2012 but multiplied by a factor of 1.34 to give estimates of emissions in those years. The difference in 2014-2020 was consistently higher and so a more conservative approach would be to use a factor based on data for all years after 2013 (1.65). However, the Winnington plant was closed in early 2014 and so the years from 2014 onwards are atypical compared with the 1990-2013 period of full operation of both processes. For 1990-1997, no data of any type are available, but since the same two sites have been in operation in the UK across the entire time-series, emissions in 1990-1997 are assumed to be at the same level as in later years.

A Carbon Capture & Utilisation (CCU) system has been installed at a CHP plant in Winnington sodium bicarbonate production facility. The steam and power produced from the plant are used onsite or by other industrial businesses in the area, whilst the captured CO₂ from the combustion process is used onsite for the production of Sodium Bicarbonate (CHP case study, Winnington CHP with CCU Technology). The inventory uses the submissions of the facility to the ETS to account for the carbon emissions from the site, and accounts for the capture against the process emission (i.e. emissions are not deducted from the combustion emissions allocated to 1A2c, instead they are deducted from 2B7).

4.12.3 Uncertainties and Time Series Consistency

The method used is regarded as the best available given the lack of any production activity data, or a time-series of coke consumption. The use of site-specific EU and UK ETS data for 2013-2022 should ensure that the emission estimates for those years are quite certain and this would avoid any double counting with regards to the utilisation of the CO₂ generated as part of the Solvay process. The poor agreement between the PI and UK/EU ETS data in 2013-2020 means that the emission estimates for 1998-2012, based on PI data, are far more uncertain. The difference between UK/EU ETS and PI data is even greater (in percentage terms) in 2014-2020 than in 2013, however both sites only operated fully throughout 2013, Winnington having closed in February 2014. We have therefore treated the 2013 UK/EU ETS/PI ratio of 1.34 (based on both plants operating throughout the year) as a more reliable guide to the potential underestimation in the PI data in earlier years. Estimates for 1990-1997 are more uncertain still due to the need to extrapolate 1998 data backwards in the absence of any specific information on production, materials usage or emissions in those years. The accounting for CCU against the process emission has a significant impact on the implied emission factor for recent years.

4.12.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.12.5 Source Specific Recalculations

No recalculations have been made to emissions from this category.

4.12.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.13 SOURCE CATEGORY 2B8 – PETROCHEMICAL AND CARBON BLACK PRODUCTION

4.13.1 Source Category Description

This category includes emissions from the following sources: 2B8a Methanol, 2B8b Ethylene, 2B8c Ethylene Dichloride, 2B8d Ethylene Oxide, 2B8e Acrylonitrile, 2B8f Carbon Black and 2B8g Other. The UK has a large petrochemical industry, with manufacture of all the chemicals explicitly mentioned in the 2006 IPCC Guidelines for at least part of the period 1990-2024, although a series of site closures in recent years has reduced the number of products manufactured.

Methanol was manufactured in the UK until 2001 in a process which was integrated with ammonia production. Ethylene was produced at five sites in 1990, although the closure of the two works in 1993 and 2010 reduced this to three at the end of 2021. The UK ethylene crackers use either naphtha or natural gas liquids as feedstocks, and off-gases from the ethylene crackers are used as fuels on-site. Ethylene dichloride (EDC) has been produced at 4 sites over the period covered by the GHGI, although only 1 is still in operation, and only 2 of those processes used the oxychlorination route that causes process emissions of CO₂. Ethylene oxide (EO) was produced at a single UK plant between 1990 and closure in January 2010. There is also a single site producing acrylonitrile (ACN): this has operated since 1990 and is still in operation. Two sites produced carbon black, until their closure at the very start, and in the middle of 2009 respectively. Most of the production was of furnace black.

A number of other chemical sites also emit CO₂ due to the use of off-gases as fuels. Emissions of CO₂ at these sites are very small relative to the emissions from ethylene production. All emissions of CO₂ from use of off-gases as fuels is reported under 2B8g, including the emissions from ethylene production.

Many chemical processes emit small quantities of methane, either as a result of fugitive releases from equipment, or as a component of tail gases released from vents. The inventory includes separate emissions data for production of ethylene, methanol, ACN, EO, and carbon black. Emissions of methane from other chemical processes are reported under 2B10.

4.13.2 Methodological Issues

Details of the methodologies used for petrochemical and related processes are shown in **Table 4.14**.

Table 4.14 Methodologies for petrochemical and related processes

Chemical product	CO ₂ reported in	CH ₄ reported in	Methodology
Ethylene	2B8g	2B8a	Site specific emissions data from UK/EU ETS (CO ₂ only), PI and from process operators. Where no emissions data are available, these are estimated by extrapolation from data available for later years, taking into account changes in plant capacity.
Methanol	2B8b	2B8b	See below for CO ₂ methodology. Emission estimates for methane are based on operator-reported data from the PI.
Ethylene Dichloride	2B8c	-	Emissions estimated using IPCC Tier 1 emission factor for process CO ₂ assuming production is 500,000 tonnes per year ^a .
Ethylene Oxide	2B8d	2B8d	CO ₂ emission estimates for 1995-2009 from the PI. The PI did not exist prior to 1995 and hence the Inventory Agency has explored options to derive GHG estimates back to the base year. A study was conducted post the 2019 in country review, to assess all available IPCC good practice methods for gap-filling to 1990 for this source. The outcome of that process determined that the least uncertain approach was to use the plant capacity data as a proxy dataset to extrapolate from 1995 to 1990, and this approach is used in the UK submission. CH ₄ estimates for 2004-2009 are from the PI. No emissions data are available for 1990-2003, so the Tier 1 IPCC default is used, combined with estimates of EO production at the plant derived from the CO ₂ emitted, and assuming a CO ₂ emission factor of 0.663 t CO ₂ / t EO (IPCC default for oxygen process, default catalyst sensitivity).
Acrylonitrile	2B8g	2B8e	CO ₂ emission estimates for 2008-2021 from UK/EU ETS. No data on emissions for earlier years, but the capacity of the plant is thought to have been unchanged since 1990, so the average emission for the 5-year period 2008-2012 is used for 1990-2007. The operator reports methane emissions to be below the 10-tonne threshold for reporting in the PI, so an emission of 5 tonnes/annum is assumed.

Chemical product	CO ₂ reported in	CH ₄ reported in	Methodology
Carbon black	2B8f	2B8f	CO ₂ emissions are reported in the PI for 1998-2009 for one site, and 2003-2008 for the other (this site closed at the start of 2009, so emissions in 2009 are assumed zero). The PI emissions are assumed to be from process sources, and emissions in earlier years are assumed to be the same as in the earliest year for which data exist. Emission estimates for methane are also based on PI data for later years, but no data are available for the period 1990-2003, and so the IPCC Tier 1 default is used instead.
Other petrochemicals	2B8gii	2B10b	Emissions data for other petrochemical processes are taken from UK/EU ETS (CO ₂ only), and the PI (English/Welsh sites) or SPRI (Scottish sites). For those years where operator-reported emissions data are not available, then emissions are assumed to be the same as for later years where data are available. There are no petrochemical processes located in Northern Ireland which would emit GHGs

a – production is not known but capacity of two plant in 1987 was 500,000 tonnes and one subsequently closed so 500,000 tonnes is considered a conservative estimate.

Methanol production, like ammonia, requires hydrocarbon fuels both as a source of raw materials and as a fuel. The UK methanol process used natural gas. Whereas in ammonia processes, natural gas is reformed to produce hydrogen for the process and carbon dioxide as a waste by-product, in the methanol process reforming of natural gas generates carbon dioxide for the process with hydrogen as the waste product. The UK's only methanol plant was integrated with one of the ammonia plants, so that carbon dioxide produced by the ammonia plant could be exported and used to synthesise methanol. This CO₂, and additional CO₂ produced in the methanol plant's own reforming process is assumed stored. The plant closed in 2001 and there is limited information on emissions and none at all on natural gas consumption at the plant. The nominal capacity of the plant was 500 ktonnes but analysis of European production data for the 1997-2001 period indicate that the UK plant production fell sharply between 1997 and 1998 as new capacity came on stream elsewhere in Europe, and the plant was closed as uneconomic in 2001. For the period 1990-1996, it has been assumed that the UK plant was running at 98% of capacity, as in 1997. The various estimates of production have then been combined with the IPCC Tier 1 emission factor for methanol using conventional steam reforming of natural gas with integrated ammonia plant (1.02 t CO₂ / t methanol) to give the emission reported in 2B8b. The production estimates are also used to calculate the CO₂ stored, and finally, both emitted CO₂ and stored CO₂ are also converted into estimates of natural gas consumed so that we can ensure there is no double-counting of that natural gas either in 2B1 or in 1A2c. **Table 4.15** summarises the data for methanol production.

Table 4.15 Estimates for methanol production (all kt)

Year	Estimated methanol production	CO ₂ emitted	CO ₂ stored
1990	488	498	671
1995	488	498	671
1996	488	498	671
1997	488	498	671
1998	232	237	319
1999	215	219	295
2000	257	262	353
2001	130	133	179
2002 onwards	0	0	0

The methodology for CO₂ emissions from 2B8g was developed through an inventory improvement research project in 2013-14 (Ricardo-AEA, 2014b), with a review conducted of available data on industrial use of process off-gases and waste residues as fuels, including consultation with operators of several of the installations that were known to use process off-gases as a fuel. The research included a review of data within the UK/EU ETS. In addition, installation-specific (but anonymised) data from the chemical industry Climate Change Agreement (CCA) data reported for 2008 and 2010 were also reviewed. CCA data was used primarily to quality check the number of sites in the chemicals sector that reported the use of waste-derived fuels, and this dataset confirmed that there were a very small number of sites reporting waste-derived fuel use. It is not possible with the current data available to distinguish between feedstock-derived off-gases that are used directly as a fuel and those used in other process-related activities that result in emissions, such as flaring, and therefore the total emissions reported for those sites are allocated to 2B8g.

4.13.3 Uncertainties and Time Series Consistency

For the use of waste residues and process off-gases as fuel in the chemical industry, the emissions estimates are somewhat uncertain as the level of completeness of the data over the whole time-series is hard to verify; the 2014 inventory improvement study, however, has confirmed that the inventory covers all high-emitting sites in the UK that have been in operation in recent years, and therefore the overall uncertainty on the UK inventory estimates, at least for the period covered by UK/EU ETS data, is not regarded as significant. Energy and environmental experts within the UK trade association for the chemical sector, the Chemical Industries Association, also confirmed that they were not aware of any other sites in the UK that used process off-gases, over and above the sites included in the UK GHGI (Personal communication, Chemical Industries Association, 2014). These are dominated by the four ethylene production sites and a handful of other sites producing organic chemicals, typically co-located with refineries.

Emission estimates for other sources are mostly based on a mixture of PI and/or UK/EU ETS data with estimates for earlier years then based on the assumption that emissions are as in later years. Tier 1 IPCC default emission factors are used for the minor sources 2B8c (for CO₂), 2B8d and 2B8f (both CH₄, part of time-series only). No UK-wide activity data (production data) are available with which to generate a better time series for any of the sub-sectors within 2B8, so the earlier part of the time-series for all of the chemical industry sectors is particularly uncertain. UK/EU ETS-based emissions are considered the most reliable basis for estimates in the GHGI and the uncertainty is estimated to be +/- 5%. PI data are more uncertain, because it is not clear what methods are used and the emission sources (combustion, process, other) are not transparent. Uncertainty for GHGI estimates based on the PI data is estimated to be +/- 15%. Emissions data for methane are likely to be more uncertain than those for CO₂ since the former are often fugitive in nature, or minor components in stack emissions (thus requiring stack monitoring to quantify).

4.13.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.13.5 Source Specific Recalculations

A review of fuel use allocations within the UK ETS data was conducted in 2025, which led to revision to the assessment of fuel type used at two petrochemical installations. Previously the "fuel gas" had been assessed as being natural gas, purchased by the operator from the gas supply grid, which is therefore already accounted for within UK energy statistics and reported under 1A2c Chemical Industry fuel combustion; however, for some lines of the ETS data it was apparent that the "fuel gas" was in fact derived from the (NEU) feedstock, and hence

should be added to the UK inventory as a process off-gas ("other petroleum gases") within the petrochemical sector, i.e. 2B8g. This revision has led to a ~10% increase in reported CO₂ emissions from the sector in 2023.

Emission estimates for acrylonitrile have been revised, as the UK production plant last reported GHG emissions under UK ETS during 2021 and has since ceased production; emission estimates previously estimated for 2022 and 2023 have therefore been removed from the UK inventory. In addition, the closure date for another UK chemical plant has been revised and the emissions removed from the 2023 estimates onwards for chemical sector process emissions.

4.13.6 Source Specific Planned Improvements

It is noted that this sector has been identified as a key category, and that not all of the estimates within this sector use a tier 2 or higher approach. The UK has recently reviewed this sector and included some additional sources using what is believed to be the best currently available data. The UK will review this position should further information come to light.

4.14 SOURCE CATEGORY 2B9 – FLUOROCHEMICAL PRODUCTION

4.14.1 Source Category Description

Emissions arise from the UK manufacture of HFCs, PFCs and HCFC-22. HFC-23 is a by-product of HCFC-22 manufacture. There are two single manufacturers of HFCs and PFCs respectively in the UK, and two companies were operating HCFC-22 plants. Both HCFC plants closed in 2008/9; one reopened in 2013 and was shut down again in 2016. HFC production ended in 2016.

There is one site in the UK manufacturing fluoropolymers (such as polytetrafluoroethylene) which has been in operation since 2007. This site reports emissions of HFC-23, HFC-32, and HFC-125.

There is no UK production of SF₆.

4.14.2 Methodological Issues

A full description of the emission model and associated methodology used for this sector is contained in AEA (2008). Within the model, manufacturing emissions from UK production of HFCs, PFCs and HFC-23 (by-product of HCFC-22 manufacture) are estimated from reported data from the respective manufacturers. Manufacturers have reported both production and emissions data, but only for certain years, and for a different range of years for different manufacturers. Therefore, the emissions model is based on implied emission factors, and production estimates are used to calculate emissions in those years for which reported data are not available. Two of the three manufacturers were members of the EU Emissions Trading Scheme. As a requirement of participation in the scheme, their reported emissions were verified annually via external and independent auditors. For PFC production, emissions are now reported to the Environment Agency (EA) Pollution Inventory (Environment Agency, 2025), and these emissions are directly used within the GHG inventory. The operator of the HFC and HCFC-22 plant provided speciated emissions data directly to the Inventory Agency, based on vent analysis and flowmeter readings, or on weighbridge differences. The other HCFC-22 plant, which closed in 2008, also reported to the Pollution Inventory and these emissions were used within the GHG inventory.

Emissions from the fluoropolymer manufacturing site are estimated using figures reported by the operator to the Pollution Inventory. These figures provide a total HFC emission value which

is disaggregated into HFC-23, HFC-32, and HFC-125 using emissions monitoring reports for the site provided by the EA for 2020-2024 (EA, 2025b). Therefore, the disaggregation for other years is based on the weighted average proportions of these HFCs from the years where we have these data. This site also reports PFC emissions; however, documents obtained from the Environment Agency indicate that these emissions are specifically Tetrafluoroethylene (C_2F_4), and Hexafluoropropylene (C_3F_6), both of which are short-lived gases with low GWPs (<1), and are not included in the list of substances to report under the UNFCCC, so these have not been included in the GHGI.

4.14.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2**, provides estimates of uncertainty according to CRT source category and fuel type. The uncertainty estimate for emissions from HFC manufacture has been revised for this submission, based on information from the plant operator.

There is a significant decrease in HFC emissions in 1998/1999. This step-change in emissions is due to the installation of thermal oxidiser pollution abatement equipment at one of the UK manufacturing sites. Fugitive HFC emissions from both an HCFC-22 plant and HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxidiser at the second of the UK's HCFC-22 manufacturing sites. This was installed in late 2003, and became fully operational in 2004. HFC-23 emissions decreased in 2009 and 2010 following the closure of both HCFC-22 manufacturing sites. A small emission of HFC-23 is also reported from the production of HFC-125 until 2013, most likely due to impurities in the feedstock. HCFC-22 manufacture restarted in 2013 and was shut down in 2016.

A significant increase in PFC emissions from the production of halocarbons is observed from 1992 to 1996 (with the trend changing after 1996). The increase in emissions was due to increasing production levels at the single UK manufacturing plant during this period. Since 1996, the level of emissions has changed each year which broadly reflects the demand (and hence production levels) for PFCs. In 2004 and 2005, emissions reported by the company increased compared with the preceding 3 years of fairly stable emission levels 2001-2003. Emissions declined sharply in 2007-2009, before increasing again in 2010 and 2011 and then declining again.

4.14.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**, and details of verification of emissions are given in **Annex 6**. Data reported via the Pollution Inventory are also further checked by the Environment Agency.

4.14.5 Source Specific Recalculations

Emissions from fluoropolymer production was included for the first time in the 2026 submission. This was identified as part of a review of Pollution Inventory reporting of F-gas emissions that only identified this site as being omitted from existing GHGI estimates.

4.14.6 Source Specific Planned Improvements

We are continuing to engage with the Environment agency regarding the fluoropolymer site to better understand emissions reported by the site. In particular, we are seeking to confirm if any other higher-GWP PFCs are being emitted from the site.

4.15 SOURCE CATEGORY 2B10 – OTHER

4.15.1 Source Category Description

The UK has a large chemical manufacturing sector and emissions of methane are reported elsewhere in 2B for emissions from specific chemical processes, but also reported in 2B10 in the case of emissions from other, general petrochemical processes. Methane emissions from ammonia production sites are included in 2B10, rather than being reported separately in 2B1.

4.15.2 Methodological Issues

Site-specific emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2025) and Welsh Emission Inventory (NRW, 2025) respectively. Reporting generally started in 1994 or 1995, and few data exist for the years prior to 1994. Site specific emissions data for processes in Scotland have been obtained from the Scottish Pollutant Release Inventory (SEPA, 2025), with data for 2002 and then 2004 onwards.

All of the data available are in the form of emission estimates generated by the process operators and based on measurements or calculated based on process chemistry. Emission factors and activity data are not available, but emission factors are estimated using the best available 'surrogate' activity data that are available across the time series; this approach then enables estimates of emissions to be made for the years prior to operator-reported emission estimates (typically pre-1994). For most commodities, the extrapolation is linked to changes in the level of output from the chemicals manufacturing sector as measured by the 'index of output' figures published by the Office for National Statistics (2025).

4.15.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Estimates for 1994 onwards are mostly based on data reported by process operators through the regulatory agency data management and checking systems that govern UK industrial emissions data within the PI, WEI, SPRI and NIPI. The dataset is evidently incomplete in some years, due to the variations through time in the reporting thresholds for different pollutants. The Inventory Agency has used good practice techniques to address these reporting inconsistencies, and therefore the completeness of the data is good through the time series.

Unfortunately, UK production data are not readily available for chemicals and other products from the sites reported under 2B8. This inhibits the Inventory Agency's ability to conduct data validation tests on the reported emissions data against a reliable time-series of production estimates. Emission estimates for the period prior to 1994 are also more uncertain due to the need for extrapolation of emissions data for 1994 or some other year backwards, using general indicators of chemical industry output.

4.15.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC by the Environment Agency before being used in the inventory.

4.15.5 Source Specific Recalculations

There have been no significant recalculations in this category.

4.15.6 Source Specific Planned Improvements

Minor revisions to emission estimates may be required periodically in order to deal with changes in the data available e.g. revisions to emissions reported to UK regulators. The Inventory Agency will continue to review the available operator-reported data and seek to derive a consistent time series of emissions.

4.16 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

4.16.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C1: Sinter plant – coke	T1, T2	CS
	Iron & steel flaring (BFG)	T1, T2	D, CS
	Electric arc furnaces	T1, T2	CR, CS
	Ladle arc furnaces	T2	CS
	Sinter plant – limestone	T2	CS
	Sinter plant - dolomite	T2	CS
	Basic oxygen furnaces - dolomite	T2	CS
	Following for precursor gases only:		
	Blast furnaces	T2	CS
	Basic oxygen furnaces	T2	CS
	Iron and Steel (other)	T2	CS
	Rolling Mills (Hot & Cold Rolling)	T2	CS

Iron and steel production may be divided into integrated (oxygen) steelworks, electric arc steelworks, downstream processes such as continuous casting, and iron & steel foundries.

Integrated or oxygen steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. For the purposes of the inventory, emissions from integrated steelworks are estimated for these three processes, as well as other minor processes such as slag processing.

Sintering agglomerates the raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter.

Blast furnaces are used to reduce the iron oxides in ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron. Gas leaving the top of the furnace has a high heat value because of the residual CO content and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. The most significant greenhouse gas emissions to occur directly from the blast furnace process are the combustion gases from the 'hot stoves' used to heat the blast air. These generally use blast furnace gas (BFG), together with coke oven gas and/or natural gas as fuels. Emissions are reported in CRT category 2C1. Gases emitted from the top of the blast furnace are collected and emissions occur when this blast furnace gas (BFG) is subsequently used as fuel.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the

metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel (basic oxygen furnace gas – BOFG – although in UK energy statistics and the UK inventory these gases are reported combined with BFG). As with blast furnace gases, some losses occur and these losses are reported with blast furnace gas losses in 2C1.

Limestone and dolomite are used in steelmaking, typically being added to sinter where they are calcined, releasing CO₂ which is emitted. Some of the limestone or dolomite used may be added directly to blast furnaces without being sintered first, which would mean that the CO₂ released would be emitted from the blast furnace stage of steelmaking rather than the sintering stage. However, this distinction is not important for GHG reporting and the practice is ignored for the GHGI with all additions and, therefore, emissions being reported as from sintering. Dolomite is also an important addition as a fluxing agent in basic oxygen furnaces and CO₂ evolved from the dolomite is reported as a separate category under 2C1.

Electric arc furnaces produce steel from ferrous scrap using electricity to generate the high temperatures necessary to melt the scrap. Carbon dioxide emissions occur due to the breakdown of the graphite electrodes used in the furnace.

The UK had one integrated steelworks (Scunthorpe) in operation at the end of 2024, following the closure of the Teesside works in September 2015 and the closure of the heavy end operations of the Port Talbot Steelworks in mid-2024, including the closure of its coke ovens, sinter plant, blast furnaces and basic oxygen furnace steelmaking. In 1990, five sites had been in operation, with the steelworks at Ravenscraig in Scotland closing in 1992, followed by the closure of Llanwern in Wales in 2001. Teesside was mothballed between January 2010 and April 2012 due to the loss in demand for its steel products. Electric steel is manufactured in 4 large steelworks, in Rotherham, Sheffield (2 sites), and Tremorfa. Other large electric arc steelworks once operated in Sheerness, and Newport.

4.16.2 Methodological Issues

The methodology for estimating CO₂ emissions from fuel combustion, fuel transformation, and related processes at integrated steelworks is based on a detailed carbon balance (this methodology is described in more detail within the section on CRT sector 1A2a). Carbon emissions from integrated steelworks are reported under 1A1c, 1B1b, 1A2a, 2A3 and 2C1, depending upon the emission source. Emissions from sintering (from use of both coke breeze and limestone & dolomite), flaring of blast furnace gas and basic oxygen furnace gas, use of dolomite in oxygen furnaces, and from arc furnaces are all reported under 2C1.

Flared losses of blast furnace gas (including basic oxygen furnace gas) are given in DUKES and carbon factors are derived using the carbon balance described previously.

The carbon balance method (described in Method Statement 4) is used for all years from 1990 to 2021. However, due to the closure of UK coke ovens at Scunthorpe in 2016 and 2023, and those at Port Talbot in early 2024, the balance was no longer able to accurately model the carbon balance in UK steelworks. Essentially it was using UK data to model processes that were now partially taking place outside the UK i.e. the production of coke that was imported following the closure of UK coke ovens at each site). The result was CEFs for coke breeze, coke oven gas, blast furnace gas and basic oxygen furnace gas for years 2022-2024 that were unrealistic and significantly different from those of the historical trends and IPCC default factors. Therefore, the emission factors for these fuels derived from the carbon balance for 2021 were used also for 2022-2024.

It is worth noting that checks between the UK inventory estimates derived from the carbon balance and emissions data from EU/UK ETS indicate that the carbon balance method produces results that are slightly conservative (for instance, being on average 4.6% higher than ETS over the 2017-2021 period). The use of the 2021 carbon balance emission factors

for 2022-2024 continues this trend of the UK inventory being conservative, although the average difference is slightly higher (7.4%).

Usage of limestone and dolomite for steel production is available from the Iron & Steel Statistics Bureau (2025). The carbon content of limestone and dolomite used at steelworks is available from operators via the UK/EU ETS data. Separate values are available for the years 2007-2024. These data show close consistency across the time series and therefore the 2007 value has been extrapolated back to 1990.

The carbon emissions from electric arc furnaces cover electrode emissions, as well as CO₂ emissions from the addition of scrap metal, alloys, carbonate minerals and other additives. The methodology also takes account of carbon stored in by-products, such as steel, slag, scales etc., produced during the steelmaking process.

Electric arc furnace operators including Liberty Steel and Marcegaglia (operating a site previously operated by Outokumpu) have provided additional information regarding the fuels used, process inputs (e.g. other carbon sources, reductants, electrodes, wastes, slags, carbonates) that underpin the carbon emissions data for their electric arc furnaces as reported via the UK/EU ETS.

[A UK GHG Inventory research paper was drafted in 2021 to summarise research in the sector and describe the development of the inventory methodology; that report (Passant and Gorji, 2021) is commercial in confidence but can be shared with an Expert Review Team on request.]

The comparison between the operators and UK/EU ETS data allows for calculation of a more detailed timeseries of emission factors for those individual sites. Further analysis was then required for the purpose of gap-filling for the periods where no or limited data were available due to the changes in the reporting procedures in different UK/EU ETS phases.

There are a number of electric arc furnace plants that have been closed over the years, and therefore further gap-filling exercise was required to estimate emissions from such plants. Based on the revision of the operations of such plants, the emission factors obtained from the first phase of the currently operational plants were deemed suitable for estimating their emissions. This method therefore allowed to account for emissions from the plants that have stopped production over the timeseries.

The Inventory Agency has developed a time series consistent method by applying IPCC good practice methods to address data gaps, as follows:

- Identification of (22) EAF sites operating in the UK across the time series; this includes several EAFs that operated only prior to the start of the EU ETS in 2005 and for which there are very scarce data on activity and emissions;
- Analysis of the ISSB production statistics on EAF steel production since 1990, including annual UK-wide statistics and also regional production data;
- Analysis of the Regulator Inventory data, to identify all available emissions data, including for smaller EAF sites that are evidently omitted from the ISSB statistics;
- Use of UK/EU ETS emissions data and ISSB regional production data to derive a time series of IEFs for production for the larger (8) EAF sites that report within UK/EU ETS;
- Development of a hybrid approach to apply operator emissions data per installation where available and to gap-fill for the remaining UK production using the IEF across the sector from the UK/EU ETS reporting, with the 2005 data back-cast to earlier years.

Emissions from the use of coke oven coke in foundries and other iron & steel industry processes are included in category 1A2a but any other process emissions from foundries of direct GHGs are likely to be very small and are not estimated. **Table 4.16** summarises the methods used for emissions reported under 2C1.

Table 4.16 Summary of Emission Estimation Methods for Source Categories in CRT Category 2C1

Source Category	Method	Activity Data	Emission Factors
Sintering – coke breeze	AD x EF	DESNZ energy statistics	<u>Carbon</u> : UK-specific factor from carbon balance <u>CH₄</u> : UK-specific based on reported emissions <u>N₂O</u> : Fynes & Sage (1994)
Sintering – carbonates	AD x EF	ISSB	<u>Carbon</u> : UK-specific from UK/EU ETS
Iron & steel - flaring	AD x EF	DESNZ energy statistics	<u>Carbon</u> : UK-specific factor from carbon balance <u>CH₄</u> , <u>N₂O</u> : IPCC (2006)
Electric arc furnaces	AD x EF	ISSB	<u>Carbon</u> : UK-specific factor <u>CH₄</u> , <u>N₂O</u> : EMEP/EEA
Ladle arc furnaces	AD x EF	ISSB	<u>Carbon</u> : UK-specific factors

4.16.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Much of the activity data used to estimate emissions from this source category come from the Iron and Steel Statistics Bureau and from DUKES. Time-series consistency of these activity data is very good due to the continuity in data in these publications.

Due to the closure of UK coke ovens, carbon balance emission factors for 2021 are now used for 2022-2024 as well (discussed in MS4). This does mean higher uncertainty in these years but the cross-check against UK ETS data suggests that emissions are only marginally more conservative than in the preceding five-year period.

4.16.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

The UK inventory carbon balance method uses the best available industry data across the time series, including UK/EU ETS data from integrated steelworks from 2005 onwards. The comparison in recent years between the UK GHGI method and the UK/EU ETS data for individual installations indicates that the GHGI method is somewhat conservative, as the GHGI data are generally slightly higher than installation data. The Inventory Agency will continue to keep the method and input data under review to ensure that the carbon balance model delivers estimates that are as accurate as possible for the UK.

4.16.5 Source Specific Recalculations

Due to a methodology update to further utilise the ETS data, a more complete timeseries of operator data has been developed. The result of this is an increase in total emissions across the timeseries, specifically an increase of 18kt in 1990 and an increase of 8kt in 2019. For further information on recalculations, see **Section 10**.

4.16.6 Source Specific planned Improvements

It is noted that this sector has been identified as a key category, and that not all of the estimates within this sector use a tier 2 or higher approach. The UK uses what is believed to be the best currently available data, and that tier 1 methods are only used for very limited parts of this sector. The UK will review this position should further information come to light. Emission factors and activity data will be kept under review. Where appropriate, fuel characterisation data from verified EU/UK ETS datasets will be considered in future GHGI cycles.

4.17 SOURCE CATEGORY 2C2 – FERROALLOYS PRODUCTION

The term ferroalloy covers a wide range of products, manufactured by various means, only some of which lead to industrial process emissions of greenhouse gases. Potential sources of CO₂ emissions include:

- Use of reductants such as coke oven coke;
- Consumption of carbon electrodes in furnaces used for melting raw materials;
- Decarbonisation of limestone or dolomite used as a fluxing agents;
- Decarbonisation of any other carbonate ores used.

The UK has been a minor producer of ferroalloys. The previous version of the BREF note (Best Available Techniques Reference document) for the non-ferrous metals industry, produced by the European IPPC Bureau⁷⁶ estimated UK production in 1993 as 55 ktonnes out of a European total production of 2,620 ktonnes while the updated version of that document, published in 2017, does not identify any production of ferroalloys at all in the UK in the period 2005-2012.

Other than the estimate for 1993 given in the BREF note, the Inventory Agency has not found any data on UK production of ferroalloys. The absence of the UK as a European producer in the recent update of the BREF note suggests that UK production is either zero or insignificant; through consultation with trade associations and industry statistics experts (ISSB) the Inventory Agency has only been able to identify a few small-scale manufacturers of specialist ferroalloys such as ferro-molybdenum and ferro-vanadium. The production data for 1993 lists 45,000 tonnes of ferromanganese production in a blast furnace (where emissions would arise from use of reductants), and 10,000 tonnes of other ferroalloys in electric furnaces. The ferroalloy producers identified as in operation in recent years either carry out exothermic processes only (for ferro-molybdenum alloys) or use electric induction furnaces for melting. None of the processes report any CO₂ emissions in the Pollution Inventory, or are included in the UK/EU ETS; the Inventory Agency has not identified any process currently in operation that would cause any industrial process emissions of direct GHGs. The estimated production of 45,000 tonnes of ferromanganese in 1993 would use coke oven coke or coal as a reductant, and therefore the emissions are already included in the inventory as all UK consumption of these fuels is assumed to lead to emissions of CO₂. Any emissions associated with ferroalloy production would therefore already be included in 1A2a or 1A2b for coal, or 1A2g or 2C6 for coke oven coke. Given the lack of a time-series of production data, or information on the type or quantities of any reductant used in the ferromanganese production, the Inventory Agency has not made any re-allocation of emissions from 1A or 2C6 to 2C2.

There is no evidence of any current use of electric arc furnaces, or the use of limestone or dolomite fluxes or carbonate ores. Therefore, UK emissions from ferroalloys are i) **Included**

⁷⁶ downloadable from <http://eippcb.jrc.ec.europa.eu/reference/>

Elsewhere in the case of any emissions from use of reductants; ii) **Not Occurring** in the case of emissions from other sources.

4.18 SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION

4.18.1 Source Category Description

Aluminium was produced by the electrolytic reduction of alumina at two UK sites at the end of 2011, although the larger of these two sites subsequently closed in early 2012, leaving just one small smelter operating in the UK. A third site had closed during 2009, and a fourth closed in mid-2000. The operational site and the recently closed processes all use or used the pre-baked anode process, whereas the plant closed in 2000 used the Soderberg Cell process. This distinction is important because of large differences in emission rates for some pollutants.

Both process types make use of carbon anodes and these anodes are consumed as the process proceeds, resulting in emissions of CO₂. The PFC species tetrafluoromethane (CF₄) and hexafluoroethane (C₂F₆) are formed if the alumina content of the electrolyte falls too low. Computerised control of alumina addition to the cells is a feature of modern plant and has helped to reduce PFC emissions from aluminium production. Emissions of methane are not estimated as there is no methodology available and emissions are considered to be negligible.

The smelter design has a large effect on the rate of PFC emissions, and point feeder prebake technology is regarded as the best option for feeding aluminium oxide into the electrolytic cells, allowing addition at controlled intervals, resulting in fewer anode effects. Over the time series, the UK operators of aluminium smelters have invested to improve plant performance, and all sites were converted to point feeder technology, leading to large reductions in PFC emissions per unit production as a result.

4.18.2 Methodological Issues

Emissions of carbon are estimated using statistics on the production of aluminium by each type of process and suitable emission factors. The carbon emission factors reflect current practice, and higher emission factors were used for earlier years, due to the production of some aluminium using the Soderberg process.

All emissions of PFCs (CF₄ and C₂F₆) occur during the aluminium smelting process during anode effects. The UK inventory data are directly reported by plant operators and are emission estimates calculated from the number and duration of anode effects at each facility.

Operators use (or used) a Tier 2 methodology of a smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients. This method uses (or used) default factors for the CWPB (Centre Worked Prebaked) plant for three of the plants and default factors for VSS (Vertical Stud Soderberg) for the plant which closed in 2000. One of the operators used the North West American Calculation assuming 3lbs PFC for every minute the cell was “on anode effect”, for the early part of the time series. The time series does not show any discontinuity as a result of the change in method.

The UK total primary aluminium production activity data are taken from the UK Minerals Yearbook (British Geological Survey, 2024) in years where complete data on production from operators are not available, 1990-2004 and 2006. In all other years of the time series, we have both the BGS data and also a complete set of operator production estimates. The two datasets are very closely consistent. The BGS data are presented rounded to 2 significant figures, and due to this lack of precision but close consistency, the UK inventory method uses the sum of all operator-reported data for 2005 and for 2007 onwards, as these are regarded as the most accurate data to use in each year.

Methodologies used for direct gases from 2C3 are summarised in **Table 4.17**.

Table 4.17 Emission Estimation Methods for Primary Aluminium Production, CRT Category 2C3

Source Category, Gas	Method	Activity Data	Emission Factors
Primary aluminium, CO ₂	AD x EF	UK Minerals Yearbook (British Geological Survey, 2024); Σ operator production data (latest from Alvalance British Aluminium, 2024)	Technology-specific default EFs for Soderberg and pre-bake processes
Primary aluminium, PFCs	Σ operator emissions data		Derived from operator reported emissions data, based on IPCC T2 method

The time series of emission factors and activity data used are reported in **Table 4.18** below. Note that the PFC EFs presented here are essentially back-calculated IEFs for the UK industry, derived from the reported production data and sum of operator-reported emissions.

Table 4.18 Activity Data and Emission Factors: UK Aluminium Production 1990-2024

Year	Activity Data (Mt Aluminium Produced)	Carbon Emission Factor (kt/Mt)	CF ₄ Emission Factor (kt/Mt)	C ₂ F ₆ Emission Factor (kt/Mt)
1990	0.290	423.8	0.601	0.075
1995	0.238	423.2	0.158	0.019
2000	0.305	420.0	0.110	0.014
2005	0.370	420.0	0.035	0.004
2010	0.186	420.0	0.079	0.010
2015	0.048	420.0	0.027	0.003
2020	0.036	420.0	0.014	0.002
2021	0.038	420.0	0.014	0.002
2022	0.031	420.0	0.011	0.001
2023	0.029	420.0	0.012	0.001
2024	0.030	420.0	0.007	0.001

4.18.2.1 Aluminium alloy production

No emissions of SF₆ are reported by any of the aluminium foundries in the Pollution Inventory or SPRI. Emissions from the use of SF₆ in the UK aluminium sector are therefore reported as Not Occurring.

4.18.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Activity data on UK aluminium production since 2006 is available from both the British Geological Survey (BGS) UK Minerals Yearbook, as well as directly from operators, with the latter data set presented at a greater level of precision. The two datasets show very close consistency over time, with small % differences year to year, which is at least partly due to the

rounding in the BGS data. The BGS data are from a long running publication, and the compilers of the activity data strive to use consistent methods to produce the activity data; there are also only a small number of UK producers, and complete reporting of their production, direct to the Inventory Agency, has occurred for over a decade.

Similarly, the methods used by operators to estimate emissions are specific to the technology of their plant, and for PFCs are consistent with the IPCC Tier 2 method across the time series.

The consistent access to good quality data from the UK industry therefore helps to ensure good time series consistency of the emission estimates across all years, despite the switch to use (more precise) operator activity data from 2007 onwards.

There was a large decline in emissions in 2012 as aluminium smelting activities came to an end in March 2012 at one of the largest UK production plants at Lynemouth. In 2010, 2011 and 2014 there was a significant increase in the implied emission factor for PFCs because of process issues during those years, for example an 'anode crisis' in 2014. In June 2024 the remaining aluminium plant upgraded the process control system, which improves the process optimisation, reducing the frequency and duration of cell anode effects and therefore PFC emission rates.

4.18.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC from the Inventory Agency.

4.18.5 Source Specific Recalculations

There have been no significant recalculations for this sector.

4.18.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.19 SOURCE CATEGORY 2C4 – MAGNESIUM PRODUCTION

4.19.1 Source Category Description

In the UK, SF₆ and an HFC act as cover gases to prevent molten magnesium from burning during the production of magnesium.

4.19.2 Methodological Issues

Sulphur hexafluoride is used as a cover gas to prevent magnesium oxidising when exposed to air, because it is non-flammable and heavier than air. SF₆ is non-flammable and non-toxic and is therefore a safe gas to use. In the UK, SF₆ has been used as an alternative cover gas to SO₂ in magnesium alloy production and sand and die-casting since the early 1990s. Since 2006, EU magnesium producers have looked for alternatives to SF₆ in response to bans in the EU F-gas Regulation 2008 (EC 842/2006). These bans were maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006. Some die casters have gone back to using SO₂. Others have used HFC-134a and a fluoro-ketone (FK 5-1-12) with the trade name Novec 1230.

⁷⁷ As part of the process of leaving the EU, EU F gas legislation, including EC 517/2014, was assimilated into UK law with technical amendments made to ensure the legislation functions properly as UK domestic law.

The UK magnesium casting industry is very small. There are three significant manufacturers (one alloy producer, one die-caster and one sand-caster) plus two very small operations (both sand-casters). Alloy production involves the use of primary magnesium ingots, recycled scrap material and second-generation magnesium materials (i.e. material already made into alloys) for the production of different alloys. Both die and sand casters use these magnesium alloys to produce specific components for a wide range of industries. For the casting industry, SF₆ is used for casting specific magnesium alloys where other cover gases, such as HFC-134a, are currently considered not suitable.

The F-gas Regulation 2014⁷⁷ prohibits the use of SF₆ in magnesium die casting. From 1 Jan 2018, the ban is extended to installations using a quantity below 850kg per year. Note that, as mentioned below, most UK magnesium production uses processes other than die casting, so this ban only has a limited impact on this sector.

A review of the data sources and methodology used to estimate emissions from F-gases used as cover gases in magnesium foundries was carried out in 2013 (Gluckman, 2013). In all cases UK magnesium companies were able to report consumption but had no actual measured data on emissions. The assumptions about the fraction of SF₆ and HFCs that are emitted from the consumption of these F-gases were reviewed through discussion with industry experts and in some cases amended. It is estimated that 95% of SF₆ consumption is emitted but that only 20% of HFC-134a consumption is emitted (as a much greater proportion reacts with the magnesium). These figures are based on expert estimates by Gluckman (2013).

For magnesium alloy production from the largest UK site, SF₆ emissions from 1998 onwards are estimated based on the data reported to the Pollution Inventory (Environment Agency, 2025), whilst emissions prior to 1998 and for smaller sites are estimated based on consultations with the plant operators.

From 2004, one of the main industry users of SF₆ as a cover gas has implemented a cover gas system using HFC-134a for some of its production capacity. There has been no use of SF₆ by this company since 2022. In addition to having a significantly lower GWP than SF₆ (and thus reducing emissions on a CO₂ equivalent basis), use of HFC-134a is further advantageous in that a significant fraction of it is destroyed by the high process temperatures (80%) thus reducing the fraction of gas emitted as a fugitive emission.

From 2008, emissions of HFCs have been reported in the Pollution Inventory (Environment Agency, 2025), and therefore the reported data are used directly.

As part of a study to update the F-gas inventory (Gluckman, 2013), castings operators were re-contacted to provide activity data for recent years (the previous survey was conducted in 2004). The two largest users of SF₆ and HFC-134a (that represent 99% of UK emissions from magnesium) are now contacted annually for their activity data (consumption of SF₆ and HFC-134a).

Emissions of FK 5-1-12 cannot currently be reported via the CRT as there is no space to report this product, it would also be a low priority to include as it is a sparingly used product with a GWP comparable to CO₂. It is estimated that the decomposition of 1 tonne of FK 5-1-12 during use as a cover gas generates ~400 tonnes CO₂e of PFCs, but as this product is used only at 1 small magnesium site and trialled at one larger site, total emissions in the UK due to the decomposition of FK 5-1-12 have been estimated to be less than 0.001% of the UK national total since 2012 and 0 beforehand. According to the UNFCCC Guidance for reporting, emissions could be "... considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions and does not exceed 500 kt CO₂ eq.". Therefore, the UK considers this a low priority to formally estimate and report emissions for. This source is included in the Assessment of completeness in **Section 1.7**.

As far as we know, HFC-134a does not decompose into other potent GHGs; any other products potentially emitted would be offset by our conservative estimate of the proportion of HFC-134a emitted.

4.19.3 Uncertainties and Time Series Consistency

The main area of uncertainty is regarding emissions of SF₆ from casting based on discussions with the sector Trade Association for the period prior to 1998. Data from the main magnesium alloy producer is also uncertain for this period.

For the period 1998-2023, the uncertainty of the time-series emissions is estimated to be significantly lower. Data received from the main magnesium alloy producer and the other 4 casting operations are associated with low uncertainty and show good consistency across the time series.

4.19.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC from the Inventory Agency.

4.19.5 Source Specific Recalculations

No significant recalculations have been made to estimates for this sector for the 2026 submission.

For information on the magnitude of recalculations to this Source Category, see **Section 10**.

4.19.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.20 SOURCE CATEGORY 2C5 – LEAD PRODUCTION

Lead production in the UK consists of one primary lead production site (now closed) and a small number of secondary lead sites. The primary lead site produced zinc, lead and other metals from imported ore concentrates and closed in 2003. This site produced more zinc than lead, and because it is not possible to split emissions between 2C5 and 2C6 (other than on an arbitrary basis), emissions for this site are reported under 2C6. Further details on this process are given in the following section. The UK also has a number of secondary lead processes, all of which involve the recovery of lead either from automotive batteries or from clean scrap. Emissions of CO₂ could, in theory, occur from the use of reductants such as coal, coke oven coke, or natural gas during secondary lead processes, however none of these secondary lead processes are known to involve the use of reductants, and therefore we do not believe that there are any process emissions of CO₂ from any of the UK's secondary lead processes. If any use of reductant did occur, it would be included in UK fuel statistics as an energy use, and thus emissions of CO₂ would in any case be included in the UK inventory, but reported under 1A2.

4.21 SOURCE CATEGORY 2C6 – ZINC PRODUCTION

4.21.1 Source Category Description

Zinc was produced in the UK until early 2003, using the Imperial Smelting Process (ISP) at a smelter operated by Britannia Zinc at Avonmouth. The site processed imported ore

concentrates and had a capacity to produce approximately 150,000 tonnes of zinc, as well as 65,000 tonnes of lead and small quantities of other metals such as cadmium. The ISP involves the use of a blast furnace to reduce zinc and lead oxides to the metal using coke as a reductant. Limestone could also be added to act as a slag-forming agent.

The UK also had two other non-ferrous metal production facilities that would have emitted CO₂ from processes. These were:

- the Capper Pass Tin Smelter at Melton, Humberside (closed in 1991)
- IMI Refiners' secondary copper smelter at Walsall (closed in 1997)

There is very little data specific to these installations available to the Inventory Agency as their closure pre-dates most of the routine annual emissions reporting regulations in the UK. Both processes used coke oven coke as a reductant that would have led to process emissions of CO₂, and since we only have data on the total use of coke oven coke in non-ferrous metal production in UK energy statistics (DESNZ, 2025a), we report all emissions from use of this coke oven coke in 2C6. Therefore, the emissions reported in 2C6 will also include emissions from these two sites, as well as emissions related to the production of lead at the Britannia Zinc site.

4.21.2 Methodological Issues

Britannia Zinc reported CO₂ emissions in the Pollution Inventory (Environment Agency, 2018) from 1998 until 2002, at which point the site ceased operation. Emissions of CO₂ occurred from the use of coke in the ISP, but also from decarbonisation of any limestone used, and from the other fuels used on site e.g. gas/oil burners used on the sinter plant and oil-fired furnaces used in the zinc refinery. No data are available on the quantities of coke and other fuels used, or the quantities of limestone that might have been used. The operator-reported CO₂ emissions in the Pollution Inventory are totals only, and do not provide any insight regarding the split of emissions source between coke, other fuels and limestone. The reported emissions are, however, much higher than would be implied by the Tier 1 factors given in the 2006 GLs for the ISP. There is insufficient data to determine whether this is due to a high level of fuel combustion emissions on site, or that the process-related emissions at this site were higher than is typical for this type of process.

The Digest of UK Energy Statistics (DESNZ, 2025a), 'DUKES', does give a full time-series of data on the consumption of coke oven coke by the non-ferrous metal industry. The consumption shown in this source is zero after 2003, confirming that after the closure of Britannia Zinc, no other non-ferrous metal processes in the UK used coke oven coke. Based on all available information, the Inventory Agency considers that no sites, other than Britannia Zinc, Capper Pass and IMI Refiners have used coke oven coke at any point in the period covered by the UK inventory.

Because all three sites have been closed for many years, there is no information on the consumption of coke oven coke at each site. Of the three, it is likely that IMI Refiners used relatively small amounts of coke, whereas the Capper Pass smelter was the largest of its kind in the world, and its closure in 1991 coincides with a big reduction in the non-ferrous metal industry's consumption of coke as shown in DUKES. There is insufficient data to split the coke consumption data between the three sites, and instead all of the coke use in DUKES is reported in 2C6. This will ensure completeness and reduce the uncertainty in the reported emissions, since only the total coke use figure is known to a high level of certainty. Carbon factors for the coke oven coke are derived from the carbon balance approach previously described for 1A2a. It should however be noted that some deviations have occurred from the carbon balance approach following the closure of the remaining coke ovens in the UK in this version of the inventory. Please refer to section 1A2a for the details.

As previously described, limestone may have been used at Britannia Zinc (and possibly in the blast furnaces at Capper Pass as well) but there is no information on which to base emission estimates. Since all of these plants closed more than 10 years ago, there is no scope to access new information to improve this situation, and therefore no emission estimates for these source categories are reported. Further, we note that the UK GHGI already includes emissions from all reported limestone and dolomite activity based on data from the British Geological Survey on UK supply and demand of these materials, and hence there is no gap in the UK GHGI, but possibly a small mis-allocation with higher estimates in another sector to counter the possible under-report here.

4.21.3 Uncertainties and Time Series Consistency

The use of DUKES data for coke consumption by non-ferrous metal processes ensures time series consistency and completeness, which is important since it is impossible to now determine how much coke oven coke was used in each of the 3 three non-ferrous metal processes that once existed in the UK. Any limestone used in the blast furnaces at Britannia Zinc and Capper Pass cannot be estimated, but emissions data for 2C1 cover all use of limestone and dolomite for blast furnaces and so overall completeness is assured.

4.21.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.21.5 Source Specific Recalculations

No major recalculations have been made to this sector.

For further information on recalculations, see **Section 10**.

4.21.6 Source Specific Planned Improvements

It is noted that this sector has been identified as a key category in this inventory submission, due to the site closures and resultant sector contribution to the UK inventory trend, and that a tier 1 method is used. The UK has recently reviewed this sector and included some additional sources using the best currently available data. Unfortunately, as the only sites in this sector have been closed for a number of years it is highly unlikely that new data will be found to derive a better estimate.

4.22 SOURCE CATEGORY 2D1 – LUBRICANT USE

4.22.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2D1: Industrial engines – lubricants	T1	D, CS
	Agricultural engines – lubricants	T1	D, CS
	Marine engines – lubricants	T1	D, CS
	Road vehicle engines – lubricants	T1	D, CS

Emissions of CO₂, CH₄ and N₂O arise from lubricant combustion in engines and other machinery. Note that waste lubricants can be recovered and subsequently used as fuels but emissions from this source are included in CRT 1.A. Where the term lubricants is referred to, this correlates to the DUKES definition of lubricating oils (and grease), i.e. “Refined heavy distillates obtained from the vacuum distillation of petroleum residues. Includes liquid and solid

hydrocarbons sold by the lubricating oil trade, either alone or blended with fixed oils, metallic soaps and other organic and/or inorganic bodies.”

4.22.2 Methodological Issues

Emissions reported in 2D1 cover all lubricants used by all sectors, with the sole exception of lubricants used in moped engines. This is deemed to be intentional fuel use and hence is reported in CRT sector 1A3biv. Detailed activity data on lubricant use by source category are not available in the UK; there is insufficient data to implement an IPCC Tier 2 method, and therefore the 2006 IPCC GLs Tier 1 method is applied. DUKES (DESNZ, 2025a) includes some limited data breakdown on sector-specific lubricant use (e.g. use by industry, agricultural sector, shipping) in addition to the total lubricant demand time-series. Lubricant consumption in road vehicle engines is estimated using the COPERT method from the EMEP/EEA Emissions Inventory Guidebook (2019).

Lubricant use in the remaining sectors uses activity data from DUKES, but the total lubricant use estimated by the inventory diverges from DUKES due to the use of the above method for road engines. While in general we would consider the totals from UK energy statistics to have a higher confidence than bottom-up estimates of demand, in this case we have taken a more conservative approach, reflecting that trends in activities that would demand lubricants do not correlate with the strong decreasing trend presented in DUKES.

The consumption estimates are used to calculate CO₂ emissions which are reported in CRT sector 1A3biv for mopeds and 2D1 for all other sectors, whereas the COPERT method directly calculates the quantity of lubricant consumed or burnt in road vehicles, for other sectors we assume that 20% of lubricant is oxidized during use. In all cases we apply a UK-specific carbon emission factor for lubricants, based on analysis of UK waste oil samples.

Emissions of CH₄ and N₂O also arise from lubricant combustion in road vehicle engines. However, the exhaust emission factors for these gases will include the contribution of, and hence the emissions of, CH₄ and N₂O (and other air pollutants estimated on a vkm-travelled basis) from lubricants are included implicitly in the hot exhaust emissions (CRT Sector 1A3b) calculated for each vehicle and fuel type. Treating emissions of these pollutants separately would lead to a double count.

4.22.3 Uncertainties and Time Series Consistency

The use of a Tier 1 methodology means that estimates are quite uncertain.

Additionally, the divergence in trend in total lubricant consumption presented by energy statistics, and bottom-up estimates of demand reflects uncertainty in activity data for this source.

4.22.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.22.5 Source Specific Recalculations

No major recalculations have been made to this sector.

For further information on recalculations, see **Section 10**.

4.22.6 Source Specific Planned Improvements

We are continuing to engage the UK energy statistics team to understand the trends in UK energy statistics for total lubricant demand, and the inventory estimates will be revisited if any major improvements are made to energy statistics.

4.23 SOURCE CATEGORY 2D2 – PARAFFIN WAX USE

4.23.1 Source Category Description

This category includes CO₂ emissions from paraffin wax use.

4.23.2 Methodological Issues

DUKES gives total consumption of petroleum waxes for the years 1990-2008 only. For 2009 onwards, petroleum wax consumption is only available as part of the much larger consumption of 'miscellaneous petroleum products'. Activity data for UK consumption of petroleum wax from 2009 onwards are available from the UK energy statistics team (Personal communication: DESNZ, 2025b) on the same basis as the earlier data, as they comprise part of other long-term energy data reporting outputs, e.g. to EUROSTAT.

Emissions are estimated using the Tier 1 ODU (Oxidation During Use) factor of 0.2, and the IPCC default carbon content of 20 kg C/ GJ (net basis).

4.23.3 Uncertainties and Time Series Consistency

Estimates for this sector are uncertain because of the use of a Tier 1 methodology. The time series consistency of the activity data is good, as they are part of a long-running routine energy data compilation and reporting system, by the UK energy statistics team in DESNZ, and also for the EFs as a Tier 1 default is used in all years.

4.23.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4**.

4.23.5 Source Specific Recalculations

No major recalculations have been made to this sector.

For further information on recalculations, see **Section 10**.

4.23.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.24 SOURCE CATEGORY 2D3 – OTHER NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE

4.24.1 Source Category Description

Emissions of CO₂ are estimated from consumption of urea by road vehicles with relevant types of catalytic converters for control of pollutant emissions and are reported under 2D3a. Urea has the chemical formula (NH₂)₂CO and is injected into the exhaust stream of certain types of diesel vehicles (currently Euro IV, V and VI HGVs and buses) as a 32.5% (by weight) aqueous solution. The catalytic process of converting NO_x to nitrogen in the exhaust leads to the release of CO₂ from the urea in the tailpipe.

Petroleum coke is known to be used by various sectors either as a fuel (e.g. at power stations and in cement kilns), or in various processes (e.g. in brickmaking, titanium dioxide manufacture, aluminium smelting, or electric arc steelmaking). The consumption of petroleum coke for each sector is either available directly from DUKES or estimated, based on ETS and other data. For most years, there is more petroleum coke listed in the UK energy statistics

than can be accounted for by these known users. In other years, the known users require more petroleum coke than is available in the energy statistics. But since there is excess petroleum coke for most years (25 out of 35) between 1990 and 2024, it is assumed that there are additional, unknown uses of the fuel in those years. The excess petroleum coke in the energy statistics is reported as being for non-energy uses but this will include both fuel grade and anode grade coke, so it is possible that the coke could be used as a fuel, or in processes, or both. In the absence of any data, and because the coke appears in DUKES as 'non-energy use', it has been assumed that it is used for an unknown process. Such uses could be non-emissive with the carbon stored, but in the UK inventory it is assumed that all carbon in this petroleum coke is emitted and reported in 2D3d.

4.24.2 Methodological Issues

The 2006 IPCC Guidelines specify two approaches for estimating CO₂ emissions from urea consumption. This is either from statistics on total urea sales or by estimating urea consumption as a proportion of the amount of fuel consumed. There are no statistics on urea sales in the UK, so the approach based on fuel consumption is used. Not all diesel vehicles use urea, so it is necessary to know the amount of fuel consumed specifically from those vehicles with the relevant exhaust after treatment technology that require urea injection.

Urea is used by HGVs and buses in the UK manufactured to Euro IV, V and VI standards. These came into effect from 2006. The EMEP/EEA Emissions Inventory Guidebook (2023) provides the means for estimating urea consumption as a proportion of fuel consumed by these specific types of vehicles. Fuel consumption by Euro IV, V and VI HGVs and buses was estimated using a bottom-up method described in **Chapter 3**. The estimations involve the use of vehicle km activity and fleet composition data from DfT and g/km fuel consumption factors, with total fuel consumption calculated for road transport by this method normalised to national fuel sales in DUKES.

Following figures given in the EMEP/EEA Guidebook for estimating other pollutant emissions, an assumption was made that 75% of Euro V HGVs and buses are equipped with SCR – the catalyst system that uses urea. The same assumption was also applied to Euro IV vehicles, and it is assumed that 100% of Euro VI vehicles are equipped with SCR. Fuel consumption was calculated for these types of vehicles using SCR technology. Following the EMEP/EEA Guidebook, urea consumption is assumed to be 4% of fuel consumption for a Euro IV HGV or bus, 6% for Euro V and 3.5% for Euro VI. Independent assessment in the UK from suppliers of urea and vehicle manufacturers supports these assumptions. These assumptions allowed the time-series for consumption of urea by UK road transport to be estimated. No urea was consumed before 2006.

A constant emission factor of 0.238 kgCO₂/kg urea solution was used, from the EMEP/EEA Guidebook. This is consistent with the factor and emission equation given in the 2006 IPCC Guidelines, assuming urea is used as a 32.5% aqueous solution which is the norm in the UK.

The emissive non-energy use of petroleum coke is assumed to result in 100% of the carbon in this fuel being emitted. The 2006 IPCC default factor for petroleum coke has been used in conjunction with calorific values for petroleum coke used in sectors other than electricity generation, taken from UK energy statistics. The relatively high calorific value given for this type of petroleum coke means that the IPCC default factor implies that this petroleum coke is over 90% carbon, which is higher than the carbon content of coke oven coke or anthracite.

4.24.3 Uncertainties and Time Series Consistency

The main uncertainty on estimates of emissions from urea consumption comes from the uncertainty in the amount of urea consumed by the categories of vehicles equipped with SCR exhaust after treatment technologies in the UK fleet. This is linked with uncertainties in the

estimates of fuel consumed by these vehicles and uncertainty in the amount of urea consumed per kg of fuel consumed. Uncertainties in the CO₂ emission factor from urea consumption are very low because the carbon content of urea is known with high accuracy.

The end uses of the petroleum coke reported in 2D3d are unknown and could actually include some use of petroleum coke as a fuel and/or some non-energy uses that result in storage of carbon, as well as emissive non-energy uses. The approach taken is conservative since we assume all of the carbon is emitted, but emissions may be wrongly allocated if some of the petroleum coke is actually used as a fuel. The uncertainty in emissions for this source is very high. Because of the use of this source as a balance against energy statistics, the time series is very erratic. There are many years where zero emissions are reported due to the UK Inventory Agency estimates for known uses for petroleum coke exceeding the UK demand figure for petroleum coke in the UK energy statistics.

4.24.4 Source Specific QA/QC and Verification

This category is covered by the general QA/QC of the inventory in **Annex 4**.

4.24.5 Source Specific Recalculations

As the estimate of these other non-energy uses of petroleum coke are a residual, they are sensitive to revisions to estimates of petroleum coke in other sectors. There have been increases to total petroleum coke consumption reported in energy statistics for 2021 and 2022 compared to what was reported previously, leading to an increase in the residual allocated to this sector. For 2023, there was a revision to increase the petroleum coke allocated residential combustion (sector 1A4bi), which left less residual fuel for this sector.

Revisions to urea use estimates are much more modest (<1% in all years) and linked to revisions to road transport estimates.

For further information on recalculations, see **Section 10**.

4.24.6 Source Specific Planned Improvements

It has been identified that some Euro 6 diesel light duty vehicles (LDVs), particularly those registered after September 2019 are expected to have SCR and therefore use urea, which is not currently captured in the NAEI estimates. The EMEP/EEA guidebook currently only provides guidance for heavy duty vehicles, and we do not currently hold data on the SCR uptake in these LDVs, meaning that further research is required to include these estimates. Note that it is expected that the urea use by LDVs is limited, as only a small proportion of the fleet as a whole is likely to require urea.

4.25 SOURCE CATEGORY 2E1 – INTEGRATED CIRCUIT OR SEMICONDUCTOR

Emissions of SF₆ and PFCs from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2G2e for reasons of commercial confidentiality. Emissions of NF₃ and HFCs from semiconductor manufacture are reported in sector 2E1. This source category (both for pollutants reported in 2E1 and 2G2e) is described in **Section 4.39**.

4.26 SOURCE CATEGORY 2E2 – TFT FLAT PANEL DISPLAY

4.26.1 Methodological Issues

ICF (2014) determined that the UK does not have volume Flat Panel manufacturing. ICF reached this conclusion after contacting the National Microelectronics Institute (NMI) who represent flat panel display manufacturers in the UK.

Further market analysis by Ricardo (2016) confirmed that there are no UK emissions from this sector. This included discussions with representatives of the flat panel supply sector and PFC supply sector – all those contacted confirmed that all flat panel displays used in the UK are imported. It was noted that in the 2006 IPCC guidelines that there was activity data given⁷⁸ for the UK in 2003-5. When using this activity data and the default methodology the resulting emission was well below the threshold to be considered insignificant, so is reported by the UK as 'NE' for years before 2014. This source is included in the Assessment of completeness in **Section 1.7**.

4.26.2 Source Specific Planned Improvements

Any emergence of volume manufacturing capacity of TFT flat panel display is kept under review.

4.27 SOURCE CATEGORY 2E3 – PHOTOVOLTAICS

4.27.1 Methodological Issues

ICF (2014) determined that the UK does not have volume photovoltaics (PV) manufacturing. ICF reached this conclusion after contacting the British Photovoltaic Association (BPA) to gather data from PV manufacturing in the UK. The BPA also confirmed that statistics on F-gas use in the PV manufacturing in the UK are not available.

Further market analysis by Ricardo (2016) confirmed that there are no UK emissions from this sector. This included discussions with representatives of the PV supply sector and PFC supply sector – all those contacted confirmed that all PV cells used in the UK are currently imported or manufactured in the UK using emerging technology that does not require F-gases in the process. It was noted that in the 2006 IPCC guidelines that there was activity data given⁷⁹ for the UK in 2003. When using this activity data and the default methodology the resulting emission was well below the threshold to be considered significant, so is reported by the UK as 'NE' for years before 2014. This source is included in the Assessment of completeness in **Section 1.7**.

4.27.2 Source Specific Planned Improvements

Any emergence of volume manufacturing capacity of photovoltaics is kept under review.

⁷⁸ Table 6.7 of Volume 3 of the IPCC 2006 Guidelines

⁷⁹ Table 6.8 of Volume 3 of the IPCC 2006 Guidelines

4.28 SOURCE CATEGORY 2E4 – ELECTRONICS INDUSTRY – HEAT TRANSFER FLUID**4.28.1 Source Category Description**

PFCs are used as heat transfer fluids (HTFs) in commercial and consumer electronic applications. The various applications of PFC as HTFs use much smaller volumes of liquid PFCs than electronics manufacturing. Some examples of consumer applications include cooling kits for desktop computers and commercial applications include cooling supercomputers, telecommunication, and radar systems, as well as drive units on high-speed trains.

4.28.2 Methodological Issues

Market analysis by Ricardo (2016) confirmed that there are no UK emissions from this sector. Discussions were held with the only 2 companies that supply the relevant PFC to the EU market (C₆F₁₄), including one company that manufactures this PFC in the UK. These discussions indicated that there is a small use of PFCs for HTF applications in some EU countries and in non-EU export markets. However, very small quantities (<2 kt CO₂e) of PFCs are sold in the UK market for this application, but it is believed that these are sold exclusively for hermetically sealed applications and products that are sold on to be used outside the UK. This source is included in the Assessment of completeness in Section 1.7.

4.28.3 Source Specific Planned Improvements

Any emergence of volume manufacturing capacity of heat transfer applications using F-gases is kept under review.

4.29 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT**4.29.1 Source Category Description**

HFCs and HFC blends have been widely used as replacement refrigerants for ozone depleting substances across virtually all refrigeration, air-conditioning and heat pump (RACHP) end-uses. They generally share many of the properties of CFC and HCFC refrigerants, namely low toxicity, zero and/or low flammability and acceptable materials compatibility. Emissions of HFCs can occur at various stages of the refrigeration/air-conditioning product life cycle:

- During the RACHP equipment manufacturing process;
- During on-site installation of equipment
- Over the operational lifetime of the RACHP unit; and
- At disposal of the RACHP unit.

This emission category contains aggregated emission estimates from the end-uses summarized in the table below. As shown, the UK inventory uses a model based on 7 main market sectors.

Table 4.19 Model End-Uses and Definitions

End-Use		Description
Residential	Domestic Refrigeration	Refrigerated appliances including refrigerators, chest freezers, upright freezers, and fridge freezers.

End-Use		Description
Commercial refrigeration	Small Commercial Stand-Alone Refrigeration Units	Small, hermetic, stand-alone refrigeration units including retail display cabinets, ice cream cabinets and drinking water coolers. These systems are commonly used in retail food stores but are also found in pubs, restaurants, and other hospitality and catering outlets such as hotels, hospitals, and schools. Each system typically has a cooling capacity in the 0.2 kW to 2 kW range.
	Condensing Units for commercial refrigeration applications	Refrigeration systems composed of one (or two) compressor(s) and one condenser, assembled into a unit, which is located external to the sales area. The condensing unit is connected by refrigerant pipework to an evaporator located in the retail sales area (e.g. in a chilled retail display). These units are typically installed in small shops, beer cellars and small walk-in cold rooms and have refrigeration capacities ranging from 1 kW to 20 kW.
	Centralised Refrigeration Systems for commercial refrigeration applications	Refrigeration systems that are comprised of racks of compressors installed in a machinery room. These systems are commonly used in supermarket applications, with many refrigerated displays connected to a central system. Each system typically has a cooling capacity in the 30 kW to 150 kW range.
Industrial refrigeration	Industrial Systems	Refrigeration systems including industrial process refrigeration and cold storage. Industrial refrigeration systems vary widely in cooling capacity. Many industrial systems are above 1,000 kW. However, the majority that use HFC refrigerants are relatively small, in the 50 kW to 200 kW range.
Comfort cooling and heating, direct	Small Stationary Air Conditioning	Includes small self-contained air-conditioning (including window units) and non-ducted single split air-conditioning. Units are used primarily in commercial applications, but there is some use in the residential sector. System cooling capacities typically range from 3 to 12 kW. The majority of modern systems are reversible – they can operate either as an air-conditioning unit or an air-to-air heat pump.
	Medium Stationary Air Conditioning	Includes non-ducted multi-split, variable refrigerant flow (VRF) non-ducted split, ducted split, and packaged air-conditioning. Units are used in the commercial UK sector. System cooling capacities typically range from 12 to 200 kW.
Comfort cooling and heating, indirect	Large Stationary Air Conditioning (Chillers)	Large water chillers used for commercial comfort air conditioning. Cooling capacity is typically in the range 100 kW to 500 kW. Some are reversible and can operate as air-to-water or water-to-water heat pumps
	Hydronic Heat Pumps	Residential and small commercial heating only heat pumps providing heat in the form of hot water, including air-source heat pumps (ASHP) (air-to-water systems) and ground-source heat pumps (GSHP).
Transport refrigeration	Land Transport Refrigeration	Refrigerated road vehicles (i.e., light commercial vehicles, trucks, trailers) and intermodal containers.
	Marine Transport Refrigeration	Refrigerated general cargo ships, container ships and fishing vessels (1,000 GT and above).
Mobile air-conditioning	Light Duty Mobile Air Conditioning	Air-conditioning systems for passenger cars and light commercial vehicles (up to 3.5 tonnes). Both of these vehicle types are covered under Directive 2006/40/EC (the MAC Directive).
	Other Mobile Air Conditioning	Air-conditioning systems for buses/coaches and railcars.

4.29.2 Methodological Issues

The UK estimates activity and emissions in this sector using a comprehensive modelling platform developed by Gluckman Consulting called *HFC Outlook* which uses a Tier 2a methodological approach.

The model makes use of a bottom-up approach with assumptions made about emission factors and stock levels. The model is verified by comparing the predicted HFC consumption for the whole Refrigeration, Air Conditioning and Heat Pumps (RACHP) sector with top-down data for the sales of HFCs in the UK and with predicted emissions made by Bristol University and the UK Met Office based on atmospheric measurements of F-Gas concentrations. The model takes full account of the impact of the assimilated F-gas Regulation⁷⁷, including bans of some higher GWP HFCs for some applications and a general phase down of HFC consumption. The model is reviewed on a regular basis.

For each of the 36 end-use sub-sectors, market data and other country-specific information were considered in the development of assumptions on equipment stocks, market growth, equipment lifetimes, refrigerant market penetrations, charge sizes, manufacturing loss rates, operational loss rates, and disposal loss rates across the 1990-2050 time-series. An extensive literature review was conducted, and key industry stakeholders were contacted. Priority industry stakeholders were selected across all end-uses and initially contacted to fill data gaps and corroborate information found in the literature. Following the development of preliminary assumptions for all end-uses, draft assumptions were then shared with a broader range of stakeholders to solicit additional industry input and vet assumptions.

In developing modelling input assumptions by end-use, expert judgment was applied to select appropriate values when more than one estimate was provided by literature and/or stakeholders. In general, more weight was given to estimates that are UK- or region specific and/or more recent. In cases of equal data quality where numerous data points were available, values were selected based on the mid-point of the data range. Where no UK- or EU-specific information was available, the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines default assumptions were relied on to estimate emissions.

The various input assumptions used by the model can be varied on an annual basis. This allows changes in response to market growth or regulatory constraint to be reflected in the bottom-up estimates of HFC emissions made by the model. For example, the 2006 EU F-Gas Regulation⁷⁷ has led to significant reductions in the levels of leakage from some RACHP sub-sectors and improvements in the level of refrigerant recovery during servicing and at end-of-life. That Regulation was revoked and replaced by the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷. EC 517/2014 continues to apply rules on leakage prevention and repair and refrigerant recovery. The impact of these provisions is reflected in the model by changes to the annual operating emission factors and end-of-life recovery factors.

A key input assumption is the split of different refrigerants used in new and existing equipment in each of the 36 sub-sectors. The accuracy of the input assumptions is checked by comparisons with top-down BRA data for the whole RAC market. The model then generates a detailed speciated split of total emissions. This is available split either by the type of refrigerant used (e.g. a blend such as R-404A) or by the individual HFC components within such blends (e.g. R-404A is a mixture of HFC-143a, HFC-125 and HFC-134a).

A summary table of the 2024 input assumptions is provided below in **Table 4.20**.

Table 4.20 Summary of 2024 Input Assumptions by End-Use

CRT Sector	UK Category	Total Stock (units)	Lifetime (years)	Charge (kg)	Most common refrigerant in new equipment, 2024 ⁸⁰	Manufacturing / Installation Loss Rate	Operational Loss Rate	Disposal Loss Rate
Domestic Refrigeration	Domestic Refrigeration	48,038,000	15	0.03 to 0.1	HC-600a	1%	0.1%	50%
Commercial Refrigeration	Small Hermetic Stand-Alone Refrigeration Units	1,952,000	15	0.2 to 1	HC-290, HC-600a	1%	1.0%	50%
	Condensing Units	536,000	15	1.5 to 15	X1500, X600, X150, R-744	3%	5.0%	30%
	Centralised Supermarket Refrigeration Systems	28,700	15	40 to 400	R-744	3%	6.8%	20%
Transport Refrigeration	Land Transport Refrigeration	64,100	9 to 15	1 to 10	R-452A	2%	6.9%	45%
	Marine Transport Refrigeration	403	25	50 to 1,500	R-744, HFC-134a, R-717	2%	7%	45%
Industrial Refrigeration	Industrial Systems	42,200	18 to 30	30 to 3,000	X1500, HFC-134a, R-717, R-744, X150	2%	5.0%	20%
Stationary Air-Conditioning	Small Stationary Air Conditioning	3,006,000	12	0.5 to 8	HFC-32	3%	2.1%	40%
	Medium Stationary Air Conditioning	309,000	15	2010 to 100	R-410A, HFC-32	2%	2.0%	40%
	Large Stationary Air Conditioning (Chillers)	56,300	15 to 21	30 to 1,500	HFC-134a, HFO-1234ze, X600	2%	1.3%	40%
	Hydronic Heat Pumps	600,000	18	3 to 150	R-410A, R-134a, HFC-32, HC-290	2%	1.8%	40%
Mobile Air-Conditioning	Light Duty Mobile Air Conditioning	35,750,000	16	0.4 to 0.8	HFO-1234yf	1%	2.4%	65%
	Other Mobile Air Conditioning	141,100	15	4 to 25	HFC-134a, R-410A	2%	5%	65%

⁸⁰ X150 = R454C or R-455A; X600 = R-450A or R-513A; X1500 = R-448A or R-449A

Speciated emissions are reported for the OTs and CDs under 2F1. Emission estimates from the UK GHGI were scaled by a territory-specific indicator. The indicators for each activity were chosen based on expert judgement and are as follows:

- GDP for refrigerated transport and commercial and industrial refrigeration
- Number of households for domestic refrigeration and stationary air conditioning for the Falkland Islands and the Crown Dependencies
- The number of households with air conditioners for stationary air conditioning in Bermuda and the Cayman Islands
- Number of vehicles for mobile air conditioning

4.29.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.29.4 Source Specific QA/QC and Verification

In the process of finalising the input assumptions, an analysis was conducted to compare estimated refrigerant consumption (calculated as the amount of refrigerant used to manufacture new equipment produced in the UK plus the amount used to service leaking equipment) with annual refrigerant sales data from the British Refrigeration Association (BRA). Further detail about this comparison is not presented due to the BRA data being confidential data.

Experts from the University of Bristol and the UK Met Office carry out measurement of atmospheric concentration data for all HFCs. These data are combined with meteorological data through a process called “Inversion Technique for Emission Modelling” (InTEM) to create an estimate of UK HFC emissions. See **Annex 6** for a description of InTEM. **Figure 4.3** shows a previous comparison of data from InTEM with the ICF model⁸¹ estimates and the *HFC Outlook* model Version 6.19. Both the ICF and HFC Outlook emissions estimates were higher than those made by InTEM in 2019 and were likely to be conservative over-estimates of HFC emissions. This chart also shows that the estimates from the HFC Outlook model Version 6.19 were much closer to the InTEM measurements than the ICF model.

In 2023 an investigation of these discrepancies was made on behalf of DESNZ. The InTEM modelling methodology was improved in 2020 and the latest 2022 InTEM estimates are generally higher than the previous estimates. The change was related to improving the uncertainty applied to each measurement, a greater emphasis was placed on matching the pollution events rather than the baseline values which is much more relevant in the UK framework. These changes were discussed in detail in the annual report to BEIS (now DESNZ) in September 2020.

At the same time, the *HFC Outlook* model had been updated to version 8.5A (see **Section 4.29.5** on Source Specific Recalculations for a description of the changes made). This created lower emission estimates than in version 6.19 and considerably better correlation to the new InTEM estimates. During the investigation further updates were made to the *HFC Outlook* model to create version 8.5B.

Figure 4.4 shows a comparison of emission estimates from InTEM and *HFC Outlook* version 8.5B, in tonnes CO₂e. This shows that in the latest *HFC Outlook* model (which is used to create the GHG Inventory estimates) the emissions estimates are very close to those made through the InTEM atmospheric measurements.

⁸¹ The ICF HFC Model was used in the NAEI prior to the development of the HFC Outlook model.

Figure 4.3 Comparison of RACHP Emissions Model Estimates with InTEM, tonnes CO₂e based on *HFC Outlook* version 6.19 and InTEM 2019

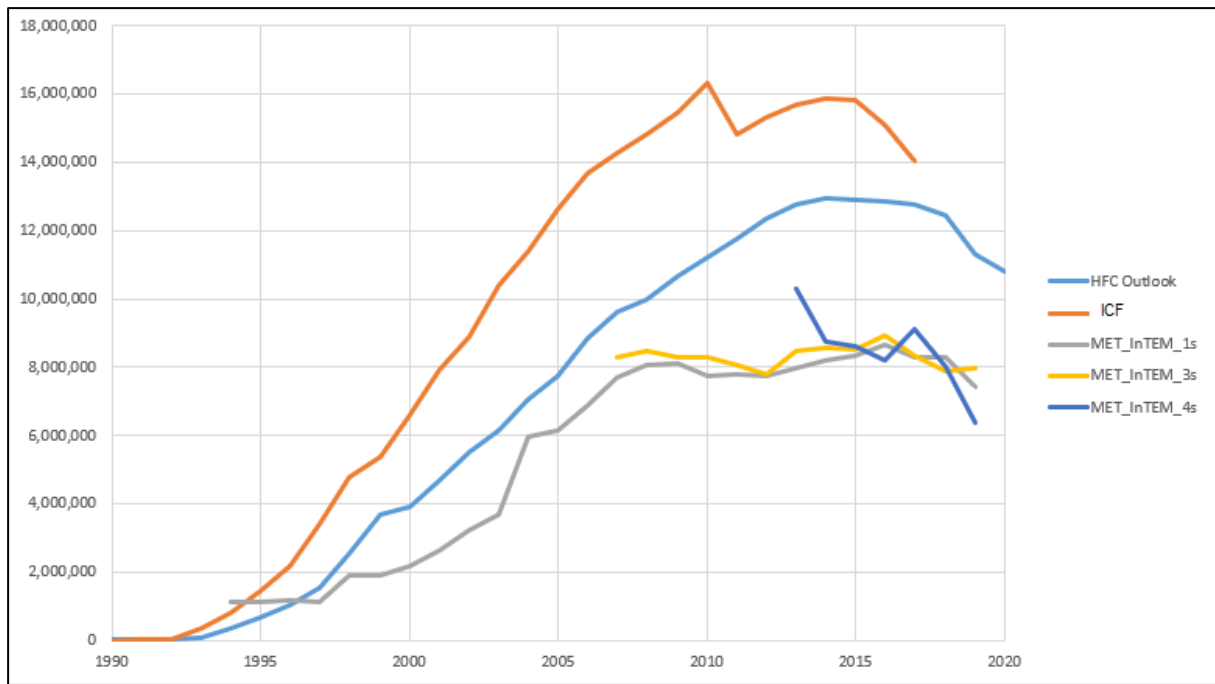
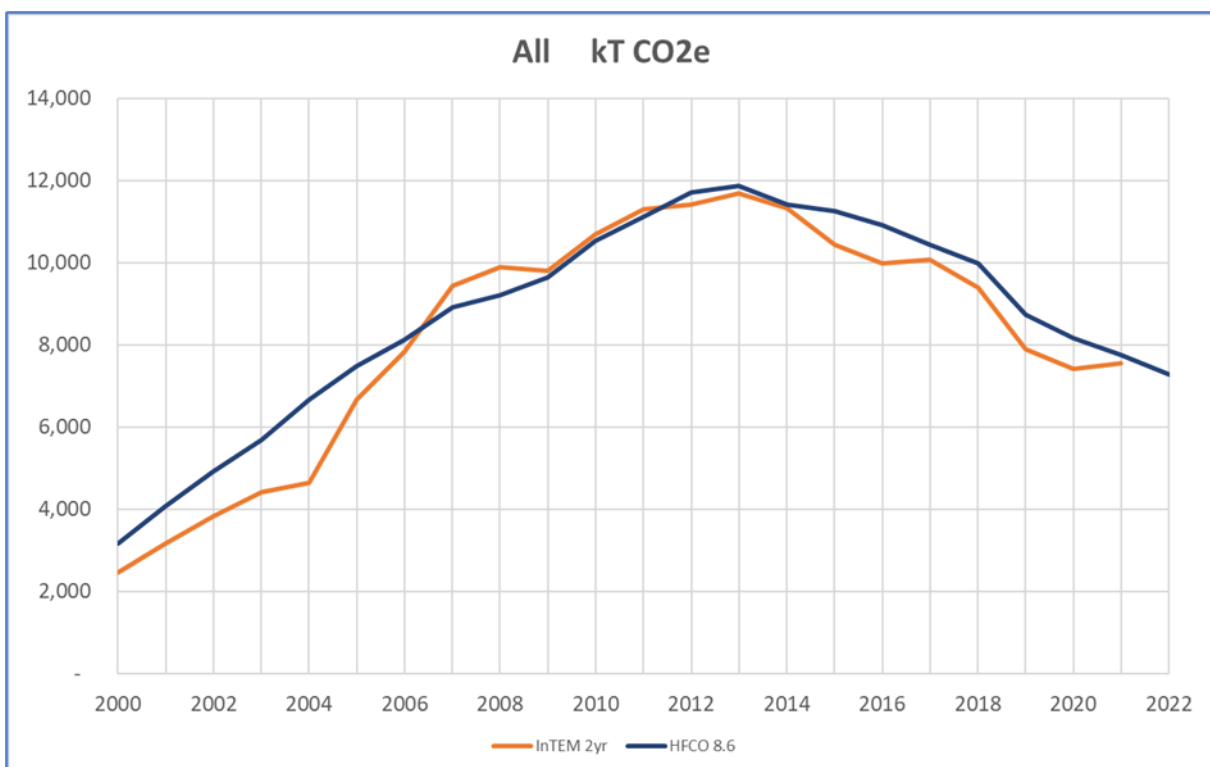


Figure 4.4 Comparison of RACHP Emissions Model Estimates with InTEM, tonnes CO₂e, based on *HFC Outlook* version 8.5B and InTEM 2022



In the UNFCCC review of the 2019 submission, it was highlighted that the UK trends in emissions presented a steep decline in emissions in recent years, which is a much stronger trend than for other EU Member States subject to the same F-gas regulations. While the model has been updated since this date, and the decline is modelled to be a few years later and less steep, the overall trend remains. This is in part due to the use of conservative emission factors,

which means that the UK's bank model will deplete historically used refrigerants (with typically higher GWPs) more quickly, and therefore the impact of legislation to improve the choice of refrigerants might be reflected earlier in the model than in practice. This is potentially verified by the atmospheric measurements and verification of UK emissions estimates provided in **Annex 6**; which, for recent years, shows a similar declining trend in emissions of some key HFCs used as refrigerants. There are also some UK-specific factors that mean we might expect emissions to be falling faster than other countries in Europe:

1. The UK supermarket sector is believed to have had historically high emissions (mainly of HFC-blend R-404A, which has a very high GWP). Since 2014, UK supermarkets have taken significant steps to rectify this situation through improved maintenance of existing systems. These improvements are taken into account in the emissions model.
2. Despite the date of the new equipment ban on refrigerants with a GWP>2500 being in 2020, the UK industry took early action and stopped using R-404A in new equipment several years earlier. For large systems (e.g. in supermarkets and industrial systems) there was little R-404A used in new equipment from around 2016. A key driver was the recognition of the "service ban" which also started in January 2020 and bans the use of virgin refrigerants with a GWP>2500 for the servicing of existing systems.
3. An important difference between the UK and most of the rest of the EU is the widespread retrofitting of R-404A systems, especially in supermarkets. R-404A (with a high GWP) can be retrofitted with several "near drop-in" alternatives. These include HFC blends R-407A and R-407F (with GWPs roughly half that of R-404A) that were used in the period 2012 to 2016 and the more recent HFC / HFO blends R-448A and R-449A (With GWPs roughly a third of R-404A). By carrying out a retrofit, any subsequent leakage emissions will have a much lower global warming impact, because of the considerably reduced GWP. One UK supermarket chain had completely retrofitted their R-404A equipment by 2014 and others did retrofit trials at that time. The old UK model assumes significant further retrofits in the period 2015 to 2019, to ensure that all large R-404A users would be compliant with the 2020 service ban. It is interesting to note that supermarkets in most other EU countries did not adopt retrofits until around 2018. The new UK model recognises that many previously planned UK retrofits were delayed for economic reasons – with few being carried out in 2015 and 2016. Most of the large UK supermarket chains started major retrofit programmes in 2017 (driven by the massive price rise that occurred before the 2018 phase-down step, which drove up the price of R-404A by around 1000%). They have combined the retrofits with a careful R-404A recovery and reclaim programme, which allows the retrofits to take place more slowly than originally modelled, during the period 2017 to 2023. The reclaimed R-404A can continue to be used for maintenance of the remaining R-404A equipment. This slower rate of retrofits does mean that 2015 to 2017 drop in emissions may be lower than predicted by the old model.

4.29.5 Source Specific Recalculations

No major recalculations have been made to this sector.

For information on the magnitude of recalculations, see **Section 10**.

4.29.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.30 SOURCE CATEGORY 2F2A – CLOSED CELLS (FOAM BLOWING AGENTS)

4.30.1 Source Category Description

Emissions of HFCs from foams can occur as follows:

- During the manufacturing process;
- Over the lifetime of the foam; most rigid foams are closed cell foams, and the blowing agent is designed to remain in the foam and contributes to its performance. Loss of HFCs is undesirable as it may affect the performance of the foam but is estimated to occur, albeit at a low rate through diffusion;
- At disposal of the foam; and
- In the waste stream, if the blowing agent is not destroyed following decommissioning

Emissions at each point vary significantly according to the type of foam and the type of application. For the bulk of product types, of the HFC used in the product, less than 10% is emitted during manufacture (although emissions may be as high as 40 to 45% for some types of foam), less than 1% per year over the useful lifetime of the product and the remainder on decommissioning and through the waste cycle⁸².

4.30.2 Methodological Issues

The methodology used to estimate emissions corresponds to the IPCC Tier 2b 'bottom-up' approach. The emission factors from the sector have been summarised below.

Emissions are considered separately from the following categories of foams:

PU Appliances (F1); PU, PIR Flexibly faced laminate (or boardstock) (F2); PU Discontinuous Panel (F3); PU Continuous Panel (F4); PU, PIR, Phenolic block (F5); Phenolic flexibly faced laminate (F6); PU Spray/injected/pipe-in-pipe (F7); Extruded polystyrene (XPS) (F8); Polyethylene Foam (F9); Integral Skin Foam (F10).

A full description of the emissions and associated methodology used for this sector is set out in Ricardo (2016), which built upon previous work (AEA, 2010). The emissions for the years 1990 to 2002 were based originally on data from March (1999). However, these and emissions data for more recent years (2003 onward) have been obtained from UK industry experts supported by market information from reputable market sources. The methodology is based on a bottom-up assessment of activity data which requires information on five elements to complete it:

- Overall dynamics of the thermal insulation market in the UK (including imports and exports);
- The market share changes on-going in the sector which determine the demand for closed cell insulation foams;
- The segregation of the insulation foam sector by manufacturing process and product type;
- The adoption of HFCs as one of the blowing agent options in any chosen process/product combination leading to market penetration assessments against other blowing agent types; and
- The formulation levels at which HFCs have been and will be used in the identified products and processes.

⁸² Any building insulation that goes into landfill degrades slowly and gives off the remaining gas over many years. This is not well documented and there is little data available on rate of degradation / emission, which is believed to vary depending on the conditions in the landfill.

The application of the relevant emission factors to this activity data delivers information not only on annual emissions, but also on how banks of blowing agents can develop in products and latterly in waste streams. These banks too will emit steadily, and because of the long lifetime of many foam applications, the emissions can take place over long periods of time, leading to a number of potential legacy issues. That said, the derived average annual emission rates are relatively low because the products rely for their performance on the retention of the blowing agents in the foam.

Emission factors are determined based on a combination of country-specific data on the HFCs contained in the foam and the time dependent rate of loss of HFCs. The model has been refined to allow the lifecycle of products to be adjusted in 5 yearly intervals. The outputs also give transparency on the source of emissions both by product type and lifecycle stage.

The model provides insight to the manufacturing and trade aspects of each product type in order to determine the amount of product placed on the market in the UK each year. This adds to the existing bank of blowing agent contained in installed products. In parallel, the blowing agent lost from product through annual emission and the decommissioning of product at end-of-life are subtracted from the bank.

The waste stream (not to be confused with decommissioning) is considered as a source of emission in its own right on the basis that a bank of blowing agent is established following decommissioning; while this source is mentioned in the 2006 IPCC guidelines, a method for estimating this source is not given. Although this reduces annual emissions when compared with the previous default assumption of full emission on decommissioning, the impact is mitigated by the long lifecycles of most products being considered. In practice, there is only limited product decommissioning taking place involving HFC-based foams in the period until 2035. Emissions from this source are estimated using a similar approach to product lifetime emissions, i.e. estimated HFCs remaining in the product after decommissioning is added to a bank of gas expected to be in landfill, and a fraction of this is emitted annually. The main difference between this stage and the product lifetime stage is that gas can only escape the bank via emissions, so eventually all of the bank is assumed to be emitted.

The species used for foam blowing are given below.

Table 4.21 Species according to application for foam blowing^a

Application		HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
Polyurethane (PU)	Boardstock	X ^b	X ^b	X ^b		
	Cont. Panel	X	X	X		
	Disc. Panel	X	X	X		
	Spray	X	X	X		
	Pipe-in-Pipe	X	X	X	X ^b	
	Appliance	X ^b	X ^b	X ^b		
	Reefer	X	X	X		
	Block - Slab	X	X	X		
	Block - Pipe	X	X	X		

Application		HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
Extruded Polystyrene					X	X
Phenolic (PF)	Boardstock	X ^b	X ^b	X ^b		
	Disc. Panel	X	X	X		
	Block - Slab	X	X	X		
	Block - Pipe	X ^b	X ^b	X ^b		

^a No emissions are occurring for this source in 1990 or in 1995. The bank also includes HFC species not previously reported in the UK GHG inventory (i.e. HFC-365mfc and HFC-245fa), since no GWP was available in the IPCC Second Assessment Report (SAR), but they are included in the 4th Assessment Report (AR4).

^b These are potentially used, but not known to be used

In the 2015 improvement programme extensive stakeholder consultation was done to determine where parameters of the model should be revised to be most representative of UK emissions. **Table 4.22** summarises the more significant deviations from 2006 IPCC default parameters and the reason for the deviation. A summary of the factors used in the foams model is provided in **Table 4.23**.

Table 4.22 Significant Deviations from 2006 IPCC GL default parameters^a

Application	EF Source	Product Lifetime (years)	Manufacturing Factor	Product Lifetime Factor	Notes
Domestic Refrigerators	IPCC 2006 GLs		4%		All HFC-containing units imported
	UK GHGI Model		0%		
Other Appliances	IPCC 2006 GLs		4%	0.5%	Wider range of products included, but lower in use losses because of better designs and thicker foams
	UK GHGI Model		6%	0.25%	
PU Boardstock	IPCC 2006 GLs	25			IPCC uses global figure influenced by timber-framed housing
	UK GHGI Model	50			
PU Cont. Panel	IPCC 2006 GLs	50			Information from major panel manufacturers suggests 30 years is a better figure although some guarantee for 40 years
	UK GHGI Model	30			
PU Disc Panel	IPCC 2006 GLs	50	12%		Better manufacturing practices. Information from major panel manufacturers suggests 30 years is a better figure although some guarantee for 40 years

Application	EF Source	Product Lifetime (years)	Manufacturing Factor	Product Lifetime Factor	Notes
	UK GHGI Model	30	6%		
PU Spray	IPCC 2006 GLs		15%		Recognises pre-2006 status of industry and improvements made
	UK GHGI Model		15-25%		
PF Block Pipe	IPCC 2006 GLs		45%		Recognises new process introduction
	UK GHGI Model		45%/7.5%		
PU/PF Block Slab	IPCC 2006 GLs	15	20%	1%	Recognises better foam structure and fabrication processes. Most slab now used for panel purposes so lifetime should be aligned.
	UK GHGI Model	30	15%	0.75%	
XPS Board	IPCC 2006 GLs		25%	0.75%	Annual cell losses greater but decreases with greater thickness
	UK GHGI Model		12-25%	2.5%	

^a Decommissioning and waste factors are not compared here as they are not comparable to the maximum potential end of life emission factors given in the 2006 IPCC guidelines.

Table 4.23 Parameters used in the foams model

Application	Product Lifetime (years)	Manufacture	Product Lifetime Factor	Decommissioning	Waste
Dom. Refr-Freezers	15	0.00%	0.25%	2.50%	0.00%
Other Appliances	15	6.00%	0.25%	5.00%	0.00%
PU Reefers-Marine	15	6.00%	0.50%	10.00%	1.00%
PU Boardstock	50	6.00%	1.00%	7.50%	2.00%
PU Continuous Panel	30	5.00%	0.50%	5.00%	0.75%
PU Disc. Panel	30	6.00%	0.50%	5.00%	0.75%
PU Spray	50	15-25% ^a	1.50%	10.00%	2.00%
PU Pipe-in-Pipe	30	6.00%	0.25%	2.00%	0.50%
PU Block-Pipe	15	45.00%	0.75%	2.50%	1.50%
PU Block-Slab	30	15.00%	0.75%	2.50%	1.50%
XPS - Board	50	12-25% ^a	2.50%	7.50%	4.00%

Application	Product Lifetime (years)	Manufacture	Product Lifetime Factor	Decommissioning	Waste
PF - Boardstock	50	6.00%	1.00%	7.50%	2.00%
PF - Panels	30	10.00%	0.50%	5.00%	0.75%
PF - Pipe	15	7.5-45% ^a	0.75%	2.50%	1.50%
PF - Block Slab	30	15.00%	0.75%	2.50%	1.50%

^a The factor varies depending on the year to reflect the impact of regulation and UK industry practice

Speciated emissions for the OTs and CDs are reported under 2F2. Emission estimates from the UK GHGI were scaled using the GDP of each territory.

4.30.3 Uncertainties and Time-Series Consistency

There are a number of parameters that feed into the modelled estimate of emissions and hence the uncertainty. Between data on foam manufacturing capacity/utilisation, the blowing agent consumption and the overall tracking of thermal insulation demand through publications such as IAL studies we can have a fairly high level of confidence in the estimate. This is despite some high uncertainties in some of the individual assumptions in the model; manufacturers were cautious in providing comment on the HFC market penetration which is the assumption that has greatest cause for uncertainty. Regulatory pressures to label products containing HFCs may help in future to hone the estimates and reduce uncertainties in activity data.

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.30.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.30.5 Source Specific Recalculations

There have not been any major recalculations to this sector this year.

For information on the magnitude of recalculations, see **Section 10**.

4.30.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.31 SOURCE CATEGORY 2F2B – OPEN CELLS (ONE COMPONENT FOAMS)

4.31.1 Source Category Description

One Component Foams (OCF) are used by building tradesmen (and in the DIY home improvement sector, to a lesser extent) to mount doors and windows and to insulate different types of open joints and gaps. When used as an OCF propellant, HFC 134a or 152a is blended with various flammable gases. HFC escapes from the foam on application, leaving small residues, which remain in the hardened foam for up to a year. These products are not manufactured in the UK, although they are imported. The use of HFCs of GWP 150 or greater in OCF was banned under the Regulation on fluorinated greenhouse gases (F-gases) 2006

(EC 842/2006) from July 4th 2008, except for where their use is safety critical. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006.

4.31.2 Methodological Issues

The method of calculation is an IPCC Tier 2 method.

UK estimates of emissions from this source were based on a European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated by GDP to provide a top-down UK estimate.

It has been very difficult to establish the exact size of the UK import market and, therefore, hard to generate an accurate estimate of emissions from the use of this product.

Harnisch and Schwarz (2003) estimated EU emissions from OCFs as follows:

- 1996: 4,000 kt CO₂ equivalent per annum (3,100 tonnes of HFC-134a); and
- 2000: 1,700 kt CO₂ equivalent per annum (1,200 tonnes of HFC-134a; 1,000 tonnes of HFC-152a)

Emissions in tonnes of CO₂ equivalent have reduced between 1996 and 2000 due to the use of HFCs with lower GWP values, and the manufacture of cans containing less HFC. In 2000, 23 million OCF cans that contained HFCs were sold in Germany while 7 million were sold to the rest of the EU market. Research indicated that Germany accounted for 77% of the total EU emission, and that out of the remaining 23%, the UK accounts for 24%, based on a percentage of total EU GDP (excluding Germany). This is equivalent to 1.68 million cans (AEA, 2008).

The estimates of HFCs assume that the ban on F-gas use in one component foams (banned from July 2008 under the EU F-gas Regulation 2008 (EC 842/2006)) has been successful, and this success has been confirmed with the UK Defra F-Gas Regulation team. Therefore, no HFC emissions occur from 2009 onwards. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006

4.31.3 Uncertainties and Time-Series Consistency

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 2**.

4.31.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.31.5 Source Specific Recalculations

There have been no recalculations to estimates from this source.

4.31.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.32 SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS

4.32.1 Source Category Description

In the UK, manufacturers of fixed suppression systems for firefighting have been using HFCs as an alternative to Halons for many years. HFC-based systems are used for the protection of various high value products such as art works and electronic / telecommunications equipment, and in military applications, records offices, bank vaults and oil production facilities.

The main HFC used in UK fixed systems is HFC-227ea. This is used as an alternative to Halon 1301 in fixed systems.

The UK makes no use of HFCs as an alternative to Halon 1211 in hand-held fire extinguishers. There is no suitable HFC used in the UK and the fire industry has switched to a range of not-in-kind technologies including water, water mist, foam spray, CO₂ and powder extinguishers. The Fire Safety Advice Centre⁸³ confirm that: “It is not the policy of the fire industry to select fluorinated gases for use in this sector except in special circumstances and none are generally available in the market at present.”

4.32.2 Methodological Issues

The IPCC 2006 GLs state that, because F-gases in fire extinguishers are emitted over a period longer than one year, countries must represent emissions from equipment charged during previous years. As such, the emission estimation equation (Equation 7.17) considers the time dependence of the emissions. Effectively, this requires disaggregating the annual bank estimates into ‘new’ versus ‘existing’ systems and then applying emission factors accordingly (i.e., applying a lifetime loss rate to banks from both new and existing systems, a servicing loss rate to the bank of existing systems, and a disposal loss rate to the bank of existing systems reaching disposal in any given year, based on an assumed average lifetime). Further, additional research was required to ensure that a manufacture loss rate should not be applied by confirming whether there is any production of F-gas fire protection agents in the UK.

ICF (ICF, 2014) reviewed available literature to confirm/update key assumptions—notably, EEA (2013)—and then refined and finalized the estimates based on consultation with ASSURE (European Association for Responsible Use of HFCs in Fire Fighting) and the UK Fire Industry Association (FIA).

4.32.2.1 Stock

Annual stock estimates for 1997-2002 were based on data reported by the Fire Industry Confederation and input from industry experts (AEA 2005) and 1995-6 based on estimates presented by March (1999). HFCs and PFCs are not believed to be used in the UK for this application before 1995.

The equipment stock in years beyond 2007 is estimated based on EEA (2023) estimates for net supply of F-gases in the fire protection sector from 2007-2012 (metric tonnes) in the EU, 85% of which is HFC-227ea, and scaled to the UK using a time-dependent GDP ratio. This annual net supply was assumed to equal annual UK consumption of fire protection agent in new and existing systems. The methodology and resulting stock estimates were reviewed and approved by ASSURE (2013) and FIA (2013). ASSURE confirmed that the estimates looked reasonable; FIA noted that the estimates looked reasonable for recent years, but that the 2000 estimates are slightly high. Additional information to refine these historical estimates was not available but this is a conservative bias as it will slightly overestimate emissions.

⁸³ <https://www.firesafe.org.uk/phase-out-of-halon-in-portable-extinguishers/>

The gap for 2003-2006 are filled by using a combination of growth assumptions, assumptions around the phase out of ODS and interpolation.

4.32.2.2 Chemicals in use

According to FIA (2013) and ASSURE (2013), HFC-227ea accounts for virtually 100% of F-gas consumption in this sector in the UK; consumption of other HFCs (e.g., HFC-23, HFC-125, and HFC-236fa) in the UK are statistically insignificant. Therefore, it is assumed that HFC-227ea accounts for 100% of HFC consumption in this sector (over the full product lifetime).

The UK has also reported emissions of PFC C₄F₁₀ from 1995 to 2007. The use of PFCs for new fire protection systems was banned under the Regulation on fluorinated greenhouse gases (F-gases) 2008 (EC 842/2006) from 2007. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006

4.32.2.3 Equipment lifetime

According to FIA (2013) and ASSURE (2013), the average equipment lifetime of fire protection systems is 20 years.

4.32.2.4 Emission factors

The emission factors used in the current inventory were reviewed by FIA (2013) and ASSURE (2013); they confirmed that no updates were required. A summary of the emission factors is provided in the table below. ASSURE emphasised that the high cost of specialty HFC fire protection systems creates a strong incentive for recovery and recycling, minimising leaks during servicing and decommissioning. Further, ASSURE confirmed that there is no F-gas production in the UK in this sector, which is also supported by Defra (2008). Thus, no manufacturing loss factors are applied.

Lifetime emission factors were applied to the entire bank, while servicing emission factors—which decrease over time as more efficient servicing techniques are assumed to be implemented—were applied to the bank of existing systems (not to new or decommissioned systems). The disposal loss rate is applied to the bank of existing systems assumed to reach disposal; because the equipment lifetime is assumed to be 20 years, the disposal emissions are only reported from 2015—i.e., 20 years following the initial installation of F-gases in 1995.

Table 4.24 Key assumptions used to estimate HFC emissions from fire extinguishers

Parameter	1990-2000	2001-2004	2005 onwards
Equipment lifetime (yrs)	20	20	20
% released through fire (lifetime)	1.5	1.5	1.5
% released through servicing	3.4	1.5-2.9 ⁸⁴	1.0
% released during recovery (disposal)	0.1	0.1	0.1

Speciated emissions for the OTs and CDs are reported under 2F3. Emission estimates from the UK GHGI were scaled by the relative GDP of each territory.

4.32.3 Uncertainties and Time Series Consistency

The GWP of HFC-227ea is very high (3,220) and the impact of the HFC phase-down under the assimilated F-gas Regulation 2014⁷⁷ has been to encourage the introduction of alternative fire suppression systems. From the early 2020s HFC-227ea was no longer used in new fire suppression systems in the UK. A widely used alternative is fluoro-ketone FK 5-1-12. Other alternatives include not-in-kind systems such as inert gases (e.g. Inergen, Argonite, CO₂) and water mist systems. HFC-227ea is still used for servicing existing installations which can have

⁸⁴ Interpolated between 2000 and 2005

lifecycles of several decades. EEA (2023) reporting also indicates that HFC use for firefighting has been strongly declining since 2014 (i.e. when the 2014 EU F-gas Regulation entered into force).

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.32.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.32.5 Source Specific Recalculations

Updates to the EEA GDP proxy dataset caused reductions in HFC emissions.

For information on the magnitude of recalculations, see **Section 10**.

4.32.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.33 SOURCE CATEGORY 2F4 – AEROSOLS

4.33.1 Source Category Description

Most aerosols use hydrocarbon propellants, with a relatively small proportion of the market favouring other volatile liquids including dimethyl ether (DME) and HFCs. Compressed gases are used in very few aerosols since they suffer from a number of disadvantages compared with liquefied gas propellants such as HFCs, DME and hydrocarbons. HFCs are used only in a few applications where the use of a more expensive propellant is required to provide a non-flammable material. The most important industrial applications in volume terms are air dusters and pipe freezing products; other applications include specialised lubricants and surface treatments, and specialised insecticides. The use of HFCs with a GWP>150 for novelty applications, such as ‘silly string’ was banned from July 2009, under the EC Regulation on fluorinated greenhouse gases (F-gases) (EC 842/2006)⁷⁷. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006. The use of HFCs with a GWP>150 was banned for technical aerosols in 2018 by EC 517/2014).

Metered dose inhalers (MDIs) are used to deliver certain pharmaceutical products as an aerosol. For patients with respiratory illnesses, such as asthma and chronic obstructive pulmonary disease (COPD), medication needs to be delivered directly to the lungs. MDIs are one of the preferred means of delivering inhaled medication to patients with these illnesses. MDIs originally used CFC propellants but, as with industrial aerosols, concern over ozone destruction led to replacement of CFCs with HFCs. Note that HFCs for use in MDIs are exempted from the phasedown of HFCs placed on the market for the first time set out in the assimilated F-gas Regulation 517/2014⁷⁷, although the Regulation is currently being reviewed.

4.33.2 Methodological Issues

4.33.2.1 Non-medical Aerosols

The methodology used to estimate emissions corresponds to an IPCC Tier 2a method. Aerosol HFC emission estimates have been derived on the basis of fluid consumption data provided by the British Aerosol Manufacturers’ Association (BAMA) up to 2012 (BAMA, 2016). BAMA

discontinued collecting data for 2013 onwards, so for these years we have projected estimates of HFC consumption using knowledge of the regulatory landscape and industry insight of the market from a contact at BAMA (BAMA, 2022). A 2006 IPCC default approach is used, of assuming that 50% of emissions occur in the year that aerosols are placed on the market, and 50% the following year.

Speciated emissions for the OTs and CDs are reported under 2F4a. Emission estimates from the UK GHGI were scaled by the population of each territory.

4.33.2.2 Metered Dose Inhalers (MDIs)

The methodology used to estimate emissions corresponds to an IPCC Tier 2a method. The current approach is essentially a “UK consumption model”. The number of MDIs prescribed each year in the UK is derived from the UK National Health Service (NHS) prescription data, and a 2006 IPCC default approach applied, i.e. of assuming that 50% of emissions occur in the year of prescription and 50% the following year. HFC emissions have been calculated with estimates of the species and volumes of HFCs used as MDI propellants. Detailed data from the UK NHS are used for estimates between 1998 and 2018. Estimates for 1990-1997 are based on extrapolated data from 1998.

The NHS data gives good estimates of the number of MDIs of each drug type that have been prescribed. However, the data gives no information about the amount of HFC propellant per MDI prescribed. The estimates assume an average figure of 12g/MDI in recent years (Gluckman, 2013). From 2021, new data from the NHS showing the propellant content of each brand of inhaler was used to provide a more accurate estimate of propellant charge, as shown in Table 4.25.

The table below shows the way in which emissions are estimated from NHS data on total number of MDIs used in the UK each year. The majority of MDIs use HFC-134a. A small number have been formulated using HFC-227ea, we have assumed this represents 8% of HFC used for MDIs based on UEP report (UNEP, 2018). The table shows the estimated number of MDIs consumed each year in the UK and the estimated charge size.

Since 2021 the NHS has encouraged GPs to take account of the high GHG emissions from MDIs and have incentivised (a) the use of non-MDI alternatives (dry powder inhalers) and (b) use of MDIs with a smaller HFC charge. The data for 2021 to 2024 in Table 4.25 shows the impact of these efforts. In 2024 the number of MDIs prescribed has fallen by 15% from a peak in 2020.

Table 4.25 Key assumptions used to estimate HFC emissions from MDIs

Year	MDI Number (thousands)	Average Propellant (g per MDI)
2006	40,146	14
2007	41,874	13
2008	45,353	12
2009	48,413	12
2010	50,190	12
2011	50,644	12
2012	52,009	12
2013	51,518	12

Year	MDI Number (thousands)	Average Propellant (g per MDI)
2014	53,317	12
2015	53,612	12
2016	54,174	12
2017	53,452	12
2018	53,155	12
2019	52,338	12
2020	54,038	12
2021	50,633	12
2022	51,001	12
2023	48,301	12
2024	45,495	12

Speciated emissions for the OTs and CDs are reported under 2F4b. Emission estimates from the UK GHGI were scaled by the population of each territory.

4.33.3 Uncertainties and Time Series Consistency

Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 2**.

4.33.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.33.5 Source Specific Recalculations

There have not been any major recalculations to this sector this year.

For information on the magnitude of recalculations, see **Section 10**.

4.33.6 Source Specific Planned Improvements

The MDI sector is currently under review. The NHS has identified that MDI-related HFC emissions are a significant part of its carbon footprint and are putting policies in place to reduce these emissions. This sector will be closely monitored to measure the impact of NHS policies. Several pharmaceutical companies are developing low GWP alternatives to the current HFC-134a and HFC-227ea propellants. The first of these are expected to enter the market by 2025 and a significant transition away from current MDIs is expected by around 2030.

Activity data and emission factors will be kept under review.

4.34 SOURCE CATEGORY 2F5 – SOLVENTS**4.34.1 Source Category Description**

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane. HFCs have been developed that are used for precision cleaning in sectors such as aerospace and electronics.

4.34.2 Methodological Issues

Emissions from solvent applications are considered to be prompt emissions because 100% of the chemical is typically emitted within two years of initial use (IPCC 2006). To calculate HFC emissions from the solvent sector using a Tier 1a method, the 2006 IPCC Guidelines specify that activity data should be the quantity of solvent sold in a given year. Therefore, obtaining annual sales of solvents in the UK is required. Using sales data, emissions of HFCs from solvent use in year t are calculated using the following equation, as provided in the 2006 GLs:

$$Emissions_t = S_t \times EF + S_{t-1} \times (1-EF) - D_{t-1}$$

Where:

$Emissions_t$ = emissions in year t , tonnes

S_t = quantity of solvents sold in year t , tonnes

S_{t-1} = quantity of solvents sold in year $t-1$, tonnes

EF = emission factor (= fraction of chemical emitted from solvents in the year of initial use), fraction

D_{t-1} = quantity of solvents destroyed in year $t-1$, tonnes

ICF reviewed available literature to confirm/update key assumptions - notably, Harnish & Schwarz (2003), and EEA (2013).

4.34.2.1 Stock

Annual sales data of HFCs in the UK solvent sector have not been identified. Therefore, consumption of HFCs in this sector was estimated using the same estimates as in the previous inventory for 2001 and 2002 (i.e., based on Harnish & Schwarz 2003) in addition to historical F-gas supply data in the EU. Because the consumption estimates in Harnish & Schwarz (2003) in years beyond 2002 were projections, EEA (2023) data on HFC-43-10mee supply data in the EU was used to estimate HFC consumption from 2007 onwards.

To estimate the amount of HFCs placed on the market in the UK, the EU estimates from EEA (2023) were scaled down using a time-dependent UK to EU GDP ratio from Eurostat (2025) and Office of National Statistics (2025c). Using GDP as a scaling factor to estimate the UK F-gas supply in the solvent sector was deemed appropriate, given the wide variety of industrial and commercial industries that use solvents.

4.34.2.2 Chemicals in use

Given the lack of data available on the extent of use of HFC-134a in the UK solvent sector, it is assumed that HFC-43-10mee accounts for 100% of UK F-gas consumption in this sector.

4.34.2.3 Product lifetime

According to the 2006 IPCC GLs, the lifetime of all solvents is assumed to be two years. Therefore, any amount not emitted during the first year is assumed to be emitted in the second, final year (IPCC 2006).

4.34.2.4 Emission factors

A lifetime emission factor is applied to the total amount of solvents placed on the market. Because the 2006 IPCC GLs provide that HFCs are emitted over a two-year period, an annual emission factor of 50%⁸⁵ was applied in this analysis using the IPCC (2006) equation above. Recovery and recycling are not considered in emission estimates, per the 2006 IPCC Guidelines.

4.34.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.34.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.34.5 Source Specific Recalculations

There have not been any major recalculations to this sector this year.

For information on the magnitude of recalculations, see **Section 10**.

4.34.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

⁸⁵ Note the ICF report (ICF, 2013) states 45%, but the spreadsheet indicates 50% was used.

4.35 SOURCE CATEGORY 2F6 – OTHER (INCLUDING TRANSPORT OF REFRIGERANTS)**4.35.1 Source Category Description**

Emissions sources	Sources included	Method	Emission Factors
	2F6b: Refrigerant Containers Refrigerant handling	CS CS	CS CS
Gases Reported	HFCs		
Key Categories	2F: Product Uses as Substitutes for ODS - HFCs (L2, T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using GDP as a scaling factor.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	No major improvements		

4.35.2 Methodological Issues

Under the 2006 GLs, a new term in the IPCC Tier 2a method emissions equation for the Refrigeration and Air Conditioning sector includes emissions from the management of refrigerant containers used to service existing refrigeration/air-conditioning equipment, including refrigerant cylinders used by professional service technicians and small cans used by Do-It-Yourselfers (DIYers). No Tier 1 methodology is provided for this source.

Emissions from refrigerant containers occur when refrigerant is transferred from bulk containers (e.g. 20-tonne isotanks) to smaller capacity containers, typically ranging from approximately 300-500 grams (small cans) to 60 - 70 kg (cylinders). Emissions also occur at time of cylinder reprocessing (for reusable cylinders) or cylinder disposal (for non-returnable cylinders) if the refrigerant “heel” is not fully recovered. IPCC 2006 GLs require that emissions from each type of refrigerant container be calculated separately for refrigerant sold in small cans and in cylinders, including both disposables and reusables. The IPCC 2006 GLs default disposal emissions factors are 20% for small cans and 2% for disposable cylinders. Although the GLs do not specify a default emission rate for losses during the transfer of refrigerant into smaller containers, they do specify a default loss rate of 0.5% during the charging of refrigeration/air-conditioning equipment.

ICF (2014) provides a review of available literature to develop key assumptions on stock and emission factors—notably, Enviro Consulting Limited (2008), Defra (2008), and BRA (2010). ICF also contacted the five largest refrigerant Fillers & Packers in the UK that reported sales data to BRA in order to confirm/refine the estimates. Further work was carried out and is reported in Ricardo (2016) to refine a refrigerant containers model that is now used for the UK emissions estimate.

4.35.2.1 Package Sizes and Types

Refrigerants are used by four different types of end users who each use different sizes of refrigerant packaging:

- a) Original equipment manufacturers that manufacture pre-charged RACHP equipment. They purchase the majority of refrigerant in large volumes e.g. 20 tonne iso-containers or 1 tonne drums.
- b) RACHP system installers that charge new systems after construction at an end user site. For larger sized systems (e.g. supermarket refrigeration systems or air-conditioning water chillers) the majority of refrigerant is supplied in large cylinders (e.g. 60 kg). For small systems (e.g. split air-conditioning) small cylinders (e.g. 15 kg) may also be used.
- c) RACHP maintenance companies that carry out regular maintenance of equipment. The majority of refrigerant used for maintenance is supplied in small cylinders.
- d) DIY activities for mobile air-conditioning – refrigerant is supplied in small cans (e.g. 0.3 to 0.5 kg) for use in the DIY market.

All large package sizes (e.g. 20 tonne iso-containers, 1 tonne drums, and 60 kg cylinders) have been sold as re-usable containers since before 1990.

A small proportion of smaller cylinders (e.g. 15 kg) were sold as non-returnable containers from 1990 to 2008. From 2008 the supply of non-returnable cylinders was banned under the 2006 EU F-Gas Regulation⁷⁷. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006.

The majority of small cans for mobile air-conditioning were sold as non-returnable containers from 1990 to 2008. From 2008 the supply of non-returnable small cans was banned under the 2006 EU F-Gas Regulation. This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006.

4.35.2.2 Sources of emission from refrigerant containers

The refrigerant containers emissions model takes into account 4 sources of HFC emission:

- a) During package filling at a specialist company that transfers refrigerant from bulk storage into the package sizes described above.
- b) During the re-processing of re-usable packages, at the specialist packer-filler companies
- c) From non-returnable cylinders in the waste stream (only until 2008 when they were banned)
- d) From the use of cylinders in the field by installers and maintenance companies.

All emissions are assumed to occur when cylinders are connected or disconnected to other equipment. There are small losses each time a cylinder is filled, used in the field or reprocessed. The emissions are on a “per event” basis. For example, each time a cylinder is filled there is a small emission – the filling emission is the same for filling a large 60 kg cylinder as for filling a small 15 kg cylinder. There are no emissions from cylinders in storage.

4.35.2.3 Number of cylinders filled, used and reprocessed

Annual estimates of cylinder use were developed using data on the sales of refrigerant into the UK market consistent with the UK RACHP model. The split of cylinder sizes for each application type was estimated through discussions with packer-fillers as summarised in the table below.

Table 4.26 Estimated split of UK refrigerant sales by cylinder size

	Bulk (1 tonne / 15 tonne)	Large cylinder (60 kg)	Small cylinder (13 kg)	Disposable cans¹ (0.34 kg)
Mobile A/C	15%	5%	70%	10%
Stationary refrigeration	5%	25%	70%	0%
Stationary air conditioning	5%	5%	90%	0%

¹ these were banned in 2008, so after this date it is assumed that small cylinders are used instead

4.35.2.4 Emission Factors

Emission factors for each type of emission have been assessed in discussion with industry experts.

4.35.2.4.1 Cylinder filling

Emissions during cylinder filling are very low. Packer-fillers use sophisticated automatic filling equipment and have taken steps to minimise losses of refrigerant when a cylinder is connected or disconnected to filling equipment, including use of “gas drawback” systems to suck gas out of connecting pipework before they disconnect a cylinder after it has been filled. Packer-fillers estimate that the loss per charging operation is under 1 gram of gas in the most sophisticated facilities. Prior to 2006 it is likely that the emission rates were higher. An emissions factor of 10 grams per charging operation has been used in the period 1990 to 2000, tapering to 2 grams after 2008 (a conservatively high estimate).

4.35.2.4.2 Returned cylinder re-processing

All used cylinders have a heel of gas left in them. This is usually a small amount (e.g. well under 5% of full cylinder quantity) although in a few cases partially filled cylinders are returned with over 50% of the original quantity. Packer-fillers treat returned cylinders with great care, partly for environmental reasons and also because of the potential value of the returned gas. Packer-fillers use one of two methods to re-process returned cylinders:

- They “de-heel” each cylinder by transferring any remaining refrigerant into a large storage drum. When this drum is full it is tested for quality and then added to the main refrigerant bulk tank for use in filling new cylinders
- They “top-fill” a cylinder with the appropriate refrigerant, filling to the required total weight.

Packer-fillers indicate negligible losses from these processes (e.g. for top fill there is no emission other than that for cylinder filling). Conservatively the model uses 10 grams per de-heeling operation in the period 1990 to 2000, tapering to 2 grams after 2008.

4.35.2.4.3 Non-returnable cylinders

Any heel left in a non-returnable cylinder will be emitted e.g. from a landfill site or a waste metal reprocessing site. There is no data on the average heel size for non-returnable cylinders or small cans. Only a small proportion of UK refrigerant was sold in non-returnable packages in the period 1990 to 2008 and none after that date (due to the ban in the 2006 EU F-Gas Regulation⁷⁷ – maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006). The model assumes a 2% heel in small cylinders (approx. 0.25 kg) and a 10% heel in small cans (approx. 30 grams).

4.35.2.4.4 Cylinder use in the field

There are losses each time a cylinder is connected / disconnected to RACHP equipment during field installation or maintenance. The loss will depend on the care taken by the technician carrying out the filling operation. Refrigerant is lost from the connection hoses when a cylinder is disconnected. Technicians are trained how to use cylinders correctly (it is part of the mandatory F-Gas handling training specified in the 2006 EU F-Gas Regulation (EC 842/2006) and in the assimilated F-gas Regulation 2014 (EC 517/2014)⁷⁷, which revoked and replaced EC 842/2006) and part of the training specified by the assimilated Ozone Regulation 1005/2009). With best practice the losses are estimated to be in the range of 0.5 to 3 grams of refrigerant per filling event, assuming only refrigerant vapour is emitted. However, with poor practice some liquid refrigerant could be emitted – this could result in an emission of 50 to 100 grams per event. Discussion with experts has established that an average loss of 10 grams per event is reasonable for properly trained technicians (allowing for one in ten filling events to be poor practice). Prior to the introduction of mandatory training loss rates were higher – the model assumes 40 grams per filling event prior to 2001, tapering to 10 grams in 2008.

Some cylinders are used multiple times in the field e.g. a 15 kg cylinder could be used to add, say 5 kg to plant A, 1 kg to plant B etc. There is no detailed data available on average cylinder use patterns. Based on discussion with experts the model assumes 5 filling events per cylinder.

A high proportion of the emissions are from cylinder use in the field. There is a drop of field emissions in the period 2000 to 2008 due to the introduction of better training. There is a drop in filling / disposal emissions in 2008 due to the ban on non-returnable cylinders and cans.

4.35.2.5 Refrigerant handling by other organisations

In addition to the Fillers & Packers, Orbia Fluor & Energy Materials, an organisation involved in HFC manufacture (outside of the UK, and in the past within the UK too), processing and bulk transportation in the UK provides estimates of the HFCs and PFCs emitted as a result of refrigerant handling separately from emissions associated with halocarbon manufacturing.

It's likely that there is some overlap in scope with the modelled approach to total UK emissions due to the transportation of refrigerants. However, we know that some of the activities being conducted – like the refinement of HFC-134a to medical grade – are not considered in the transport of refrigerants model, so we include both to ensure completeness.

4.35.3 Uncertainties and Time Series Consistency

As discussed above, emissions in the field dominate the total. From 2009 the emissions from filling and disposal of cylinders are well under 10% of the total. There is a high confidence in the estimates for filling and disposal post-2009. Prior to 2008 the filling and disposal estimates have a lower confidence because of uncertainties regarding the quantity of refrigerant left in non-returnable cylinders/cans on disposal. There are significant uncertainties regarding cylinder use in the field. In particular, there is no data on the proportion of “poor practice” filling events or on the average number of filling events per cylinder.

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.35.4 QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.35.5 Source Specific Recalculations

There have not been any major recalculations to this sector this year.

For information on the magnitude of recalculations, see **Section 10**.

4.35.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.36 SOURCE CATEGORY 2G1 – ELECTRICAL EQUIPMENT

4.36.1 Source Category Description

Sulphur hexafluoride has been used in high and medium voltage switch gear and transformers since the mid-1960s. The physical properties of the gas make it highly effective as an arc-quenching medium and as an insulator. Consequently, it has gradually replaced equipment using older technologies, namely oil filled and air blast equipment.

Recently, alternatives such as fluoro-nitrile based blends (e.g. EconiQ a blend of CO₂, O₂ and a fluoro-nitrile with a GWP around 100 times lower than SF₆) are being commercially deployed as much lower GWP alternatives to SF₆ for many types of electrical insulation, including retro filling of SF₆-based systems in some cases. In December 2021 National Grid carried out a pilot project to deploy an alternative product at a substation⁸⁶. This was successful and further installations at voltages up to 400 kV are being deployed and will play a significant role in the operator's target to reduce SF₆ emissions by 50% by 2030.

4.36.2 Methodological Issues

A review of the data sources and methodology used to estimate emissions from electrical switchgear was carried out in 2013. Data is reported by the key UK users of Gas Insulated Switchgear (GIS), including National Grid and the UK electricity distribution companies via the electricity industry Regulator, Ofgem. Data was also obtained from ENA (Electrical Networks Association) and data for power stations that use relatively small amounts of SF₆ for switchgear from the environmental regulators' inventories (EA, NRW, SEPA and NIEA; all 2025). Since the introduction of the EU F-Gas Regulation in 2006⁷⁷, the UK electricity industry has made significant efforts to monitor and reduce consumption of SF₆.

The operator-reported annual data are used to estimate the size of the SF₆ bank in GIS and emissions for 2013 onwards. Estimates for 2008-12 are based on reporting from the National Grid and each of the distribution companies. Emissions from earlier years were estimated by extrapolating the data backwards, using the previously reported bank size in 1995 and 2000 and previously reported leakage rates.

4.36.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.36.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.36.5 Source Specific Recalculations

Recalculation due to revisions to Ofgem data from operators.

⁸⁶ <https://www.nationalgrid.com/national-grid-and-hitachi-energy-announce-world-first-collaboration-replace-sf6-existing-high>

For information on the magnitude of recalculations, see **Section 10**.

4.36.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.37 SOURCE CATEGORY 2G2A – MILITARY APPLICATIONS – AWACS

4.37.1 Source Category Description

Military applications include Airborne Warning and Control System (AWACS), which are military reconnaissance planes. In AWACS, the SF₆ is used as an insulating gas in the radar system.

4.37.2 Methodological Issues

Estimates for this source are based on data supplied by the MoD Defence Equipment & Support Secretariat (MoD, 2022). Data supplied includes:

- Measurements of SF₆ emitted from AWACS systems for 2016-2022
- Estimates of SF₆ emitted from AWACS systems based on logistic throughput for 2014 and 2015
- The number of AWACS active in the UK fleet for 1990-2021
- Confirmation that the fleet was sold in 2021, but that emissions continued in 2022 as part of training provided as part of selling the fleet

The estimates for 2014-2022 have been used directly in the NAEI for those years, and emissions are zero from 2023. For years prior to 2014, where measurements data are not available, an implied emission factor for SF₆ emissions per active AWACS has been determined using the data based on measurements and applied to the time-series of active AWACS.

4.37.3 Uncertainties and Time Series Consistency

Uncertainties for this source for recent years are low given the data received from the MoD on actual SF₆ data. Time-series consistency for earlier years is achieved by using MoD data on the number of active AWACS for each year since 1990 as a proxy for emissions in years where actual SF₆ data are available. Where data are available there are fluctuations in the levels of emissions as reported by the MoD, where emissions fall in 2022 reflecting that lower levels of emissions occurred for the final year that the systems remained in the UK before falling to zero in 2023.

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.37.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.37.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector.

4.37.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.38 SOURCE CATEGORY 2G2B – PARTICLE ACCELERATORS**4.38.1 Source Category Description**

Particle accelerators are used for research purposes (at universities and research institutions), for industrial applications (in cross-linking polymers for cable insulation and for rubber parts and hoses), and in medical (radiotherapy) applications.

Estimates of emissions in the UK are confined to those from research and university particle accelerators.

4.38.2 Methodological Issues

The emissions from industrial particle accelerators are a result of leakage during operation and repair. Research and industrial high voltage systems usually need to be opened more frequently than industrial low voltage accelerators. Hence the emission factor of low voltage industrial accelerators is comparably lower. In the case of radiotherapy applications, industrially pre-set particle accelerators with hollow conductors filled with SF₆ are used. The emissions of SF₆ are planned releases. Radiotherapy accelerators are typically opened two times a year when being serviced and the SF₆ contained is not captured but completely released. (Schwartz, 2005).

SF₆ emissions from research and university accelerators are estimated using an IPCC Tier 2 method – an accelerator-level emission-factor approach. This required information on the individual charge of the various research and university accelerators operating in the UK. This information is used in the following equation along with default emission factors (IPCC 2006):

$$\text{Total emissions} = \text{University and research particle accelerator Emission Factor} \times \sum \text{Individual Accelerator Charges}$$

Where:

SF₆ university and research particle accelerator Emission Factor = 0.07 kg SF₆ per kg SF₆ charge, the average annual university and research particle accelerator emission rate as a fraction of the total charge.

Individual Accelerator Charges = SF₆ contained within each university and research accelerator.

The SF₆ emissions from medical and industrial accelerators are estimated using a Tier 1 method – country-level method. Given the scale of the number of medical and industrial particle accelerators, it was not feasible to collect individual charge information of each accelerator. The Tier 1 estimation method consists of the following equation, which relies on default emission factors (IPCC 2006):

$$\text{Emissions} = (\text{number of particle accelerators that use SF}_6 \text{ by process description in the country}) \times (\text{SF}_6 \text{ charge factor, kg}) \times (\text{SF}_6 \text{ applicable particle emission factor})$$

Where:

Number of particle accelerators by type in the country = the total number of particle accelerators by type (industrial high voltage, industrial low voltage and radiotherapy)

SF₆ charge factor = the average SF₆ charge in a particle accelerator by process description.

SF₆ particle accelerator Emission Factor = the average annual SF₆ particle accelerator emission rate as a fraction of the total charge by process description. These factors are presented in **Table 4.27** below.

Table 4.27 IPCC default Tier 1 particle accelerator emission factors

Process Description	SF ₆ Charge Factor, kg	Emission Factor, kg/kgSF ₆ charge
Industrial Particle Accelerators – high voltage (0.3-23 MV)	1300	0.07
Industrial Particle Accelerators – low voltage (<0.3 MV)	115	0.013
Medical (Radiotherapy)	0.5	2.0

For the Particle Accelerators sector, ICF (ICF 2014) contacted the Science and Technology Facilities Council (STFC) and the Cockcroft Institute to gather activity data for the Tier 1 and Tier 2 methods. STFC and the Cockcroft Institute were able to provide ICF with the charge information, years of operation and status of usage of SF₆ in the research and university particle accelerators in the UK. It is assumed that the charges of the accelerators are constant for all the years. For one facility whose charge was unavailable, a default charge in Tier 1 was assumed.

The Cockcroft Institute also provided an approximate estimate of the number of low voltage industrial accelerators in the UK for 2012—approximately 100 (Cockcroft Institute 2013). The total number of medical accelerators for 2012 was estimated from a list of accelerators compiled by a member of STFC, estimated at 50 (STFC, 2013). Due to the large number of medical and industrial accelerators, collecting accelerator-specific charge data was not feasible. Therefore, a Tier 1 approach was used to estimate emissions. To confirm the number of accelerators, ICF also solicited information from the National Physical Laboratory and the Institute of Engineering and Technology, but without success. In the absence of specific information on the number or percent of medical particle accelerators that use SF₆, ICF conservatively assumed that 100% of UK medical particle accelerators use and emit SF₆. To estimate SF₆ emissions for years 1990-2011 and 2013 onwards, emissions have been scaled from the 2012 estimate based on historical UK GDP growth rates.

4.38.3 Uncertainties and Time Series Consistency

Emissions of research and university particle accelerators are very high for the period 1990-1992. This is because of the operation of the Nuclear Structure Facility that held 135 tonnes of SF₆ charge. After its closure in 1992 (assumed to be at the end of 1992), the emissions of research and university particle accelerators and medical and industrial accelerators are comparable. In 2004, the only operational particle accelerator ceased usage of SF₆ and, hence, the emissions are considered to be zero. Three other particle accelerators began operation in 2010, 2011, and 2012, respectively, leading to non-zero but small SF₆ emissions due to their small charges.

For the medical and industrial particle accelerators, the emissions rise as they were estimated based on GDP as proxy.

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

4.38.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.38.5 Source Specific Recalculations

There have been no major recalculations to emissions from this sector.

For information on the magnitude of recalculations, see **Section 10**.

4.38.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.39 SOURCE CATEGORY 2G2E – SF₆ AND PFCS FROM OTHER PRODUCT USE

4.39.1 Source Category Description

Emissions of PFCs and SF₆ from the production of semiconductors, and PFCs and SF₆ from sporting goods (training shoes) have been combined to preserve the confidentiality of estimates of emissions of SF₆ and PFCs used in training shoes. Emissions from the use of SF₆ as a tracer gas are also reported under 2G2Eii, and the methodology described in this section of the NID.

The semiconductors industry uses PFCs for:

- Cleaning of chambers used for chemical vapour deposition (CVD) processes;
- Dry plasma etching;
- Vapour phase soldering and vapour phase blanketing;
- Leak testing of hermetically sealed components; and
- Cooling liquids, e.g. in supercomputers or radar systems.

In addition, SF₆ is used in etching processes for polysilicon and nitride surfaces, and there is some usage of CHF₃ (also referred to as HFC-23), NF₃ and some other fluorine compounds.

In the semiconductor manufacturing process, the fluorinated gases (PFCs, SF₆, HFCs and NF₃) are mainly used as a source of highly reactive fluorine ions that are used in plasma etching and plasma cleaning. The stable fluorinated molecules are converted into a plasma (via high voltage electrical breakdown) and the majority of fluorine ions react with other materials to create stable molecules that are not GHGs. Hence emissions of the F-Gases are only a small proportion of consumption.

The UK uses of SF₆ as a tracer in scientific research.

A sports goods manufacturer selling shoes in the UK used SF₆ as a cushioning material in a range of training shoes from 1990 to 2003. Prior to 1990, the manufacturer used perfluoroethane (a PFC) for cushioning. SF₆ is well suited to this application because it is chemically and biologically inert and its high molecular weight means it cannot easily diffuse across membranes. This means the gas is not released until the training shoe is destroyed at the end of its useful life.

The manufacturer committed itself to eliminating SF₆ from its training shoes by 30 June 2003 – a goal which was achieved. It had originally planned to replace all SF₆ applications with nitrogen-filled cushioning, but technical difficulties mean it had to switch temporarily to perfluoropropane (a PFC) in some high-performance applications. The use of F gases in footwear was banned in 2006 by the F-gas Regulation (EC 842/006) and discussions with the

manufacturer have confirmed that they are no longer using PFCs or SF₆. (This ban was maintained in the assimilated F-gas Regulation 2014 (EC 517/2014)⁸⁷, which revoked and replaced EC 842/2006).⁸⁷

Cushioning units typically outlast the lifetime of the training shoe because the rate of diffusion of SF₆ is so slow. In the UK, training shoes are generally sent to landfill at the end of their useful lives, where any SF₆ or PFC will eventually leak to the atmosphere.

4.39.2 Methodological Issues

4.39.2.1 Semiconductor manufacture:

For the semiconductor manufacture sector, the methodology adopted follows the T2a approach described in Volume 3 chapter 6 of the 2019 refinement to the 2006 IPCC guidelines (IPCC 2019).

The 2019 refinement Tier 2a method is represented by equations 6.5-6.9 as follows:

$$E_i = C_i * (1 - U_i) * (1 - D_i)$$

$$BPE_k = \sum_i C_i * B_{k,i} * (1 - D_k)$$

$$EAB_{CF_4,i} = C_i * (1 - U_i) * (1 - \eta) * AB_{CF_4,i}$$

$$D_i = a_i * d_i * UT$$

Where: i = Input gas;

E_i = emissions of gas i (kg);

C_i = consumption of input gas i (kg);

U_i = use rate of gas i (fraction destroyed or transformed in process) (fraction);

D_i or D_k = Overall reduction of mass of gas i or k emissions;

k = By-product gas;

BPE_k = Emissions of by-product k generated from the conversion of all input gases (kg);

$B_{k,i}$ = Emission factor for by-product k generated from input gas i (kg of by-product gas k created per kg of gas i consumed);

$EAB_{CF_4,i}$ = Emissions of CF₄ from hydrocarbon-fuel-based combustion emissions control systems when direct reaction with hydrocarbon fuel and fluorinated species i is not certified not to occur by the emissions control OEM or electronics manufacturer (only for i = NF₃ used in remote clean process or F₂) (kg);

η = Ratio of emissions control systems certified not to form CF₄ within emissions control systems to the total number of emissions control systems in the facility (site-specific fraction);

$AB_{CF_4,i}$ = Mass fraction of i in process exhaust gas that is converted into CF₄ by direct reaction with hydrocarbon fuel and F₂ gas in a combustion emissions control system;

a_i = Estimate of the fraction of gas i emitted from process tools equipped with suitable emissions control technologies (site-specific fraction);

⁸⁷ As part of the process of leaving the EU, EU F gas legislation, including EC 517/2014, was assimilated into UK law with technical amendments made to ensure the legislation functions properly as UK domestic law.

d_i = Destruction Removal Efficiency (DRE) for gas i (fraction); and,

UT = Average uptime factor of all emissions control systems (site-specific fraction).

The 2019 refinement also sets out equations for determining a_i , and UT , but as the UK does not hold data that would be required to make these calculations but does have input from stakeholders on suitable assumptions for the equivalent to $(a_i * UT)$, these equations are not required for the UK approach.

4.39.2.1.1 Activity Data

Estimates of PFC used for the UK semiconductor industry in 2001 were provided by UK Microelectronics Environmental Advisory Committee, based on 2001 purchases of PFCs as reported by individual companies in the UK semiconductors industry. No suitable further activity data have been identified during consultations with relevant UK and EU trade bodies, although, UK industry have contributed to determining suitable estimates of the trends, including trends in total semiconductor industry trends, the relative use of different PFCs, and the installation of abatement technology (AEAT, 2004).

Specific trends which stakeholders have indicated include:

- A 3% growth rate in input gas per unit production required between 1990 and 1996;
- A -8% growth rate in CF_4 and C_2F_6 demand per unit production between 2005 and 2010 as part of a global semiconductor industry drive to reduce PFC emissions;
- The output of the sector has grown 15% per year between 1990 and 2000;
- The output of the sector contracted by 39% in 2001⁸⁸; and,
- Mixed assessments of how the sector will grow after 2003.

In addition to the 2004 study, more recent engagement with the UK trade association TechWorks, who represent all UK semiconductor manufacturers, has indicated that it is likely that the sector has contracted in recent years, and in 2023 a survey of operators was facilitated by TechWorks, which provided consumption of each F-gas for 2016-2021 (Gluckman Consulting, 2023). Not all semiconductor manufacturers engaged in the survey, but we estimate that those that did would represent 80% of F-gas use in the UK, and therefore activity data are uplifted to account for this.

When the uplifted 2023 data were compared with estimates previously extrapolated based on the qualitative information from stakeholders, we found very similar total CO_2e emissions estimates, although there were some significant differences in which specific substances were estimated to be used.

The uplifted 2023 survey data are used as the activity data for 2016-2021. Estimates for 2002-2015 are estimated by linear interpolation, and for 2022 onwards, activity is assumed to be constant at 2021 levels.

The NF_3 consumption has been divided into NF_3 remote clean and all other NF_3 consumption (i.e., for in-situ chamber clean and etch processes). NF_3 remote clean refers to a cleaning method for chemical vapour deposition chambers in which the film cleaning-agents formed from NF_3 (F-atoms) are produced in a plasma upstream (remote) from the chamber being cleaned. In situ chamber cleans are chemical vapour deposition chamber cleaning processes, which may use NF_3 or other F-gases to generate F-atoms in the chambers whose walls are being cleaned. NF_3 may also be used to etch patterns (i.e., circuits) on semiconductors. The use of NF_3 remote clean is assumed to start in 2003 and growing increasingly over time. As

⁸⁸ This reflects our understanding of the semiconductor industry over this period where there was a closure of several operators in the UK, particularly those linked to 'silicon Glen'. 'Silicon Glen' was the name given to a region in Scotland where the UK semiconductor industry was focussed, and after strong growth throughout the 90s, but many of these businesses closed in quick succession in the early 2000s in part triggered by the bursting of the dotcom bubble.

no data on the UK's use of NF₃ remote clean processes was made available from NMI, the US semiconductor market was used as a proxy to estimate the use of NF₃ in remote clean processes relative to all other processes.

Specifically, the share of NF₃ remote clean versus other uses was estimated based on industry reported NF₃ usage data from US semiconductor manufacturers for the years 2009 and 2010 (US EPA, 2011). This US data was readily available and is believed to be a good proxy for the UK given that semiconductor processes do not typically vary by world region. The ratio of NF₃ remote to other uses was interpolated for years between 2003 and 2010, assuming zero before 2003.

The final activity data assumptions used are summarised in **Table 4.28**.

Table 4.28 Summary of UK assumptions of activity data for semiconductor manufacture for early years

Year	Output growth rate	Input gas per unit production growth rate
1990-1996	15%	3%
1997-2000	15%	0%
2001	-39%	0%

4.39.2.1.2 Emission factors and other default factors

A summary of the model parameters used from the 2019 refinement to the 2006 IPCC guidelines Tier 2a method is provided in the table below. Values are taken from tables 6.7, 6.17 and page 21 of Volume 3, chapter 6.

Table 4.29 Summary of 2019 refinement Tier 2a model parameters for the semiconductor manufacture sector (kg per kg input gas)

Model Parameter ⁸⁹ (column headings are the input gas, <i>i</i>)	CF ₄	C ₂ F ₆	C ₃ F ₈	c-C ₄ F ₈	CHF ₃	NF ₃ Remote	NF ₃	SF ₆
(1 - <i>U_i</i>)	0.73	0.55	0.4	0.13	0.47	0.02	0.18	0.55
<i>B_{CF4,i}</i>	NA	0.19	0.2	0.099	0.082	0.034	0.067	0.12
<i>B_{C2F6,i}</i>	0.043	NA	0.000018	0.02	0.045	NA	0.014	0.095
<i>B_{C3F8,i}</i>	NA	NA	NA	NA	NA	NA	NA	NA
<i>B_{CHF3,i}</i>	0.04	0.002	0.000012	0.022	NA	NA	0.0068	0.0014
<i>AB_{CF4,i}</i>	NA	NA	NA	NA	NA	0.093	NA	NA
<i>d_i</i>	0.89	0.95	0.99	0.98	0.98	0.95	0.95	0.95

NA = Not Applicable.

The degree of abatement utilisation (equivalent to $a_i * UT$ as defined at the beginning of **Section 4.39.2.1**) has been estimated using information from stakeholders collected during the 2003 study (AEAT, 2003), specifically:

- Abatement was not used in UK operations until 2003;
- It is expected that all fabrication plants opened after 2003 will have abatement installed; and,
- Semiconductor fabrication plants have a lifetime of 25 years.

This allows us to model the turnover of semiconductor fabrication plants, and therefore the rate at which modern plants with higher degrees of abatement substitute legacy unabated plants. We are continuing to engage the UK semiconductors industry to understand how successful the sector were in having abatement installed in post-2003 plants, and in the meantime have made the conservative assumption that abatement is only applied to half of

⁸⁹ As defined at the beginning of **Section 4.39.2.1**

production at new fabrication plants. This means that we estimate that in 2002 $a_i * UT = 0$, and this increases over almost⁹⁰ 25 years to $a_i * UT = 0.5$

Due to the toxicity of NF_3 , it is assumed that all use of NF_3 is abated, i.e. $a_{NF_3} * UT = 1$.

4.39.2.1.3 Justification for using a 2019 refinement to the 2006 IPCC guidelines methodology

The conclusions and recommendations from the 18th meeting of greenhouse gas inventory lead reviews⁹¹ states in paragraph 12a that:

“...The LRs also noted that for categories and subcategories covered by the 2006 IPCC Guidelines, the ERT should review whether (1) the methodologies, emission factors (EFs) and/or assumptions taken from the 2019 Refinement or a country-specific approach based on or consistent with the 2019 Refinement are well documented, (2) the Party demonstrated that they better represent the national circumstances and justified their use in its NID, and (3) emission and removal estimates are accurate and time-series consistency has been maintained in accordance with the 2006 IPCC Guidelines...”

The UK believes that these are addressed in this case, as:

- (1) The methodology adopted is documented in the preceding sections
- (2) The 2019 refinement utilises more recent studies and understanding of emissions from this source and the methodology presented accounts for more features; we argue that means that the methodology should be better representative of UK emissions. The UK trade association TechWorks, who represent all UK semiconductor manufacturers, were engaged during the development of the UK implementation of the 2019 refinement approach, and there were not any more UK-specific parameters identified.
- (3) The methodology has been applied to the entirety of the time-series estimated, and activity data have been reviewed with stakeholder support to ensure that they are consistent and representative of UK trends.

4.39.2.2 Use of SF_6 as a tracer gas in scientific research:

SF_6 is used in the UK as a tracer gas to certify fume hoods and in studies of greenhouse gas emissions.

ICF investigated the use of SF_6 as a tracer gas to certify fume hoods, which is a practice established by ASHRAE in the test procedure ASHRAE-110, “Method of Testing Performance of Laboratory Fume Hoods” (ASHRAE, 1995). SF_6 is emitted in the fume hood and the concentration of the gas is measured after some time has passed. This is to ensure that the gases created under the fumes, toxic or otherwise, are properly ventilated. The amount of gas used per test is dependent on the tester. All of the SF_6 used in tracer tests is lost in the atmosphere and so the emissions are treated as prompt emissions—i.e., each test results in direct emissions of SF_6 (IPCC 2006). SF_6 is also used for tracer testing of nuclear power plant control room emergency ventilation systems (CARB, 2009).

Due to data limitations, SF_6 emissions were estimated using a slightly modified Equation 8.23 of Volume 3 of the 2006 GLs. The SF_6 emission is calculated on a per-use basis as opposed to the amount purchased/sold as provided in the equation. This modified method relies on the number of tracer tests conducted annually as the activity data, which when multiplied by the emissions per test as the emission factor, gives the total SF_6 emissions from this sector. This method is represented in the following equation:

⁹⁰ Because we model the sector to have contracted in 2001, we assume that there were not any new plants installed between then and 2003, meaning that it took less time for the oldest legacy plants to be replaced than might otherwise be expected.

⁹¹ https://unfccc.int/sites/default/files/resource/Conclusions%20GHG_LR%202021.pdf

Total emissions = emissions per test x number of tests

Additional emissions may also occur from bottling, leakage, and piping; however, such emissions cannot be estimated without activity data and are believed to be de minimis.

In order to apply the method above, ICF had to gather information on the number of tracer tests conducted annually (activity data) and the emissions per test (emission factor). ICF first identified various companies that performed fume hood tracer testing. ICF contacted the three largest companies that perform tracer tests in the UK (Crowthorne, Dale Flow, and Invent-UK) and obtained the company-specific emissions per test and the total number of tests performed in 2012 (Crowthorne 2013, Dale Flow 2013, Invent-UK 2013). For the prior years, the total numbers of tests have been estimated by scaling the number of tests performed in 2012 to the UK's historical GDP growth rate. The amount of emissions per test for prior years was held constant unless a company specified that the volume had increased after a certain period. The value of the emissions per test differed among companies and ranged from 0.033 to 0.046 kg SF₆ per test.

ICF also verified when these companies came into existence. Other, smaller companies were identified but were not contacted as—according to qualitative information from Dale Flow (2013)—the bulk of the market is covered by the three major companies, and any additional research was not expected to result in significant changes to the emission estimates, which only account for a very small share of total F-gas emissions.

ICF also contacted Sellafield Ltd, a nuclear decommissioning company, which uses SF₆ to conduct tracer tests, and included their company specific emission factor and total number of emissions (Sellafield, 2013).

Finally, ICF contacted the UK Nuclear Regulation Agency to confirm if there is any use of SF₆ in the tracer testing of nuclear power plant control room emergency ventilation systems in the UK. ICF was unable to obtain information because the inquiry did not fall within the remit of the Office of Nuclear Regulation/Health and Safety Executive. However, ICF experts believe that such use was replaced many years ago.

SF₆ has been used as a tracer gas in UK studies of greenhouse gas emissions from ruminant livestock. It is currently the only viable way to measure emissions of methane from ruminant livestock individuals at pasture (Defra, *per. comm.*).

A small charge of SF₆ is stored in a permeation tube, which is then introduced to the rumen of the animal. The gas emissions are vacuum sampled from eructation via a tube near the animal's muzzle connected to an evacuated flask. The total CH₄ emissions are inferred from the differential concentrations of SF₆ and CH₄ between the flask and atmosphere.

The total amounts of SF₆ used are given in the table below:

Table 4.30 Quantities of SF₆ used in scientific research

Year	kg SF ₆
2011	1.224
2012	1.433
2013	0.270
2014	0.273
Total	3.200

More details of the work can be found at www.ghgplatform.org.uk. This research project ended in 2014, so emissions from this source do not occur in 2015 onwards.

4.39.2.3 Use and disposal of training shoes:

Estimates of emissions from sports-shoes were based on a bottom-up bank model comparable to a Tier 2a method for emissions from fluorinated substitutes for ODS, using activity data supplied in confidence by the manufacturer.

A full description of the emissions and associated methodology used is contained in AEA (2004) and AEA (2008).

4.39.3 Uncertainties and Time-Series Consistency

Estimates of emissions in some categories of this sector are based on very limited and uncertain data and are therefore uncertain.

More information on uncertainty data used in the uncertainty analysis is presented in **Annex 2**.

4.39.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**. Details of verification of emissions are given in **Annex 6**.

4.39.5 Source Specific Recalculations

There have been no major recalculations to emissions from this sector.

For information on the magnitude of recalculations, see **Section 10**.

4.39.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.40 SOURCE CATEGORY 2G3A – MEDICAL APPLICATIONS

4.40.1 Source Category Description

This category includes emissions from N₂O used as an anaesthetic.

4.40.2 Methodological Issues

Emissions have been calculated using the outcomes of a study by NHS England (2013). This report calculates the total N₂O emissions based on the number of bed-days in NHS England 2011 – 2012, multiplied by the EU GHG inventory derived emission factor of 10.3 kg N₂O/bed/year⁹². This provides an estimated total N₂O emission of 1,641,147 kg per annum, arising from the use of anaesthetic at NHS England facilities. This is not the recommended methodology given in the 2006 IPCC guidelines, but as we have been unable to obtain the data required to follow the default methodology (sales of N₂O for anaesthetic use) this was considered the best approach to a country specific estimate for this source. Suppliers of N₂O for anaesthesia were contacted, but they declined to provide data.

In order to expand this figure to incorporate all emissions within the United Kingdom a per-capita N₂O emission of 0.031 kg per annum has been derived from the total N₂O figure provided in the Carbon Footprint report. This has then been applied to the total population for

⁹² <http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2013>

the England, Wales, Scotland and Northern Ireland to provide a complete time-series of emissions.

4.40.3 Uncertainties and Time Series Consistency

As the duration of a patient's hospital stay can vary considerably, the use of bed-days as an indicator of N₂O should be considered to have a high degree of uncertainty. The methodology doesn't take into account N₂O used in non-NHS hospital environments (for example dental and veterinary practices or private hospitals), however total emissions from these sources are estimated to be much smaller than the uncertainty in the conservative NHS estimate.

The time series estimate does not consider trends in the uptake of alternative anaesthetics or alternative approaches to applying N₂O as an anaesthetic, as some methods can reduce the consumption of N₂O. Though using population as an indicator of trend should well reflect demand for anaesthetics, it would not take into account changing practices. We also make the assumption that the rest of the UK consumes anaesthetic in the same way as England.

4.40.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

In the case of Gibraltar, we have actual data on N₂O imports for anaesthetic use for one year. When compared to the population of Gibraltar this yields an IEF of 0.015 kg per capita. In addition to providing robust data upon which to base Gibraltar emission estimates (using population data to generate a time-series), this improves our confidence that the UK estimate is of the correct order of magnitude.

4.40.5 Source Specific Recalculations

There are no major recalculations to this source for this submission. For information on the magnitude of recalculations, see **Section 10**.

4.40.6 Source Specific Planned Improvements

The inventory team will continue to search for data relating to the sales of N₂O for anaesthetic use and will make improvements to the methodology when this information is available.

4.41 SOURCE CATEGORY 2G3B – OTHER PRODUCT USES OF N₂O

4.41.1 Source Category Description

This category includes emissions from N₂O use as a propellant for whipped cream, and for recreational use of N₂O.

Very little UK data are available on the use of N₂O in cream products, therefore the approach adopted has been based on the method used in the Danish GHG Inventory (Hjelgaard, 2015). The method therefore assumes:

- 1% of cream consumption is in the form of whipped cream sprays;
- N₂O consumption in those sprays is equal to 5% of the mass of the cream; and
- All N₂O is emitted.

UK cream consumption data are available from Government (DEFRA) statistics (Defra, 2025).

Activity data on the number of adults using new psychoactive substances in the UK is available from 2012 in the Home Office Drug Misuse tables, which is now maintained by ONS (Office of

National Statistics, 2025b), whilst frequency of use is available only for financial years 2017/8, 2018/19, and 2019/20. It is therefore assumed that:

- The average frequency of use for 2017 to 2020 is appropriate for other years of the time-series;
- Each recorded use of new psychoactive substance amounts to 5 canisters;
- An N₂O cartridge contains 7.5g of N₂O and,
- All N₂O is emitted.

4.41.2 Uncertainties and Time Series Consistency

The UK method for cream consumption relies upon the assumption that UK consumption of whipped cream sprays is similar to that in Denmark i.e. 1% of total cream consumption. Overall cream consumption in Denmark and the UK are similar on a per-capita basis, but the market share of whipped cream sprays in the UK is not known, and so the 1% assumption is the most significant source of uncertainty for the UK estimates. The assumption regarding the 5% usage of N₂O relative to cream content is expected to be reasonable – there is no reason to think that the products sold in Denmark and the UK will differ significantly in design. UK cream consumption data are available for the full time-series from 1990 onwards.

The UK method for recreational use of N₂O relies on the assumptions that the canister volume and pressure are similar to those used in the whipped cream industry in the absence of more robust data.

Activity data on the number of adults who use new psychoactive substances is available on an annual basis since 2012 with some gaps. In these cases, the number of adults is gap-filled by interpolation of the surrounding years. Prior to 2012, no data is available. In these years, the Inventory Agency believes that the level of emissions will not exceed the value of 2012 and therefore are insufficient to demand estimates are made, and therefore are recorded as “Not Estimated”.

4.41.3 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

4.41.4 Source Specific Recalculations

There are minor recalculations for the recreational use of N₂O related to data revisions to the statistics used, and the replacement of extrapolated data with actual data for 2023.

For information on the magnitude of recalculations, see **Section 10**.

4.41.5 Source Specific Planned Improvements

No improvements are planned.

4.42 SOURCE CATEGORY 2G4 – CHEMICAL INDUSTRY – OTHER PROCESS SOURCES

4.42.1 Source Category Description

This category reports N₂O emissions from the chemical industry that are not captured elsewhere. All chemical sites reporting significant N₂O emissions are included where that emission is believed to be from a chemical process, rather than combustion. Other sites do report N₂O emissions, but those are small, and there is no evidence that they are from chemical

processes. As such, the estimates reported in 2G4 are thought to be complete. Emissions from nitric and adipic acid are not included here, as these are reported in 2B2 and 2B3.

4.42.2 Methodological Issues

The UK has a large chemicals sector and all manufacturing sites are regulated and required to report emissions of N₂O (as well as other pollutants). From 1998, when reporting was first required, until 2001 there was no threshold for reporting N₂O, but since 2002, reporting is required only when emissions exceed 10 tonnes. Across the time-series, N₂O emissions have been reported in at least one year for about 30 sites permitted by the EPR which could include chemical manufacturing. For most of those sites, N₂O is reported for only one or two years out of the time-series and we think it is likely that the reported N₂O is an error (operators do occasionally confuse N₂O and NO_x on their reporting submissions) and in a few other cases it is likely that the N₂O occurs from the substantial combustion processes that constitute part of the reporting installation. In four cases however N₂O is reported in multiple years, from processes which are either known to emit the gas, or thought to be the most likely source:

- A process to manufacture nitrous oxide, and to transfer it into gas cylinders for sale. This process was commissioned in 2004;
- A process manufacturing industrial gases, which probably also supplied nitrous oxide in cylinders and which closed in 2008;
- A process manufacturing pharmaceutical products. This process has been in operation since at least the early 90s; and,
- A catalyst manufacturing process which involves dissolving metals in nitric acid, leading to emissions of oxides of nitrogen (including both NO_x and N₂O). This process has been in operation since the 1940s.

Emission estimates are based on the data reported by the process operators to the Environment Agency for inclusion in the Pollution Inventory (PI). A gap in the reported data for the first site listed above (for 2004) is filled by assuming that operation started half-way through the year and that emissions were 50% of the level reported in 2005. The second plant only reports N₂O back to 2002, but reports NO_x in 2002 as well, and also in 1997-2001. Emissions of N₂O in the years 1997-2001 are therefore assumed to follow the same trend as for NO_x back to 1997 and to be at 1997 levels prior to that. Emissions for the third site for 1990-2005 are assumed to be the same as 2006, i.e. the earliest year where nitrous oxide emissions are reported, and for 2013 onwards, emissions have been below the reporting threshold, so we have conservatively assumed that emissions were at the reporting threshold. Emissions for the fourth site for the years 1990-1997 i.e. before reporting of N₂O was required, are assumed to follow the same trend as emissions of NO_x, which is reported back to 1995, and to be the same as in 1995 before that. Using this approach suggests that emissions from this plant were about 2 times higher in 1990 than in 1998, when data are first reported.

4.42.3 Uncertainties and Time Series Consistency

Gaps in the PI data for the three sites is the most significant source of uncertainty in the estimates. It is possible that other sites that report N₂O emit the gas from chemical manufacturing processes but if this were the case, these emissions would be smaller than those from the three sites currently included.

4.42.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the inventory in **Annex 4** and the source emissions data from plant operators is subject to the QA/QC procedures of the PI.

4.42.5 Source Specific Recalculations

This year's submission features two notable recalculations to 2G4. One is that for one of the previously included sites it has now been determined that the emissions were actually of NO_x rather than N₂O and have therefore now been removed. This site was only in operation since 2021 and accounted for around 4% of the emissions from this sector for 2021-2023.

The other recalculation is due a methodology improvement for the monitoring of N₂O emissions from one of the sites. As part of the compilation of the 2025 submission it was noted that the data in the PI for one site was notably higher in 2023 than in previous years. After consultation with the Environment Agency it was determined that the 2023 value was legitimate and as such to ensure consistency we applied an uplift to the historical data for that site. In this year's submission we have received revised figures for the historical data from the operator themselves which we are now using. The impact of this is an increase of 0.23 MtCO₂e in 1990 and an average increase of around 0.1 MtCO₂e across the rest of the timeseries (no change in 2023). For information on the magnitude of recalculations, see **Section 10**.

4.42.6 Source Specific Planned Improvements

The estimates will be kept under review, and additional sites added if appropriate.

4.43 SOURCE CATEGORY 2H1 – PULP AND PAPER INDUSTRY

4.43.1 Source Category Description

The UK paper industry is mainly confined to the production of pulp from recycled material and the production of papers using imported virgin pulp, recycled pulp or a combination of the two. Production of virgin pulp is limited to a few processes producing mechanical or neutral sulphite semi-chemical pulp. Emissions from UK paper processes consist largely of emissions from the associated combustion processes and these are reported under CRT category 1A2d. Other emissions of GHGs from UK paper and pulp processes will be minor and are not estimated.

4.44 SOURCE CATEGORY 2H2 – FOOD AND BEVERAGES INDUSTRY

4.44.1 Source Category Description

Food and drink processes will use fuels and emissions from this fuel use are reported in 1A2e. No process emissions of GHGs have been identified, however.

5 Agriculture (CRT sector 3)

5.1 OVERVIEW OF SECTOR

CRT Categories Included	3A: Enteric Fermentation 3B: Manure Management 3D: Agricultural Soils 3F: Field Burning of Agricultural Residues 3G: Liming 3H: Urea application
Gases Reported	CO ₂ , CH ₄ , N ₂ O, NO _x , CO, NMVOC, SO ₂
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	3A: Enteric Fermentation - CH ₄ (L2, T1, T3) 3A1: Enteric fermentation from Cattle - CH ₄ (L1, T3) 3A2: Enteric fermentation from Sheep - CH ₄ (L1, T3) 3B1: Manure management from Cattle - CH ₄ (L1, T3) 3B2: Manure Management - N ₂ O (L1) 3D: Agricultural soils - N ₂ O (L1, T1, L2, T2, T3)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .
Completeness	A general assessment of completeness for the inventory is included in Section 1.7
Major improvements since last submission	Re-parameterisation of the dairy cow mature liveweight. An adjustment to the assumed metabolisable energy density of grazed grass in sheep. Updated amount of manure destined for anaerobic digestion Representation of long-term genetic gain in grass yields and nitrogen uptake. Introduction of a new source of ammonia deposition (from crop residues), leading to greater indirect N ₂ O emissions. Revisions to urea-based fertiliser use. Update of surveyed fertiliser use for Northern Ireland in the year 2023.

In the agriculture sector, the UK reports emissions from the following categories: enteric fermentation (CH₄) (Table 3A), manure management (CH₄, N₂O) (Table 3B), agricultural soils direct and indirect (N₂O). These categories include synthetic fertiliser, manures and digestates applied to soils, urine and dung deposition during grazing, sewage sludge, mineralisation, crop residues, histosols (only direct) (Table 3D); urea application (CO₂) (Table 3H); liming (CO₂) (Table 3G). Emissions from fuel use on UK farms are reported in the Energy sector.

Emissions from rice cultivation (Table 3C) and land burning (Table 3E) do not occur in the UK, and field burning of crop residues (Table 3F) only occurred and is reported until 1993.

Emissions of other pollutants reported include NMVOCs, NO_x and PM (Tables 3B and 3D).

5.1.1 Agriculture Emissions in the UK Inventory: Trends and drivers

The UK total emissions from agriculture have decreased since 1990 (Figure 5.1) with a reduction of 19.7% between 1990 and 2024 and 2.5% between 2023 and 2024.

Emissions of CH₄ were the largest contributor to total emissions in 2024 (66.6%) followed by N₂O (29.9%) and CO₂ (3.5%) (Figure 5.2).

Key events and drivers of UK agriculture emission trends include the following:

- Long term trends are primarily impacted upon by the key underlying activity data such as livestock numbers and crop production across the UK;
- The 2001 UK foot and mouth crisis led to the culling of large numbers of livestock (6.5 M animals) to mitigate the spread of the disease, resulting in a significant short-term decline in livestock numbers.
- Other livestock diseases, such as bird flu, with several outbreaks in 2021, 2022, and 2024 resulting in culling of large bird populations.
- Annual fertiliser application rates and associated emissions are strongly affected across the time series by periods of poor weather, most commonly when the UK experiences very wet autumn/winter weather, inhibiting the sowing of winter crops and lowering the fertiliser application overall. This explains the lower agricultural soil emission of nitrous oxide from inorganic fertiliser application in years including: 2020, 2013, 2001 and 1993. In all cases the fertiliser rates declined and then recovered the following year.
- In recent years, higher energy prices have increased the price of fertiliser production, leading to higher costs of inorganic fertilisers to farmers. The UK inventory trends reflect that there has been a consequent shift by some farmers to use more urea-based inputs and less inorganic fertiliser use due to these higher costs of inorganic fertilisers.
- Changes in organic fertilisers, for example an increase in the production of digestate from anaerobic digestion plants. Also, changes in manure management, particularly due to the implementation of UK or devolved government policies such as the requirement of covers in slurry tanks (Nutrient Action Programme Regulations in Northern Ireland).
- Differences in data collation and management at regional level

Figure 5.1 Time series 1990-2024 of CH₄, N₂O and CO₂ emissions from the Agriculture sector in the UK inventory

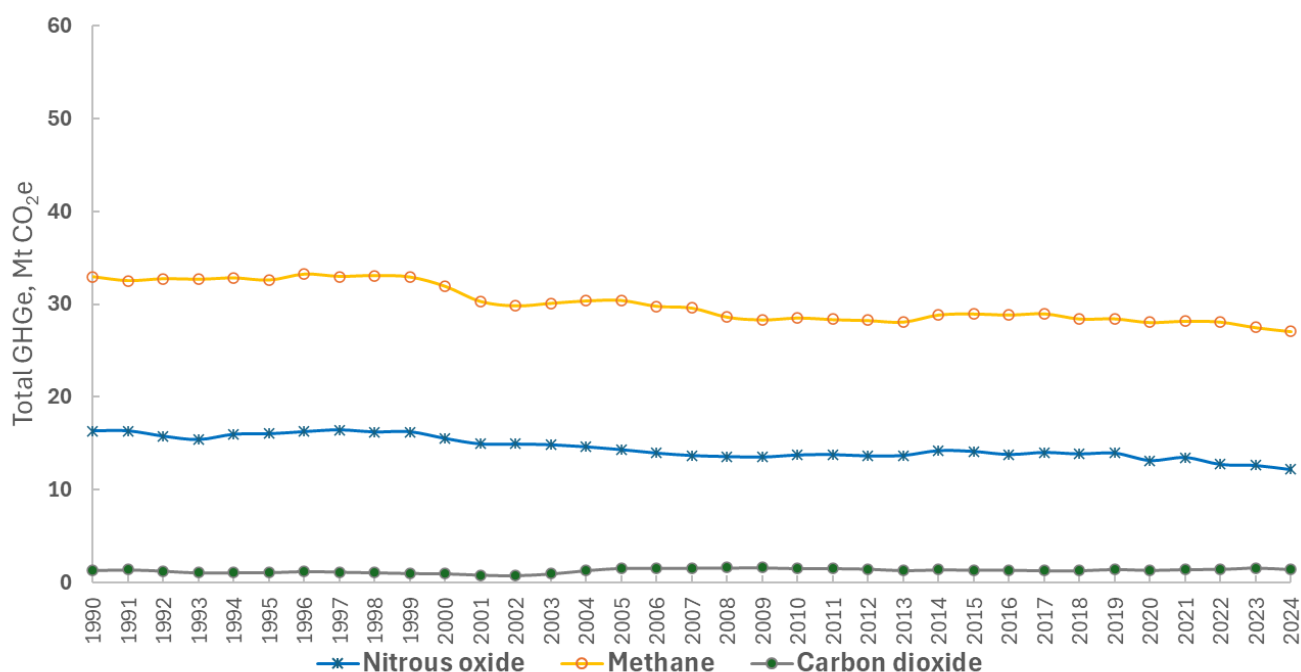
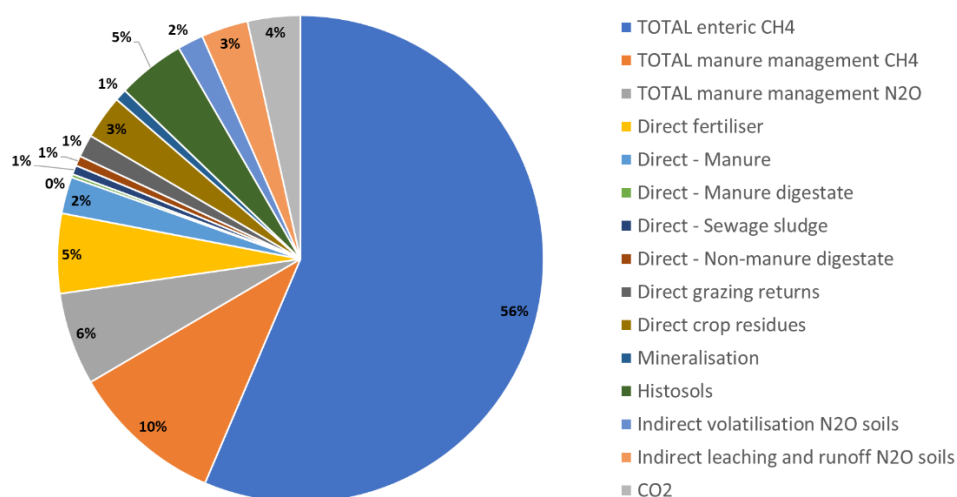


Figure 5.2 Contribution (%) to the UK agricultural GHG inventory from all sources in 2024. Total emissions 40.67 MtCO₂e.



5.1.2 Agriculture Inventory: National System, Stakeholders and Management of Improvements

The UK agriculture inventory of GHGs and ammonia is managed by the UK Department of Environment, Food and Rural Affairs (Defra), which is the UK Government department with policy responsibility for farming, food standards and air quality (AQ) emissions. The inventory is used as a reporting mechanism for UK, England and devolved government emissions, as well as to underpin emission projections and policy scenario analysis. As such, it is developed and managed via a network of stakeholders to identify new / emerging data, to keep pace with UK, England and devolved government regulations, farm practices, mitigation actions, scientific and policy research.

Defra funds the compilation and reporting of the agriculture GHG and ammonia inventory via a multi-year contract, managed by ADAS (from August 2023). The outputs are incorporated into the wider UK GHG inventory via the National Atmospheric Emissions Inventory (NAEI) database, which is managed by the UK Department of Energy Security and Net Zero (DESNZ). DESNZ is the UK's Single National Entity for GHG submissions to the UNFCCC. The Defra-funded agriculture consortium sector experts compile and report emissions for the Agriculture sector, whilst the DESNZ-contracted Ricardo consortium is the Inventory Agency overall and compiles the GHGI for other sectors.

The process for inventory review, identification of new data and method improvements, prioritisation and implementation, compilation and reporting involves a range of stakeholders. This can be summarised as follows:

- **January to March:** The inventory consortium conducts a post-submission review of the latest compilation cycle, including to consider findings from latest UN and other reviews and from engagement with research and industry contacts (e.g. academic researchers, Agricultural Industries Confederation (AIC), Defra policy leads). The team identifies new data and/or methodological improvement options, prioritising key source categories, sources of high uncertainty and sources where mitigation actions are planned or implemented and not currently represented in the inventory. In the latest cycle, some elements of this process have been formalised via the creation of two agriculture-focused expert groups:
 - The **Technical Advisory Committee (TAC)** is a group of leading UK academic researchers with expertise across the range of emission sources from the sector, including from livestock, soils, manure management. The TAC meets once per year, typically in February, and provides technical support and steering to the inventory consortium. The primary activities are: (i) communication of latest / ongoing research studies, to help identify potential future inventory improvement opportunities, (ii) critical review and feedback upon any ongoing or recently completed agriculture inventory improvements, and (iii) where necessary, the TAC may provide or recommend expert peer reviewers to support inventory improvement studies.
 - The **Defra and Devolved Government steering group**. Defra has formalised a steering group to bring together agriculture statistics, science and policy leads from within Defra and the devolved governments of Wales, Scotland and Northern Ireland, to act as an agriculture sector forum to support the work of the inventory consortium. The steering group meets typically twice per year, once usually in March, and again ahead of the autumn meeting of the National Inventory Steering Committee (NISC) in November. The steering group helps to identify and prioritise inventory improvements (in March) and then reviews the implementation of inventory data, methods and improvements (in November).
- **April to May:** Following consultation with the TAC and Defra/DG steering group, the inventory consortium presents priority inventory improvements to the NISC, advisory and

executive stakeholders, i.e. across industry and Government; through discussion at the NISC, the highest priority improvement actions are identified for implementation in the next inventory cycle. At this stage, the inventory team specifies data requirements, key stakeholders and (where necessary) any peer review function to support the research.

- **June to October:** The team seeks to access new data and research, consult stakeholders (e.g. AIC, Defra, devolved governments of Scotland, Wales and Northern Ireland) develop new methodologies, and where necessary consult with peer reviewers (UK, international) to test and refine the new methods; this process includes consideration of potential cross-sectoral impacts (where appropriate) and communication with other inventory experts (e.g. waste, bioenergy, LULUCF). Where there are also impacts on AQ pollutant emissions, e.g. ammonia, consultation is undertaken with the Defra-led Air Quality Inventory Steering Group which comprises AQ modellers and researchers.
- **November to December:** The Inventory Agency prepares documents to share with the NISC (Advisory panel) in late November as part of the pre-submission review process for the UK inventory, to present the new data / methods and the impacts on level and trend of emissions, to outline uncertainties and any next steps. The NISC Executive then meets to consider the improvement and sign it off or indicate that further work is needed prior to acceptance within the UK submission.
- **January to March:** The Inventory Agency finalises the UK agriculture inventory submission, i.e. updates the UK inventory central estimates and uncertainty analysis and then starts again with the post-submission review.

5.1.3 The UK Greenhouse Gas Inventory Model for the Agriculture sector

This section provides an overview of the UK GHGI model for agriculture; for more details on the model, please see **Annex 5.1 Section A 5.1.3.6**.

The UK Government funded a major programme between 2011 and 2017 to substantially improve the calculation methodology, emission factors and sector representation in the estimate of GHG emissions for the agriculture sector. This culminated in the development of a sector-specific model with a fully revised structure to enable representation of the key underlying driving variables of the GHG emissions, including soils, climate, livestock and cropping characteristics and farm management practices including the uptake of specific mitigation methods. The model also includes detailed representation of uncertainties, allowing full uncertainty analyses to highlight areas for future improvement. The UK inventory undergoes continuous improvement to reflect developments in source data and scientific understanding, for example when inventory guidance is updated to improve methods, new EFs or to add new emission sources. The inventory improvements are documented in the relevant sections below.

5.1.3.1 Model description

The agriculture sector model is written in C#, calling on a SQL server database, using stored queries. The coded model covers the major sources of the agriculture sector with a separate module for each source, drawing on source-specific input tables and generating source-specific output tables, including for:

- enteric CH₄ emissions,
- manure management CH₄ and N₂O emissions from Dairy, Beef, Sheep, Swine, Poultry, Goats, Horses and Deer;
- direct and indirect N₂O emissions from synthetic N fertiliser, organic N (e.g., animal manure, sewage sludge and digestate) applied to grassland and arable crops, and crop residues;

- N₂O emissions from urine and dung N deposited on pasture from Dairy, Beef, Sheep, Swine, Poultry, Goats, Horses and Deer.

N₂O emissions from mineralisation and histosols and CO₂ emissions from liming and application of urea to soils and NMVOC emissions from rough grazing are estimated using simpler Excel spreadsheet models.

Data are collated and calculations performed by year (from 1990) and by country (England, Wales, Scotland and Northern Ireland) at a 10 x 10 km grid cell resolution, the results being aggregated across the four countries to derive UK totals. The choice of grid size reflects uncertainty in agricultural holdings that are variously geo-referenced by parish, holding office or field centroids, but is principally justified by the confidentiality restrictions placed on the mapping of inventory input and output datasets.

5.1.3.2 Activity data handling

When there are data gaps for one historic year in livestock numbers or crop areas, holding level data for an adjacent year are used. If no data are available for the current submission, an extrapolation using the time series trend, or the same data from the previous submission may be used, this would be described under the relevant sector. Scaling factors are applied where necessary to ensure that the sum of all holding level data equates with the official statistics for national totals, for a given category. For example, if the sum of all holding level data (of a given category) is 100, and the official statistic reported national total is 101, a scaling factor of 1.01 would be applied to all holding values (to ensure the holding level data matches national totals).

5.1.4 General sector characteristics

Activity data that apply to more than one source category are: (i) farm types (**Section 5.1.4.2**); (ii) livestock types and numbers (**Section 5.1.4.3**); (iii) crop types and crop areas (**Section 5.1.4.4**); (iv) fertiliser types and application rates (**Section 5.1.4.6**). These are described in this section and are referred to in the relevant sections throughout this chapter. The data relevant to the calculation of emissions from crop residues are described in **Section 5.1.4.5**. The emission factors used to estimate N₂O emissions from synthetic fertiliser applications to soils are determined via an empirical model that relies on environmental factors and is described in **Section 5.1.4.8**.

Year-specific activity data and EFs are provided in the Annex document and supplementary tables as Excel files, respectively: Supplementary file EFs UK inventory agriculture_1990-2024.

A full uncertainty analysis is conducted using Monte Carlo simulation based on probability distribution functions for all key model input parameters and variables. This is not run annually because of resource implications (long model run times) and there is little change in results between years. The Monte Carlo approach is therefore run approximately every 5 years, or when significant methodological changes are introduced to the model. For the years in between we assume the uncertainty to be similar to previous years and simply offset the uncertainty distribution to align with the revised expected value. This was the case for the 1990-2024 inventory for which no significant methodological changes occurred. Further details of the uncertainty analysis for this submission are in **ANNEX 2**

5.1.4.1 Soils and climate

Soil properties, notably field capacity, plant available water and percent clay and organic carbon content are used as input to inventory calculations of grass growth and N leaching following application of fertilisers, managed manures and excreta returns. The improved inventory uses the RB209 (MAFF, 2000) soils classification, based on soil texture and depth to rock, with seven soil types (light sandy, shallow, medium, deep clay, deep fertile silty, organic, peaty). For each country, soil scientists from the James Hutton Institute (Scotland),

National Soils Resources Institute University (England and Wales) and the Agri-Food and Biosciences Institute (Northern Ireland) applied the RB209 soil typology to national digital soils datasets. The resulting United Kingdom map of RB209 soil types was spatially intersected with the reference 10 by 10 km grid to provide a statistical summary of the percent of the agricultural land area located on each of the RB209 soil types. The same national digital soils datasets were also used to calculate the percent of the soil area within each grid cell (excluding peaty soils) that is alkaline, based on top-soil measurements of pH (≥ 7), which is used in calculations of ammonia emissions from synthetic fertilisers.

Long-term annual and monthly average rainfall and air temperatures were obtained under project license from the Met Office. Met Office UKCP09 baseline average datasets are for the period 1981 to 2010 (Jenkins et al., 2008). The data were made available at a 5 by 5 km resolution and summarised to the reference 10 by 10 km grid cell. Daily time-series of measured rainfall derived from the UK synoptic network for the MORECS model (Hough and Jones, 1997) were obtained under project licence from the Met Office. Time series for the period 1981 to 2010 were made available at a 40 by 40 km resolution. The probabilities of more than 5 mm of rainfall falling in 24 hours within 1 to 6 days (or more) of a N application to land (used in calculations of ammonia emissions from synthetic fertilisers), occurring with equal probability on each day of the year, were calculated for each of the MORECS grid squares. The resulting probabilities were correlated with annual rainfall and downscaled to the reference 10 by 10 km grid cell.

5.1.4.2 Farm types

Farm types may be associated with specific structures and practices (from survey data stratified by Farm Type) which can be used to provide better representation in the emission calculations. The classification of agricultural holdings by Farm Type as used in the UK inventory is based on the method described in the EC typology book ([EC typology handbook](#)). It is based on the type of farming and economic size, determined on the basis of Standard Output (SO) coefficients and structural information (area of crops and number of heads of livestock) of the various types of agricultural production. Ten robust farm types (RFT) are applied at England and devolved government level (Wales, Scotland and Northern Ireland): (1) cereals; (2) general cropping; (3) horticulture; (4) specialist pig; (5) specialist poultry; (6) dairy; (7) grazing livestock (LFA); (8) grazing livestock (lowland); (9) mixed; (10) other.

5.1.4.3 Livestock types and numbers

There are eight livestock categories in the UK inventory: dairy cattle, beef cattle, sheep, swine, poultry, goats, deer and horses. The June Agricultural Survey (JAS) data (Defra, 2025a) provide a number of sub-categories within the major livestock categories (dairy and beef cattle, sheep, swine, poultry), which are used as the basis for subsequent emission calculations. Since 2005, Cattle Tracing Scheme (CTS) data from the British Cattle Movement Service (Jon Ellerbeck (2025) of APHA and BCMS, 2024) are used to provide further detail of all cattle across England, Wales and Scotland, based on analysis of cattle movement records. In the case of Northern Ireland, the data are provided by DAERA (DAERA, 2024).

Actual subcategories included in the JAS vary across years and countries, so standard methods for category aggregation (or occasionally disaggregation) have been developed to provide a consistent set of livestock categories across all countries and years, in accordance with the approaches set out in the individual livestock sector methodologies derived in Defra AC0114 GHG platform project for GHGI data management (Ulli Dragosits and Steven Anthony, 2016). All livestock are associated with a holding, located within a 10 by 10 km grid cell, and with a Farm Type. For animals which are present for less than 1 year (e.g. broilers, finishing swine, lambs) the survey data are assumed to represent the number of animal places and all subsequent calculations are performed on an animal place basis (e.g. N excretion calculations will account for the number of crop cycles within a year for broilers). Note that for animals which

are present for less than 1 year (e.g. broilers, finishing pigs) and as the survey data represents a screenshot of one day in the year, the value corresponds to a statistical estimate of the average number of 'occupied' places – and estimates of excretion, emissions per animal etc need to treat it accordingly. This can be conducive of errors in these particular livestock sectors. More details of individual sector structure are given below, also in the Annex document: JAS pre-processing and RFT calculation (1990-2024).

5.1.4.3.1 Dairy Cattle

For the purposes of inventory calculations, dairy cattle are disaggregated into three production/breed types (large, medium, small), associated with different average milk yields for each year (high, medium, low) and into four sub-categories by age and physiological status (dairy calf < 1 year, dairy replacement > 1 year not in calf, dairy replacement in calf, dairy cow). Data have been derived from the CTS (BCMS, 2024) at a monthly resolution for England, Wales and Scotland since 2005. Each animal is categorised by breed, gender, age and parity (if relevant) and associated with a holding. Breed is associated with a role (dairy, beef, dual purpose). All dairy females are included in the dairy sector; bulls used in the dairy sector and replacements for adult bulls are included with all other bulls in the beef sector. This is because of the difficulties of differentiating bulls between the sectors and thus ensures complete reporting of total emissions from UK agriculture. Dual purpose animals are assigned as dairy or beef according to the majority cattle type on the specific holding. Each breed type is associated to one of the inventory categories of large, medium or small.

For the years prior to the introduction of the CTS in England, Scotland and Wales (1990-2004), and for Northern Ireland for the entire timeseries, annual data were derived from the JAS at holding level. Monthly cattle numbers for these years are assumed to be equal to the annual JAS total. Dairy industry data were used to characterise the proportion of dairy cattle associated with each production system for pre-CTS years, i.e. 1990 to 2004 for England, Wales and Northern Ireland. Breakdown of dairy cow breed types for 1990 was derived from Dairy Facts and Figures, 1992 (Milk Marketing Board), with the breeds being associated with the inventory production system categories. Data for 1991 to 2005 were interpolated between Dairy Facts and Figures for 1990 and CTS data for 2006 onwards. Straw use is a fixed quantity per head based on survey data⁹³.

5.1.4.3.2 Beef cattle

Beef cattle are disaggregated into 15 age bands, four breed types (continental, lowland native, upland native and all dairy males) and six sub-categories by role, associated with different live weights, growth rates and management practices. The roles include heifers for breeding, beef females for slaughter, bulls for breeding, cereal fed bulls for slaughter, steers for slaughter and beef cows. Data from the CTS (BCMS, 2024) are used to populate the inventory categories at a monthly resolution for England, Scotland and Wales from 2005 onwards. Prior to this date, JAS data are used with monthly population scalars applied as derived from the period 2005 to 2009 when both CTS and JAS data were available. For Northern Ireland, JAS data are used for the entire time series. Straw use is a fixed quantity per head based on survey data.

5.1.4.3.3 Sheep

Sheep are disaggregated into three production systems (hill, upland and lowland) associated with different livestock parameters and management practices, and three types (ewe, lamb and ram) using data from the JAS (Defra, 2025a), the December Agricultural Survey (1993 to 2010), a specific survey on the disposal of lambs and their slaughter age from the United Kingdom sheep flock (Wheeler et al.; 2012) and the occasional surveys of the Breeding

⁹³ <https://www.planet4farmers.co.uk/Content.aspx?name=PLANET>

Structure of the British Sheep Industry (Maniatis and Pollott, 1998; Pollott and Stone, 2006; Pollott, 2012; and Pollott and Boon, 2021).

The ewe category includes replacement breeding sheep and cull ewes, as well as the ewes and ewe lambs that were successfully lambed in the survey year. The lamb category includes slaughtered lambs and those retained for breeding. The proportions of replacement ewes that are first mated as ewe-lambs is based on an analysis of an extended time-series from the December Agricultural Census (1993 to 2010), that was verified against the latest Breeding Structure of the British Sheep Industry survey (Pollott and Boon, 2021).

The JAS count of lambs is raised in England, Wales and N Ireland by 5%; and Scotland by 1%.to account for the fraction of early spring lambs that are born, reared and marketed before the survey takes place (Pollott and Stone, 2006; Wheeler et al., 2012; Pollott and Boon, 2021).

Animal numbers are split between hill, upland and lowland systems (associated with breed and management practices), based on holding location with respect to the Less Favoured Areas (LFA) weighted by survey data from Wheeler et al. (2012), and verified against historical records of payments made under the Hill Livestock Compensatory Scheme (Agricultural Notebook, 2003). For each system, the proportions of lambs finished at grass, finished as stores, or used for breeding replacements, are derived from analyses of the survey data collected by Wheeler et al. (2012), and verified against the occasional surveys of the Breeding Structure of the British Sheep Industry (Maniatis and Pollott, 1998; Pollot and Stone, 2006; Pollot, 2012; and Pollot and Boon, 2021).

Bedding straw use in housing is calculated from how much urine an individual sheep produces, and the quantity of straw that is required to absorb the urine, based on absorbance measurements reported by Misselbrook and Powell (2005) and Olson (1940).

5.1.4.3.4 *Swine*

Six categories of swine are included: (1) sows (including sows in pig, sows being suckled and dry sows being kept for further breeding); (2) gilts (including gilts in pig and gilts not yet in pig); (3) boars for service; (4) fattening swine >80 kg (including barren sows for fattening); (5) fattening swine 20-80 kg; (6) fattening swine <20 kg. Data are obtained from the JAS (Defra, 2025a) for England, Wales, Scotland and Northern Ireland, and where JAS categories do not match the inventory categories, consistent data translation rules are applied from the Defra AC0114 project (Ulli Dragosits and Steven Anthony, 2016). The JAS has not collected information on all fattening pig sizes since 2009, estimates of the proportions are based on earlier census returns in every year since. The format of the census also changed in the 2024 submission with a new explicit accounting for weaners.

5.1.4.3.5 *Poultry*

Eight categories of poultry are included: (1) growing pullets; (2) laying hens; (3) breeding flock; (4) broilers; (5) turkeys; (6) ducks; (7) geese; (8) all other poultry (exc. turkeys, ducks and geese). Data are obtained from the JAS (Defra, 2025a) for England and the DGs, and where JAS categories do not match the inventory categories, consistent data translation rules are applied from the Defra AC0114 project (Ulli Dragosits and Steven Anthony, 2016). Data for England & Wales in 1996 were missing from the agricultural census (holding level) data and have been recreated by scaling these at a holding-level with the 1995 census to national totals.

5.1.4.3.6 *Goats, deer, and horses*

The number of goats, deer and horses are derived from JAS holding level data (Defra, 2025a), and for horses not kept on agricultural holdings, from the British Equestrian Trade Association national survey (BETA, 2019). This dataset has not been updated since 2015 due to lack of access, so we report UK population of professional horses as 95,000 and domestic horses as 631,000 (derived from reported percentages). Missing data for some years were gap-filled by extrapolation, using data from adjacent years.

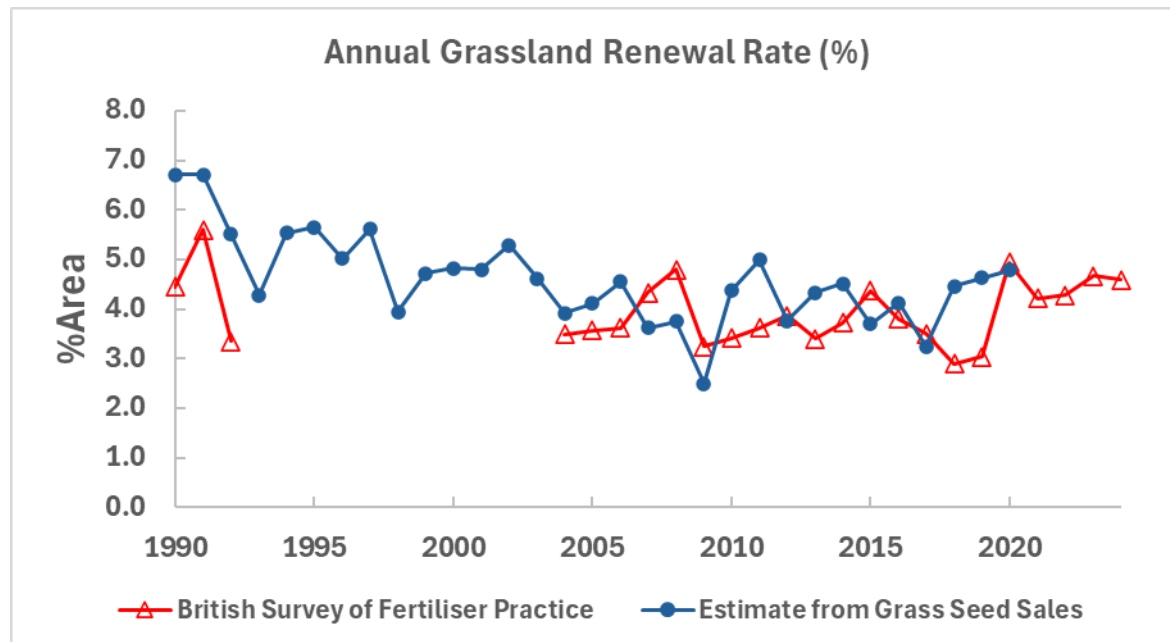
5.1.4.4 Crop types and crop areas

Data are required on crop type, end purpose, location, rates, timing and type of fertiliser or manures applied, crop yields, residue management practices, residue N concentrations and mitigation methods.

Forty-eight annual and perennial crops (and composite crop groups) are categorised in the UK inventory. Cereals comprise oats, wheat, barley and other minor cereals (with disaggregation for spring and winter types and end uses (e.g. milling vs feed wheat) where possible); other crops include field beans and peas; potatoes, sugar beet, oilseed rape, maize (for silage), root crops, leafy forage and other fodder crops; vegetables and other horticultural crops, soft and top fruit, miscanthus coppice, willow, vine grapes, linseed and flax. Full details of crops are in the supplementary material.

Grassland is classed as improved temporary (sown within the last 5 years), improved permanent (not sown with the last 5 years), and unimproved (Unimproved Sole Right Rough Grazing and Unimproved Common Grazing). Areas are estimated using a new categorisation of holding level records from the JAS (Defra, 2025a). Improved grass area is disaggregated between representative farm types, defined by enterprise share of standard output. Values for the proportion of the improved grassland area that is renewed annually are 16.6%, 5.4% and 12.1%, for England, Wales and Scotland, respectively for temporary grass, and 3.1%, 2.7% and 2.5% for England, Wales and Scotland, respectively for permanent grass (BSFP, 2025). The estimates of the renewed grassland areas are verified using two different data sources (**Figure 5.3**), and modelled DM offtake and N offtake are compared to field data.

Figure 5.3 Comparison of two datasets for the annual grassland renewal rate



For the estimate of emissions from mineralisation, the land use change areas have been significantly updated. Previously they were based on decadal matrices derived from the Countryside Survey data. In this submission, minor changes to soil N mineralisation were carried out in all DGs from 2010 onwards from updates to deforestation areas from 1990 onwards as well as minor changes to organic soil areas.

5.1.4.5 Crop residues

Calculations of N inputs from the biomass in crop residues include UK-specific data on above ground biomass, management methods and the N concentrations in such biomass (Williams and Goglio, 2017). Nitrogen inputs from cereal crop and oilseed rape residues are estimated in the UK inventory using an approach based on the Harvest index parameterised using mostly UK (and some European) data. The IPCC Tier 1 method considerably overestimates cereal crop residues when primary yields are as high as those in the UK. Activity data on residue management available since 2004 from the British Survey of Fertiliser Practice (BSFP, 2025) enable limited disaggregation by country, crop and farm type.

Residues from grassland are calculated using a UK-specific semi-empirical N mass-balance model which captures the effect of level of N fertilisation, soil water stress and cutting frequency on dry matter (DM) production, N off-take and N leaching. The structure of the model is informed by existing grassland N-balance (Scholefield et al, 1991; and Rijtema, 1980) and nitrate leaching models (SLIM: Addiscott and Whitmore, 1991; and SLIMMER: Anthony et al., 1996) and calibrated against national field trials.

Areas of crop residues that were harvested or burned came initially from national level surveys from 1990 to 1993 (when straw burning was made illegal in the UK) and then from the BSFP field level data from 2004 to the latest year (BSFP, 2025). Primary crop yields are taken from official statistics, except for some minor crops that are taken from the main farm management guides (Nix, 2024; Mowbray, 2023). Regional yields of major cereals in England became available from 1999 and these are used in preference to the national values for England (Defra, 2025a; Defra, 2025d). Farm practice data in Northern Ireland (NI) are supplied by the lead NI government agricultural statistician (DAERA, 2025).

In this submission, we have introduced NH_3 emissions from decomposing plant residues from grass left on the soil surface which also affect indirect N_2O emissions.

Details of values used are in the **Annexes**.

5.1.4.6 Inorganic fertiliser types and application rates

Six N fertiliser types are considered in the UK greenhouse gas inventory: 1) ammonium nitrate, 2) urea, 3) urea ammonium nitrate, 4) ammonium sulphate/diammonium sulphate (considered together), 5) calcium ammonium nitrate, and 6) all other N fertilisers. The inventory uses data from the BSFP for England, Wales and Scotland (BSFP, 2025) and the Farm Business Survey (FBS) for Northern Ireland (DAERA, 2025) on application rates to crop type and the relative use of different fertiliser types. The data from before 2004 are sourced from paper reports of the BSFP (1990 to 2003). From 2004, field level data are available from BSFP enabling N applications for most crops (or crop groups) to be disaggregated to the levels of country, region and Farm Type. Fewer data exist for minor crops which are disaggregated at the country level.

For grassland, emissions are calculated for improved temporary and permanent grassland; it is assumed that no N is applied, and no renewal takes place in sole rights or commons rough grazing land. Field average fertiliser N application rate for improved temporary and permanent grassland are calculated separately, by Farm Type, using additional information sourced from these surveys on the proportion of the grass area receiving fertiliser N.

Figures 5.4 and 5.5 show a comparison of the overall average nitrogen fertiliser application rate derived directly from the BSFP (as reported in official government publications), and from the product of the individual crop areas and fertiliser application rates used in the Inventory calculations. Some differences occur due to different survey stratification weights (the Inventory uses weights derived from surveyed crop areas in the reporting year, whilst the BSFP uses weights derived from crop areas for the previous year) and because the official BSFP reporting includes industry adjustments to the raw survey data for trade and sales data. There has been a long-term decrease in nitrogen application rates to grassland (Figure 5.5), and a

recent decline in applications to both crop & grass associated with an increase in energy and input prices. As an additional check on our processing of the BSFP, we compare our estimates of the quantity of each fertiliser type used with independent analyses of the BSFP that are reported by IFASTAT. **Figures 5.6 and 5.7** illustrate the long-term trend in the contributions of urea and ammonium nitrate, where comparable data are available from IFSTAT (1990 to 2023). The independent analyses of the BSFP show similar long-term trends, and both capture the recent increase in urea usage.

Figure 5.4 Comparison of the BSFP data and values used in the inventory for the overall N application rate to crops

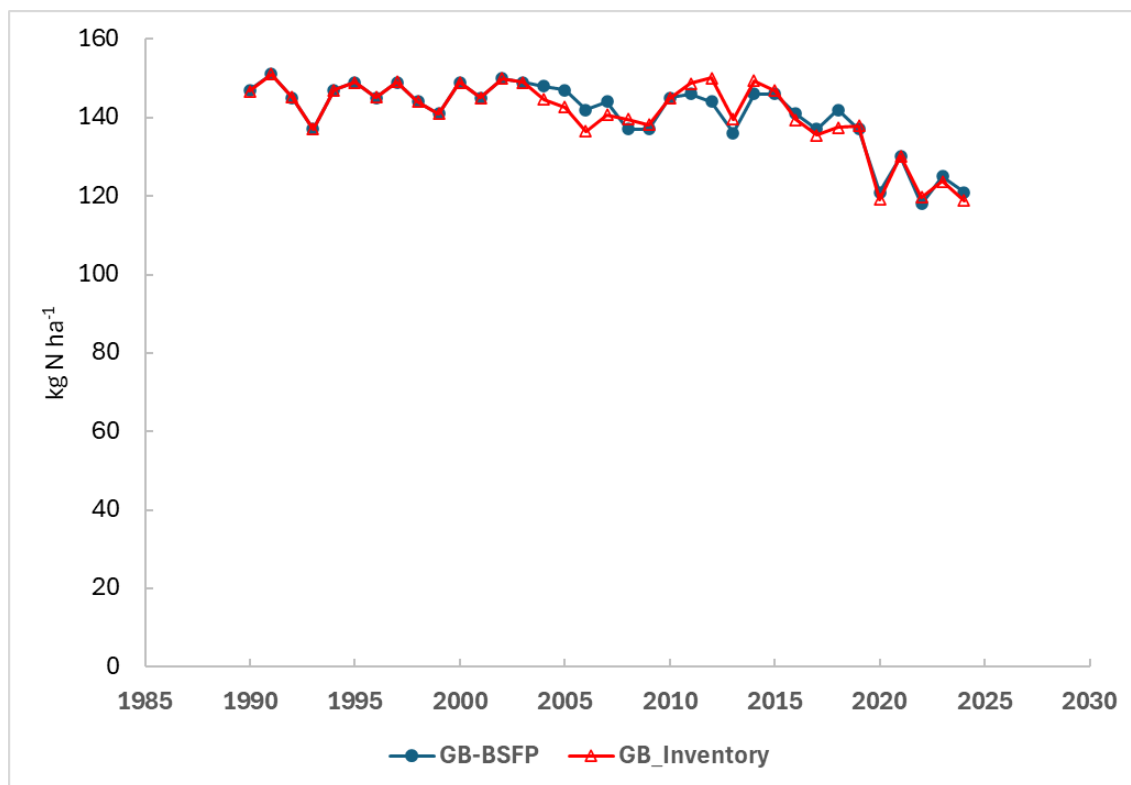


Figure 5.5 Comparison of BSFP data and values used in the inventory for the overall N application rate to grass

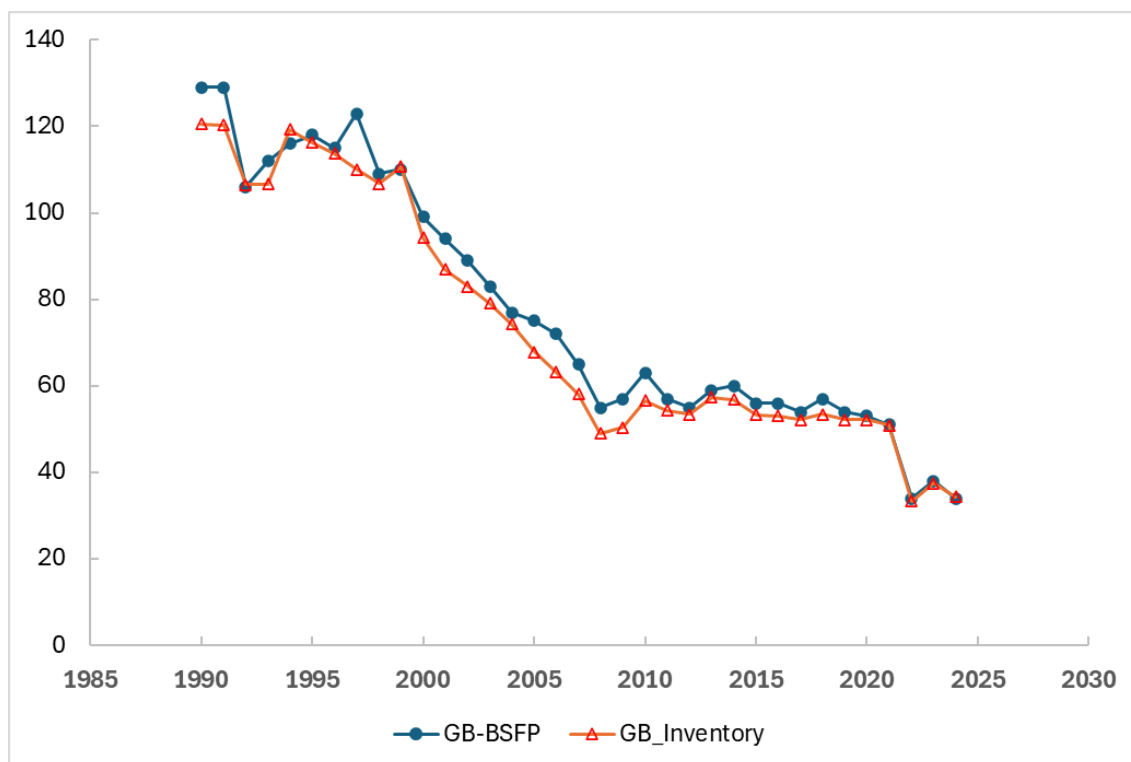


Figure 5.6 Comparison of IFA data and values used in the inventory for urea contribution to total fertiliser use

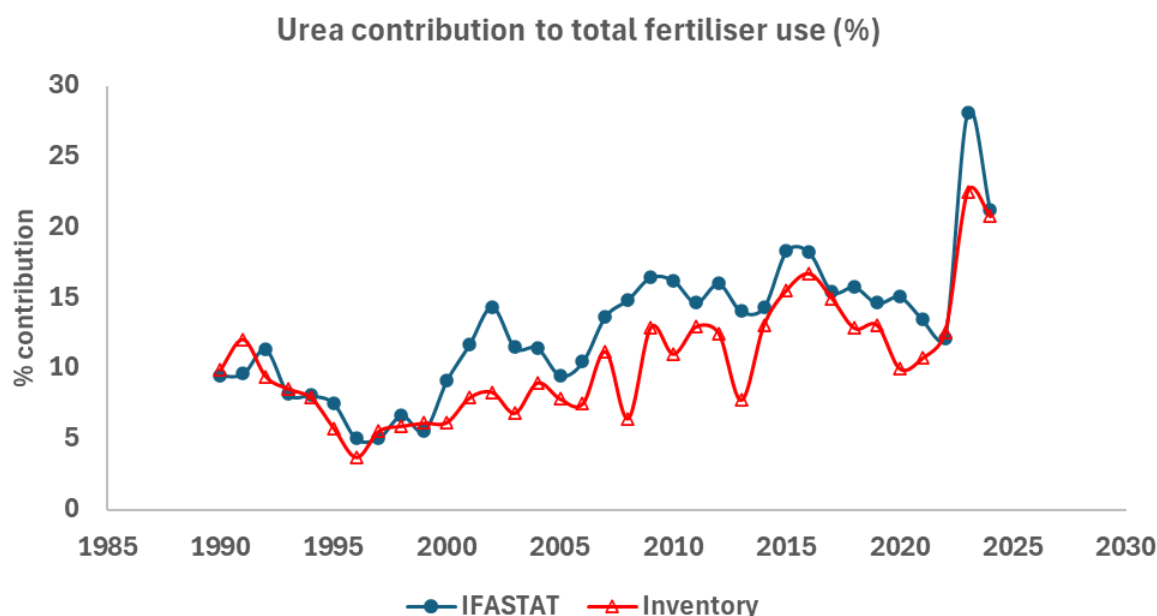
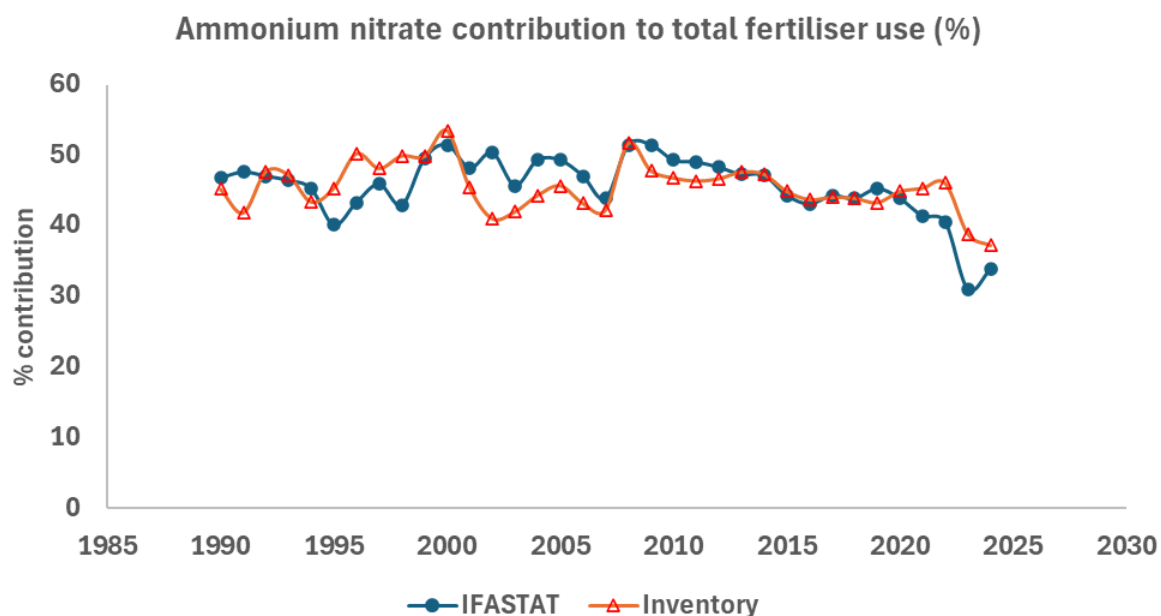


Figure 5.7 Comparison of IFA data and values used in the inventory for ammonium nitrate contribution to total fertiliser use



5.1.4.7 Organic fertilisers

The data sources, application and deposition of animal manures are described in **Chapters 5.3** and **5.4**. In addition, other organic N additions are also applied in the UK:

- a) Sewage sludge (liquid or as sludge cake)
- b) Digestates from the anaerobic digestion of livestock manure
- c) Digestates from the anaerobic digestion of energy crops, food waste and other organic residues
- d) Composted green waste applied to land (emissions from which are currently NE as no activity data are available)

Emissions are estimated based on the quantities of the different organic N additions being applied to land, the characteristics of those N additions (e.g. N content, total ammoniacal N (TAN) content), the land use to which they are being applied (arable or grassland), the appropriate emission factor for each greenhouse gas or air quality pollutant (see Chapters 5.4 and 5.5) and a reduction factor for the proportion to which specific mitigation measures are implemented.

Emissions of N₂O are calculated as:

$$E_{N_2O} = Q \times TN \times EF_{N_2O}$$

Where Q is the quantity of organic material applied (m³), TN is the total N content of the material (kg m⁻³); EF_{N₂O} is the emission factor applied (as % of the TN applied). Month of application (to account for seasonal differences in practices and emission factors if such data become available) and Robust Farm Type (RFT, to reflect differences in practices if such data become available) are considered. Indirect N₂O emissions from volatilised and leached N are calculated according to IPCC 2006 Guidelines, using default IPCC N₂O emission factors EF₄ and EF₅ and applying UK-specific values for FRAC_{leach}.

5.1.4.8 Animal waste manure systems

The split of manures into different management systems is based on data from several reference sources: Smith (2012); Smith and Williams (2016); Parsons and Williams (2015); DAERA personal communication, 2019 (see details in Annex 5.1).

5.2 EMISSION FACTORS

The UK Emission Factors used for the 1990-2024 inventory are in a supplementary file in Excel format.

5.3 SOURCE CATEGORY 3A – ENTERIC FERMENTATION

5.3.1 Source category description

	Source included	Method	Emission Factors
Emissions sources	3A1: Dairy Cows Enteric	T3	CS
	Non-dairy cattle Enteric	T3	CS
	3A2: Sheep Enteric	T3	CS
	3A3: Swine Enteric	T1	D
	3A4: Goats Enteric	T1	D
	3A4: Horses Enteric	T1	D
	3A4: Deer Enteric	T1	D
Gases Reported	CH ₄		
Key Categories	3A: Enteric Fermentation - CH ₄ (L2, T2) 3A1: Enteric fermentation from Cattle - CH ₄ (L1, T1, T2) 3A2: Enteric fermentation from Sheep - CH ₄ (L1, T1)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	Updates to activity data: Re-parameterisation of dairy cow mature liveweight (whole timeseries) Adjustment to the assumed metabolisable energy density of grazed grass by sheep. Correction to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations.		

Methane is produced in herbivores as a by-product of enteric fermentation. Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and some non-ruminant animals (e.g. swine and horses) produce CH₄, although ruminants are the largest source per unit of feed intake.

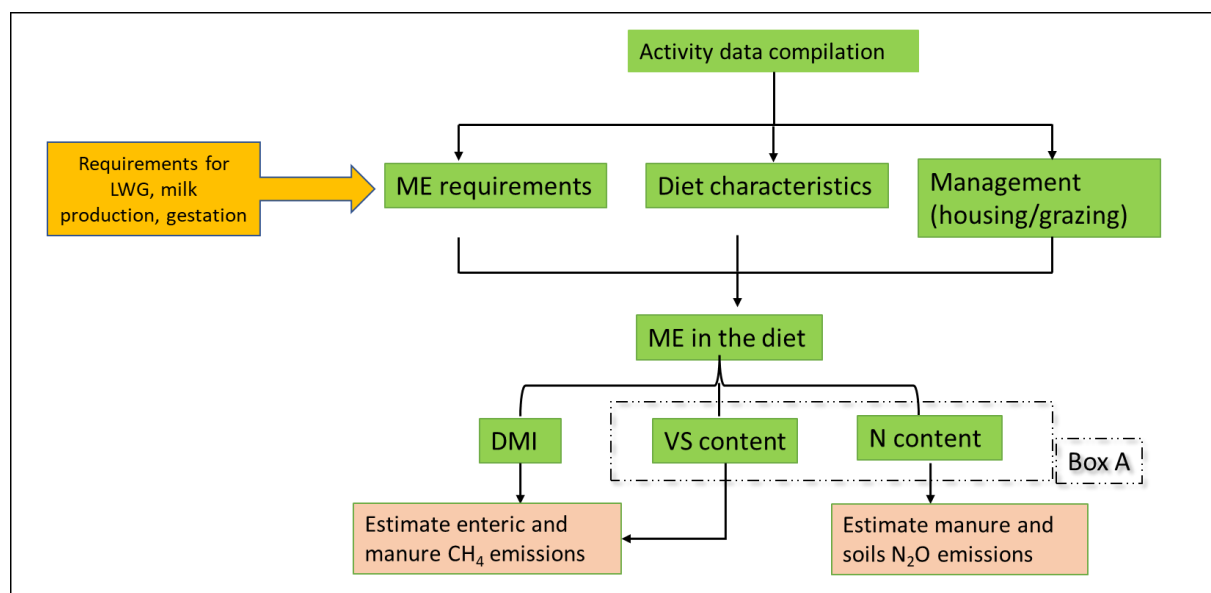
Source category emissions: significance, trends and drivers

Between 1990 and 2024, total UK emissions of enteric CH₄ decreased by 18.2% and compared with 2023, emissions were 1.7% lower in 2024. Total enteric CH₄ emissions in 2024 were 819.5 kt CH₄.

5.3.2 Methodological Issues

Enteric CH₄ emissions are estimated from the intake and diet characteristics for ruminants. The steps are described in Schematic diagram 1.

Schematic diagram 1: highest Tier method used for estimating dry matter intake (DMI) and N content in the diet from ruminant livestock.



For non-ruminants, calculations for N₂O and manure CH₄ start from *Box A* using Country Specific N contents and default VS; enteric CH₄ is estimated using IPCC default methodology. ME is metabolisable energy, VS is volatile solids and LWG is liveweight gain.

5.3.2.1 Dairy cows

Enteric CH₄ emissions for dairy cows are estimated using a UK-specific relationship between daily enteric emission and feed dry matter intake, as developed under Defra-funded projects AC0115 (Defra, 2014a) and AC0114 (Compton et al., 2022):

$$CH_{4\_enteric\_dc} = (15.8185 \times DMI) + 88.6002$$

Where:

CH_{4_enteric_dc} is the enteric CH₄ emission per dairy cow, g d⁻¹; DMI is feed dry matter intake, kg d⁻¹; and standard error values for the slope and intercept are 0.8338 and 14.5782, respectively.

Calculations are performed at a monthly resolution, with characterisation of production, management and feed by dairy cow category for each month. Further details are given in **Annex 5.1.3**.

5.3.2.1.1 Feed intake

Dry matter intake by dairy cows is determined using UK-specific energy balance equations as published in Feed into Milk (Thomas, 2004), based on metabolisable energy (ME). The daily ME intake by the animal is assumed to correspond with the requirement for live weight gain, activity, milk and gestation. Average milk yield per cow is derived from official statistics provided by each country and this is disaggregated to breed type (large, medium, small) based on industry data regarding yields for specific breeds (www.nbdc.uk). Breed-specific data are available back to 1999 and extrapolated back to 1990 based on the trend from 1999-2014. All are then normalised against the devolved government (DG) data, and finally UK statistics on average milk yield.

5.3.2.1.2 Live weight (LW)

A standard growth curve is defined for dairy cattle, based on that given by Coffey et al., (2006), and is used to define live weights for each age category, with annual data for mature cow weight by proxy breed type being obtained from UK slaughter statistics as analysed by SRUC. Calf birth weight is related to mature cow weight (AFRC, 1993). Average age at conception for first calving is defined as 19, 20 and 18 months for large, medium and small breed proxies for GB, respectively. For NI it is defined as 20, 23 and 25 months, respectively. Respective age at first calving is 28, 29 and 27 months for GB and 29, 32 and 34 for NI, for which relevant live weights can be derived. There is no evidence from industry data of any consistent trend over time in age of first calving.

5.3.2.1.3 Diet

Standard dietary components have been defined and associated with the outdoor grazing and indoor housing periods for each production system. Cattle are assumed to be fed concentrates at an average level as reported annually in Nix Farm Management Pocket book (Redman, 2023) for GB cattle, and Ferris (2021) for NI cattle, with the remainder of the diet derived from forage (at grazing or fed as conserved silage). Forage diet components include grazed grass (with and without clover), grass silage, maize silage and whole crop silage. Increasing use of forage maize, with associated higher energy and lower crude protein content, is reflected in the time series.

5.3.2.1.4 Housing and grazing period

Dairy cattle are managed according to four regimes: year-round housing, winter housed and summer part-housed (overnight), winter housed and summer grazing, extended grazing. The proportion of the national herd associated with each management regime is based on a survey reported by March et al. (2014) for GB cattle and Ferris (2021) for NI cattle and industry expert judgement on trends since 1990, assuming no year-round housing.

5.3.2.2 Other cattle

Enteric CH₄ emissions from other cattle, including dairy sector replacements and calves, and all beef sector cattle, are estimated using the same approach as for dairy cows but with different relationships between enteric emission and DMI for lactating and non-lactating cattle. For lactating cattle (i.e. beef suckler cows) the same equation as for dairy cows (presented above in 5.3.2.1) is used. For all non-lactating cattle, the relationship as developed under Defra-funded projects AC0115 (Defra, 2014a) and AC0114 (Compton et al., 2022) is:

$$CH_{4\_enteric\_oc} = (17.5653 \times DMI) + 45.8688$$

Where: $\text{CH}_{4\_enteric\_oc}$ is the enteric CH_4 emission per other cattle, g d^{-1} ; DMI is feed dry matter intake, kg d^{-1} ; and standard error values for the slope and intercept are 2.4112 and 16.1505, respectively.

As for dairy cows, DMI for other cattle categories is determined using UK-specific energy balance equations, derived for non-lactating cattle from AFRC (1993) combined with cattle category- and system-specific production and diet characteristics at a monthly resolution as described for dairy cows (and further detail given in **Annex 5.1.3**).

5.3.2.2.1 Feed intake

The AFRC (1993) recommendations on the energy allowances for cattle are used to estimate the metabolisable energy (ME) needs of cattle (based on liveweight, growth rate, gestation and lactation). The ME coupled with activity data from a Defra FBS module (Parsons and Williams, 2015) is used to derive diets, characterised by composition of ME (MJ/d), gross energy (GE) and crude protein (CP) in each diet. DMI (kg/d), GE and CP intakes are derived from the ME needs (MJ/d) and the ME density in feed (MJ/[kg DMI]).

5.3.2.2.2 Cattle live weights (LW)

Cattle live weights are based on a Michaelis-Menten type growth model (López et al., 2000). The model requires mature LW, calf LW and two fitted parameters. Mature LW data are obtained from the established time series of slaughter weights that are collected at national level annually (Defra, 2025b) and supplemented with a very large sample of data from which separate populations are derived of the breed types and age bands used in the model (Wall and Pritchard, 2017). Calf weights are calculated from an established equation in AFRC (1993). Parameters were fitted from a variety of industry and literature sources, as summarised in Williams and Sandars (2017).

The fractions of cattle lactating and/or gestating are derived from industry performance data and an analysis of the CTS dataset. The fractions of cattle lactating and/or gestating are applied uniformly over the population throughout the year. The ME needs for maintenance, growth, lactation and gestation are calculated for every age band and cattle type to estimate the DM intake and intakes of CP and GE, which are used to calculate enteric CH_4 emissions, volatile solids (VS) excretion and N excretion.

5.3.2.2.3 Diets

There are 11 standard diets assumed for cattle, three corresponding to different types of grass and two corresponding to suckled calves at grazing with mixed nutrition from milk and grass. Data for feeds used (by material) are from the FBS (Parsons and Williams, 2015) and nutritional properties of each material in the diets are derived mainly from the Feed Composition Tables (MAFF, 1992), with some from Ewing (1998). Diet data for dairy replacements and calves follows the same approach as for dairy cows with data derived from the same sources.

5.3.2.2.4 Housing and grazing period

Data from a FBS module (Parsons and Williams, 2015) and other farm practices surveys (Defra, 2025c) were used to derive the grazing season lengths across the UK at DG level and with England split into three parts. These applied to cattle roles and ages, although age bands were more highly aggregated than the CTS-based age bands. Farm practices survey data are used to quantify the housing systems and manure management regimes used as follows: (1) Housed all year; (2) Housed in the winter, out in the summer; (3) Outside all year; (4) Housed all year + yards; (5) Housed winter, out summer + yards. The housing management regimes were used to define cattle locations by month, i.e. grazing, in resting areas and in feeding yards. Each of these has its own emission factors for ammonia and N_2O .

5.3.2.3 Sheep

The same approach to estimating enteric emissions for cattle is taken with sheep, but using a UK-measurement derived relationship between enteric emission and DMI specific to sheep (Compton et al., 2017):

$$CH_{4\_enteric\_sheep} = (12.3894 \times DMI) + 5.1595$$

Where: $CH_{4\_enteric\_sheep}$ is the enteric CH_4 emission per sheep, $g\ d^{-1}$; DMI is feed dry matter intake, $kg\ d^{-1}$; and standard error values for the slope and intercept are 1.483 and 0.8301, respectively.

5.3.2.3.1 Feed intake

Feed intake is calculated using a modified version of the AFRC (1993) energy requirements to meet the metabolisable energy needs of the animal. It is applied to a description of the live-weight gain of the animal from birth to slaughter. Each type of ewe and lamb has separate growth-curves, access to housing and handling yards, and different access to forage, concentrate and conserved feeds that determine its feed intake. The energy requirement is a function of the animal's live-weight, stage of pregnancy, growth rate and production of milk. Application of the model is dependent on estimates of live-weight at slaughter, derived from national slaughterhouse statistics and of age at slaughter, derived from a national survey of lamb slaughter age (Wheeler et al., 2009).

5.3.2.3.2 Sheep live weights (LW)

The inventory uses country- and system-specific values for the LW of the adult ewe and lamb, and for the rate of weight gain. The annual average weight of ewes and slaughter weight of lambs are calculated separately for each country based on average carcase weights and a fixed killing-out percentage of 42 and 45% respectively, derived from national slaughterhouse statistics⁹⁴. The relative ewe weights for the hill, upland and lowland systems within each country are estimated based on an analysis of breed lists and expected mature weights and are centred on the country average.

5.3.2.3.3 Diets

Fresh grass is the most important feed, with a metabolisable energy content of $11.1\ MJ\ kg^{-1}$ DMI and a crude protein content that varies spatially in response to the clover content and level of synthetic N fertiliser applied to pasture. Ewes and rams are fed a supplement of conserved silage and hay for 120 days over-winter, and store lambs are fed silage, hay and roots for 100 days. The metabolisable energy contents are $10.6\ MJ\ kg^{-1}\ dm$ for silage, $9.4\ MJ\ kg^{-1}\ DMI$ for hay, and $9.2\ MJ\ kg^{-1}\ DMI$ for roots. The crude protein contents are $130\ g\ kg^{-1}\ DMI$ for silage, $111\ g\ kg^{-1}\ DMI$ for hay, and $192\ g\ kg^{-1}\ DMI$ for roots. Lambs are provided with an average creep feed ration of c. $0.150\ kg\ day^{-1}\ DMI$ for 42 days prior to weaning, and ewes are provided with a concentrate ration of c. $0.130\ kg\ day^{-1}\ DMI$ in the 56 days before and after lambing. The crude protein and metabolisable energy content of concentrate are $198\ g\ kg^{-1}\ DMI$ and $12.5\ MJ\ kg^{-1}\ DMI$ for the ewe and $209\ g\ kg^{-1}\ DMI$ and $12.6\ MJ\ kg^{-1}\ DMI$ for the lamb.

5.3.2.3.4 Housing and grazing periods

The pregnant ewe and ewe lamb is housed for 42 days prior to lambing. The fraction of ewes housed varies with system from 40% (hill) to 75% (lowland) (Roderick, 2001). Straw is added to excreta in housing at a rate of $0.60\ kg\ FW\ day^{-1}$. All ewes occupy handling yards for an

⁹⁴ Rural and Environment Science and Analytical Services (Annual), Economic Report on Scottish Agriculture, Scottish Government Directorate for Environment and Forestry (<https://www.gov.scot/collections/economic-report-on-scottish-agriculture/>), Department of Agriculture, Environment and Rural Affairs (Annual) Output Value of Farm Products (<https://www.daera-ni.gov.uk/publications/output-value-farm-products>), Hybu Cig Cymru (Meat Promotion Wales) Welsh Monthly Slaughtering (<https://meatpromotion.wales/en/markets/livestock-market-trends/uk-monthly-average-carcase-weights>), Defra Latest Cattle, Sheep and Pig Slaughter Statistics (<https://www.gov.uk/government/statistics/cattle-sheep-and-pig-slaughter>)

overall average of 5 days, for essential welfare tasks. Feed and manure management is assumed to be the same as during housing. Lambs finished at grass are slaughtered at between 133 and 172 days, and store lambs at between 276 and 331 days, varying with country and system (Wheeler et al., 2012). Lambs intended for breeding replacement, and all ewes and rams are present all year.

5.3.2.4 Swine

Enteric emissions for swine are estimated using IPCC (2006) Tier 1 methodology, with a Tier 1 default EF and UK-specific activity data on animal numbers from the JAS (Defra, 2025a).

5.3.2.5 Minor livestock

Enteric emissions for goats, horses and deer are estimated using IPCC (2006) Tier 1 methodology, with a Tier 1 default EF and UK-specific activity data on animal numbers. The EF for goats of 9 kg/head/y, is according to the IPCC 2019 refinement to the 2006 guidelines for high production systems, as this is regarded as the most representative of UK farming practices in the expert judgement of the UK Inventory Agency. Whilst the UK GHG Platform research has not led to the derivation of a UK-specific EF, we note that the UK evidence was used to derive a value consistent with the value presented in the 2019 Refinement, and hence in our expert judgement to use the 2019 Refinement EF is the most representative EF option available to best reflect UK circumstances; we consider that applying that EF minimises the uncertainty in the UK Inventory for this source.

5.3.2.6 Overseas Territories and Crown Dependencies

Emission estimates were compiled using animal numbers sourced from the territories directly and can be found in **Annex A5.1.6**. In the case of OTs, IPCC default EFs were applied to animal numbers. For CDs, UK implied EFs were applied.

5.3.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category.

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC using the new Tier 3 models derived for the UK greenhouse gas inventory. Model runs are computationally intensive and so a preliminary analysis was undertaken to determine the number of samples needed. This analysis showed that 2500 samples were sufficient to estimate the 95% confidence interval with 95% confidence. Once samples have been computed suitable distributions are fitted to the outputs and fed forward to the wider inventory calculations.

Emissions are calculated from animal population data and appropriate EF. The animal population data are collected in the JAC, published annually by the devolved governments (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

Control measures introduced in response to the bovine spongiform encephalopathy (BSE) outbreak in the UK introduced an inconsistency in the slaughter weight statistics and the derived dairy cow live weights for the years 1997 to 2005. To correct for the artefacts introduced by these control measures in the data time-series, data for this period were interpolated using the linear trend of increasing live weight with time for the years immediately prior to and following this period.

As noted in **Section 5.1.4**, a full uncertainty analysis using Monte Carlo simulation is not run annually because of resource implications (long model run times) and there is little change in

results between years. For the years in between we assume the uncertainty to be similar to previous years and simply offset the uncertainty distribution to align with the revised expected value. This was the case for the 1990-2024 inventory for which no significant methodological changes occurred.

To address finding 5.A.1 (a) from the 2024 In Country Review of the UK submission, note that the UK Tier 2 method for methane emissions from cattle enteric fermentation draws upon two UK industry-approved modelling frameworks to calculate cattle energy requirements, namely:

- The 1993 Agricultural Food and Research Council (AFRC) framework, applied for beef cattle and young dairy stock; and
- The 2004 Feed Into Milk modelling framework (Thomas, 2024), applied for adult dairy cattle.

These UK frameworks are implemented within the UK inventory, via annually updated statistics on animal weight and productivity which ensures that the estimation method is time-series-consistent and accurately tracks changes in the UK's cattle herd over time.

5.3.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

Details of the QAQC across the agriculture inventory model and methods are described within **Annex A5.1.3**. Some of the data validation checks are also presented within the supplementary MS Excel file that accompanies the NID and within the NID (sections 5.1.4.4 and 5.1.4.5). Specific to the Enteric Fermentation source category, the UK sector experts conduct the following QC activities on the cattle data:

- In Cattle Tracing Scheme (CTS) data processing, QC is conducted to identify cattle that are mixed breeds (dairy/beef) and to review the holding level information across the time series to ascertain the type of farm and likely cattle type; additional QC identifies any new breeds and flags those to sector experts to assign them to dairy or beef sector.
- Completeness and time series consistency checks against other herd statistics (e.g. from Defra JAS/C data) are conducted at the DG / livestock type level. In the annex, we describe the flow for the CTS data processing.

5.3.5 Source-specific recalculations

In this submission, the Inventory Agency has introduced a re-parameterisation of the dairy cattle growth curve using slaughter-weight data. This has resulted in an increase in liveweight of all dairy animals and enteric CH₄ emissions.

In addition, in this submission the Inventory Agency has updated the metabolisable energy content of grass in preferential grazing areas for the rapidly growing lamb and lactating ewes in the sheep sector. This improvement draws upon measurements made on dairy, beef and sheep farms participating in the Grass Check Northern Ireland (n 35) and Great Britain (n 50) schemes, with a maximum increase from 11.1 to 11.6 MJ kg⁻¹ dm in accessible grass quality. This has resulted in an increase in enteric CH₄ emissions.

Changes in activity data and to emission factors due to these recalculations to are given in the tables below.

Table 5.1 3A Source specific recalculations to emissions since previous submission (kt)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.A.1.a	Enteric fermentation – Dairy cattle	279.44	226.96	280.64	227.47	kt	Replaced slaughter weight timeseries (from 2016). Updated milk yield (2022-2023) to match published stats. Re-parameterisation of the dairy cow mature liveweight (whole timeseries)
3.A.1.b	Enteric fermentation – Non-Dairy cattle	476.49	409.05	481.57	414.06	kt	Replaced slaughter weight timeseries and re-parameterisation of the dairy cow mature liveweight (growth curve for followers/calves based on cow mature weight) (whole timeseries)
3.A.2	Enteric fermentation – Sheep	209.66	161.71	215.91	166.83	kt	A downward adjustment was made in the assumed metabolisable energy density of grazed grass for rapidly growing lambs and lactating ewes that directly resulted in an increase in total dry matter intake to meet the energy requirements of an animal; Correction to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations

Table 5.2 3A Recalculations to Emission Factors since the previous inventory (kg/head/yr)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.A.1.a	Enteric fermentation – Dairy Cattle	98.11	123.28	98.53	123.56	kg/hd/year	Reason for change as above
3.A.1.b	Enteric fermentation – Non-Dairy Cattle	51.36	54.11	51.91	54.78	kg/hd/year	Reason for change as above
3.A.2	Enteric fermentation – Sheep	4.61	4.98	4.75	5.14	kg/hd/year	Reason for change as above

5.3.6 Implied emission factors

The implied emission factors for CH₄ emissions from enteric fermentation for dairy, non-dairy cattle and sheep (123.51, 54.5, 5.1 kg/head/yr, respectively) were different to IPCC 2006 default values (109, 57, 8 kg/head/yr) due to the application of country specific data.

5.3.7 Source-specific planned improvements

There are a number of methodological improvements that the UK Inventory Agency will consider for future submissions, dependent on the availability of resources and evidence from research and statistics agencies, including:

We plan to make improvements to the estimates of emissions from cattle through:

- Revision of the parameters applied in the energy balance equations for non-lactating cattle based on recent and ongoing research from the Agri-Food and Biosciences Institute (AFBI). AFBI are currently sourcing data from other UK and Ireland-based research agencies to validate the findings from a series of respiratory calorimeter chamber experiments for cattle representative of the UK herd. Subject to satisfactory data validation and resources, it is planned to implement this improvement in the next submission.
- Access, analysis and use of cattle data for Northern Ireland that are more detailed than those currently available via annual surveys; we anticipate that – subject to gaining access to the Northern Ireland cattle database – this will enable development of an inventory method for the Northern Ireland herd that is similar to that underpinned by the CTS dataset within Great Britain, improving the accuracy and representativeness of the inventory. Subject to data access and resources available to the Inventory Agency, this improvement is planned to be implemented in the next submission.
- As a result from the In Country Review of the 2024 submission, the UK was recommended to enhance the description of the methodologies, parameters and data used to estimate emissions for key categories. In order to demonstrate that there have been no major changes in agricultural management practices or other factors that could affect the main assumptions and parameters used in the time series to estimate country-specific EFs, the UK was recommended to include references to the most recent national studies, surveys and/or expert judgment. The UK stated that the assumptions made during the compilation of the agricultural sector inventory are still valid. Recent studies, surveys and expert judgement do not indicate any significant changes that could affect the main assumptions and parameters used to estimate country-specific EFs for the agriculture sector. The UK will continue to maintain the UK inventory to identify where any parameters may be updated to be more representative of current UK farming practices and circumstances.

5.4 SOURCE CATEGORY 3B – MANURE MANAGEMENT

5.4.1 Source category description

	Source included	Method	Emission Factors
Emissions sources	3B11: Dairy Cattle Wastes	T2	CS, D
	Non-Dairy Wastes	T2	CS, D
	3B12: Sheep Wastes	T2	CS, D
	3B13: Swine Wastes	T2	D
	3B14: Goats Wastes	T1	D
	3B14: Horses Wastes	T1	D
	3B14: Broilers Wastes	T2	D
	Laying Hens Wastes	T2	D
	Other Poultry Wastes	T2	D
	3B14: Deer Wastes	T1	D
	3B21: Dairy Cattle Wastes	T2	CS, D
	Other Cattle Wastes	T2	CS, D
	3B22: Sheep Wastes	T2	CS, D
	3B23: Swine Wastes	T2	CS, D
	3B24: Goats Wastes	T2	D
	3B24: Horses Wastes	T2	D
	3B24: Poultry Wastes	T2	CS, D
Gases Reported	CH ₄ , N ₂ O		
Key Categories	3B1: Manure management from Cattle - CH ₄ (L1, T1) 3B2: Manure Management - N ₂ O (L1)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	There are no UK activity data for the practice of composting of manure within MMS and hence no CH ₄ nor N ₂ O emissions for this source are currently reported in the GHGI. A general assessment of completeness for the inventory is included in Section 1.7 .		
Major improvements since last submission	Activity Data: Re-parameterisation of the dairy cow mature liveweight (whole timeseries). Correction to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations.		

Methane is produced from the decomposition of manure under anaerobic conditions during its storage and treatment. This applies mainly for liquid systems, whilst for solid systems and deposition of excreta during grazing, conditions are less anaerobic, so less CH₄ is expected to be emitted. The main factors affecting emissions are the quantity of manure and temperature during storage. Nitrous oxide is also produced from manure as a result of nitrification and

denitrification occurring during its storage and treatment. The main factors affecting emissions are the quantity/quality of the manure (C, N content), duration of the storage and type of treatment. Indirect emissions from manure also occur, through volatilisation of N (as NH_3 or NO_x) and leaching as NO_3^- .

In the UK, livestock manure is mainly managed as liquid slurry or solid manure (Farmyard Manure, FYM), and as urine and dung deposited to pasture. Manures based digestate are also managed and have increased in importance in the last few years.

Source category emissions: significance, trends and drivers

Total UK CH_4 emissions from manure management in 2024 were 147.4 kt CH_4 . Emissions in 2024 were 12% lower than in 1990 and 0.7% lower than 2023.

Emissions of N_2O from manure management in 2024 were 9.4 kt N_2O . Emissions in 2024 were 20% lower than in 1990 and 0.6% lower than 2023.

The main drivers of these trends are the changes in livestock numbers per livestock type across the time series.

5.4.2 Methodological Issues

5.4.2.1 Methane emissions from animal manures and manure-based digestates

The EFs for manure management are calculated following IPCC Tier 2 methodology for cattle, sheep, swine and poultry, according to IPCC (2006) Equation 10.23.

For **cattle and sheep**, country-specific values for volatile solids (VS) excretion are derived by animal sub-category and production system using the UK-specific ME balance equations (as described in **Section 5.1**) and an estimate of GE intake (based on estimated DMI and feed energy content) according to a variation of IPCC (2006) Equation 10.24:

$$VS_{ex} = \left(GE_i \times \left(1 - (DE\%/100) \right) \right) \times ((1 - ASH)/(GE_i/DMI))$$

Where: VS_{ex} is the volatile solids excretion, kg d^{-1} ; GE_i is the gross energy intake, MJ d^{-1} ; ASH is the ash content of the manure as a fraction of the dry matter feed intake; DE is the digestibility of the feed; DMI is the dry matter intake, kg d^{-1} . The calculation of the digestibility is dependent on available data.

UK-specific data on the CH_4 producing potential (Bo) of cattle excreta were not significantly different from IPCC (2006) default values (Defra 2014a), so the default values were retained.

In the case of **sheep**, VS excretion also accounts for varying energy content of urine, varying with feed protein level. VS values are calculated using the AFRC (1993) energy balance model and calculated enteric methane emissions (Crompton et al., 2017). The range of calculated volatile solids excretion is 33 to 67 kg hd^{-1} for lambs, 129 to 161 kg hd^{-1} for rams and 128 to 155 kg hd^{-1} for ewes. Default methane conversion factor (MCF) for excreta are applied, at grazing of 1% and for manure managed as 'solid storage' of 2%, expressed as a fraction of the default maximum methane producing capacity ($0.19 \text{ m}^3 \text{ CH}_4 \text{ kg}^{-1}$) of the excreted volatile solids. The effective methane conversion factor (MCF), expressed as a fraction of the gross energy intake, is in the range 4.4 to 5.0% for lambs and 4.8 to 5.3% for ewes, in comparison to IPCC (2006) default values of 4.5% and 6.5% respectively.

For **swine**, IPCC (2006) default values for VS and Bo are used. Manure is split into 3 management systems, slurry, FYM and outdoor systems. Animals are on fully slatted floor, part slatted floor, solid floor with bedding or outdoors.

For **poultry**, IPCC (2006) default values for VS and Bo are used.

Default IPCC (2006) Methane Conversion Factor (MCF) values (IPCC Table 10.17) are applied, with the exception of liquid/slurry systems with a natural crust cover, where no reduction in the MCF value is assumed in accordance with recent literature evidence (e.g. Petersen et al., 2013). Country-specific MCF values are used for the anaerobic digestion of livestock manures based on the values used in the German inventory. These data are combined with country-specific data for the proportion of manure from each livestock type managed according to the different animal waste management systems (AWMS). The EFs are listed in **Table A 5.1.8** in **Annex 5.1**. **Table A 5.1.9** in **Annex 5.1** shows the methane conversion factors assumed for the different systems.

There are no UK activity data for the practice of composting of manure within Manure Management Systems (MMS) and hence no CH₄ nor N₂O emissions for this source are currently reported in the GHGI. The composting of manures is a very minor activity in the UK and, as noted in recent UNFCCC reviews, the omission of this activity is not expected to lead to an under-report in UK emissions. The separate reporting of manure being composted would be expected to lead to lower overall emissions from manure management; CH₄ emissions would be lower, as CH₄ conversion factors for composting are lower than for most other manure management systems (in particular, lower than for solid storage and liquid systems). In the view of recent ERTs, the actual difference in N₂O emissions would depend on the management system that is diverting manure to composting, but any underestimation would likely be small and the impact on overall emissions negligible. The UK will retain this completeness issue on our inventory improvement log, seeking activity data to address this omission.

For **goats, deer and horses**, IPCC (2006) Tier 1 default emission factors were used (IPCC Tables 10.15). For broilers the VS excretion value of 0.02 kg/head/d, is applied according to the IPCC 2019 refinement to the 2006 guidelines. This value is regarded as the most representative of UK farming practices in the expert judgement of the UK Inventory Agency. Whilst the UK GHG Platform research has not led to the derivation of a UK-specific EF, we note that the UK evidence was used to derive a value consistent with the value presented in the 2019 Refinement, and hence in our expert judgement to use the 2019 Refinement EF is the most representative EF option available to best reflect UK circumstances; we consider that applying that EF minimises the uncertainty in the UK Inventory for this source.

5.4.2.2 Nitrous oxide emissions from Animal Waste Management Systems

Animals are assumed not to give rise to N₂O emissions directly, but emissions will arise from N excreted by livestock. Emissions from manures during storage are calculated for different animal waste management systems (AWMS) as defined by IPCC methodological guidance. Emissions from the following AWMS are reported under the Manure Management CRT category:

- Liquid/slurry;
- Solid storage/deep litter/poultry manure;
- Anaerobic digestion
- ✕ [Uncovered anaerobic lagoons are 'not occurring' in the UK]

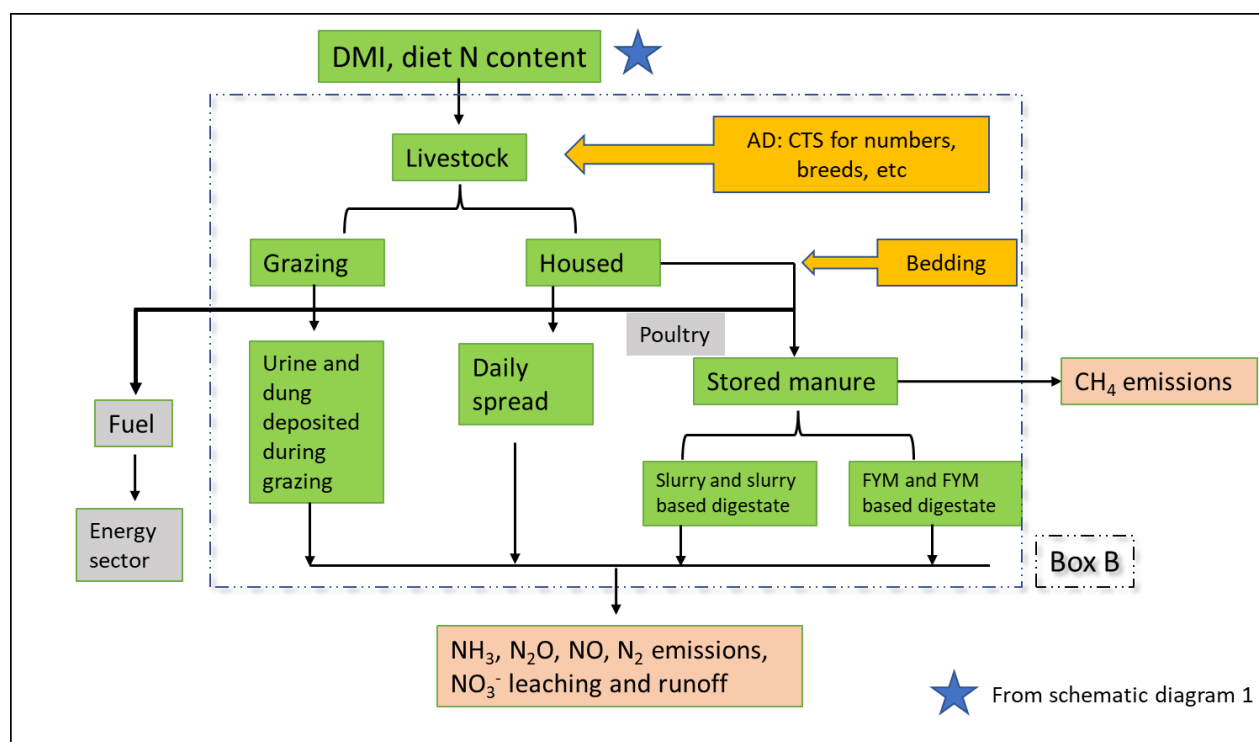
The following AWMS are reported in the Agricultural Soils category, applying methods consistent with the IPCC 2006 guidelines, unless stated otherwise:

- All animal manures, slurries and digestates applied to soils; and
- Pasture range and paddock

The IPCC 2019 Guidelines value for the EF for N₂O emissions from slurry tanks with natural crust cover or cover for dairy cows' slurry of 0.5% is applied (Table 10.21 of the IPCC, 2019 guidelines) (the previous guidelines recommend '0' Table 10.21 IPCC, 2006). For liquid/slurry without a natural crust cover the default value of 0% is applied.

The inventory incorporates the effect of firm and funded policies for the Devolved Governments when data are available. For slurry storage in all new above ground tanks in Northern Ireland it is required they are fitted with a cover, as well as the implementation of Low Emission Slurry Spreading Equipment (LESSE) (including incorporation).

Schematic diagram 2: Manure management systems in the UK agriculture inventory. [Box B contains all the manure management systems relevant for the UK.]



[DMI: dry matter intake; AD: activity data; CTS: Cattle Tracing Scheme]

5.4.2.2.1 Livestock N excretion

Nitrous oxide emissions from manure management are estimated following IPCC (2006) (equation 10.25) for each livestock category and subcategory, using country-specific data for N excretion by the different livestock types and for the proportion of manure managed according to the different AWMS, and a combination of default and country-specific EFs for the different AWMS. The UK has implemented a detailed N-flow model describing the flow of N from livestock excretion through the manure management chain (based on Webb and Misselbrook, 2004), accounting for all N losses (via NH₃, N₂O, NO, N₂ and N leaching) and transformations (immobilisation, mineralisation) at each manure management stage (i.e., housing and yarding, storage, land spreading, grazing).

For cattle and sheep, N excretion is estimated as the balance of N intake and N retained in live weight gain, milk, wool and developing foetus, specific to livestock sub-category, production system and diet. N intake is estimated from the calculation of DMI, based on energy requirement and feed characteristics (**Section 5.1**), and the crude protein content of the feed.

For **cattle**, N excreta are partitioned to urine N and dung N, based on literature equations relating N excreta to N intake (Reed et al., 2015). The urine N is assumed to rapidly convert to ammoniacal N whereas the dung N remains as organic N. These different N forms have important implications for subsequent N losses and transformations through the manure management chain (Webb and Misselbrook, 2004). In this submission, N₂O emissions from slurry tanks with a cover are calculated following IPCC 2019 guidelines (Table 10.21).

For **sheep**, based upon a national survey by Roderick (2001) of 2,649 flocks managed by members of the National Sheep Association, the inventory calculations assume that 75% of ewes associated with lowland systems, 60% with upland systems, and 40% with hill systems are housed in the last weeks of pregnancy. Also, that housed breeding ewes are housed for 42 days prior to lambing, and that neither the ewe nor new-born lamb are housed post lambing. The effect of excluding new-born lambs from the housing calculations is a negligible (< 1%) reduction in the quantity of managed manure. Data from 2 other surveys by Lima et al. (2018) (England and Wales) and Bohan et al. (2017) (Ireland) were used to support the assumption that no lambs are housed during the finishing period. Other assumptions regarding handling of sheep manure for short periods in housing or yards are based on smaller surveys (Defra 2004; Dauven and Crabb, 1998; Webb et al., 2001) and communications from sheep experts (*Pers. comm.*: Kate Phillips, formerly ADAS Livestock Consultant).

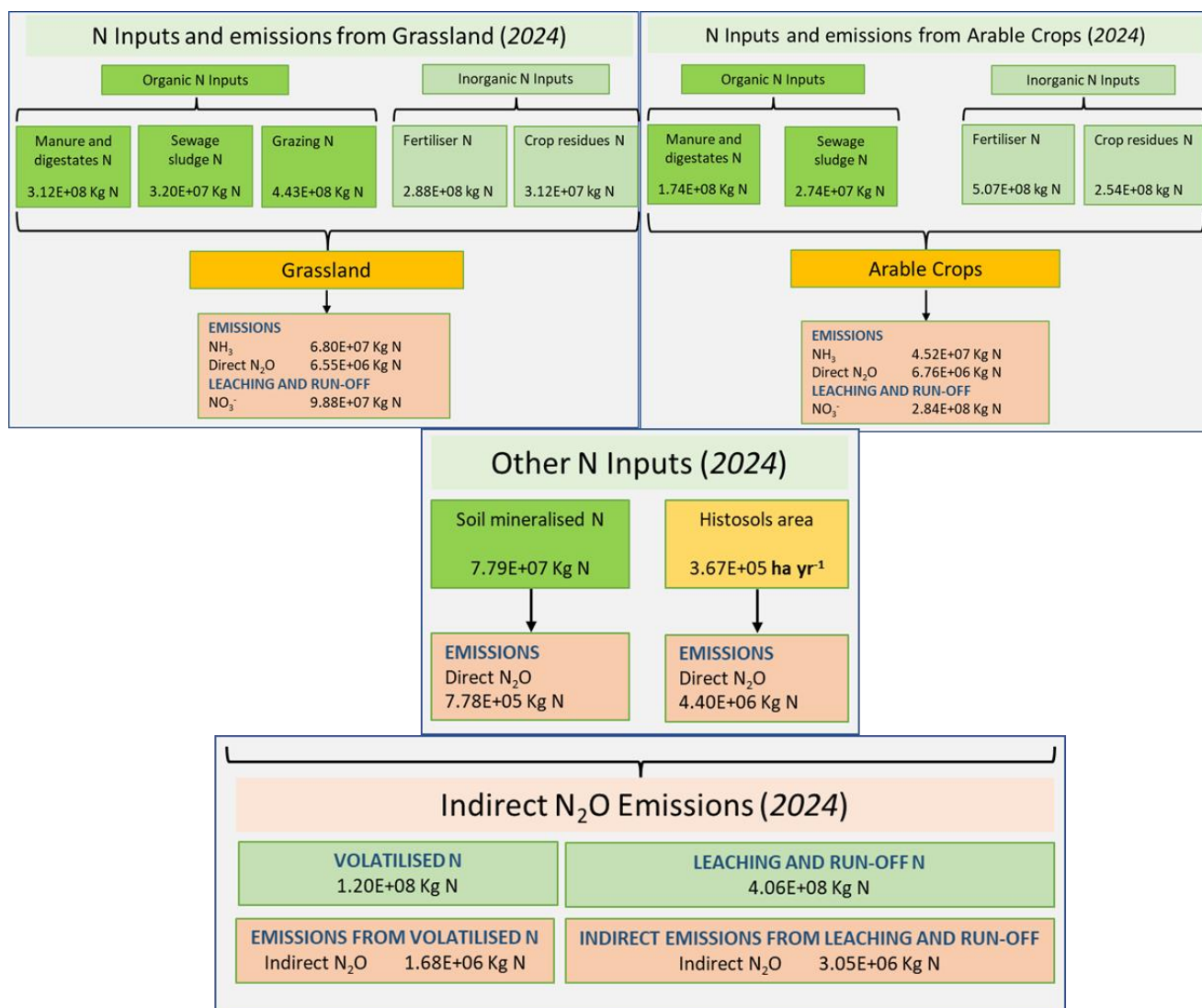
For sheep, the partition of excreta N between urine and dung is dynamic and from these 85% of urine N is TAN, and 15% of dung N is TAN, estimated from separate regression equations for excreta and urine N on the dietary protein content taken from the meta-analysis published by Decandia et al. (2011).

The N excretion values for lambs may appear low in comparison to published values for other countries, as these are often presented on the assumption that a lamb is present for a complete year (365 days) before slaughter. Statistical analyses of UK-surveyed slaughter ages (after Wheeler et al., 2012) indicate that lambs are present on average for only 237 days. The N excretion value of around 4 kg N/lamb is therefore for a 237-day period, and not for a complete year (365 days). In the case of sheep, the weighted average N excretion rate from all sheep categories is 7.5 kg N yr⁻¹ (2019). We report N excretion values of around 4 kg N/lamb produced (see important note on N excretion above); around 11 kg N yr⁻¹ per ram; and around 9 kg N yr⁻¹ per ewe.

Average N excretion values for neighbouring countries reported in their NIDs (previously NIRs) in 2019 are for all sheep 7.8 kg N yr⁻¹ (Germany) and 6.6 kg N yr⁻¹ (Denmark); and for ewes they range from 6.5 kg N yr⁻¹ for upland ewes (Ireland) to 12.9 kg N yr⁻¹ for lactating ewes (France).

Decandia et al. (2011) reported published N excretion rates data from sheep. The total N excretion rate averaged 13.9 g N day⁻¹ for growing sheep (n 52); 16.7 g N day⁻¹ for rams (n 20); 15.5 g N day⁻¹ for dry ewe (n 21); and 40.4 g N day⁻¹ for lactating ewe (n 26). The values for the dry and lactating ewe can be weighted by the UK surveyed average number of days from birth of lamb until weaning (around 120 days) to give an average yearly value of 23.7 g N day⁻¹ per ewe. These average literature values are either the same or lower than the UK inventory values of 17.3 g N day⁻¹ for all lambs, both finished and replacements; 30.9 g N day⁻¹ for rams; and 23.8 g N day⁻¹ for all ewes. These reported data support the UK country specific values.

Schematic diagram 3: N inputs in the UK inventory to calculate N emissions for 2024



For **other livestock** types, country-specific values for N excretion were derived from the Defra project WT0715NVZ report (Cottrill and Smith, 2007), with interpretation by Cottrill and Smith (ADAS), and Defra WT1568 (Defra, 2016b), presented in **Table A 5.1.10** in **Annex 5.1**.

For swine and poultry, 70% of excreta are assumed to rapidly become ammoniacal N with 30% remaining as organic N. For goats, horses and deer, the respective excretal proportions are assumed to be 60 and 40%.

The revised N excretion values for **swine** were interpolated using data from Defra WT0715NVZ (for 2004, Cottrill and Smith, 2007): for sows, maiden gilts, boars, fatteners >110 kg, fatteners 80-110 kg, fatteners 50-80 kg, fatteners 20-50 kg and weaners (<20 kg): 20.5, 15.5, 25, 17.6, 17.6, 12.7, 12.7, 4.0 kg N hd⁻¹ y⁻¹, respectively. Data reported by Defra WT1568 (for 2016, Defra, 2016b) for the same categories were: 21.1, 11.7, 18.9, 13.2, 13.2, 9.6, 9.6, 4.0 kg N hd⁻¹ y⁻¹, respectively. For 1990, values were assumed to be 15% greater than those of 2004, except for gilts where the value was kept constant.

In the case of **poultry**, the N excretion values were revised by interpolating data from Defra WT0715NVZ (for 2004, Cottrill and Smith, 2007) for: laying hens – cages, laying hens - barn, perchery, laying hens - free-range, broilers, pullets, breeding hens, turkeys (m), turkeys (f), ducks (and geese), other poultry: 0.75, 0.75, 0.84, 0.51, 0.34, 1.08, 2.10, 1.40, 1.60 and 1.60 kg N hd⁻¹ y⁻¹ respectively. Values from Defra WT1568 (were used for 2016, Defra, 2016b), for

the same categories: 0.66, 0.66, 0.83, 0.28, 0.36, 1.14, 2.10, 1.47, 1.20 and 1.20 kg N hd⁻¹ y⁻¹, respectively. A proportional uplift in N excretion for outdoor laying hens is included.

N excretion values are for **goats** (from 20.6 to 8.4 kg y⁻¹) and **deer** (from 13 to 29.3 kg y⁻¹) according to IPCC 2019 refinement of the 2006 guidelines.

5.4.2.2.2 Direct N₂O emissions

The conversion of excreted N into N₂O emissions is determined by the type of manure management system used. The distribution of AWMS is given in **Table A 5.1.11** in **Annex 5.1**. For manure types with bedding addition, the N content of the added bedding is included in the manure N content. Default emission factors (IPCC, 2006; Table 10.21) are assumed except for cattle, pig, sheep, goat, deer and horse deep litter systems where a UK-specific EF of 2.0% of total nitrogen excreted is used and for poultry manure where a UK-specific EF of 0.5% of total nitrogen excreted is used, as derived from UK measurements (Misselbrook, 2017, Cardenas et al., 2013b) (**Table A 5.1.14** in **Annex 5.1**).

UK data relating to direct N₂O emissions from manure management were reviewed as part of Defra project AC0114 (Smith and Williams, 2011). There were a limited number of studies, the mean EF for which are summarised in **Table A 5.1.14**, and no data were available for some emission sources. The UK country specific values for cattle and pig FYM are greater than the default values given in the 2006 IPCC Guidelines (but much closer to the IPCC 2000 Good Practice Guidance value of 2%), and this higher value is also supported by other UK studies not included in the literature review (Moral et al., 2012; Defra project AC0112 – unpublished). The values are not significantly different, so a value of 2% is applied to both cattle and pig FYM. The mean measured EF for broiler litter is also greater than the default 2006 IPCC Guidelines value and therefore a country specific value of 0.5% is applied to poultry manure management. UK measurements of emissions from pig slurry storage were very low and support the zero-emission factor default given by the 2006 IPCC Guidelines which is therefore applied in the UK inventory.

A review of the literature on livestock housing and manure management practices (Smith and Williams, 2013), updated with survey data on manure spreading practices from the BSFP (BSFP, 2025), and data from DAERA statistics for NI (DAERA, 2024) was used as the basis for developing the 1990 to 2024 time series of livestock housing and manure management practices for England and each DG (Wales, Scotland and Northern Ireland) from which a weighted average was derived for the UK. Underlying data sources include routine and ad-hoc surveys such as the Defra Farm Practices Surveys (Defra, 2025c) and published manure management surveys (Smith et al., 2000, 2001a, 2001b).

The proportions of cattle manure management practices were based on a UK data synthesis by Smith and Williams (2016). The housing period for beef animals was derived from Parsons and Williams (2015).

In the In Country Review of the UK 2024 BTR submission, the reviewers recommended the UK to include information in the NID to justify the selection of input data (EFs) and assumptions within country-specific methods, to demonstrate that the methods remain representative of national circumstances for cattle manure management systems (finding 5.A.1 (b)) and the housing period for beef cattle (finding 5.A.1 (c)). To address these findings, the UK notes that the synthesis of available UK data for dairy cattle manure management ensures that the Tier 2 methodology is representative for the entire time series. Assumptions regarding manure management practices for other cattle are applied across the time series due to a lack of available data. Information specific to manure spreading practices is updated based on annual BSFP data, whereas assumptions pertaining to housing, yards and storage are based on the 2015 and 2016 studies noted above. The Inventory Agency will continue to seek additional data to update (or validate) the UK inventory methods, for example from UK farm surveys and via consultation with industry representatives.

During 2025, the UK Inventory Agency has engaged in a peer review of cattle data and assumptions, led by a panel of agriculture sector researchers via the Rural and Environment Science and Analytical Services (RESAS) division of Scottish Government. The study sought to challenge and improve the current suite of country-specific inventory assumptions regarding cattle housing, diet, manure management and productivity. The review included a desk-based review of the UK inventory activity data tables and key assumptions, comparing the data against recent farm survey information, sector-specific research and the expert judgement of the panel. Once the outcomes of the peer review are published, the findings will be used to inform inventory improvements in future submissions.

Within the sheep sector, all (100%) manure from the ewe housing period is assumed to be managed as solid farmyard manure with additions of straw bedding. All (100%) manure from the housing period is assumed to be stored for a period of several months as a field heap on grass before spreading to land. It is assumed that 75% of ewes associated with lowland systems, 60% with upland systems, and 40% with hill systems are housed in the last weeks of pregnancy and that these breeding ewes are housed for 42 days prior to lambing, and that neither the ewe nor new-born lamb(s) are housed post-lambing (Roderick, 2001). Management for other activities (e.g. shearing) were obtained from various sources (Defra, 2004; Webb et al., 2001).

For swine and other minor livestock, bedding N at housing is included in the calculations before estimating emissions.

Poultry manure going to incineration in power stations is associated with N₂O emissions during the housing/storage phase using the proportions as per **Table A 5.1.11** and EF as per **Table A 5.1.14**. The amount of poultry litter incinerated in each year is obtained directly from MRE UK⁹⁵; the amounts exported from Northern Ireland to be incinerated in Scotland and England are provided by DAERA (**Table A 5.1.12** showing transfers between DGs). The quantities going for incineration are deducted prior to calculations of emissions from land spreading. Manure types going to incineration are assumed to be broiler and turkey litter and the reported quantities incinerated are converted to a proportion of the total manure for these poultry categories based on estimated manure outputs per bird.

5.4.2.2.3 Indirect N₂O emissions

For estimation of indirect N₂O emissions from manure management, country-specific values for Frac_{GASM} and Frac_{LEACH} are used. Frac_{GASM} is derived directly as output from the UK N-flow model for each livestock x AWMS combination, as the sum of the NH₃-N and NO-N emissions (further details can be found in the UK Informative Inventory Report for reporting of air pollutant emissions to the UNECE). A country-specific value of 2.4% of manure N for Frac_{LEACH} is used, based on Nicholson et al. (2017) and applied only to solid manure heaps stored in fields. For manure heaps stored on concrete pads, the leachate is assumed to be collected and is subsequently included in the N content of liquid/slurry managed manure. Indirect emissions from manure management due to volatilisation and leaching are then calculated according to IPCC (2006) equations 10.27 and 10.29, respectively, applying the IPCC 2019 refinement to the 2006 Guidelines default value ('wet climate') for EF₄ (1.4%) and the IPCC 2006 Guidelines default value for EF₅ (0.75%), as these are regarded as the most representative for UK conditions.

5.4.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category.

⁹⁵ <https://www.mreuk.com/>

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC using the new Tier 3 models derived for the UK greenhouse gas inventory. The uncertainties in the estimates of livestock data were provided by the devolved governments.

Emissions are calculated from livestock population data and appropriate emission factors. The livestock population data are collected in the JAC, published annually by the devolved governments (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

As noted in section 5.1.4 a full uncertainty analysis using Monte Carlo simulation is not run annually because of resource implications (long model run times) and there is little change in results between years. For the years in between we assume the uncertainty to be similar to previous years and simply offset the uncertainty distribution to align with the revised expected value. This was the case for the 1990-2024 inventory for which no significant methodological changes occurred.

5.4.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

Source-specific QA/QC steps and data verification activities conducted by the Inventory Agency for emission sources in category 3B include the following:

- An AWMS nitrogen flow and mass balance table is constructed, inputting values from across the various stages of waste management, in order to conduct accuracy and consistency checks. Please see the supplementary file 'Manure Management N Flow.xls' for the N-flow balance for the latest year of the submission.
- Inventory-calculated animal nitrogen excretion rates are compared with reference values of per head nitrogen excretion in national Nitrate Vulnerable Zone regulations. Additional data comparisons (e.g. against other country submission data) and steps to validate UK CS N excretion rates per livestock type are set out in section 5.4.2.2.1 above;
- Inventory calculations of the nitrogen content in consumed grass and animal feeds are compared against the independent Inventory calculations of nitrogen intake by grazing animals – to check that the nitrogen consumed by animals and entering the manure management chain broadly agrees with the nitrogen content of what is being produced to feed animals in the UK (net of nitrogen retention);
- Inventory modelled nitrogen content of manures & slurries as they leave storage (so post volatilisation, mineralisation, dilution etc) are compared against datasets of measured nitrogen contents of stored manures;
- Inventory calculations of the components of a soil surface nitrogen balance are compared against the components of an existing government reporting tool;

In addition, the UK Inventory Agency has sought to test the potential for improvements of the AWMS methods. To QA the current method and seek any recommendations for improvements, the Inventory Agency drafted a methodological paper for peer review by leading European AWMS experts. The paper described UK data (scope, resolution) and current methods and set out ideal options for disaggregation of the inventory calculations, to develop

separate calculations for the individual AWMS stages, i.e. from housing and storage into individual stages. The objective is to develop more highly resolved calculations, more accurate, representative AD and EDs per stage and therefore to develop a method that is more accurate and sensitive to mitigation actions along the AWMS chain. The peer reviewers fed back on the veracity of the current method and noted data limitations to overcome prior to further development of an improved method.

5.4.5 Source-specific recalculations

In this submission, we introduced a re-parameterisation of the dairy cattle growth curve using slaughter-weight data – this resulted in an increase in liveweight of all dairy animals.

We have also introduced country-specific LESSE uptake from data from the BSFP for cattle and pig slurry – the data are now expressed as percent of slurry spread instead of the number holdings.

Adjusted metabolisable energy content of preferential grazing areas for the rapidly growing lamb and lactating ewes in the sheep sector, drawing upon measurements made on dairy, beef and sheep farms participating in the Grass Check Northern Ireland (n 35) and Great Britain (n 50) schemes, with a maximum increase from 11.1 to 11.6 MJ kg⁻¹ dm in accessible grass quality – this resulted in an increase in N excretion

Changes in activity data and emission factors due to these recalculations to are given in the tables below.

Table 5.3 3B Source specific recalculations to emissions since previous submission (kt)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.B.1.a	Manure management: Methane emissions – Dairy Cattle	63.90	70.01	64.35	69.84	kt	Replaced slaughter weight timeseries (from 2016). Updated milk yield (2022-2023) to match published stats. Re-parametrisation of the dairy cow mature liveweight (whole timeseries). Updated amount of manure destined for anaerobic digestion (from 1991).
3.B.1.b	Manure management: Methane emissions – Non-Dairy Cattle	59.25	51.17	60.12	51.74	kt	Replaced slaughter weight timeseries and re-parameterisation of the dairy cow mature liveweight (growth curve for followers/calves based on cow mature weight) (whole timeseries). Updated amount of manure destined for anaerobic digestion (from 1991)
3.B.2	Manure management: Methane emissions – Sheep	5.19	4.10	5.66	4.48	kt	A downward adjustment was made in the assumed metabolisable energy density of grazed grass for rapidly growing lambs and lactating ewes that directly resulted in an increase in total dry matter intake to meet the energy requirements of an animal. Correction to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations
3.B.3	Manure management: Methane emissions – Swine	35.00	18.70	35.00	18.68	kt	Updated amount of manure destined for anaerobic digestion (from 2005).
3.B.4	Manure management: Methane emissions – Poultry	2.19	3.25	2.19	3.29	kt	Updated quantities of litter going to anaerobic digestion and incineration (from 2005).
3.B.1.a	Manure management: Nitrous Oxide emissions – Dairy Cattle	1.48	1.35	1.49	1.36	kt	Small changes in N excretion associated with changes to milk yield (2022-2023) and updating slaughter weight timeseries (from 2016). Re-parameterisation of the dairy cow mature liveweight (affects whole timeseries)
3.B.1.b	Manure management: Nitrous Oxide emissions – Non-Dairy Cattle	5.17	4.22	5.23	4.27	kt	Small changes in N excretion associated with updating slaughter weight timeseries and re-parameterisation of the dairy cow mature liveweight (growth curve for followers/calves based on cow mature weight) (whole timeseries).
3.B.2	Manure management: Nitrous Oxide emissions – Sheep	0.11	0.08	0.12	0.09	kt	Correction to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.B.5	Manure Management: Indirect N ₂ O Emissions	2.24	1.74	2.26	1.75	kt	Volatilisation: As direct manure management above plus changes in ammonia emission, e.g. small change to storage mitigation in the pig sector, contribute to changes in indirect nitrous oxide emissions from the re-deposition of NH ₃ and NO _x nitrogen. Leaching: Changes in N excretion or manure management result in changes in the quantity of nitrate leached and the indirect nitrous oxide emitted from leached nitrate.

Table 5.4 3B Recalculations to Emission Factors since the previous inventory (kg/head/yr)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.B.1.a	Manure management: Methane emissions – Dairy Cattle	22.44	38.03	22.59	37.94	kg/hd/year	Reason for change as above
3.B.1.b	Manure management: Methane emissions – Non-Dairy Cattle	6.39	6.77	6.48	6.84	kg/hd/year	Reason for change as above
3.B.2	Manure management: Methane emissions – Sheep	0.11	0.13	0.12	0.14	kg/hd/year	Reason for change as above
3.B.3	Manure management: Methane emissions – Swine	4.637	3.993	4.637	3.988	kg/hd/year	Reason for change as above
3.B.4	Manure management: Methane emissions – Poultry	0.0158	0.0182	0.0158	0.0185	kg/hd/year	Reason for change as above
3.B.1.a	Manure management: Nitrous Oxide emissions – Dairy Cattle	0.52	0.73	0.52	0.74	kg/hd/year	Reason for change as above
3.B.1.b	Manure management: Nitrous Oxide emissions – Non-Dairy Cattle	0.558	0.558	0.563	0.564	kg/hd/year	Reason for change as above
3.B.2	Manure management: Nitrous Oxide emissions – Sheep	0.002	0.003	0.003	0.003	kg/hd/year	Reason for change as above

5.4.6 Implied emission factors

The CH₄ implied EFs from manure management for major categories such as dairy and non-dairy cattle in the UK inventory (38.0, 6.8 kg/head/yr, respectively) are higher than the IPCC default values for Western European systems with an annual average temperature of around 10°C, as applicable in the UK: 21 and 6 kg/head/yr, respectively. See the 2006 IPCC Guidelines, Vol. 4 Ch. 10, Table 10.14. (IPCC, 2006).

UK country-specific values for sheep and swine (0.14, 4.0 kg/head/yr, respectively) are lower than the IPCC default values that are applicable for the UK circumstances (Western Europe, developed country, ~10°C annual average temperature, of: 0.19 kg/head/yr for sheep (2006 IPCC Guidelines, Vol. 4 Ch.10, Table 10.15) and 6.0 kg/head/yr for market swine (2006 IPCC Guidelines, Vol. 4 Ch.10, Table 10.14. (IPCC, 2006).

In the case of N₂O, the implied EFs from manure management for dairy and other cattle in the UK inventory are 0.74 and 0.56 kg N₂O/head/yr respectively, whilst the values for sheep and swine are 0.003 and 0.162 kg N₂O/head/yr respectively.

5.4.7 Source-specific planned improvements

There are a number of methodological improvements that the UK Inventory Agency will consider for future submissions, dependent on the availability of resources and evidence from research and statistics agencies, including: We plan to make improvements to the estimates of emissions from cattle through:

- Revision of the parameters applied in the energy balance equations for non-lactating cattle based on recent and ongoing research from the Agri-Food and Biosciences Institute (AFBI). AFBI are currently sourcing data from other UK and Ireland-based research agencies to validate the findings from a series of respiratory calorimeter chamber experiments for cattle representative of the UK herd. Subject to satisfactory data validation and resources, it is planned to implement this improvement in the next submission.
- Access, analysis and use of cattle data for Northern Ireland that are more detailed than those currently available via annual surveys; we anticipate that – subject to gaining access to the Northern Ireland cattle database – this will enable development of an inventory method for the Northern Ireland herd that is similar to that underpinned by the CTS dataset within Great Britain, improving the accuracy and representativeness of the inventory. Subject to data access and resources available to the Inventory Agency, this improvement is planned to be implemented in the next submission.

The Review Team in the In Country Review of the 2024 submission recommended that the UK reports CH₄ and N₂O emissions from composting of manure under category 3.B manure management. The UK Inventory Agency is consulting with the farming sector and statistical agencies to seek any activity data or evidence that this source occurs in the UK. This activity is not widespread within the UK and to date no activity data have been identified. We will continue to seek to collect AD on composted-manure spreading on agricultural land in order to calculate emissions from this source in future submissions.

5.5 SOURCE CATEGORY 3D – AGRICULTURAL SOILS

5.5.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3D1: Direct N ₂ O Emissions from Managed Soils 3D2: Indirect N ₂ O Emissions from Managed Soils	T1, T2, T3 T1	D, CS D
Gases Reported	N ₂ O		
Key Categories	3D: Agricultural soils - N ₂ O (L1, T1, L2, T2, T3)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	A general assessment of completeness for the inventory is included in Section 1.7 Emissions from the composting and subsequent land application of livestock manures are currently Not Estimated due to a lack of activity data.		
Major improvements since last submission	Inclusion of indirect nitrous oxide emissions resulting from the atmospheric re-deposition of nitric oxide released during residue decomposition. Inclusion of ammonia emissions from decomposing plant residues on the soil surface generating an increase in indirect nitrous oxide emissions. Update of uptake of Low Emission Slurry Spreading Equipment (LESSE) using data extracted from the BSFP publication. Updates to activity data: i) revision of N rate applied to grassland in Northern Ireland in 2023; ii) update of provisional average milk yields; iii) small updates to the slaughter weight activity data have been made for the years 2016-2019, 2022-2023; iv) revised mature liveweight of cattle in the growth curve; v) without update to the quantity poultry litter incinerated, the percentage of poultry litter incinerated was calculated based on the quantity of litter leaving housing and entering the storage phase; vi) 'floating' and 'rigid' covers have been made incompatible in the pig sector.		

Emissions of N₂O from agricultural soils occur due to an increase in available N promoting nitrification and denitrification in soil. These happen due to the application of N amendments or due to management practices that stimulate mineralisation of organic N, including land use change or cultivation of organic soils. Emissions are influenced by environmental conditions including ambient temperature, soil moisture conditions, the addition of other nutrients such as organic fertilisers. The latter include livestock manures, excreta deposition from grazing animals, digestate, sewage sludge, compost.

UK emissions of N₂O from agricultural soils are estimated using IPCC (2006) Tier 1, 2 (IPCC Equations 11.1, 11.2) and Tier 3 methodology, implementing UK-specific EF and parameters

where available. The Tier 3 corresponds to the emissions estimates via an empirical model developed from country specific emissions data.

The IPCC (2006) method involves estimating direct emissions from (see also Figure 5.8):

- (i) The use of inorganic fertiliser
- (ii) Application of livestock manures to land
- (iii) Application of sewage sludge and other organic N additions materials to land
- (iv) Urine and dung deposited by grazing animals on pasture, range and paddock
- (v) Crop residues returned to soils
- (vi) Mineralisation
- (vii) Cultivation of histosols (organic soils)

Indirect N_2O emissions are estimated from 2 sources:

- (viii) Atmospheric deposition of agricultural NO_x and NH_3 (from (i), (ii), (iii) and (iv))
- (ix) Leaching and run-off of agricultural nitrate (from (i), (ii), (iii), (iv), (v) and (vi)).

Further details on activity data and EF are given in **Annex 5.1.3**.

Source category emissions: significance, trends and drivers

The total emissions of N_2O in 2024 from UK agricultural soils (3D) were 36.5 kt. Emissions have decreased by 26.8% since 1990 and -4.3% between 2023 and 2024.

Figure 5.8 Sources of N_2O emissions from soils

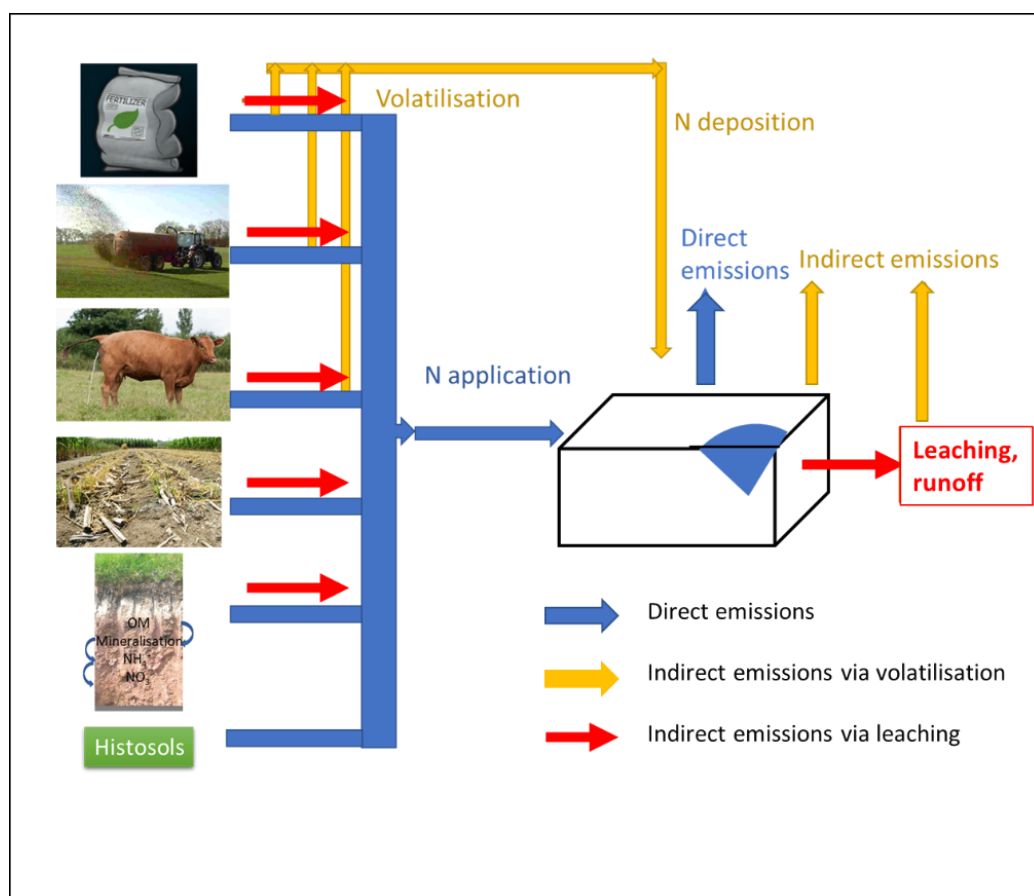
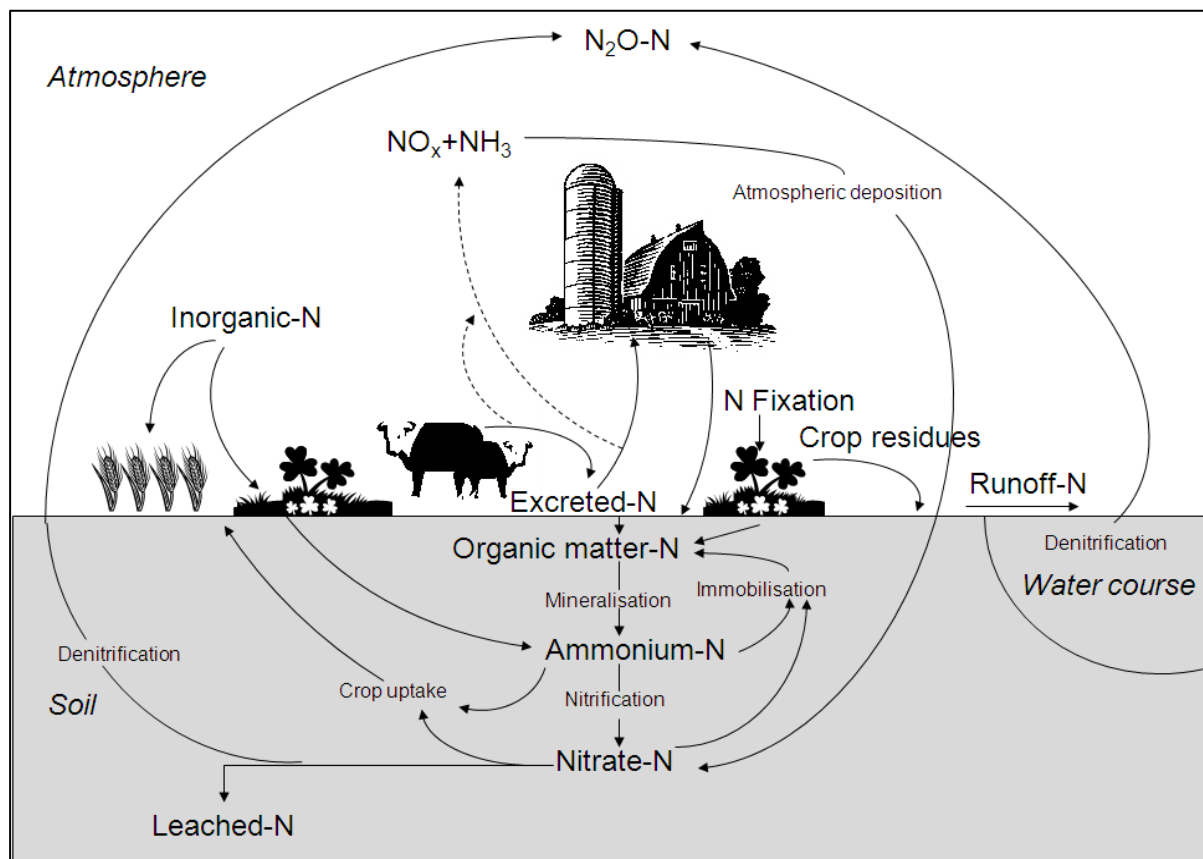


Figure 5.9 Simplified nitrogen cycle highlighting the steps involved in the production of N_2O from agriculture



5.5.2 Methodological Issues

Sources leading to N_2O emissions include slurry, farmyard manure (FYM), sewage sludge, digestates, fertiliser, and dung and urine depositions to grazed lands. Detailed information on some of the individual experiments that provided the data for the analysis can be found in reports (Smith and Williams, 2011; AC0116) and journal articles (e.g. Bell et al., 2016a; Bell et al., 2016b; Bell et al., 2015; Sylvester-Bradley et al., 2015). Following the guidelines of the IPCC (2006) for the derivation of N_2O EFs, all the data from the experiments were collected over a 12-month period. The static chamber methodology was used for emission measurement, which is consistent with the Global Research Alliance guidelines (de Klein and Harvey, 2012; Charteris et al., 2020). Data were collated by N-source: surface-spread and broadcast slurry, FYM, dung and urine, and ammonium-based and urea-based fertilisers. In all experiments, a control treatment which received no organic or inorganic fertiliser was included. In all cases, as well as the emissions and the N application rates, data on the soil characteristics, total rainfall (RainYr, mm) and the average daily temperature for the 365 days associated with the experimental period were collated. The analysis was carried out by using Restricted maximum likelihood (REML) regression using Genstat 17th Edition Release 17.1 VSN International Ltd., Oxford. With the exception of the fertiliser N category 'Other N to grassland', the EFs for fertiliser application, FYM, broadcast slurry and grazing were lower than the IPCC default value of 1%.

5.5.2.1 Inorganic Fertiliser

Direct N_2O emissions from fertiliser N applications are calculated using values of EF_1 derived from UK-specific measurements (Topp et al., *in prep*). Direct N_2O emission is related to fertiliser type, application rate and average annual rainfall, with the relationship for urea-based

fertilisers as in equation 1. For all other fertiliser types, the calculation involves fertiliser rate applied and average annual rainfall (equation 2) (see small changes in parameters compared to previous years).

$$\ln(\text{CumN}_2\text{O} + 1.63) = 0.8404(\pm 0.06846) + 0.001518(\pm 0.0001077) * \text{NRate} \quad (\text{eq.1})$$

$$\ln(\text{CumN}_2\text{O} + 1.63) = 0.5700(\pm 0.1107) - 0.0001942(\pm 0.0001968) * \text{NRate} + 0.3962(\pm 0.1326) * \text{RainYr} + 0.003284(\pm 0.0002291) * \text{NRate} * \text{RainYr} \quad (\text{eq.2})$$

CumN₂O = cumulative annual N₂O-N emission (g ha⁻¹)

Nrate = rate at which fertiliser N is applied (kg ha⁻¹)

RainYr = annual average rainfall (m) limited to 0 to 1.3 m.

EF are derived as shown in equation 3.

$$((\text{CumN}_2\text{O at specified NRate} - \text{CumN}_2\text{O at zero NRate}) / \text{NRate}) \quad (\text{eq.3})$$

The correction multipliers to the total N₂O losses due to the bias for the log transformation were: 1.011 and 1.02 for urea and ammonium nitrate application, respectively.

The activity data for annual fertiliser applications are primarily obtained from the British Survey of Fertiliser Practice (BSFP, 2025) which provides sampled data from a stratified survey of farm types across Great Britain. These data are analysed and upscaled to generate UK-wide fertiliser application data by fertiliser type and crop type. In addition, the BSFP data provide temporal information that enables analysis of the timing of fertilisers by type across the year; this added detail enables the UK method to reflect the different climatic conditions that prevail at the time of fertiliser application, which impacts upon the emissions. For a couple of fertiliser types that are not produced in the UK, the activity data are obtained from fertiliser import data. In the case of NI, as the BSFP does not cover data for fertiliser applications, we use data from DAERA's Survey of Fertiliser Delivered (SFD).

As a data validation step, the UK inventory team also consults with the farming industry, such as the Agricultural Industries Confederation (AIC), to compare the inventory fertiliser activity data against other statistics that are gathered from suppliers. If the inventory data deviate from the industry statistics, the Inventory Agency will explore the reasons for these differences with the fertiliser suppliers to seek any potential improvement in total fertiliser application per fertiliser type.

Crop data are shown in **Annex tables A 5.1.12 to Table A 5.1.21**.

5.5.2.2 Application of livestock manures to land

Emissions are calculated following the IPCC methodology (2006, equation 11.1) using country-specific EFs. Proportions of managed manure N applied to GB cropland are derived from Smith (2012). Assumptions regarding proportions of manures spread to land for Northern Ireland were made based on data provided directly by DAERA (DAERA, 2024). The values assumed (see following paragraphs) are constant throughout the time series with the exception of poultry as described below.

The nature of manure management differs between farm types, with more manure retained on farms with grazing livestock than on pig and poultry farms and also more is spread on grassland for those farm types than to arable crops. In general, slurries are less likely to be transported long distances than solid manures. The fate of manure is estimated by considering spatial disaggregation as in the BSFP. On broiler and turkey farms a proportion of the excreted N is deducted to allow for that amount going to biomass power stations and the remainder is assumed to be applied to land in the neighbourhood.

In the case of dairy cattle, the UK inventory assumes for England, Wales and Scotland that 24% of slurry and 40% of FYM is spread to cropland. For Northern Ireland, 9.5% of slurry is

spread to cropland and 25.5% of FYM is spread to cropland. In the case of beef cattle, for England, Wales and Scotland it is assumed 12% of slurry and 33% of FYM is spread to cropland and for Northern Ireland the values are 9.5% and 20% for slurry and FYM, respectively.

For sheep, all (100% as FYM) of managed manure is assumed to be spread to improved grassland as a simplification of actual practice. Based on statistical analyses of a limited number of survey records from the BSFP (2007 to 2012) for England and Wales we estimated that 87% of all managed manure from all sheep in the UK is spread to improved grassland, and 13% to cropland. The country-specific data show that 94.7% of managed sheep manure in Wales was spread to improved grassland and the remainder to cropland; and that 77.5% of managed sheep manure in England was spread to improved grassland and the remainder to cropland.

No survey records are available for Scotland and Northern Ireland, but the location of managed manure spreading is likely to be more similar to Wales than England, on the basis of the similarity of relative national crop and grass areas (England 50% grass; Wales 92% grass; Scotland 70% grass; and Northern Ireland 93% grass). The model assumption of 100% applied to grassland has no actual impact on the emission estimate.

In the case of pigs, for England, Wales and Scotland, 54% of slurry and 78% of FYM is spread to cropland. For Northern Ireland, 16% of slurry is spread to cropland and 78% of FYM is spread to cropland.

In the case of poultry, the percentage of layer manure and all other poultry manure spread to cropland across the time series in the UK is detailed in **Table A 5.1.15** (Smith et al., 2001b; Defra, 2025c). The amount of manure sent for incineration is excluded from these data.

The inventory method assumes that all (100%) of managed manure from minor livestock (horse, goat and deer) is deposited on improved grassland. Due to the lack of data, this inventory assumption is based on a conservative approach.

Country-specific direct N₂O EF values were derived from a large number of experiments distributed across the UK (Defra, 2016a, Defra, 2014b). Derived values for the direct N₂O EF are 0.75, 0.33 and 1.01% of applied N for slurry, farmyard manure and poultry manure, respectively (Topp et al., *in prep.*).

5.5.2.3 Application of other organic sources to land

Emissions of N₂O are calculated from:

$$E_{N_2O} = Q \times TN \times EF_{N_2O}$$

Where Q is the quantity of organic material applied (m³), TN is the total N content of the material (kg m⁻³); EF_{N₂O} is the emission factor applied (as % of the TN applied).

For sewage sludge and non-manure based digestates the default IPCC EF₁ of 0.01 kg N₂O-N per kg total N applied is used to estimate direct N₂O emissions. For manure-based digestates the same EF as slurry is used (0.75% of N applied).

5.5.2.3.1 Sewage sludge

Emissions from sewage sludge application to land are calculated following the IPCC methodology (2006, equation 11.1). The calculation involves estimating the amount of N contained per DM unit of sludge that is applied to land. Activity data are provided by Ricardo from a combination of the UK regulatory agencies and water companies. The N content is assumed to be 3.6% of the DM content. According to CEH (2017), in the UK 95% of sewage sludge is assumed to be applied as sludge cake and 5% as a liquid (ADAS, personal communication, December 2006), with no change across the time series. The data are

disaggregated at the constituent country level (i.e. England, Wales, Scotland, Northern Ireland), with the proportions applied to arable and grassland being derived from the BSFP from 2005. Uniform application rates across land are assumed per constituent country. The inventory calculation applies the average RB209 value for the total N content of biosolids (4 categories: digested cake, thermally dried, lime-stabilised and composted), assuming equal proportions of each, giving 3.7% on a DM basis. For the purposes of expressing the NH_3 emission factor as a %TAN applied, the TAN content is assumed to be 10% of the TN content (RB209) for sludge cake and 50% (assumed similar to livestock slurry) for liquid sludge. The N_2O EF from application of sewage sludge is presented in **Table A 5.1.17**.

No data are available regarding the proportional split in application to grassland and arable land; hence it is assumed that sewage sludge is applied approximately in proportion to the ratio of improved grassland to arable land per constituent country. Based on 2010 land area values (and used across the time series for simplicity) this gives a proportional application to improved grassland of 50%, 94%, 71% and 93% for England, Wales, Scotland and Northern Ireland, respectively, with the remainder to arable. Sewage sludge activity data was last updated for 2023. Data for 2024 is assumed to be the same as 2023.

5.5.2.3.2 Manure-based digestate and other non-agricultural organic N additions

Application to agricultural land in GB was addressed according to Hulin et al. (2015). These included: Digested liquid sewage sludge, composted green manure, digested sludge cake, thermally dried sludge cake, lime-stabilised sludge and biosolids. The N_2O EFs for these categories are in **Table A 5.1.17**.

Four categories of digestate applied to land are included depending on feedstock: livestock manure, energy crops, food-waste and other organic residues, and for the purpose of the emission calculations each is treated individually (i.e. excludes any potential interactions that may arise through co-digestion). Emissions from digestate arising from the anaerobic digestion of livestock manures are included in the relevant livestock sector calculations. Emissions from spreading of digestate arising from the anaerobic digestion of manures, food waste, energy crops and other organic residues are included in this sector.

Material inputs to anaerobic digestion facilities are derived from the National Non-Food Crops Centre (most recently NNFCC, 2024), with estimated capacity and type of feedstock. Total N content of digestates is based on literature review (Tomlinson et al., 2019) giving mean values of 5.00, 3.97 and 3.35 kg t^{-1} for food-waste, energy crop and other organic residue based digestates, respectively, and it is assumed there is no trend across the time series. The TAN content of all digestate types is assumed as 80% of the total N content (RB209). Although co-digestion of two or more feedstocks is commonly practiced, for the purpose of the emission calculations each is treated individually. As with sewage sludge, no data are available relating to the proportion of digestate applied to grassland or arable land, so the same assumptions are applied (i.e. application in proportion to total land area as improved grassland or arable per constituent country). Thus, the proportion applied to improved grassland is assumed as 50%, 94%, 71% and 93% for England, Wales, Scotland and Northern Ireland, respectively, with the remainder to arable, and constant across the time series. There have been no updates to the quantity of dairy, beef, pig and poultry manure anaerobically digested due to difficulties in sourcing data from the National Non-Food Crops Centre (NNFCC) for this submission. Consistent with IPCC good practice for data gap-filling, the dataset used in the 1990-2022 inventory submission has been used for the current inventory submission with the 2022 data being extrapolated to both 2023 and 2024. The same gap-filling approach has also been applied for non-manure based digestate.

Composted materials subsequently applied to land include green wastes, other organic N additions (e.g. kitchen wastes) and mixed other materials (e.g. cardboard), with activity data

for recent years sourced from government and local authority statistics and the Waste Data Interrogator returns system (Tomlinson et al., 2019). Emissions from the composting process are reported in the Waste sector. Emissions from the composting and subsequent land application of livestock manures are currently not estimated in the UK GHGI due to a lack of activity data; as described in the improvements section, the UK are in the early stages of obtaining activity data for this source.

The EFs to estimate emissions of N_2O from dairy, sheep, pig, poultry and minor livestock manure spread to land (as a % of N applied) were derived from a large number of experiments distributed across the UK also under Defra project AC0116 (Topp et al., *in prep.*). The resulting values are: for slurry 0.7475%, and for FYM and poultry manure 0.3635%, for digestate is assumed to be the same as that for slurry.

5.5.2.4 Urine and dung deposited by grazing animals in the field

Emissions are calculated with a slightly modified IPCC methodology (equation 11.1), as different EFs are applied for urine and dung in the case of cattle and sheep. Estimates of the times of the year when ruminant stock types are housed were made by Parsons and Williams (2015) in a module of the Farm Business Survey (FBS) in England. It is assumed that all excretion from grazing livestock is deposited on grassland. N excretion by cattle is partitioned to urine and dung N as described in **Section 5.3.2.2**, and the separate UK-specific values for EF_3 for urine and dung are applied accordingly (**Annex 5.1.3, Table A5.1.17**). As the UK does not have any experimental data specifically for sheep grazing, EF_3 for sheep excreta deposited to land is estimated by scaling down from cattle the ratio of EF_3 for excreta from sheep vs cattle as exactly 50% of the country specific values for cattle urine and dung. For swine, poultry, goats, deer and horses where behaviour of outdoor animals is quite different to that of cattle and sheep, the default value in IPCC (2019) EF_3 is used, as this EF is regarded as the most representative of UK circumstances in the expert opinion of the UK Inventory Agency.

The UK applies a country specific N_2O EF for cattle urine and dung, based on measurements, but there are insufficient country specific data for N_2O emissions from sheep excreta during grazing. According to the 2006 IPCC Guidelines (vol. 4, chap. 11, table 11.1), the N_2O EF for sheep excreta is 50% of the value for cattle excreta. This is supported, for sheep urine, by information in the 2019 Refinement to the 2006 IPCC Guidelines (Table 4A.1 on wet climates gives a revised value of 0.39% for sheep compared with 0.77% for cattle), while the EF for sheep dung contained therein is less than 50% of the value for cattle (0.04% for sheep compared with 0.13% for cattle). On the basis of this information, the UK has derived an N_2O EF for sheep urine and dung by halving the country specific values for cattle urine and dung. We note that the resulting values (0.315% and 0.097% for sheep urine and dung, respectively) are closely comparable the revised values for sheep given in the 2019 Refinement to the 2006 IPCC Guidelines, and hence the UK considers that their use is justified and representative of UK circumstances.

5.5.2.5 Crop Residues returned to soils

Direct N_2O emissions from crop residues are estimated following IPCC (2006, equation 11.2) using the default value for EF_1 . However, a country-specific approach is taken for deriving the quantity of N returned in crop residues, based on UK-specific data for the harvest index and, where available, UK-specific data for N content of crop residues (**Annex Tables A 5.1.20 and A 5.1.21**). More specifically, the IPCC calculation involves the ratio of crop yield (DM) to total above-ground dry weight (DM harvest index, HI DM). The harvest index can also be defined with respect to nitrogen (N) as nitrogen harvest index (NHI).

The DM harvest index is the ratio of the primary crop DM yield of crop T over the sum of the primary crop DM yield ($Crop_T$) and the above ground biomass DM (eq. 4). The NHI is shown in eq. 5 and with data for the DM harvest index, AG DM(T) can be calculated by rearranging eq.5 to obtain the above ground residue per unit area ($AG_{DM(T)}$) (eq.6 and 7).

$$H_{DM} = \text{Crop}_T / \text{Crop}_T + AG_{DM}(T) \quad (\text{eq.4})$$

$$H_{IN} = (\text{Crop}_T * \text{Crop}_{N(T)}) / (\text{Crop}_T * \text{Crop}_{N(T)} + AG_{DM}(T) * N_{AG}(T)) \quad (\text{eq.5})$$

$\text{Crop}_{N(T)}$ = fraction of N in the DM of crop_T .

$$AG_{DM}(T) = \text{Crop}_T - (\text{Crop}_T * H_{DM})H_{DM} / H_{DM} \quad (\text{eq.6})$$

$$AG_{DM}(T) = (1 - H_{DM}) * \text{Crop}_T / H_{DM} \quad (\text{eq.7})$$

The IPCC default values for the ratio of above to below ground biomass were used, except for crops not defined by the IPCC. These include oilseed rape, linseed and flax, vegetables, other horticultural crops, fruit and energy crops for which the value given is 0.349 (*pers. comm.* Adrian Williams). In the case of sugar beet, we updated the methodology in the previous submission by using primary yields and harvest index to calculate the total above and below ground residue, i.e. deriving a country-specific parameter for sugar beet residue emissions (Sylvester-Bradley et al., 2015). These were evaluated by Williams and Goglio (2017).

Estimates of the N returned to soil under cover crops were made from the NDICEA crop simulation model (van der Burgt et al., 2006), which was calibrated and tested in UK conditions by Smith et al. (2015).

5.5.2.6 Mineralisation

N₂O emissions from mineralisation of soil organic matter on land converted to Cropland more than 20 years ago are included in the Agricultural inventory (emissions from more recent land use change are included in the LULUCF inventory). Details are included in the LULUCF chapter (**Section 6.3** Category 4B Cropland and in **Annex 5.1**).

N₂O emissions from mineralisation of soil organic matter as a result of Cropland Management activities are estimated from the change in soil carbon stocks due to Cropland Management using a Tier 1 approach with the mineralised N calculated from:

mineral soil carbon stock losses * (1/C:N ratio), where C/N is the IPCC default value of 15

The N in mineral soils that is mineralised as a result of historical land use change to Cropland was 78 kt N/y in 2024, and the amount mineralised as a result of Cropland Management was 0.1 kt N/y. The methodology used to assess change in soil carbon stocks due to Cropland Management is described in **Section 6.3** and **Annex 5.1** and briefly consists of using a Tier 3 model described in section A 5.1.4.2 of the NID annex.

5.5.2.7 Cultivation of histosols (organic soils)

Direct N₂O emissions from the cultivation of histosols are estimated following IPCC (2006, equation 11.2) using UK-specific data for the area of cultivated histosols. Areas are based on an estimate from a BEIS (now DESNZ)-funded research project (Evans et al., 2017), specified as cropland or intensive grassland (368,3 kha combined areas in 2024). IPCC Tier 2 EFs from the Peatland Code report (Defra, UK - Science Search) are used for cropland and intensive grassland (see LULUCF chapter, **Section 6.3** Category 4C Grassland). **Annex section A 5.1.4.7** covers emissions from organic soils and EFs are listed in a supplementary Excel file (*see Supplementary file EFs UK inventory agriculture_2025 submission.xlsx*)

Updates to the deforestation areas on organic soils feed through into changes to the total cropland and intensive grassland areas on organic soils over time.

Activity data and emissions are shown in **Annex Table A 5.1.23**.

5.5.2.8 Atmospheric deposition of NO_x and NH₃

Indirect emissions of N₂O from the atmospheric deposition of NH₃ and NO_x are estimated according to IPCC (2006, equation 11.9) using a country-specific value for EF₄ (*Pers. comm.*: Anthony, 2022). The derived overall emission factor is similar to the recently revised IPCC

(2019) default N_2O EF₄ of $1.4 \pm 0.15\%$, for a ‘wet climate’ where annual rainfall exceeds potential evapotranspiration, based on an updated global database of measurements of emissions following applications of synthetic fertiliser N and organic manures (excluding urine and dung) to agricultural land (IPCC 2019; Table 11.3). Whilst the UK GHG Platform research has not led to the derivation of a UK-specific EF, we note that the UK evidence was used to derive a value consistent with the value presented in the 2019 Refinement, and hence in our expert judgement to use the 2019 Refinement EF is the most representative EF option available to reflect UK circumstances; we consider that applying that EF minimises the uncertainty in the UK Inventory for this source. Country-specific values were also applied for the fraction of N that is volatilised as NH_3 and NO_x from inorganic fertiliser and organic (livestock manure, sewage sludge, digestate, grazing returns) N applications to land ($\text{Frac}_{\text{GASF}}$ and $\text{Frac}_{\text{GASM}}$, respectively) derived directly from the combined ammonia and greenhouse gas inventory model for UK agriculture, using an N-flow approach (Webb and Misselbrook, 2004). UK-specific NH_3 EFs are used for inorganic fertiliser and organic manure applications to land, as detailed in the UK Informative Inventory Report. $\text{Frac}_{\text{GASF}}$ values range between 0.026-0.043 and $\text{Frac}_{\text{GASM}}$ values range between 0.080-0.087; the NH_3 EFs are given in a supplementary excel file. NO_x emissions from fertiliser, organic manure applications, grazing returns to grassland, and for crop residues are assumed to be a factor of 0.6 of the N_2O emissions estimated for each source, whereas those from applications to arable land are assumed to be a factor of 0.4 (see detail in the UK Informative Inventory Report). The method used corrects for the N content of manures used as fuel (poultry litter incineration) which are therefore not applied to land.

5.5.2.9 Leaching and runoff

Indirect emissions of N_2O from leaching and runoff are estimated according to IPCC (2006, equation 11.10) using the default value for EF₅. The sources of N considered are synthetic fertiliser application, animal manures, digestates and sewage sludge applied to soils, excretal grazing returns (dung and urine), crop residues and mineralisation. A country-specific value for the proportion of N applied that is leached ($\text{Frac}_{\text{LEACH}}$) is used for both inorganic fertiliser and manure application to grassland and excretal returns from grazing livestock, based on the UPCYCLE model (*Pers. comm.*: Anthony, 2022). For fertiliser and manure application to arable land, crop residues and sewage sludge the default IPCC (2006) $\text{Frac}_{\text{LEACH}}$ value is used as this was supported by Cardenas et al. (2013a) for UK conditions. For mineralisation, the default IPCC (2006) value is also used. The method used corrects for the N content of manures used as fuel (poultry litter incineration) which are not applied to land. For other organic sources applied to land, $\text{Frac}_{\text{LEACH}}$ values of 10 and 30% of applied N are used for grassland and arable land, respectively, to estimate leached N based on Cardenas et al. (2013a). In the case of NO_x , the emission multiplier was set to 0.60 and 0.40 of direct emission from N application to grassland and arable land, respectively. In the case of swine and goats, the value was set to 0.60 of direct N_2O emissions for outdoor pigs.

Activity data and emissions are shown in **Annex Table A 5.1.22** and **Table A 5.1.23**.

5.5.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category.

The estimates of uncertainties in emissions were calculated using Approach 2 (Monte Carlo simulation) described by the IPCC. The uncertainties in the estimates of crop areas were provided by the devolved governments, and the uncertainties in estimates of fertiliser application rates to crops were calculated from the BSFP. Together these give estimates of fertiliser use. Estimates of the uncertainty in the amount of sewage applied to the land were omitted but will be included in further developments of the model. The uncertainties in the new

UK specific emission factors and model parameters were calculated from the data used to derive the emission factors.

Emissions are calculated from a range of activity data and appropriate emission factors (see **Annex 5.1**). Emissions of N₂O from the use of fertilisers are important in this source category. The annual consumption of synthetic fertiliser is estimated based on crop areas (crop area data reported annually by the devolved governments) and fertiliser application rates (reported annually in the BSFP). These are both long running datasets and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

The UK has applied the indirect N₂O EF₄ (mean and uncertainty parameters) for poultry, deer and goats, EF₅ (uncertainty bounds only) and the N₂O EF₃ (mean and uncertainty, lower mean value and narrower uncertainty bounds) for poultry, deer, horses, pigs and goats according to the IPCC 2019 Refinement to the 2006 Guidelines, as they are regarded as more representative of UK circumstances based on the expert judgement of the UK Inventory Agency.

As noted in section 5.1.4 a full uncertainty analysis using Monte Carlo simulation is not run annually because of resource implications (long model run times) and there is little change in results between years. For the years in between we assume the uncertainty to be similar to previous years and simply offset the uncertainty distribution to align with the revised expected value. This was the case for the 1990-2024 inventory for which no significant methodological changes occurred.

5.5.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

Source-specific QA/QC for emissions from agricultural soils includes the validation checks on animal N-excretion rates and the construction of an annual N-flow balance, as described in section 5.4.4.

In addition, the annual estimates of mineral fertiliser applied to soils is subject to calculation checks by the Inventory Agency, compared to published BSFP estimates, and further data validation checks against industry fertiliser sales data from the AIC, as described in section 5.5.2.1.

5.5.5 Implied emission factors

The direct UK N₂O IEFs differ from the IPCC default value of 1% for inorganic and manure fertilisers: 0.65 and 0.60, respectively. Values for application of sewage sludge, crop residues and mineralisation agree with the default value. The UK value for pasture, range and paddock (0.33%) is lower than the IPCC default (2% for cattle), and the value for histosols with 11.9 kg N ha⁻¹, is higher than the IPCC default values of 8 kg N ha⁻¹, respectively.

5.5.6 Source-specific planned improvements

There are a number of methodological improvements that the UK Inventory Agency will consider for future submissions, dependent on the availability of resources and evidence from research and statistics agencies, including:

The Review Team during the In Country Review of the 2024 submission recommended that the UK reports CH₄ and N₂O emissions from composting of manure under category 3.B manure management. The UK is currently working in the early stages of collecting AD on composted-manure spreading on agricultural land and currently lacks all the information required to

calculate emissions from this source but plans to continue compiling the data for potentially implementing in future submissions.

5.5.7 Source-specific recalculations

In this submission we have introduced a new source of NH_3 emissions from decomposing plant residues from grass on the soil surface which resulted in an increase in NH_3 and indirect N_2O emissions. We also imposed a long-term trend in improved grass yield and nitrogen uptake resulting in increased N_2O emissions from residues decomposition and decreased indirect from leaching.

Changes in activity data and to emission factors due to these recalculations to are given in the tables below.

Table 5.5 3D Source specific recalculations to emissions since previous submission (kt)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.D.1.a	Direct N ₂ O Emissions from Managed Soils: Inorganic N fertilisers	20.14	8.46	20.14	8.72	kt	Updated estimate of the quantity of fertiliser nitrogen spread to grassland in N Ireland in the year 2023, replacing an extrapolated estimate with a new value from the Farm Business Survey, plus a smaller re-calculation for Scotland in the year 2023 where the nitrogen application is based on a rolling 3-year average on the Dairy farm type
3.D.1.b.i	Direct N ₂ O Emissions from Managed Soils: Organic N Fertilisers – Animal Manure Applied to Soils	4.63	3.77	4.66	3.76	kt	N entering spreading and therefore emissions affected by the upstream changes detailed for 'Manure management: Nitrous Oxide emissions'
3.D.1.b.ii	Direct N ₂ O Emissions from Managed Soils: Organic N Fertilisers – Sewage Sludge Applied to Soils	0.35	0.92	0.35	0.93	kt	Updated amounts of sewage sludge spread to land (2023)
3.D.1.b.iii	Direct N ₂ O Emissions from Managed Soils: Organic N Fertilisers - Other Organic Fertilisers Applied to Soils	0.00	1.30	0.00	1.34	kt	Updated amounts of manure-based digestate spread to land
3.D.1.c	Direct N ₂ O Emissions from Managed Soils: Urine and Dung Deposited by Grazing Animals	2.98	2.34	3.01	2.35	kt	Emissions from urine and dung affected by the changes detailed for 'Manure management: Nitrous Oxide emissions', i.e. changes in cattle N excretion associated with changes to milk yield and slaughter weights; For sheep, a downward adjustment was made in the assumed metabolisable energy density of grazed grass for rapidly growing lambs and lactating ewes that directly resulted in an increase in total dry matter intake to meet the energy requirements of an animal, and therefore of nitrogen intake
3.D.1.d	Direct N ₂ O Emissions from Managed Soils: Crop Residues	4.50	4.91	4.50	4.97	kt	Grassland: Representation of long-term genetic gain in grass yields and nitrogen uptake, resulting in direct increase in quantity of residue nitrogen and nitrous oxide emissions

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
							Arable: Small re-calculations of the yield of some crops in Defra statistics
3.D.1.e	Mineralisation/Immobilization Associated with Loss/Gain of Soil Organic Matter	0.61	1.22	0.61	1.25	kt	Minor changes to soil N mineralisation from 2010 onwards from updates to deforestation areas; Cropland Management: Updated crop type data for England (from 2019). Updated crop type data for Northern Ireland for 2023. New year of manure management data impacts average used for pre-2008 interpolation (small changes for Northern Ireland from 1990-2007).
3.D.1.f	Direct N ₂ O Emissions from Managed Soils: Cultivation of Organic Soils	7.31	6.89	7.31	6.92	kt	Changes to organic soil areas due to new rewetting data for England (2021-2024) from DEFRA's Peatland Register, which in previous inventories had been projected from 2013-present, and Scotland (2013-2024); Minor changes to forest planting data.
3.D.2.a	Indirect N ₂ O Emissions From Managed Soils – Atmospheric Deposition	3.03	2.69	3.09	2.79	kt	As 'Direct N ₂ O Emissions from Managed Soils' - Changes in ammonia emission as a result of, e.g. a introduction of a new source of ammonia (from crop residues), amounts of N fertiliser applied, changes to N excretion and revised manure spreading mitigation contribute to changes in indirect nitrous oxide from the re-deposition of ammonia nitrogen.
3.D.2.b	Indirect N ₂ O Emissions From Managed Soils - Nitrogen Leaching and Run-off	6.16	5.07	6.17	5.10	kt	As 'Direct N ₂ O Emissions from Managed Soils' - Changes in e.g. amounts of N fertiliser applied and N excretion result in changes in the quantity of nitrate leached and the indirect nitrous oxide emitted from leached nitrate.

Table 5.6 3D Recalculations to Emission Factors since the previous inventory (kg N₂O-N/kg N)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3.D.1.a	Direct N ₂ O Emissions from Managed Soils: Inorganic N fertilisers	0.00815	0.00637	0.00815	0.00645	kg N ₂ O-N/kg N	Reason for change as above
3.D.1.b.i	Direct N ₂ O Emissions from Managed Soils: Organic N Fertilisers – Animal Manure Applied to Soils	0.00610	0.00606	0.00609	0.00604	kg N ₂ O-N/kg N	Reason for change as above
3.D.1.b.iii	Direct N ₂ O Emissions from Managed Soils: Organic N Fertilisers - Other Organic Fertilisers Applied to Soils	na	0.0093	na	0.0092	kg N ₂ O-N/kg N	Reason for change as above
3.D.1.c	Direct N ₂ O Emissions from Managed Soils: Urine and Dung Deposited by Grazing Animals]	0.00333	0.00330	0.00333	0.00331	kg N ₂ O-N/kg N	Reason for change as above
3.D.1.f	Direct N ₂ O Emissions from Managed Soils: Cultivation of Organic Soils	11.863	11.945	11.862	11.945	kg N ₂ O-N/kg N	Reason for change as above

5.6 SOURCE CATEGORY 3E – PRESCRIBED BURNING OF SAVANNAS

This source is not relevant in the UK. It does not occur.

5.7 SOURCE CATEGORY 3F – FIELD BURNING OF AGRICULTURAL RESIDUES

5.7.1 Source category description

	Source included	Method	Emission Factors
Emissions sources	3F11: Wheat 3F12: Barley	T1 T1	D D
Gases Reported	CH ₄ , N ₂ O, NO _x , CO, NMVOC, SO _x		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	No major improvements.		

5.7.2 Methodological Issues

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration. The estimates are derived from methodology and emission factors according to IPCC (1996) and from EMEP/EEA (2016).

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data from DEFRA (England & Wales), The Scottish Government (Scotland) and DAERA (Northern Ireland), a UK-specific harvest index approach to derive residue amounts (Williams and Goglio, 2017) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, so no estimates are reported from 1993 onwards. The CO₂ emissions are not estimated because these are part of the annual carbon cycle.

5.7.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category.

Field burning ceased in 1993, and emissions are reported as NO after this date

5.7.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

5.7.5 Source-specific recalculations

No recalculations were carried out in this sector

5.7.6 Source-specific planned improvements

No improvements are planned.

5.8 SOURCE CATEGORY 3G - LIMING

5.8.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3G1: Limestone CaCO_3	T1	D
	3G2: Dolomite $\text{CaMg}(\text{CO}_3)_2$	T1	D
Gases Reported	CO_2		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	No major improvements		

CO_2 emissions from liming occur as carbonates in the form of limestone ($\text{Ca}(\text{CO}_3)$) and dolomite ($\text{CaMg}(\text{CO}_3)_2$) are applied to soils to increase their pH.

Source category emissions: significance, trends and drivers

Total UK CO_2 emissions from liming in 2024 were 1058.8 kt CO_2 . Emissions in 2024 were 3.7% higher compared to 1990 and 11% lower in 2024 compared to 2023.

5.8.2 Methodological Issues

CO₂ emissions due to the application of lime and related compounds are estimated using the Tier 1 IPCC (2006) methodology. For calcium carbonate (limestone, chalk and sugar beet lime - LimeX) an emission factor of 120 t C / kt applied is used, and for dolomite application, 130 t C / kt. These factors are based on the stoichiometry of the CO₂ loss from the carbonates and assume pure limestone/chalk and dolomite.

Liming activity data (% area limed and application rate to three land use types: 'all tillage', 'grass under 5 years old' and 'grass 5 years and over') were obtained from the BSFP (Table EW1.4 for England & Wales and Table SC1.4 for Scotland) from 1992 onwards; activity data for 1990 and 1991 were assumed to be the same as for 1992. The % area limed and application rate of lime in Northern Ireland was assumed to be the same as that for Scotland by land use type. For each of the liming types in BSFP: i) ground limestone, ii) ground chalk, iii) magnesian limestone, iv) sugar beet lime, iv) other), the application rate and % area limed were multiplied by the area of 'all tillage', 'grass under 5 years old' and 'grass 5 years and over' to derive the total limestone and dolomite applied for each devolved government.

The 'other' category in BSFP is made up of Ag slag, calcified pelleted limestone, Calcifert, granules, Humistar, lime slag, screed lime (Defra, *pers. comm.*); the majority of these are CaCO₃ based limes and thus were included in the activity data for limestone.

Limex is assumed to have 46% CaCO₃ content (British Sugar, Chemical Safety Data; Median of LimeX45 (45%) and LimeX70 (52%) CaCO₃ content).

Activity data and emissions are shown in **Table A 5.1.26**.

5.8.3 Uncertainties and time-series consistency

Uncertainty in both the activity data and emission factor are judged to be low. The main source of uncertainty in the estimates is caused by non-publication of some activity data due to commercial restrictions although these are not judged to be very significant.

There is good time series consistency as there has been continuity in the published data sources.

5.8.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

5.8.5 Source-specific recalculations

Table 5.7 3G Source specific recalculations to emissions since previous submission (kt)

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3G	Liming						[No recalculations]

5.8.6 Source-specific planned improvements

Emission factors and activity data will continue to be reviewed when new data are available.

5.9 SOURCE CATEGORY 3H - UREA APPLICATION

5.9.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	3H: Urea Application	T1	D
Gases Reported	CO ₂		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	See Section 5.10 .		
Completeness	A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	No major improvements		

The application of urea (CO(NH₂)₂) fertiliser generates CO₂ emissions due to its conversion to bicarbonate (HCO₃⁻).

Source category emissions: significance, trends and drivers

Total UK CO₂ emissions from urea application in 2024 were 366 kt CO₂. Emissions in 2024 were 25% higher compared to 1990 and 10% lower in 2024 compared to 2023. In recent years, due to the higher price of fuel and feedstock leading to higher inorganic fertiliser prices, the UK has seen a reported increase in urea use by farmers, via the BSFP, driving this trend.

5.9.2 Methodological Issues

The annual amount of fertiliser as urea, alone or as part of urea ammonium nitrate (UAN), used in kt N was estimated from the BSFP (for England, Wales and Scotland) and the Northern Ireland Fertiliser Supply statistics. Both fertilisers are applied to grassland and cropland in the UK. It was assumed that 35% of UAN was urea. The EF used was the IPCC (2006) default value of 0.2 tonne of C per tonne of urea, and emission estimates were made using IPCC Tier 1 (2006, equation 11.13).

Activity data and emissions are shown in **Table A 5.1.27**.

5.9.3 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category. The same data source is used for the entire time series to ensure consistency.

5.9.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 5.11**.

5.9.5 Source-specific recalculations

Details of and justifications for recalculations to activity data and to emission factors are given in the table below.

Table 5.8 **3H Source specific recalculations to emissions since previous submission (kt)**

CRT Category	Source Name	2025 submission		2026 submission		Units	Comment/Justification
		1990	2023	1990	2023		
3H	CO ₂ from Urea Application	292.95	400.81	292.95	405.53	kt	Revisions to urea-based fertiliser use as detailed in 'Direct N ₂ O Emissions from Managed Soils: Inorganic N fertilisers'

5.9.6 Source-specific planned improvements

Emission factors and activity data will continue to be reviewed when new data are available.

5.10 AGRICULTURE EMISSIONS IN THE OVERSEAS TERRITORIES (OT) AND CROWN DEPENDENCIES (CD)

5.10.1 Description

Emissions sources	3A: Enteric Fermentation 3B: Manure Management 3D: Agricultural Soils 3F: Field Burning of Agricultural Residues 3G: Liming 3H: Urea application In the CRT, all UK overseas territories and crown dependencies emissions data are reported in sector 3J.
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	Tier 1
Emission Factors	Default EFs (OTs), UK implied EFs (CDs)
Key Categories	None identified
Key Categories (Qualitative)	None identified
Completeness	Emissions are not estimated for 3G Liming for Bermuda, Cayman Islands and the Falklands, for 3H Urea application for Bermuda and the Falklands, and for 3F Field Burning of Agricultural Residues for any OT.
Major improvements since last submission	No major improvements.

Livestock and crop production occur in all of the UK overseas territories (OTs) and crown dependencies (CDs), resulting in emissions from categories 3A, 3B and 3D for all OTs and CDs. Agricultural GHG emissions from OTs and CDs combined made up less than 1% of the total UK agricultural emissions in 2024.

Note that no agricultural activities occur in Gibraltar, so emissions and activity data are zero for Gibraltar for all agriculture sector sources.

5.10.2 Methodological Issues

5.10.2.1 Emissions from livestock

The CDs have similar farming systems to the mainland of the UK and are located nearby with a similar climate. Due to this similarity, emissions for CDs are calculated by applying implied EFs calculated from the UK GHGI to data on livestock numbers for CDs aggregated to a basic classification. The implied EFs are calculated for each year, so that the implied EF can vary across the time series. Tables of animal numbers used in calculations are presented in **Annex 5.1.6**.

For OTs, emissions from livestock are calculated using Tier 1 methodology from the IPCC 2006 Guidelines (2019 Refinement for deer enteric fermentation and wastes), by applying default EFs for the appropriate geographic region and climate type to the number of livestock reported.

For both CDs and OTs, data on livestock numbers were provided by local contacts (Bermuda Government, 2025; Cayman Islands Government, 2025; Falkland Islands Government 2025; Government of Jersey, 2025; Isle of Man Government, 2025; States of Guernsey Government, 2025).

5.10.2.2 Emissions from 3D Agricultural Soils

For the CDs, estimates of emissions from agricultural soils for all sub-categories were made by applying UK GHGI implied EFs to animal numbers (for livestock manure-related activities) and areas of cropland and grassland (for non-manure fertilisers and emissions related to loss of soil carbon). For OTs, the Tier 1 methodology from the 2006 IPCC Guidelines was applied to calculate emissions from agricultural soils. Livestock numbers, mineral fertiliser application and crop production data were provided by each of the OTs or sourced from FAO; these data can be found in **Annex 5.1.6**. Emission factors taken from the 2006 IPCC guidelines were applied to all activity data from OTs.

In the Falklands, according to local expert judgement, no synthetic fertilisers are applied, so emissions from this source are not estimated there.

In the Falklands, despite there being a very large area of grassland histosols, N₂O emissions from managed histosols are only reported for cropland areas. The reason for this is that information from local experts indicates that grasslands are unmanaged (i.e. no fertilisation, liming, drainage or cultivation) and livestock density is low, so these soils are not likely to be a source of N₂O emissions. The UK understands managed organic soils to be present only in the Falkland Islands and the Isle of Man and absent from all other CDs and OTs.

5.10.2.3 Emissions from other agriculture categories

For the CDs, emissions from 3F Field Burning of Agricultural Residues and 3H Urea Application are estimated in the same way as emissions from 3D Agricultural soils, by applying implied EFs from the UK GHGI to the area of cropland (for both field burning and urea application) and grassland (for urea application only). Emissions for 3H Urea Application are not estimated for Jersey due to local experts indicating that the activity does not occur. Emissions from 3G Liming are calculated using the default 2006 IPCC EF of 0.12 kg C/kg limestone, and are applied to data on the quantity of limestone applied.

For the OTs, no emissions were estimated for categories 3F Field Burning of Agricultural Residues due to a lack of available activity data. Emissions were not estimated for 3G Liming due to local experts indicating that relevant activities do not occur. Emissions from 3H Urea Application are estimated for the Cayman Islands only from 2014. Total agricultural land area and emissions from 3F, 3G, and 3H for each territory are presented in **Table 5.9**.

Table 5.9 Total agricultural area (kha) and emissions (kt) from 3F, 3G and 3H for the UK, Isle of Man, Falkland Islands, all other crown dependencies and all other overseas territories

Territory	Category	1990	1995	2000	2005	2010	2015	2020	2022	2023	2024
UK	Cropland area (kha)	5,420	5,376	5,287	5,137	4,947	4,890	4,782	4,742	4,721	4,700
	Grassland area (kha)	10,281	10,160	9,808	10,065	9,980	9,880	10,042	10,136	9,730	9,380
Isle of Man	Cropland area (kha)	11.2	10.4	10.4	10.5	10.4	8.6	7.2	7.7	7.7	7.7
	Grassland area (kha)	35.7	36.3	36.1	35.9	35.8	37.6	38.9	38.4	38.4	38.4
	3F emissions (ktCO ₂ e)	0.466	NO	NO	NO	NO	NO	NO	NO	NO	NO
	3G emissions (ktCO ₂ e)	0.592	0.565	0.571	0.574	0.570	0.531	0.531	0.531	0.531	0.531
	3H emissions (ktCO ₂ e)	0.178	0.112	0.086	0.119	0.158	0.175	0.103	0.110	0.110	0.110
Falkland Islands	Cropland area (kha)	0.566	0.566	0.566	0.566	0.793	0.793	0.793	0.793	0.793	0.793
	Grassland area (kha)	1,215	1,215	1,215	1,215	1,215	1,215	1,215	1,215	1,215	1,215
	3F emissions (ktCO ₂ e)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	3G emissions (ktCO ₂ e)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	3H emissions (ktCO ₂ e)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Jersey, Guernsey	Cropland area (kha)	6.86	7.03	6.61	5.89	6.34	5.82	5.84	5.84	5.84	5.84
	Grassland area (kha)	4.83	4.66	4.85	5.17	4.52	5.11	5.04	5.03	4.98	4.97
	3F emissions (ktC2e)	0.0174	NO	NO	NO	NO	NO	NO	NO	NO	NO
	3G emissions (ktCO ₂ e)	0.0691	0.0691	0.0691	0.0688	0.0685	0.0683	0.0683	0.0683	0.0683	0.0683
	3H emissions (ktCO ₂ e)	0.0066	0.0045	0.0038	0.0077	0.0137	0.0185	0.0129	0.0129	0.0129	0.0129
Bermuda, Cayman Islands	Cropland area (kha)	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740
	Grassland area (kha)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	3F emissions (ktCO ₂ e)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	3G emissions (ktCO ₂ e)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	3H emissions (ktCO ₂ e)	NE	NE	NE	NE	NE	0.000356	0.000745	0.001245	0.001245	0.001245

Note: NO = not occurring, NE = not estimated

To provide an indication of the magnitude of emissions reported as “not estimated” (NE) for 3F Field Burning and 3H Urea Application, cropland areas for the OTs were calculated as a percentage of UK cropland area. Cropland area in the Falkland Islands does not exceed 0.02% of UK total cropland area, as is the case for Bermuda and the Cayman Islands. The magnitude of emissions currently not estimated is therefore below the threshold of significance.

Whilst grassland area in the Falklands Islands is a sizeable proportion of UK grassland area at 13%, local contacts indicate that liming does not occur, and that synthetic fertiliser (including urea) application is minimal.

5.10.3 Uncertainties and time-series consistency

Activity data available for several sub-categories are incomplete, including for field burning activity, crop production, application of synthetic fertiliser, liming and urea application.

- Livestock statistics are not collected every year for all livestock types in all the OTs and CDs, so in some cases extrapolation was necessary, such as for non-cattle livestock for Jersey and all livestock types for Bermuda.
- For synthetic fertiliser application, in the Cayman Islands there are no data available before 2010, so this is extrapolated backwards based on an average. In Bermuda, only a single value is available for the whole time series, which has been assumed to remain constant.
- For emissions from crop residues, no data are available for the Falkland Islands so this source is not estimated. For Bermuda, crop production data are sourced from FAO up to the year 2016 but are not available for later years, so 2016 values have been extrapolated.
- For the CDs, data on the application of limestone were compiled until 2015 but are not now available, so 2015 values have since been extrapolated.
- Due to a lack of activity data for any year, emissions are not estimated for 3G Liming for Bermuda, for 3H Urea application for Bermuda and the Falklands, and for 3F Field Burning of Agricultural Residues for any OT.

IPCC Tier 1 default factors from the 2006 Guidelines have been used to estimate emissions for the OTs, using the closest regional values matching the climate and production systems. However, this does introduce uncertainty, as local geography, livestock breeds and production practices may differ. A similar uncertainty in CD emissions arises from the use of UK GHGI implied emission factors because local production practices may differ significantly from the UK average. However, there is generally a lack of available data and resource to support using higher-tier methods or developing local-specific EFs.

Due to the proportionally small contribution of OTs and CDs to the national inventory, for simplicity the UK presents all OT and CD agriculture data in the CRT against 3J.

5.10.4 Planned improvements

It has been added to the improvement plan to discuss the changes to the institutional structure to make it more feasible to fully integrate emissions from the OTs and CDs and other data, into the appropriate CRT categories, rather than having emissions reported under 3J.

The Inventory Agency is consulting with stakeholders to seek more complete activity data for the OTs and CDs where these are currently lacking, including updated livestock, fertiliser and crop production data from OTs, and liming data from the CDs. Further, the Inventory Agency will review assumptions based on local expert judgement, e.g. that no synthetic fertiliser, limestone or urea is applied in the Falklands.

5.11 GENERAL COMMENTS ON QA/QC

The UK Agriculture Inventory has a documented QA/QC plan covering the annual compilation of the inventory by the contracted consortium (led by ADAS) addressing governance, data management, quality control (procedures and checks) and quality assurance activities. The organisational roles and responsibilities of the delivery team and government stakeholders are described in section 1.2.2. The inventory compilation, reporting, review and improvement cycle for an annual submission to UNFCCC and UNECE is outlined with an overview of the key QC and QA activities at different stages in the cycle, including the timings for the annual compilation cycle and details of source-specific quality checks to be performed on the incoming data, the calculation models and the data validation checks on model outputs. The QA/QC plan is subject to annual review.

The agriculture inventory data quality objectives are based on the inventory quality objectives of Transparency, Accuracy, Consistency, Comparability and Completeness (TACCC) as set out in the IPCC national inventory reporting guidelines and clear statements are provided as to how these are to be met. Security, scope and timeliness of data supply are addressed, with Data Supply Agreements being developed with suppliers of key input data.

Procedures are in place for the management of confidential data (e.g. farm holding level data) and for data storage, back-up and archiving.

During the finalisation of the agriculture “master” dataset and the integration of these data into the wider UK inventory data for onwards submission to the UNFCCC and UNECE, there are iterative quality checks performed by the Inventory Agency (under contract to DESNZ) to highlight any data anomalies, recalculations and inventory trends compared against previous inventory submissions. There is then a period of dialogue and clarification of the agriculture data and supporting information is provided to the Inventory Agency where applicable.

Peer reviews and bilateral reviews of the Agriculture inventory have been conducted, and the revised methodological approaches introduced in the 2018 submission through the Defra GHG improvement programme were reviewed by an international Research Expert Group (including several IPCC Inventory Review Experts) as part of the programme. An inventory method improvement has been considered to disaggregate the activity and emissions across the livestock manure management systems (MMS), aiming to develop a method that will more accurately represent the emissions and the fate of materials across different manure management stages: in storage, in housing and at the point of spreading, for slurry and manure materials. UK sector experts prepared a draft paper for submission to international peer reviewers from Ireland, Denmark and France. Peer reviewer feedback on the proposed method indicated that the rationale and objective of the proposed improvement is sound and should be explored further, noting that further work is needed to address data and evidence gaps before the UK can move to implementation. The inventory team will progress this item, subject to resource availability and identification of relevant evidence to populate the proposed new method.

6 Land-Use, Land-Use Change and Forestry (CRT Sector 4)

Table 6.1 gives an overview of the LULUCF sector, which includes carbon stock changes and emissions of greenhouse gases and precursors (CO₂, CH₄, N₂O, NO_x and CO) from Land Use, Land-Use Change and Forestry (LULUCF) activities. Removals of carbon dioxide are conventionally presented as negative quantities.

The numbers presented in **Table 6.1** are for the UNFCCC submission.

Table 6.1 LULUCF Sector Overview (GBR submission)

LULUCF Greenhouse Gas Source and Sink Categories	KCA Rank ¹ (gas)	Uncertainty ²	1990 emissions total (Mt CO ₂ e)	2023 emissions total (Mt CO ₂ e)	2024 emissions total (Mt CO ₂ e)	Recalculations 1990 ³ (Mt CO ₂ e)	Recalculations 2023 ³ (Mt CO ₂ e)
Total LULUCF	-	-	10.3	0.4	0.3	-0.4	-0.7
A. Forest Land	11 (CO ₂)	15%	-14.2	-18.2	-17.9	-0.4	-0.6
B. Cropland	13 (CO ₂)	15%	15.4	13.3	13.2	0.0	0.0
C. Grassland	25 (CH ₄), 30 (CO ₂)	35%	2.3	0.0	0.0	0.0	-0.1
D. Wetlands	26 (CH ₄)	50%	2.9	3.1	2.8	-0.1	-0.1
E. Settlements	22 (CO ₂)	50%	5.9	4.3	4.3	0.0	0.0
G. Harvested Wood Products	29 (CO ₂)	15%	-2.0	-2.1	-2.2	0.1	0.1

¹These values are the rank for each category given in the KCA Ranking in **Annex Table A 1.5.1**

²All values for uncertainty refer to those associated with the latest year CO₂ emissions

³The values given are the difference in 1990 or 2023 emissions/removals from the data reported in the previous UK GHGI submission using AR5 GWP values (without feedbacks).

The summary analysis of the trends in greenhouse gas emissions from the LULUCF sector is provided in **Section 2**. The methodological differences since the previous UK GHGI submission are explained in this chapter. This information is presented in the last cell of the tables at the start of each section providing an overview of each of the LULUCF categories (*Major improvements since last submission*).

The LULUCF sector covers emissions and removals of direct greenhouse gases under seven categories, of which Forest Land (4A) and Harvested Wood Products (4G) are net sinks, and Cropland (4B), Grasslands (4C), Wetlands (4D), and Settlements (4E) are net sources (**Figure 6.1**). The UK does not report any emissions or removals from the Other Land (4F) category.

The LULUCF sector is the only sector within the national greenhouse gas inventory which reports both sources and sinks. The sinks are provided by CO₂ removals from carbon stock gains in above-ground and below-ground biomass, litter, deadwood, soils and harvested wood products. The sources of emissions are carbon stock losses from those same pools and GHG emissions (CO₂, CH₄ and N₂O) from LULUCF activities (Figure 6.2).

Figure 6.1 LULUCF emissions and removals from the UK 1990-2024 by category

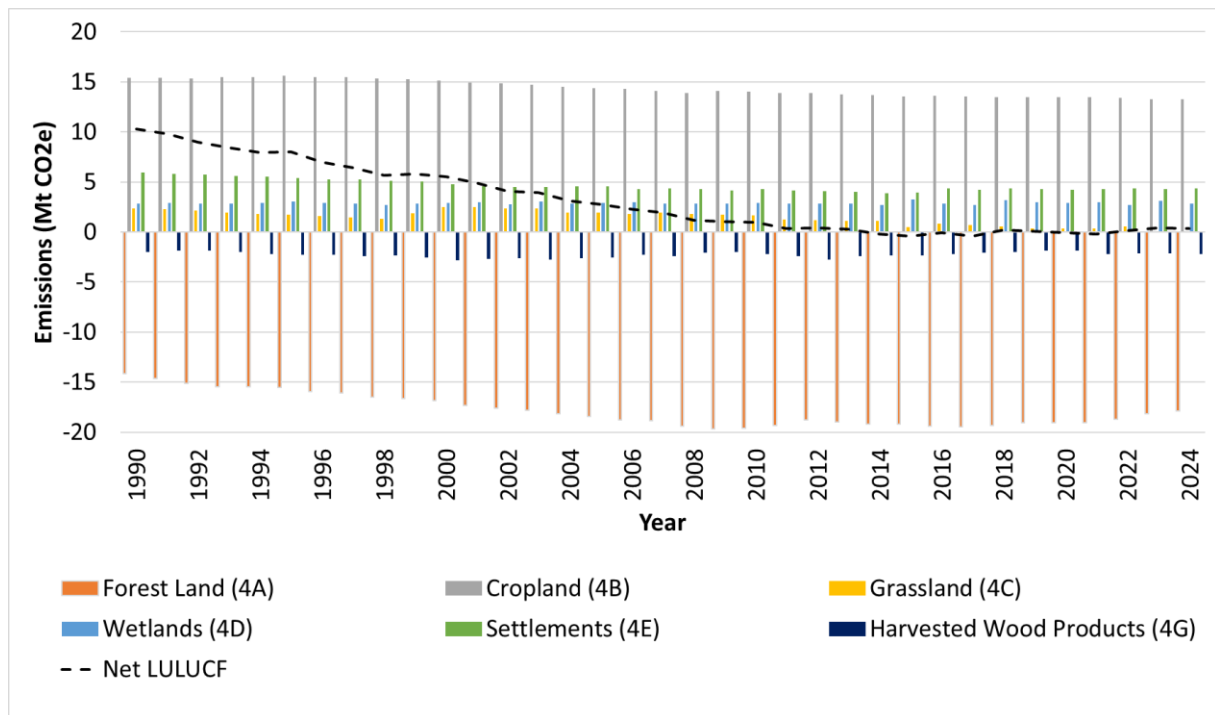
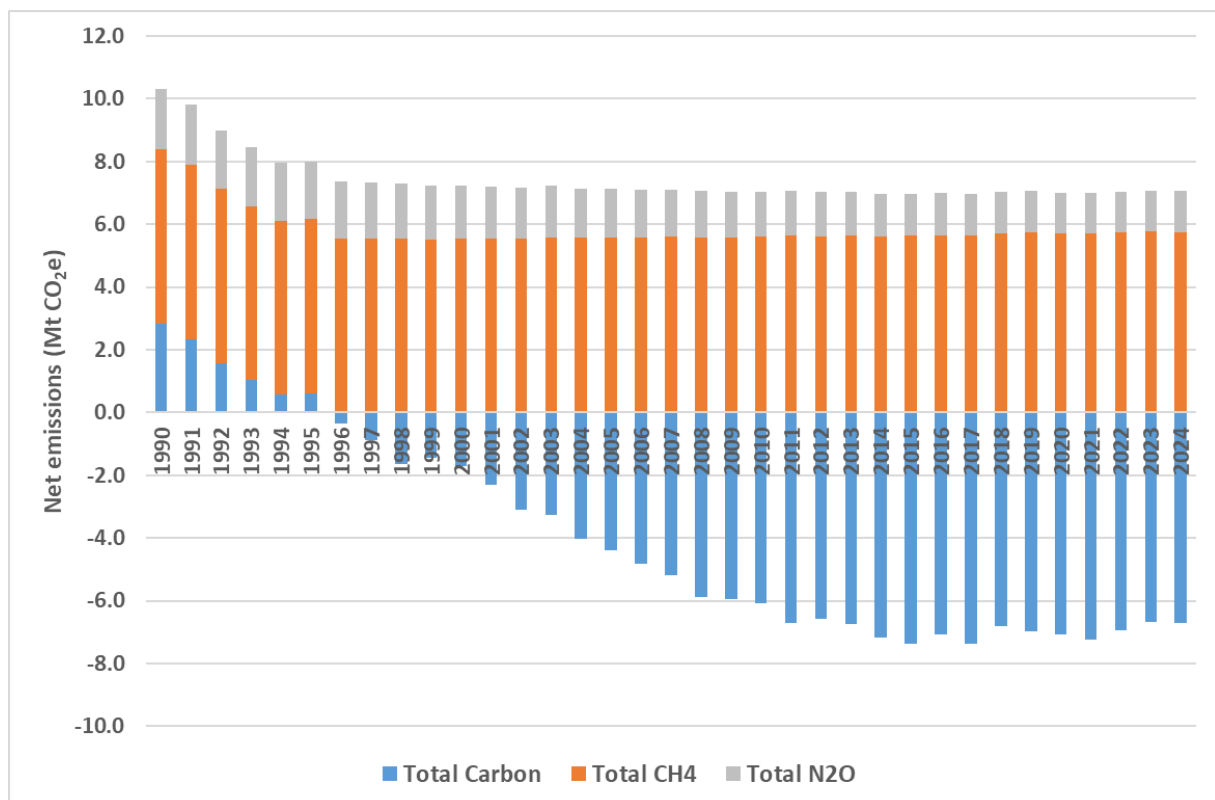


Figure 6.2 Contribution of all gases to net LULUCF emissions



6.1.1 The land use transition matrix

The areas used for the three UK CRT submissions are based on the Standard Area Measurement to mean high water is used for the total area of the UK (24,438.5 kha) (Office for National Statistics 2017) and the land areas reported in statistics for the OTs and CDs:

- Gibraltar: 0.7 kha
- Isle of Man: 57.2 kha
- Guernsey: 6.3 kha
- Jersey: 12.0 kha
- Cayman Islands: 26.4 kha
- Falkland Islands: 1,217.3 kha
- Bermuda: 5.4 kha.

Only the UK, Jersey, Guernsey and the Isle of Man are included in the Paris Agreement submission. All areas are assigned to one of the LULUCF land use categories (Forest Land, Cropland, Grassland, Wetland, Settlements, Other). All land use is considered to be managed: a small area of wetland (0.12 kha) in Jersey has been used for land reclamation from the sea since 2009, and was therefore previously unmanaged.

Approach 2 (IPCC 2006) is used for the representation of land use areas in the inventory. UK land use change is estimated using a Bayesian data assimilation approach (**Annex 5.1.4.3.1**). This constrains estimates of gross land-use change with national-scale census data, whilst retaining the detailed information available from other land-use data sources. The data sources are compiled at the individual country level (England, Scotland, Wales and Northern Ireland) and results are combined to give UK totals.

In order to maintain consistency in both the annual matrices (Table 4.1 for each year in the CRT Reporter) and the CRT carbon stock reporting tables, it is assumed for the UK that:

- The total areas of land use categories from recent reports (2015 or 2024) are the most reliable;
- The areas of LUC used for carbon stock changes are the most consistent sources of land-use change available.

For the UK the baseline areas in **Table 6.2** are used as the initial land use areas in the 2015 land use matrix. The initial land use areas in 2015 are also the final land use areas in 2014. These are used with the transitions to and from each land use category in 2014 (see the individual land use category **Sections 6.2 to 6.6** for details) to calculate the initial land use areas in 2014 and area of each category that does not undergo any change. This approach is used to calculate the initial and final land use areas back in time to 1990, and forward in time from 2015. Forest Land is the exception- the area in the latest inventory year is considered to be the most reliable and the initial and final areas are calculated back in time from that point.

Land cover surveys and agricultural land statistics are used to compile annual land-use change matrices for the OTs and CDs. Information on these data sources is given in **Annex 5.1.4.11**.

Table 6.2 Data sources and areas for the UK 2015 baseline land-use matrix

LULUCF Category	Source dataset	Relevant components of dataset	Area in 2015, kha
Forest Land	National Forest Inventory (NFI) (GB) ¹ and Northern Ireland Woodland Base Map Annual afforestation and deforestation areas 1990-2024	NFI main dataset (woods >0.5 ha) Tree cover outside woodland (0.1-0.5 ha) ¹	3,601

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LULUCF Category	Source dataset	Relevant components of dataset	Area in 2015, kha
Cropland	UK Agricultural Census (Defra, DAERA, Scottish Government, Welsh Government)	Arable land Orchards and perennial crops Fallow and set-aside land	4,892
Grassland	ONS Standard Area Measurement land area – area of other categories ³	NA	12,799
Wetlands	ONS Standard Area Measurement (water bodies >1 km ²) UK Directory of Mines and Quarries, Google Earth imagery and Growing Media Association data (peat extraction sites) Peat condition maps (Evans <i>et al.</i> 2017), Growing Media Association and Peatland Action (peatland restoration data)	Natural water bodies and reservoirs > 1 km ² Active and inactive peat extraction sites Areas of near-natural and rewetted wetlands	960
Settlements	Land Cover Map 2015 (UKCEH 2015)	Urban land cover class Suburban land cover class	1,765
Other Land	Land Cover Map 2015 (UKCEH 2015)	Inland rock, supra-littoral rock, supra-littoral sediment and freshwater classes, adjusted for area of inland water included in Wetlands category	422

¹ Forestry Commission (2017) “Tree cover outside woodland in Great Britain” and Hunter, F. et al. (2025) “NCEA: National Trees Outside Woodland Map” reports

Annual land use matrices for the GBR submission are shown in Table 6-3. Total areas in each year summed across all LULUCF categories may not equal the total land area in some years because of small rounding differences. The area of unmanaged wetland in Jersey 1990-2014 is not included for reasons of space.

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Table 6.3 Annual land-use change matrices for the GBR submission, kha (Total land area is 25 763.5 kha) (GBR - UK, 3 CDs, 4 OTs)

Year	Forest area at start of year	Forest Land converted to	Forest land converted to	Forest land converted to	Forest Land converted to	Cropland area at start of year	Cropland converted to Forest	Cropland converted to	Cropland converted to	Cropland converted to	Grassland area at start of year	Grassland converted to Forest	Grassland converted to	Grassland converted to	Grassland converted to	Wetland area at start of year	Settlement area at start of year	Settlement converted to Forest	Settlement converted to	Settlement converted to	Other land area at start of year
1990	3121.2	0.0	0.3	0.0	0.7	5444.9	6.4	63.5	0.0	2.6	14112.6	41.5	66.8	0.0	8.6	950.0	1712.6	1.0	0.4	1.8	422.5
1991	3169.0	0.0	0.3	0.0	0.7	5439.6	3.0	71.4	0.0	0.8	14061.3	23.4	68.5	0.9	7.4	950.0	1721.4	0.9	0.8	2.0	422.5
1992	3195.2	0.0	0.3	0.0	0.6	5433.8	2.9	66.5	0.0	1.5	14034.8	24.1	67.9	0.0	8.2	950.8	1726.6	0.4	0.5	1.9	422.5
1993	3221.6	0.0	0.3	0.0	0.6	5431.4	3.9	69.0	0.0	2.8	14003.2	24.1	66.4	0.0	8.7	950.8	1734.1	0.4	0.5	2.0	422.5
1994	3249.1	0.0	0.3	0.0	0.6	5422.6	3.6	68.2	0.0	1.2	13975.2	29.2	65.8	0.0	5.5	950.9	1743.3	1.1	0.3	2.6	422.5
1995	3282.1	0.0	0.3	0.0	0.6	5415.8	4.2	75.0	0.0	3.5	13945.8	24.5	61.6	0.3	8.2	950.9	1746.7	0.7	0.3	1.4	422.5
1996	3310.6	0.0	0.3	0.0	0.6	5395.0	3.7	70.7	0.0	2.2	13927.8	24.4	61.8	0.0	4.2	951.2	1756.6	0.6	0.6	2.2	422.5
1997	3338.4	0.0	0.4	0.0	0.7	5380.8	3.3	66.9	0.0	2.8	13910.6	24.7	58.2	0.0	4.3	951.2	1760.3	0.7	0.7	1.3	422.5
1998	3366.0	0.0	0.3	0.0	0.7	5366.7	3.0	63.6	0.0	1.5	13892.0	25.3	57.6	0.0	2.5	951.2	1765.3	0.5	0.6	1.7	422.5
1999	3393.9	0.0	0.3	0.0	0.8	5356.9	4.6	60.8	0.0	0.8	13872.0	24.2	53.4	0.0	2.6	951.2	1767.2	0.8	0.6	3.0	422.5

Land-Use, Land-Use Change and Forestry (CRT Sector 4) **6**

Year	Forest area at start of year	Forest Land converted to	Forest land converted to	Forest land converted to	Forest Land converted to	Cropland area at start of year	Cropland converted to Forest	Cropland converted to	Cropland converted to	Cropland converted to	Grassland area at start of year	Grassland converted to Forest	Grassland converted to	Grassland converted to	Grassland converted to	Wetland area at start of year	Settlement area at start of year	Settlement converted to Forest	Settlement converted to	Settlement converted to	Other land area at start of year
2000	3422.4	0.0	2.7	0.3	0.3	5344.8	2.7	81.8	0.3	1.8	13855.8	26.7	46.5	0.0	3.2	951.2	1767.1	0.8	0.1	1.9	422.5
2001	3449.3	0.0	3.1	0.3	0.3	5304.7	2.8	77.4	0.3	0.6	13865.9	19.4	51.3	0.0	2.6	951.8	1769.5	1.2	0.7	2.5	422.5
2002	3468.9	0.0	2.8	0.3	0.3	5275.6	2.7	81.1	0.3	1.1	13875.7	19.1	44.9	0.0	2.2	952.4	1768.5	0.8	0.3	1.5	422.5
2003	3488.1	0.0	3.2	0.3	0.6	5235.7	3.2	77.9	0.3	1.3	13894.9	17.1	48.4	0.2	2.3	953.0	1769.5	0.4	0.2	2.4	422.5
2004	3504.7	0.0	2.2	0.3	1.0	5201.6	2.4	71.1	0.3	1.0	13910.4	13.9	53.6	0.2	2.9	953.9	1770.6	0.8	0.2	1.6	422.5
2005	3518.2	0.0	2.5	0.3	0.9	5180.7	1.5	72.6	0.3	1.6	13914.8	12.8	49.7	0.2	3.0	954.7	1772.9	0.7	0.3	1.6	422.5
2006	3529.4	0.0	2.0	0.3	0.3	5154.9	3.6	95.1	0.3	1.7	13925.7	11.5	50.2	0.1	3.3	955.5	1775.7	0.8	0.5	1.3	422.5
2007	3542.6	0.0	2.8	0.5	0.7	5104.9	1.7	84.3	0.3	1.0	13959.2	10.1	54.4	0.1	2.9	956.2	1778.4	0.7	0.4	1.5	422.5
2008	3551.1	0.0	2.5	0.5	0.6	5072.4	1.2	86.0	0.3	0.9	13980.3	9.0	50.6	0.2	3.0	956.9	1780.4	0.2	0.5	1.9	422.5
2009	3558.0	0.0	2.6	0.5	0.5	5035.2	0.4	78.3	0.3	0.5	14008.0	9.0	48.6	0.1	1.9	957.9	1782.2	0.0	0.7	1.6	422.5
2010	3563.9	0.0	2.6	0.5	1.0	5005.1	1.3	85.8	0.3	2.2	14031.0	10.9	49.2	0.1	1.8	958.7	1782.7	0.5	0.2	1.4	422.5

Land-Use, Land-Use Change and Forestry (CRT Sector 4) **6**

Year	Forest area at start of year	Forest Land converted to	Forest land converted to	Forest land converted to	Forest Land converted to	Cropland area at start of year	Cropland converted to Forest	Cropland converted to	Cropland converted to	Cropland converted to	Grassland area at start of year	Grassland converted to Forest	Grassland converted to	Grassland converted to	Grassland converted to	Wetland area at start of year	Settlement area at start of year	Settlement converted to Forest	Settlement converted to	Settlement converted to	Other land area at start of year
2011	3572.5	0.0	2.0	0.5	0.8	4964.9	1.5	64.0	0.3	0.8	14058.9	15.6	55.4	0.0	2.5	959.4	1785.5	0.8	0.3	1.8	422.5
2012	3587.1	0.0	2.0	0.5	0.8	4954.0	1.1	67.9	0.3	0.4	14053.2	12.7	56.2	0.7	2.6	960.2	1786.7	0.7	0.2	1.9	422.5
2013	3598.4	0.0	1.9	0.3	0.8	4940.7	1.8	67.4	0.3	0.9	14052.7	12.3	56.3	0.0	1.7	961.7	1787.7	0.2	0.2	2.3	422.5
2014	3609.9	0.0	2.0	0.1	0.6	4926.9	1.4	69.3	0.3	1.4	14053.9	10.0	53.6	0.0	2.4	962.2	1788.4	0.3	0.2	1.7	422.5
2015	3618.9	0.0	0.9	1.5	0.8	4908.4	0.2	58.9	0.3	0.8	14060.8	6.5	56.2	0.0	2.7	962.6	1790.5	0.3	0.5	2.0	422.5
2016	3622.8	0.0	1.4	0.5	1.8	4905.0	0.8	82.7	0.3	1.6	14057.1	5.8	56.3	0.1	2.2	964.4	1792.0	0.4	0.0	2.1	422.5
2017	3626.1	0.0	1.4	0.2	1.4	4876.0	0.7	66.2	0.3	1.4	14078.9	7.8	55.3	0.0	3.0	965.2	1795.2	0.2	0.4	1.5	422.5
2018	3631.8	0.0	1.2	1.6	1.7	4863.1	1.9	81.3	0.3	3.3	14081.9	10.3	46.1	0.0	5.0	965.7	1798.9	0.4	0.1	2.1	422.5
2019	3640.0	0.0	1.2	0.9	1.4	4822.5	1.1	56.6	0.3	1.5	14105.1	12.0	53.5	0.0	3.6	967.5	1806.3	0.6	0.5	2.9	422.5
2020	3650.1	0.0	1.2	0.7	1.1	4817.0	0.7	65.0	0.3	4.2	14096.7	11.8	49.6	0.0	4.9	968.7	1808.8	0.9	0.2	1.9	422.5
2021	3660.5	0.0	1.4	1.0	1.3	4796.7	0.7	65.2	0.0	4.2	14098.5	12.1	49.4	0.0	4.9	969.7	1816.0	1.0	0.2	1.9	422.5

Land-Use, Land-Use Change and Forestry (CRT Sector 4) 6

Year	Forest area at start of year	Forest Land converted to	Forest land converted to Grassland	Forest land converted to Wetland	Forest Land converted to Settlement	Cropland area at start of year	Cropland converted to Forest	Cropland converted to Grassland	Cropland converted to Wetland	Cropland converted to Settlement	Grassland area at start of year	Grassland converted to Forest	Grassland converted to	Grassland converted to Wetland	Grassland converted to Settlement	Wetland area at start of year	Settlement area at start of year	Settlement converted to Forest Land	Settlement converted to Cropland	Settlement converted to Grassland	Other land area at start of year
2022	3670.5	0.0	2.1	0.4	1.3	4776.2	0.8	65.0	0.0	4.2	14100.5	11.5	50.1	0.0	4.9	970.8	1823.4	0.9	0.2	1.9	422.5
2023	3680.0	0.0	1.0	1.4	1.1	4756.5	1.2	65.0	0.1	4.2	14103.0	16.3	49.4	0.0	4.9	971.2	1830.8	1.2	0.2	1.9	422.5
2024	3695.2	0.0	1.3	0.8	1.1	4735.6	1.4	65.0	0.1	4.2	14100.2	14.5	49.4	0.0	4.9	972.7	1837.7	1.0	0.2	1.9	422.5

6.2 CATEGORY 4A – FOREST LAND

6.2.1 Description

Emissions sources	4A Forest Land: carbon stock change 4(I).A Direct and indirect nitrous oxide (N ₂ O) emissions from nitrogen (N) inputs to managed soils 4(II).A Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(III).A Direct and indirect nitrous oxide (N ₂ O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils 4(IV).A Biomass burning
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	T3 for carbon stock changes, T2 for direct CO ₂ and CH ₄ and N ₂ O, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories	4A: Forest land - CO ₂ (L1, L2, T1, T2)
Key Categories (Qualitative)	None identified
Completeness	N/A
Major improvements since last submission	Improvements to the CARBINE process modelling and minor activity data updates

This section describes LULUCF emissions and removals from Forest Land in the UK. A description of LULUCF emissions and removals from the OTs and CDs is given in **Section 6.9**.

Forest Land includes carbon stock gains and losses and GHG emissions from forest management and overall is the biggest net sink in the UK. All UK forests are temperate and about 74% of these have been planted since 1921 on land that had not been forested for many decades.

The UK reports carbon stock changes in all forests. Forest surveys have been intermittent in the UK and to date there has been no network of permanent sample plots suitable for constructing a GHG inventory. Consequently, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history, assessed tree age class area distributions and productivity (yield class) estimates, and assumptions over approaches to forest management. Forest carbon stock changes and fluxes are modelled by CARBINE, the Forest Research forest carbon stock and carbon balance model (described in the [CARBINE technical guide](#), Forest Research, 2025a and **Annex 5.1.4.1**). CARBINE takes account of the effects of forest management on carbon stocks and estimates the carbon stocks in the Harvested Wood Products pool.

Carbon stock changes resulting from afforestation on Cropland, Grassland and Settlement on both mineral and organic soils are calculated. Conversion of Other Land or Wetland to Forest Land does not occur in the UK. The reported forest area and carbon stock changes take account of losses of forest land converted to other land use categories (deforestation) and the associated carbon stock changes and emissions and removals are then estimated and reported under the category concerned. Associated direct and indirect N₂O emissions from N mineralization are reported under 4(III).A.

In the UK inorganic nitrogen fertilisers are only applied to forest when absolutely necessary. This occurs during the first rotation on 'poor' soils, such as reclaimed slag heaps, impoverished brown field sites and upland organic soils, hence N fertilisation is assumed for all areas of Settlements converted to Forest Land and Grassland converted to Forest Land on organic soils. Direct and indirect N₂O emissions from this fertilisation are reported under 4(I).A.2. Nitrogen fertilisers are not generally applied to native woodlands, mature forests or re-planted forests in the UK, so emissions of N₂O from N fertilisation of forests for 4(I).A.1 are reported as Not Occurring.

Drainage of forest land occurs in UK forests planted on certain soil types. It is assumed that all forests planted on organic soils are drained prior to planting. Forests planted on mineral or organo-mineral soils which have slow natural drainage and are prone to waterlogging are also assumed to be artificially drained. CO₂ emissions from drainage are included with carbon stock changes in Table 4.A. CH₄ and N₂O emissions from drainage are included in 4(II)A. Rewetting of forests on organic soils results in a land use change and emissions are reported under 4D2.c.i Forest converted to other wetlands and 4(II).D.2.c.i

Controlled burning of forest land (for example for habitat management) does not take place in the UK. Wildfires do occur but the activity data are not sufficient to split reporting between 4.A.1 and 4.A.2. Therefore, emissions of greenhouse gases from wildfires are all reported under 4(IV).A.1 in Table 4(IV). It is assumed that land-use change does not occur following wildfire.

Carbon losses due to other forms of natural disturbance are not explicitly modelled. In the UK, the majority of the trees lost to wind or pest and disease will be salvage logged and therefore it is assumed that the losses will be included as part of the estimation of losses due to harvesting. It is assumed that losses due to flooding and geological disturbances are negligible. The impact of historical levels of drought on forests will be included by implication, since the yield tables are based on empirical measurements of forests grown in UK conditions and the assessed yield class will include the impact of drought on the growth of the measured stands.

The UK does not plan to apply the natural disturbance provisions from the IPCC guidelines as the level of natural disturbance to date has not led to inter-annual variations that mask the long-term trend in emissions/removals. This would be reviewed if there were a natural disturbance that would lead to this becoming more of an issue, for instance if there were to be a situation where there was a large pest/disease outbreak where the timber could not be salvage-logged or felled in anticipation.

6.2.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The agencies responsible for forests in the UK are the Forestry Commission (England), Forestry England, Scottish Forestry, Forestry and Land Scotland, Natural Resources Wales and the Northern Ireland Forest Service. Areas of forest planted annually are published in Forestry Statistics⁹⁶ and a detailed breakdown (by forest type and management) is used as input to the CARBINE model, supplemented by information from the National Forest Inventory (NFI) field survey and the Northern Ireland Woodland Register. The allocation of land-use change from other land use categories is based on the proportional changes in the land-use change matrices from the data assimilation of multiple land-use data sources (see **Section 6.3** and **Annex 5.1.4.3**). More information on the stratification of the UK forest area can be found in Annex 5.1.4.3 and the UK National Forestry Accounting Plan 2021-2025⁹⁷.

⁹⁶ <https://www.forestryresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2025/>

⁹⁷ <https://www.gov.uk/government/publications/uk-national-forestry-accounting-plan-2021-to-2025>

The area of forests on organic soils in the UK was based on peatland extent and condition mapping outputs from the BEIS-funded project to implement the 2013 IPCC Wetlands Supplement (Evans *et al.* 2017) (see **Annex 5.1.4.7**).

6.2.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

The UK uses the following definition of forest for reporting of Forest land in the UK's greenhouse gas inventory submitted under the UNFCCC:

- Minimum area of 0.1 hectares;
- Minimum width of 20 metres;
- Tree crown cover of at least 20 per cent, or the potential to achieve it;
- Minimum height of 2 metres, or the potential to achieve it.

This definition includes felled areas awaiting restocking and integral open spaces (open areas up to 1 hectare). The total area of woodland greater than 0.5 ha is reported in the annual Forestry Statistics (Forest Research, 2025b). The area of small woodlands (0.1 – 0.5 ha) is reported in the 2017 “Tree cover outside woodland” report, for Scotland and Wales (Forestry Commission, 2017), and in the more recent “NCEA: National Trees Outside of Woodland Map” for England (Hunter *et al.* 2025). The definitions are consistent with information provided by the UK to the Food and Agriculture Organization of the United Nations (FAO). If an international source uses a different minimum area definition, for example 0.5 ha in the Global Forest Resource Assessment 2010, the UK areas are adjusted to this different definition (FAO, 2010).

All forest areas in the UK can be regarded as managed from the point of view of regulation against deforestation and protection against fire, storms and disease. In general, forest areas are actively managed for landscape, soil protection, habitat conservation, amenity and recreation, which may or may not include active management for wood production.

6.2.4 Methodological Issues

In this inventory submission, the carbon stock change of UK forests is calculated using a Tier 3 carbon accounting model, CARBINE (Forest Research, 2025a). Overall carbon stock change is calculated as the net change in the pools of carbon in standing trees, dead organic matter, soil and products from harvested material, for conifer and broadleaf forests. The model is able to represent all of the introduced and native plantation and naturally occurring species relevant to UK forestry, the different growth rates of forests and four broad classes of forest management (clear-fell with thinning, clear-fell without thinning, thinned but not clear-felled, and no timber production).

The CARBINE model produces separate estimates of gains and losses for carbon stock change in above- and below-ground living biomass, rather than net change. The forest carbon sub-model is further compartmentalised to represent fractions associated with tree stems, branches, foliage, and roots. Carbon stock changes in dead wood, litter, and soil are also reported. Further detail on the CARBINE model is given in The CARBINE-R Technical Guide (Forest Research, 2025a).

There have been revisions to the activity data for afforestation for this submission: these revisions and their impact are described in the recalculations (**Section 6.2.7**). Emissions from fluvial carbon from forest on organic soils are reported using the Tier 1 emission factors from the 2013 IPCC Wetlands Supplement (IPCC 2014a) for dissolved organic carbon and particulate organic carbon.

Areas of forest planted on organic soils are estimated by overlaying a map of soils with the forest map from the National Forest Inventory in England, Scotland and Wales. For Northern Ireland a similar method was used to estimate areas based on the NI woodland basemap. Further details on this work are given in **Annex 5.1.4.7**.

Other greenhouse gas emissions, including those arising from forest fertilisation and wildfires together with estimates of N₂O emissions from forest drainage, are estimated using Tier 1 or Tier 2 approaches, and are described in **Annex 5.1.4.2**.

6.2.5 Uncertainties and Time-Series Consistency

The uncertainty in 1990 and 2024 respectively are estimated at 20% and 15% for CO₂, 85% in both years for CH₄, and 80% and 90% for N₂O.. Details are provided in **Annex 5.1.4.12**.

The planting statistics used as activity data mostly come from operational systems, for grants and for planting on the National Forest Estates of the four countries comprising the UK (supplemented by information from the NFI field survey). Complete geographical coverage of the UK in these statistics and accurate division of the UK into the four constituent countries is assumed and the associated statistical uncertainties are assumed to be negligible. Grants are paid once planting has occurred. The grant-aided planting is allocated by year of payment, so all the recorded planting should have taken place.

The total area of forest in GB is based on the new NFI woodland map, plus the area of small woodlands between 0.1 and 0.5 ha (Forestry Commission, 2017; Hunter *et al.* 2025). Estimates of new planting and deforestation are then applied to track the change forest area through time. The sub compartment database is used to determine the area, composition and management of publicly owned forests. The NFI field survey used to estimate the stocked area and composition (including age distribution) of the privately owned forests, based on a sub-sampling of the population and scaling to the mapped level.

With regard to series consistency:

- For forest carbon stock changes, N fertilization of forests and emissions from drainage, time series consistency is expected to be good as activity data are obtained consistently from the same national forestry sources;
- For emissions from wildfires, data have been collated from several published sources. From 1990 – 2004 all data originate from the state forestry agencies so there is good time series consistency during this period. Data have been extrapolated for 2005-2009. A newer and more complete data source for England, Scotland and Wales is used from 2010 onwards, and gives wildfire burnt areas which are the same magnitude as the previous dataset.
- Emissions from forests on organic soils: it is assumed that all organic soils planted with forests are drained and there has been no recorded planting of new forests on organic soils since 2012. An area of 13.179kha has been rewetted to Wetland since 2000.

A significance analysis has been undertaken for key categories in the LULUCF sector. In Forest Land carbon stock changes in soil, living biomass, dead wood and litter in the 4.A.1 Forest Land remaining Forest land and 4.A.2.b Grassland converted to Forest Land are the most significant sub-categories/pools (**Table 6.4**).

Table 6.4 Significance analysis of the key sub-categories/pools in the Forest Land category

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2024 total ¹
CO ₂			

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2024 total ¹
4(IV) Biomass burning		0%	0%
A.1. Forest Land remaining Forest Land		68%	92%
	Carbon stock change in above-ground biomass, below-ground biomass, dead wood and litter	58%	67%
	Mineral Soils	9%	23%
	Organic Soils	2%	2%
A.2.a. Cropland converted to Forest Land		2%	1%
A.2.b. Grassland converted to Forest Land		29%	7%
A.2.d. Settlements converted to Forest Land		1%	0%

¹ Percentages may not sum to 100% due to rounding

6.2.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**. Information on the area affected by wildfires is consistent with that reported to the FAO (2005, 2010, 2015).

As part of a separate research project, a comparison was made of the predictions made by the UKCEH C-Flow model and Forest Research CARBINE model. The results demonstrated that the models produce consistent predictions when given the same input data and assumptions (e.g. about woodland management practices). Further work has been undertaken comparing the inventory as predicted by CARBINE to the inventory as predicted by C-Flow and detailing the changes in assumptions that drive the changes in the inventory (Matthews et al., 2014). Verification of carbon stock changes will be undertaken once the data from second cycle of the NFI is available (after 2025).

A review of inventory data and models has been undertaken (Levy and Rowland, 2011), during which data were collated and critically assessed soil carbon stocks following afforestation. In the UK, afforestation of former croplands generally increases soil carbon stocks, whereas on former grasslands and peatlands, soil C stocks are unchanged or even reduced following afforestation (Mayer et al, 2020). In fact, in the UK studies which attempt to measure this, soil carbon stocks in forested plots were 15 to 60 % lower than in adjacent unplanted, grassland or moorland (Reay et al., 2001; Chapman et al. 2003; Zerva and Mencuccini 2005; Mitchell et al. 2007; Bellamy and Rivas-Casado 2009; Levy and Clark 2009). These results are in agreement with global meta-analyses, which have reported mean changes in soil carbon stocks of around -10 %, -7 %, +3 % and -4 % associated with conversion of pasture to forest plantation (Guo and Gifford 2002; Laganier, Angers et al. 2010; Poeplau, Don et al. 2011 respectively). The treatment of the litter layer in these studies is a significant uncertainty, as it is possible that some of the reported decreases in soil carbon following afforestation were compensated by increases in carbon stocks of the above-ground litter layer which is not included in the soil samples.

The full specification and information on the validation of the soil and litter model that has been implemented in CARBINE will be published in a separate technical report. In broad terms, the comparisons done so far show that the model gives broad-scale soil carbon stock results that are consistent with collected data and reported estimates. Verification of the carbon stock changes in soils is made more difficult by the general lack of repeat measurement and we are attempting to identify potential sources of additional data. An analysis of existing data sources

and literature helped to identify data gaps and prioritise additional data collection. Additional measurements of soil carbon stocks in England, Scotland and Wales have been made and will help with this validation.

In 2018, a new automatic algorithm was introduced in CARBINE to adjust the assumptions about forest management to ensure a good match between modelled forest harvest, and thus HWP, and the published wood production statistics (Forest Research, 2025b). This has also improved the repeatability and QC of this part of the inventory. As part of this project, the timber volume production module of CARBINE was re-implemented to enable that automation. This semi-independent implementation of this part of the model was cross validated against the version in the CARBINE model.

6.2.7 Category-Specific Recalculations

The reported overall net GHG sink in category 4.A has decreased between -0.2 and -0.7 Mt CO₂e (3.2-3.7%) across the time series compared to the previous inventory.

The changes were mainly seen in the carbon stock changes in the carbon pools for Forest Remaining Forest and Land converted to Forest. The main cause of this change was updates to activity data and to the CARBINE model.

The changes and their justification are:

- **Updated wildfire activity data.** Wildfire activity data from Wales was not available for 2023 in the previous submission but is now included. There were also minor updates to the England and Scotland historical wildfire activity data.
- **Updates to the CARBINE model.** These include improved species and Yield Class (growth rate) distribution for post-2011 afforestation to better reflect recent planting practices; a closer match to total wood production across the time series; the inclusion of carbon transfer from branches on dead trees into the soil; and the inclusion of inputs from competition-based mortality in young (pre-first thinning age) stands into the deadwood carbon pool.
- **Updated forest land activity data** including: new planting estimates and wood production estimates from the 2025 preliminary Forestry Statistics; new planting estimates for Northern Ireland for 1900-1921; an increase in the England small woodland area estimate from the 2025 report “NCEA: National Trees Outside Woodland Map”; and corrections to the area of unmapped woodland to remove double counting of afforestation in 2014-2015. .

The magnitude of the changes and the abbreviated justification are given in **Table 6.5**.

Table 6.5 4A Category specific recalculations since previous submission (UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.A.1/4(IV)	Biomass burning - wildfires	10.36	50.81	10.28	61.27	Gg C	Updated wildfire data Updates to the CARBINE model
4.A.1	Carbon stock change in living biomass - gains	-10649.82	-16627.47	-10596.48	-16663.99	Gg C	Updates to the CARBINE model. Updated forest land activity data.
4.A.1	Carbon stock change in living biomass - losses	7998.80	14121.22	7904.67	14053.47	Gg C	
4.A.1	Net carbon stock change in dead wood	-635.51	-1006.88	-640.21	-1051.61	Gg C	
4.A.1	Net carbon stock change in litter	-150.44	-149.07	-150.85	-154.93	Gg C	
4.A.1	Net carbon stock change in soils - mineral soils	-565.72	-1288.35	-547.72	-1255.74	Gg C	
4.A.1	Net carbon stock change in soils - organic soils	126.33	-43.58	98.41	-108.58	Gg C	
4.A.2.a	Carbon stock change in living biomass - gains	-85.47	-24.21	-87.11	-25.23	Gg C	
4.A.2.a	Carbon stock change in living biomass - losses	17.70	4.60	17.68	4.56	Gg C	
4.A.2.a	Net carbon stock change in dead wood	-2.77	-0.59	-2.80	-0.59	Gg C	
4.A.2.a	Net carbon stock change in litter	-2.37	-0.56	-2.42	-0.58	Gg C	
4.A.2.a	Net carbon stock change in soils - mineral soils	54.28	23.26	55.66	23.18	Gg C	
4.A.2.a	Net carbon stock change in soils - organic soils	16.76	0.86	14.24	0.77	Gg C	

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CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.A.2.b	Carbon stock change in living biomass - gains	-1046.58	-190.94	-1049.20	-194.92	Gg C	Updates to the CARBINE model. Updated forest land activity data.
4.A.2.b	Carbon stock change in living biomass - losses	214.03	35.66	209.31	34.78	Gg C	
4.A.2.b	Net carbon stock change in dead wood	-35.12	-4.86	-34.75	-4.77	Gg C	
4.A.2.b	Net carbon stock change in litter	-31.67	-4.87	-31.83	-4.89	Gg C	
4.A.2.b	Net carbon stock change in soils - mineral soils	456.33	192.73	464.18	191.52	Gg C	
4.A.2.b	Net carbon stock change in soils - organic soils	422.03	11.51	358.71	10.34	Gg C	
4.A.2.d	Carbon stock change in living biomass - gains	-18.89	-9.95	-19.01	-10.08	Gg C	
4.A.2.d	Carbon stock change in living biomass - losses	3.79	1.85	3.71	1.79	Gg C	
4.A.2.d	Net carbon stock change in dead wood	-0.62	-0.25	-0.61	-0.25	Gg C	
4.A.2.d	Net carbon stock change in litter	-0.53	-0.25	-0.53	-0.25	Gg C	
4.A.2.d	Net carbon stock change in soils - mineral soils	8.08	9.92	8.22	9.83	Gg C	
4.A.2.d	Net carbon stock change in soils - organic soils	7.56	0.52	6.35	0.47	Gg C	
4.A.1/4(IV)	Biomass Burning - wildfires	0.14	0.76	0.15	1.03	Gg CH ₄	Updated wildfire data. Updates to the CARBINE model.

Land-Use, Land Use Change and Forestry (CRT Sector 4) 6

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.A.1./4(I)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	1.80	3.59	1.79	3.59	Gg CH ₄	Updates to the CARBINE model. Updated forest land activity data.
4.A.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.06	0.00	0.06	0.00	Gg CH ₄	
4.A.2.b./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	1.50	0.04	1.51	0.04	Gg CH ₄	
4.A.2.d./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.03	0.00	0.03	0.00	Gg CH ₄	
4.A.1/4(IV)	Biomass Burning - wildfires	0.008	0.042	0.008	0.057	Gg N ₂ O	Updated wildfire data. Updates to the CARBINE model.
4.A.1./4(I)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.630	1.175	0.628	1.178	Gg N ₂ O	Updates to the CARBINE model. Updated forest land activity data.
4.A.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.018	0.001	0.018	0.001	Gg N ₂ O	

Land-Use, Land Use Change and Forestry (CRT Sector 4) 6

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.A.2.a/4(II I)	Direct and Indirect N ₂ O from N mineralisation	0.070	0.030	0.071	0.030	Gg N ₂ O	Updates to the CARBINE model. Updated forest land activity data.
4.A.2.a./4 (I)	Direct and Indirect N ₂ O Emissions from N Inputs to Managed Soils	0.056	0.007	0.056	0.007	Gg N ₂ O	Updated forest land activity data.
4.A.2.b./4 (II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.443	0.012	0.445	0.012	Gg N ₂ O	Updates to the CARBINE model. Updated forest land activity data.
4.A.2.b./4 (III)	Direct and Indirect N ₂ O from N mineralisation	0.586	0.247	0.596	0.246	Gg N ₂ O	
4.A.2.d./4 (II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.008	0.001	0.008	0.001	Gg N ₂ O	
4.A.2.d./4 (III)	Direct and Indirect N ₂ O from N mineralisation	0.010	0.013	0.011	0.013	Gg N ₂ O	

6.2.8 Category-Specific Planned Improvements

DESNZ have funded a program of work looking at improving estimates of GHG emissions/removals relating to forest land, including validation of the existing models, targeted improvements to the models and collection of additional forest soil carbon measurements. This work is intended to lead to improvements in both activity data and modelling of emissions/removals. Specific improvements intended for inclusion in the near term are:

- the impacts on litter, deadwood and soil of a fallow period following felling;
- the impact of species change when restocking to comply with guidance outlined in the UK forestry standard;
- any improvements to the soil model as a result of the current validation work.

6.3 CATEGORY 4B – CROPLAND

6.3.1 Description

Emissions sources	4B Cropland: carbon stock change 4(II).B Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(III).B Direct and indirect nitrous oxide (N ₂ O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils 4(IV).B Biomass burning
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	T3 for carbon stock changes, T2 for organic soils, T1 for other emissions
Emission Factors	Country-specific for T3 methods, T2 for direct CO ₂ and CH ₄ emissions from organic soils, T1 for other emissions
Key Categories	4B: Cropland - CO ₂ (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Completeness	No known omissions.
Major improvements since last submission	No major improvements

This section describes LULUCF emissions and removals from Cropland in the UK. A description of LULUCF emissions and removals from the OTs and CDs is given in **Section 6.9**.

Net emissions from the Cropland category include carbon stock gains and losses and GHG emissions due to land-use change (LUC), cropland management, drainage and biomass burning. Overall, the Cropland category is the largest net source in the LULUCF sector.

Ongoing carbon stock changes in soils arising from LUC to Cropland are reported under both 4.B.2. (for LUC in the past 20 years) and 4.B.1 (for historic LUC >20 years before the inventory reporting year). These non-organic soil net carbon stock changes are the largest component of the category total emissions and are calculated using a Tier 3 dynamic soil carbon model. Carbon emissions from drainage of cropland on organic soils are the next largest component

and are reported under 4.B.1 and 4.B.2. They are calculated using Tier 2 country-specific emission factors.

Other contributors to the Cropland net total emissions are:

- CH₄ emissions resulting from drainage of organic soils (4(II).B);
- carbon stock changes in biomass and soils resulting from changes in cropland management (4.B.1);
- biomass carbon stock changes due to LUC (4.B.2);
- N₂O emissions from soil disturbance associated with LUC (4(III).B);
- biomass burning emissions of GHGs from controlled burning following forest land conversion to cropland (4(IV).B.2); and
- biomass burning emissions of GHGs due to wildfires (4(IV).B.1).

All forms of land-use change, including deforestation, are considered and both mineral and organic soils are included. In some categories, e.g. Forest Land converted to Cropland, the area of land undergoing transition falls to zero and is subsequently reported as Not Occurring for some carbon stock changes and emissions.

Ongoing N₂O emissions from soil as a result of land-use change > 20 years ago and from drainage of organic soils are reported in the Agricultural sector inventory as N₂O emissions from managed agricultural soils. UKCEH provide the appropriate areas and emission factors to Rothamsted Research. Nitrous oxide emissions from loss of soil organic matter as a result of Cropland Management are also reported in the Agricultural sector inventory as N₂O emissions from managed agricultural soils.

Emissions of CO₂, CH₄ and N₂O from controlled biomass burning arising from Forest Land conversion to Cropland are reported in Table 4(IV). Burning of agricultural residues (cereal straw or stubble) are reported under category 3F Field Burning of Agricultural Residues. Full details of the method and activity data are given in **Annex 5.1.4.5**.

6.3.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory and compiles several different data sources into a non-spatially-explicit land use conversion matrix (see **Annex 5.1.4.3.1** for details).

Data sources that contain area information for reporting carbon stock changes and/or emissions from Cropland are:

- Habitat/landscape surveys
 - The Countryside Survey (DAERA 2016, UKCEH 2020a) which gives repeated field surveys of stratified 1km sample squares.
 - Monitoring Landscape Change (MLC 1986) habitat survey based on aerial photo interpretation.
- Extent of cropland on organic soils and rewetting of cropland back to wetland (Evans et al. 2017 and further updates).
- Agricultural survey data
 - Areas of the main crop types are obtained from the June Agricultural Censuses for each UK administration.
 - Agricultural holdings data: farm-level detail on agricultural land areas.
 - IACS: field-level register of agricultural subsidy claims under the EU Common Agricultural Policy.
 - CROME: crop classification of satellite imagery for England, with ground-truth data from agricultural subsidy inspectors

- The areas of Cropland receiving inputs of manure, fertiliser and crop residues are obtained from the British Survey of Fertiliser Practice.
- Land-cover from satellite imagery classification
 - Land Cover Map (UKCEH 2020b): thematic land-cover classification of satellite image data covering the UK;
 - Land Cover® plus: Crops (UKCEH 2016): Based on the LCM parcel framework with additional crop information from satellite data
 - CORINE Land Cover (CORINE 2020): Survey of European land cover and land cover change from semi-automatic interpretation of high-resolution satellite imagery.
- Data on wildfires on agricultural land from Fire and Rescue service and satellite data.
 - Areas of wildfire on Cropland for 2010 to the present come from Fire and Rescue service data.
 - Between 2001 and 2009 the area of wildfire on Cropland is calculated by using satellite data on the total area of wildfires in the UK which are apportioned to land use using the same ratios as found in the Fire and Rescue service data 2010-present.
 - Cropland wildfire areas prior to 2001 are extrapolated (see **Annex 5.1.4.6** for details)

6.3.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Cropland is defined in accordance with the Agriculture, Forestry and Other Land Use Guidance (IPCC 2006). The crop types in the different data sources that contribute to the Cropland category are described in **Annex 5.1.4.3.1**.

6.3.4 Methodological Issues

6.3.4.1 Land-Use Change

Activity data for land-use change are estimated using a land-use change (LUC) matrix approach. Detailed descriptions of the methods, emission factors and data flows used for Cropland activities are given in **Annex 5.1.4.3**.

Land use change on organic soils is split out from the land-use change matrices to produce a non-organic soil set of LUC change matrices. Emissions arising from land-use and land-use change on organic soils are calculated using methodologies consistent with chapters 2 and 3 of the 2013 IPCC Wetlands supplement (IPCC 2014a) described in **Annex 5.1.4.7**.

A dynamic model of carbon stock change is used with the non-organic LUC matrices to estimate non-organic soil carbon stock changes due to LUC. Non-organic soil carbon stock changes are modelled as changing exponentially between initial and final land uses.

The carbon stocks on non-organic soils for each land use category are calculated as averages for Scotland, England, Northern Ireland and Wales using a database of soil carbon density for the UK (Milne and Brown 1997; Cruickshank *et al.* 1998; Bradley *et al.* 2005) which has been constructed based on information on soil type, land cover and carbon content of soil cores to a depth of 1 m or to bedrock, whichever was the shallower, for mineral and organo-mineral soils. The rate of loss/gain of soil carbon is dependent on the type of land use transition. A Monte Carlo approach is used to vary the rate of change, the area activity data and the values for soil carbon equilibrium, under initial and final land use. The mean soil carbon flux for each region is summed to give the UK total for the Inventory.

Biomass carbon stock change is calculated using the LUC matrix and literature-derived Tier 2 stock change factors, with all stock gains or losses assumed to occur in a single year.

Direct and indirect N₂O emissions associated with non-organic soil disturbance from LUC are reported using the areas of Forest land and Grassland converted to Cropland from the LUC matrices and the IPCC Tier 1 emission factors (see **Annex 5.1.4** for details).

6.3.4.2 Cropland management

Carbon stock change (CSC) in mineral soils as a result of cropland management is estimated using agricultural survey activity data, country-specific soil carbon densities and Tier 1 CSC factors for most activities except for tillage reduction (Tier 2).

Carbon stock changes in biomass due to cropland management activities are estimated using literature-derived Tier 2 stock change factors and activity data from agricultural surveys. Carbon stock changes in biomass can arise from changes in annual crops, orchards, bioenergy crops and shrubby perennial crops (see **Annex 5.1.4.3.2** for details).

6.3.4.3 Drained organic soils

Emissions of carbon and CH₄ from Cropland on drained organic soils are reported using Tier 2 emission factors (**Annex 5.1.4.7**). Emissions of N₂O from cropland on organic soils are calculated using the same activity data and are reported in category 3.D in the Agriculture sector.

6.3.4.4 Biomass burning emissions

Emissions from controlled burning on cropland are only reported for Forest Land conversion to Cropland and are estimated using Tier 1 emission factors and country-specific fuel densities.

Emissions from wildfires on Cropland are reporting using Tier 1 emission factors and activity from a range of sources (see **Section 6.3.2**).

6.3.5 Uncertainties and Time-Series Consistency

The uncertainty in 1990 and 2024 respectively are estimated at 15% for CO₂, 65% and 70% for CH₄, and 40% for N₂O. These uncertainties are based on an uncertainty analysis using the updated activity data and methodology for this submission. Details are provided in **Annex 5.1.4.12**. The areas undergoing land-use change are the biggest source of uncertainty in the LULUCF inventory.

With regard to time series consistency:

- Drainage of organic soils: it is assumed that all drainage of organic soils on Cropland occurred before 1971 as recent policy has favoured protection of organic soils. There have been no policy incentives to encourage new land drainage for agricultural use since 1990, and major drainage of large areas of Cropland on organic soils in areas such as the East Anglian fens is known to have occurred well before this. A small area has been rewetted to Wetland since 2000 (5.680 kha), almost all of which is in England.
- Changes in biomass and soil carbon due to LUC: the land-use change data assimilation methodology draws on multiple data-sources and takes account of random uncertainty and false positive rates. The time series now show more inter-annual variation but more gradual temporal trends (see **Figure A 5.6** in **Annex 5.1.4.3.1**).
- Controlled biomass burning after conversion of Forest Land to Cropland: there is good time series consistency as there has been continuity in the activity data source.
- Wildfires: a consistent dataset is used from 2010 onwards. Burnt areas are extrapolated back to 2001 based on remote sensing data, but between 1990 and 2001 there are no observed data on the extent of wildfires on Cropland, and the time series is filled by extrapolating the 2001 – 2011 average wildfire area.

- Cropland management: The June Agricultural censuses are very long-standing datasets with good time series consistency. The British Survey of Fertiliser Practice has contained information on the proportion of Cropland receiving manure since 2008. For years prior to 2008, the 2008 – 2015 average value has been used. The British Survey of Fertiliser Practice has contained information on the proportion of Cropland receiving fertiliser since 1992. For years prior to 1992, the 1992 - 2001 average value has been used.

A significance analysis has been undertaken for key categories in the LULUCF sector. In Cropland the 4.B.2.b Grassland converted to Cropland and the 4.B1 Cropland remaining Cropland are the most significant sub-categories (**Table 6.6**), with soil carbon stock change in mineral and organic soils the biggest pool contributions.

Table 6.6 **Significance analysis of the key sub-categories/pools in the Cropland category**

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2024 total ¹
CO₂			
4(IV) Biomass Burning		0%	0%
B.1. Cropland remaining Cropland		41%	62%
	Carbon stock change in living biomass	0%	0%
	Carbon stock change due to cropland management (soils and biomass)	0%	0%
	Mineral Soils (due to land use change)	14%	32%
	Organic Soils	27%	30%
B.2.a. Forest Land converted to Cropland		1%	0%
B.2.b. Grassland converted to Cropland		57% (mineral soils)	37% (mineral soils)
B.2.d. Settlements converted to Cropland		1%	1%

- ¹ Percentages may not sum to 100% due to rounding

6.3.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Annex 4**.

A resampling of the 1980-based National Soil Inventory (NSI) in England and Wales in 1995-2003 found large losses of soil carbon across all land use types (Bellamy *et al.* 2005). It was hypothesized that this loss was due to climate change because all land uses showed losses and the size of the loss was related to initial carbon concentration, suggesting that the UK's LUC modelling approach was incorrect. In contrast, a more recent study using Countryside Survey (CS) data (Reynolds *et al.* 2013) found no significant change in soil carbon stocks under most Grassland habitat types between 1978 and 2007. The reason for the different results obtained by NSI and CS is not clear (Kirk *et al.* 2011), although there are methodological differences between the two surveys. Subsequent modelling studies (e.g. Smith *et al.* 2007, Barraclough *et al.* 2015) have shown that climate changes could only account for a small part of the decrease in soil carbon reported in Bellamy *et al.* (2005). The

importance of prior land use history in priming soil carbon dynamic models has also been highlighted.

A new study (Bentley et al. 2025) has identified a reversal in the trend in soil organic carbon loss from cropland topsoils in Great Britain. This increase may represent net carbon sequestration from increased sustainable land management or carbon redistribution (geographic or vertical). Better representation of the impact of agricultural management on soil carbon stocks is an area of potential future improvement.

6.3.7 Category-Specific Recalculations

The reported overall net GHG source in category 4B has decreased by <-0.01 Mt CO₂e (0%) across the time series compared to the previous inventory. The changes were primarily due to minor changes in activity data.

The changes and their justification are:

- **Updates to organic soil areas.** New peatland restoration data for England has replaced extrapolated average rates for 2021-2024. There have been minor updates for restoration activity data for Scotland..
- **Updates to cropland management activity data.** Activity data for England has been updated for the timeseries since 1990, and new data for Scotland included, which replaces interpolated data..
- **Updates to the CARBINE model** – see **Section 6.2.7**. These updates have affected biomass and dead organic matter losses following deforestation and controlled burning.
- **Updates to wildfire activity data** – see **Section 6.2.7**.

Changes in emissions are described in **Table 6.7**.

Table 6.7 4B Category specific recalculations since previous submission (UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.B.1	Carbon stock change in living biomass	6.16	0.96	6.16	1.03	Gg C	Updates to cropland management activity data
4.B.1	Net carbon stock change in soils - mineral soils	497.05	1141.97	498.28	1146.93	Gg C	
4.B.1	Net carbon stock change in soils - organic soils	1146.66	1074.11	1146.67	1079.70	Gg C	Updates to organic soil areas
4.B.2.a./4(IV)	Biomass Burning - controlled burning	0.24	0.00	0.26	0.00	Gg C	Updates to the CARBINE model
4.B.2.a.	Carbon stock change in living biomass	0.35	0.00	0.34	0.00	Gg C	
4.B.2.a.	Net carbon stock change in dead organic matter	0.08	0.00	0.11	0.00	Gg C	
4.B.1/4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	11.868	11.311	11.868	11.352	Gg CH ₄	Updates to organic soil areas
4.B.1./4(IV)	Biomass Burning - wildfires	0.005	0.002	0.006	0.002	Gg CH ₄	Updates to wildfire activity data
4.B.2.a./4(IV)	Biomass Burning - controlled burning	0.003	0.000	0.003	0.000	Gg CH ₄	Updates to the CARBINE model
4.B.1./4(IV)	Biomass Burning - wildfires	0.000	0.000	0.000	0.000	Gg N ₂ O	Updates to wildfire activity data
4.B.2.a./4(IV)	Biomass Burning - controlled burning	0.000	0.000	0.000	0.000	Gg N ₂ O	Updates to the CARBINE model

6.3.8 Category-Specific Planned Improvements

The first Greenhouse Gas Inventory Improvement Programme has been completed (March 2025). A second programme is being commissioned, with a dedicated LULUCF strand. This programme will take forward improvements to the inventory, based on UK government priorities and informed by previous prioritisation work.

The 2019 UNFCCC review team inquired about the estimation, and reporting of, inorganic carbon stock change in soil. A subsequent review team stated that this only needs to be considered when the necessary data, a monitoring system for routinely collecting such data, and appropriate (Tier 3) soil process-modelling capacity becomes available. Therefore, no further work on inorganic soil carbon stocks is currently planned.

6.4 CATEGORY 4C – GRASSLAND

6.4.1 Description

Emissions sources	4C Grassland: carbon stock change 4(II).C Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(III).C Direct and indirect nitrous oxide (N ₂ O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils 4(IV).C Biomass burning
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	T3 for carbon stock changes, T2 for organic soils, T1 for other emissions
Emission Factors	Country-specific for T3 methods, T2 for direct CO ₂ and CH ₄ emissions from organic soils, T1 for other emissions
Key Categories	4C: Grassland - CO ₂ (L1, L2, T1), CH ₄ (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	No major improvements

This section describes LULUCF emissions and removals from Grassland in the UK. A description of LULUCF emissions and removals from the OTs and CDs is given in **Section 6.9**.

Net emissions from the Grassland category include carbon stock gains and losses and GHG emissions due to land-use change (LUC) and GHG emissions from grassland management, drainage and rewetting and biomass burning. Grassland is a small net source that reduces across the time series.

Ongoing carbon stock changes in soils arising from LUC to Grassland are reported under both 4.C.2 Land Converted to Grassland (for LUC in the past 20 years) and 4.C.1 Grassland Remaining Grassland (for historic LUC >20 years before the inventory reporting year). These soil carbon stock changes and CO₂ emissions from mineral and organic soils are the largest

components of the category total emissions and removals. Carbon stock changes on mineral soils are calculated using a Tier 3 dynamic soil carbon model and CO₂ emissions from organic soils are calculated using Tier 2 country-specific emission factors.

The area of undisturbed grassland on mineral soils which has not been converted from other land uses in the past is reported in 4.C.1. “Undisturbed” grassland. This sub-category is used as a buffer category on the recommendation of UNFCCC reviewers, as Grassland is the most extensive land type in the UK. The undisturbed grassland area is calculated as the difference between the total land area (from the official statistics of UK land area, Office for National Statistics) and the sum of all other land use areas (calculated from land use matrices, afforestation areas, organic soil areas etc.) for each year. No anthropogenic emissions or removals are associated with this undisturbed area.

The Evans *et al.* (2017) report identified large areas of grassland on organic soils in the UK that are not intensively cultivated but nevertheless have been degraded by anthropogenic activities, for example by over-grazing or management for game species. Emissions of N₂O from these unintensive grassland areas are reported under 4C Grassland, while N₂O emissions from intensive cultivated grassland on organic soils are reported under 3D in the Agriculture sector.

Other contributors to the Grassland net total emissions are:

- CH₄ emissions resulting from drainage and rewetting of organic soils (4(II).C);
- N₂O emissions from drainage and rewetting of unintensive grassland on organic soils (4(II).H);
- carbon stock changes in biomass resulting from changes in grassland management (4.C.1);
- biomass carbon stock changes due to LUC (4.C.2);
- N₂O emissions from mineral soil disturbance associated with LUC (4(III).C);
- biomass burning emissions of GHGs from controlled burning following forest land conversion to grassland (4(IV).C.2.a); and
- biomass burning emissions of GHGs due to wildfires (4(IV).C.1.b).

Full details of the methods and activity data are given in **Annex 5.1.4**

6.4.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory and compiles several different data sources into a non-spatially explicit land use conversion matrix (see **Annex 5.1.4.3.1** for details).

Data sources that contain area information for reporting carbon stock changes and/or emissions from Grassland are:

- Habitat/landscape surveys (see **Section 6.3.2**).
- Extent of grassland on organic soils and rewetting of grassland that stays within the grassland category (Evans et al. 2017 and further updates).
- Agricultural survey data (see **Section 6.3.2**).
- Land-cover from satellite imagery classification (see **Section 6.3.2**).
- Data on deforestation areas from various sources:
 - Post-2000 deforestation areas are assessed from the NFI and administrative records of the conversion of areas in the public forest estate as part of habitat restoration and windfarm development.
 - 1990-1999 deforestation areas are estimated from unconditional felling licence data (felling licences granted without a requirement to restock), national forest

estate administrative information and land conversion ratios from Countryside Survey. Details are given in **Annex 5.1.4.5**.

- Data on wildfires on agricultural land and moorland from Fire and Rescue service and satellite data (see **Section 6.3.2** for further details).

6.4.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Grassland that has undergone land-use change and direct management is defined in accordance with the Agriculture, Forestry and Other Land Uses guidance (volume 4, IPCC 2006). There are also large areas of extensively grazed semi-natural grassland on mineral soils, which are assigned to the 4.C.1 “Undisturbed grassland” sub-category and calculated as the area remaining after all other land use areas are subtracted from the total UK land area. This is the buffer land use category for the UK, so may contain small areas of other land uses that are not directly managed.

Grazing is the main land use on semi-natural peatland habitats that would otherwise fall within in the Wetland category, so areas of peatland habitat not used for peat extraction or not explicitly identified as near-natural bog or fen, are included in the Grassland category. Areas of grassland that have undergone rewetting (or other activities that restore peatland habitats and reduce emissions) remain within the Grassland category.

The grassland and semi-natural habitat types in the different data sources that contribute to the Grassland category are described in **Annex 5.1.4.3.1**.

6.4.4 Methodological Issues

6.4.4.1 Land-use change

Activity data for land-use change are estimated using a land-use change (LUC) matrix approach. Detailed descriptions of the methods, emission factors and data flows used for the Grassland activities are given in **Annex 5.1.4.3**.

Land use change on organic soils is split out from the land-use change matrices to produce a non-organic soil set of LUC change matrices. Emissions arising from land use and land-use change on organic soils are calculated using methodologies consistent with chapters 2 and 3 of the 2013 IPCC Wetlands Supplement (IPCC 2014a) described in **Annex 5.1.4.7**. The dynamic model of soil carbon stock change is described in **Section 6.3.4.1**. Biomass carbon stock change is calculated using the LUC matrix and literature-derived Tier 2 stock change factors with all stock gains or losses assumed to occur in a single year.

Direct and indirect N₂O emissions associated with the non-organic soil disturbance from LUC are reported using the appropriate areas of Grassland remaining Grassland and Forest land converted to Grassland from the LUC matrices and the IPCC Tier 1 emission factors.

6.4.4.2 Grassland management

Carbon stock changes in biomass due to grassland management activities are estimated using literature-derived Tier 2 stock change factors and activity data from agricultural surveys. All carbon stock changes associated with changes in the length and condition of hedgerows are reported under this activity.

6.4.4.3 Drained organic soils

Emissions of carbon and CH₄ from Grassland on drained and undrained organic soils, and N₂O emissions from unintensive grassland, are reported using Tier 2 emission factors (**Annex 5.1.4.7**). Emissions of N₂O from intensive grassland on organic soils are calculated using the same activity data and are reported in category 3.D in the Agriculture sector.

6.4.4.4 Biomass burning emissions

Emissions from controlled burning on grassland are only reported for Forest Land conversion to Grassland and are estimated using Tier 1 emission factors and country-specific fuel densities. See **Annex 5.1.4.6** for further discussion of controlled burning for game management on upland habitats.

Emissions from wildfires on Grassland (agricultural grassland and semi-natural grassland) are reporting using Tier 1 emission factors and activity from a range of sources (see **Section 6.3.2**).

In 2023 the DESNZ-funded GHG Inventory Improvement Project “Earth Observation Detection of UK Wildfires for LULUCF Reporting” investigated whether the use of earth observation/satellite imagery could improve the wildfire activity data timeseries and potentially be implemented in calculations for emissions from wildfire burning of soil organic matter (on organic soils). A key finding was that satellite burnt area products could not be used as stand-alone datasets to reliably estimate wildfire burnt areas, as there was poor correspondence with fire locations in the administrative records, producing high random uncertainty. The results of this project have not been implemented in the current inventory.

6.4.5 Uncertainties and Time-Series Consistency

The uncertainty in 1990 and 2024 respectively are estimated at 15% for CO₂, 35% for CH₄, and 40% for N₂O. These uncertainties are based on an uncertainty analysis using the updated activity data and methodology for this submission. Details are provided in **Annex 5.1.4.12**. The areas undergoing land-use change are the biggest source of uncertainty in the LULUCF inventory (see **Annex 5.1.4.12**).

With regard to time series consistency:

- Drainage of organic soils: it is assumed that all drainage of organic soils under Grassland occurred before 1990, as recent policy has favoured protection of organic soils. There have been no policy incentives to encourage new land drainage for agricultural use since before 1990, and major drainage of large areas of improved Grassland on organic soils in areas such as the Somerset Levels fens is known to have occurred well before this. An area of 120.400 kha of grassland has been rewetted since 1990, and an area of 1.476 kha has been converted to peat extraction since 1990.
- Changes in biomass and soil carbon due to LUC: the land-use change data assimilation methodology draws on multiple data-sources and takes account of random uncertainty and false positive rates. The time series now show more inter-annual variation but more gradual temporal trends (see **Figure A 3.6 in Annex 5.1.4.3.1**).
- Controlled biomass burning after conversion of Forest Land to Grassland: there is good time series consistency as there has been continuity in the activity data source.
- Grassland management: activity data come from Countryside Survey, which is also used to estimate change in carbon stocks due to land-use change and has good internal consistency.
- Wildfires: a consistent dataset is used for 2010 onwards. Burnt areas are extrapolated back to 2001 based on remote sensing data, but between 1990 and 2001 there are no observed data on the extent of wildfires on Grassland, and the time series is filled by extrapolating the 2001 - 2011 average wildfire area.

A significance analysis has been undertaken for key categories in the LULUCF sector (**Table 6.8**). The largest contributing sub-categories/pools for carbon dioxide are from Grassland remaining Grassland organic and mineral soils and Cropland converted to Grassland mineral

soils. The largest contributory sub-category for methane is almost entirely emissions from drainage and rewetting of organic soils.

Table 6.8 Significance analysis of the key sub-categories/pools in the Grassland category

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2023 total ¹
CO₂			
4(IV) Biomass burning		0%	1%
C.1. Grassland remaining Grassland		61%	67%
	Carbon stock change in living biomass due to land use change	0%	0%
	Carbon stock change in living biomass due to grassland management	5%	0%
	Mineral Soils	12%	32%
	Organic Soils	44%	35%
C.2.a. Forest Land converted to Grassland		1%	4%
C.2.b. Cropland converted to Grassland		35% (mineral soils)	26% (mineral soils)
C.2.d. Settlements converted to Grassland		3%	2%
CH₄			
4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils		100%	99%
4(IV) Biomass burning		0%	1%

¹ Percentages may not sum to 100% due to rounding

6.4.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**.

As discussed in **Section 6.3.6** resampling of the 1980-based National Soil Inventory (NSI) in England and Wales in 1995-2003 found large losses of soil carbon across all land use types (Bellamy *et al.* 2005) but, a more recent study using Countryside Survey (CS) data (Reynolds *et al.* 2013) found no significant change in soil carbon stocks under most Grassland habitat types between 1978 and 2007. The possible reasons for these differences are unclear, as discussed in **Section 6.3.6**.

6.4.7 Category-Specific Recalculations

The Category 4C net source has changed by -0.1 to 0.1 Mt CO₂e across the time series compared to the previous inventory. These differences are due to carbon stock change as a result of changes in deforestation activity data and new peatland restoration data.

The changes and their justification are:

- **Updates to organic soil areas.** New peatland restoration data for England has replaced extrapolated average rates for 2021-2024. An updated split in the restoration of pasture and semi-natural grassland types on organic soils has been applied.

- **Updates to deforestation areas.** Newly available activity data for deforestation to grassland has been included for England and Scotland.
- **Updates to wildfire activity data.** See section 6.2.7.
- **Updates to the CARBINE model** – see section 6.2.7. These updates have affected biomass and dead organic matter losses following deforestation and controlled burning.

Changes in emissions are described in **Table 6.9**.

Table 6.9 4C Category specific recalculations since previous submission UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.C.1	Net carbon stock change in soils - organic soils	1589.65	1333.98	1591.34	1336.26	Gg C	Updates to organic soil areas
4.C.2.a/4(IV)	Biomass burning - controlled burning	5.76	55.07	6.17	40.72	Gg C	Updates to deforestation areas. Updates to the CARBINE model.
4.C.2.a	Carbon stock change in living biomass - Losses	8.19	74.67	8.12	47.21	Gg C	
4.C.2.a	Net carbon stock change in dead organic matter	1.91	21.86	2.69	24.16	Gg C	
4.C.2.a	Net carbon stock change in soils - organic soils	0.10	21.80	0.10	22.51	Gg C	
4.C/4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	99.969	101.505	100.124	101.718	Gg CH ₄	Updates to organic soil areas
4.C.1/4(IV)	Biomass burning - wildfires	0.330	0.201	0.327	0.142	Gg CH ₄	Updates to wildfire activity data
4.C.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.002	0.360	0.002	0.372	Gg CH ₄	Updates to organic soil areas
4.C.2.a/4(IV)	Biomass burning - controlled burning	0.063	0.605	0.068	0.447	Gg CH ₄	Updates to deforestation areas. Updates to the CARBINE model
4.C/4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.417	0.348	0.418	0.349	Gg N ₂ O	Updates to organic soil areas

Land-Use, Land Use Change and Forestry (CRT Sector 4) **6**

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.C.1/4(IV)	Biomass burning - wildfires	0.030	0.018	0.030	0.013	Gg N ₂ O	Updates to wildfire activity data
4.C.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	0.017	0.000	0.018	Gg N ₂ O	Updates to organic soil areas
4.C.2.a/4(IV)	Biomass burning - Controlled Burning	0.003	0.033	0.004	0.025	Gg N ₂ O	Updates to deforestation areas. Updates to the CARBINE model

6.4.8 Category-Specific Planned Improvements

See **Section 6.3.8** for planned improvements also affecting the Grassland and Settlement categories.

6.5 CATEGORY 4D – WETLANDS

6.5.1 Description

Emissions sources	4D Wetlands: Carbon stock change 4(II).D Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(IV).D Biomass burning
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	T2 for organic soils, T1 for water bodies
Emission Factors	T2 for direct CO ₂ and CH ₄ emissions from organic soils, T1 for other emissions
Key Categories	4D Wetlands- CH ₄ (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	No major improvements

This section describes LULUCF emissions and removals from Wetland in the UK. A description of LULUCF emissions and removals from the OTs and CDs is given in **Section 6.9**.

Net emissions from the Wetlands category includes emissions from: peatlands that are cleared and drained for peat production (for energy or horticultural purposes); areas of near-natural peatland; areas of former peat extraction, forest and cropland that are now rewetted; and areas converted to permanently flooded land (reservoirs).

Emissions from on-site peat production and off-site emissions from horticultural peat are reported under 4.D.1.a and 4(II).D.1.a. Areas of former peat extraction that are now rewetted are reported under 4.D.1.c and 4(II).D.1.c. Areas of conversion to Wetland of grassland converted to Wetland for peat extraction are reported under 4.D.2.a and 2(II).D.2.a; grassland converted to flooded land are reported under 4.D.2.b and 4(II).D.2.b; and rewetted former forest and cropland are reported under 4 D.2.c and 4(II).D.2.c. The associated emissions and living biomass carbon stock changes estimated using the appropriate Tier 1 or 2 methodologies.

The area of UK natural inland water is reported in the category Other Wetlands remaining Other Wetlands (4.D.1.c) and the area of reservoirs created before 1990 is reported in Flooded Land remaining Flooded Land (4.D.1.b).

6.5.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approach used for representing Wetlands differs from that used for other land use categories because peat extraction sites and reservoirs are not explicitly identified in the habitat and landscape surveys used for the land use matrix. The area of wetlands on organic soils in the UK was revised based on peatland extent and condition mapping outputs from the

BEIS-funded project to implement the IPCC Wetland Supplement (Evans *et al.* 2017) and subsequent updates. This included areas of near-natural wetlands and rewetted organic soils as well as areas of inactive peat extraction (see **Annex 5.1.4.7** for details).

This information is supplemented by the areas of active peat extraction obtained from the Directory of Mines and Quarries, Google Earth, the Minerals Extraction in Great Britain report (and its predecessor the Minerals Raised Inquiry, Office for National Statistics), and site operations data provided by Growing Media Association. These sources and papers on peat extraction in Northern Ireland were used in combination to produce an activity dataset for active peat extraction areas in the UK (see **Annex 5.1.4.8** for further details).

Activity data for post-1990 constructed reservoirs were compiled from the Public Register of Large Raised Reservoirs (supplied by the Environment Agency for England and Wales) and the SEPA Water Body Classification database (see **Annex 5.1.4.9** for further details).

The remaining area of inland water (natural water bodies and reservoirs established before 1990) is known from the area of inland water reported as part of the Standard Area Measurement. There are no emissions or removals associated with this area.

6.5.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Areas of active peat extraction are defined as areas that are currently undergoing, or have recently undergone, peat extraction activities (locations are known from administrative records: see **Section 6.5.2**). It is assumed that extraction areas continue to produce emissions while there is visible evidence of exposed peat soil from Google Earth satellite imagery, and do not convert back to functioning peatlands without restoration intervention. An extraction site is considered to have ceased emissions when there is visible evidence of the re-establishment of wetland vegetation cover on the satellite imagery and evidence of rewetting (ditch blocking) from online documentation of the restoration works and communication with site managers.

“Near-natural” peatlands are areas that were identified in Evans *et al.* (2017) as having no anthropogenic degradation but which can still be considered as managed e.g. for biodiversity purposes. They are a carbon sink but also a source of CH₄ emissions. Rewetted peatlands are those that have undergone restoration activities to restore normal peatland biogeochemical functioning. These have been identified from a database of peatland restoration projects (see **Annex 5.1.4.7**) and more recent government-funded restoration.

The area of inland water is taken from the “UK Standard Area Measurements” (Office for National Statistics). It defines inland water as ‘bounded’ permanent water bodies, e.g. lakes, lochs and reservoirs, exceeding 1 km² (100 hectares) in area. ‘Open’ tracts of water, e.g. rivers, canals and streams are excluded from this definition. Reservoirs (flooded land) were identified either by their inclusion in the Public Register of Large Raised Reservoirs or by their classification as “Heavily modified” in the SEPA Water Body Classification database. Areas of water below the size threshold are included in the 4F Other Land category.

6.5.4 Methodological Issues

6.5.4.1 Peat extraction

Emissions from peat extraction are estimated using Tier 1 and Tier 2 methodology, which does not distinguish between peat extraction production phases, i.e. it includes conversion and vegetation clearing. On-site emissions associated with peat extraction are reported under 4.D.1.a. For on-site emissions due to extraction activities and drainage, a Tier 2 CO₂ emission factor is employed for Industrial (horticulture) Extraction, and a Tier 1 CO₂ emission factor (IPCC, 2014a) is used for Domestic (fuel) Extraction. A Tier 2 CH₄ emission factor and Tier 1 N₂O emission factor is applied to emission estimates for both Industrial and Domestic Peat

Extraction (see **Annex 5.1.4.7**). Off-site carbon emissions from horticultural peat that has been extracted are assumed to be emitted during the extraction year. Mapping outputs from Evans et al. (2017) and administrative records categorise sites as producing horticultural or energy source (fuel) peat. Further information is given in **Annex 5.1.4.8**.

Google Earth imagery is used to track the area change of individual extraction sites over time. Google Earth imagery is checked annually and extraction site areas are updated as new imagery becomes available.

The site records show that the area under active horticultural peat extraction between 1990 and 2023 diminished for England, and decreased slightly overall for Scotland, but is more variable for Northern Ireland. No peat extraction is reported in Wales. The time series of active fuel peat extraction has decreased across the UK. Sites that have no active record of extraction, and show no change in area on the Google Earth imagery, are assumed to be abandoned extraction sites that are still producing emissions (reported under 4D1). Sites where extraction is no longer visible on the Google Earth imagery are identified as potentially being restored to rewetted Wetland and investigated further. As these sites are often part of peatland restoration schemes managed by UK nature reserves, information on site history and success of the restoration (rewetting) works are gathered online and from reserve managers to support reporting a condition change. Changes in organic soil carbon from this condition change are estimated using a Tier 2 approach based on the IPCC 2013 Guidelines (IPCC 2014).

A small area of land conversion to Wetlands (all from Grassland) occurs across the time series. This area and the associated on-site emissions are reported under 4.D.2.a Land converted to Wetlands. Rewetted former peat extraction sites remain as Wetland and are reported under 4.D.1.c.

6.5.4.2 Land converted to Flooded Land

A Tier 1 methodology was applied for emissions from Flooded Lands (4.D.2.b). This estimated carbon stock changes in living biomass stock in the year of flooding (for reservoirs established since 1990) but not carbon stock changes in soils. The locations of the reservoirs were established on maps, and due to their location in upland areas, all were assumed to be Grassland prior to flooding. A living biomass density of 2 t dry matter/ha was used to estimate carbon stock losses.

6.5.4.3 Land converted to other wetlands

Forest and cropland on organic soils that undergo rewetting are converted to Wetlands (4.D.2.c.i and 4.D.2.c.ii, respectively) as they do not retain their original land use. A Tier 2 methodology using areas and EFs from Evans et al (2017) is applied. Emissions from controlled burning following deforestation and carbon stock changes in biomass and dead organic matter are also calculated for conversion of forest land to wetland.

6.5.5 Uncertainties and Time-Series Consistency

The uncertainty in 1990 and 2024 respectively are estimated at 40% for CO₂, 50% for CH₄, and 120% and 95% for N₂O. These uncertainties are based on an uncertainty analysis using the updated activity data and methodology for this submission. Details are provided in **Annex 5.1.4.12**.

Time-series consistency for activity data for peat extraction sites is affected by uncertainty in survey dates but has been improved by the incorporation of additional site data from the Growing Media Association. Time-series consistency for flooded lands was good due to the complete nature of the data set.

Methane emissions from category 4.D are a key category and are 100% due to emissions from drainage and rewetting (CRT table 4(II)) of organic soils.

6.5.6 Category-Specific QA/QC and Verification

Operational site areas are provided by the Growing Media Association (GMA). The UKCEH peat extraction database matched the GMA data closely for Scotland, Wales, and Northern Ireland, but were adjusted accordingly where more robust data were available. For England, the inventory areas were revised downwards based on improved on-site information primarily for complicated sites.

The peat extraction site activity dataset has also been partially verified by comparing the measured areas with reported areas of planning permission, which were available for some extraction sites in England and Scotland. The measured areas either matched or were smaller than the planning permission areas, which is to be expected as it is known that not all areas with planning permission are undergoing active extraction.

The locations and previous land-use of new reservoirs were verified using the www.magic.gov.uk geographic information portal.

6.5.7 Category-Specific Recalculations

The Category 4D net source has reduced by between -0.1 and 0.0 Mt CO₂e (-1.8 to -2.2%) across the time series compared to the previous inventory. This is mainly due to updates in the activity data for forest rewetting.

The changes and their justification are:

- **Changes in domestic peat extraction activity data.** Historic domestic peat extraction areas in England have been reassigned to less degraded peatland categories (e.g., semi-natural grassland, rewetted bog, flooded land/lakes) following a Defra-funded field-based project in 2024/25 to assess the recovery of historic domestic peat extraction sites.
- **Updates to organic soil areas.** New peatland restoration data for England has replaced extrapolated average rates for 2021-2024.
- **Updates to forest rewetting activity data.** Areas of deforestation to wetland have been updated due to a recalculation of the hydrological buffer/footprint applied to the length of ditches blocked from 50m to 30m, to align with Peatland Code methodology. Additional restoration areas have also been included for Scotland.
- **Updates to the CARBINE model.** – see section 6.2.7. These updates have affected biomass and dead organic matter losses following deforestation and controlled burning.

Table 6.10 4D Category specific recalculations since previous submission (UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.D1.a	Net carbon stock change in soils - organic soils - peat extraction	651.97	528.15	640.08	515.60	Gg C	Changes in domestic peat extraction activity data.
4.D.1.c	Net carbon stock change in soils- organic soils	-495.98	-495.04	-496.74	-495.78	Gg C	Updates to organic soil areas
4.D.2.a/4(IV)	Biomass burning - controlled burning	0.00	57.41	0.00	56.16	Gg C	Updates to forest rewetting activity data. Updates to the CARBINE model
4.D.2.c.i	Carbon stock change in living biomass - losses	0.00	74.12	0.00	63.97	Gg C	
4.D.2.c.i	Net carbon stock change in dead organic matter	0.00	26.51	0.00	34.47	Gg C	
4.D.2.c.i	Net carbon stock change in soils- organic soils	0.00	0.96	0.00	0.93	Gg C	
4.D.2.c.ii.	Net carbon stock change in soils - organic soils	0.00	0.27	0.00	0.23	Gg C	Updates to organic soil areas
4.D.1.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	10.215	9.409	9.991	9.172	Gg CH ₄	Changes in domestic peat extraction activity data
4.D.1.c./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	72.252	73.889	72.345	74.003	Gg CH ₄	Updates to organic soil areas
4.D.2.c.i./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	1.315	0.000	1.273	Gg CH ₄	Updates to forest rewetting activity data.
4.D.2.c.i./4(IV)	Biomass burning - controlled burning	0.000	0.631	0.000	0.617	Gg CH ₄	Updates to forest rewetting activity data. Updates to the CARBINE model

Land-Use, Land Use Change and Forestry (CRT Sector 4) **6**

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.D.2.c.ii./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	0.580	0.000	0.504	Gg CH ₄	Updates to organic soil areas
4.D.1.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.071	0.066	0.070	0.064	Gg N ₂ O	Changes in domestic peat extraction activity data
4.D.1.c./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	0.000	0.000	0.000	Gg N ₂ O	Updates to organic soil areas
4.D.2.c.i./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	0.001	0.000	0.001	Gg N ₂ O	Updates to forest rewetting activity data.
4.D.2.c.i./4(IV)	Biomass burning - controlled burning	0.000	0.035	0.000	0.034	Gg N ₂ O	Updates to forest rewetting activity data. Updates to the CARBINE model

6.5.8 Category-specific planned improvements

There are ongoing discussions with policy experts and peatland managers to improve the register of peat restoration activities across all nations of the UK and update the rewetting activity data as appropriate.

BEIS commissioned a review of current knowledge and gaps of GHG emissions and removals from UK coastal wetlands, which provided recommendations for moving towards inclusion of saltmarshes in the UK GHGI (Burden and Clilverd, 2022). Evidence gaps identified in this report were addressed in a Defra-funded project to provide a roadmap for inclusion of saltmarsh in the UK GHGI by defining terminology, and mapping implications of different terminologies on saltmarsh areal extent (Burden et al. 2024). Subsequent government-funded projects are underway to: - 1) compile a database of carbon stocks and GHG fluxes, 2) develop Tier 2 emission factors for saltmarsh, and 3) develop a baseline map of UK saltmarsh extent.

6.6 CATEGORY 4E – SETTLEMENTS

6.6.1 Description

Emissions sources	4.E Settlements: Carbon stock change 4(II).E Emissions and removals from drainage and rewetting and other management of organic and mineral soils 4(III).E Direct and indirect nitrous oxide (N ₂ O) emissions from nitrogen (N) mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils 4(IV).E Biomass burning
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	T3 for carbon stock changes, T2 for organic soils, T1 for other emissions
Emission Factors	Country-specific for T3 methods, T2 for direct CO ₂ and CH ₄ emissions from organic soils, T1 for other emissions
Key Categories	4E: Settlements – CO ₂ (L1, T1, L2, T2)
Key Categories (Qualitative)	None identified
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	No major improvements.

This section describes LULUCF emissions and removals from Settlement in the UK. A description of LULUCF emissions and removals from the OTs and CDs is given in **Section 6.9**.

Net emissions from the Settlements category include carbon stock gains and losses due to land-use change (LUC) and associated GHG emissions. It is the second largest net source in the LULUCF sector.

Ongoing carbon stock changes in soils arising from LUC to Settlements are reported under both 4.E.1 Settlements remaining Settlements (for historic LUC >20 years before the inventory reporting year) and 4.E.2 Land converted to Settlements (for LUC in the past 20 years). Direct

and indirect N₂O emissions from N mineralization from these land use changes are reported in 4(III).E. These non-organic soil net carbon stock changes are the largest component of the category total emissions and are calculated using a Tier 3 dynamic soil carbon model.

Other contributors to the Settlements net total emissions are:

- Carbon, CH₄ and N₂O emissions resulting from drainage of organic soils (4.E and 4(II).E);
- biomass carbon stock changes due to LUC (4.E.2);
- N₂O emissions from soil disturbance associated with LUC (4(III).E); and
- biomass burning emissions of GHGs from controlled burning following forest land conversion to Settlements (4(IV).E.2.a).

Full details of the methods and activity data are given in **Annex 5.1.4**.

6.6.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory and compiles several different data sources into a non-spatially-explicit land use conversion matrix (**Annex 5.1.4.3.1** for details).

Data sources that contain area information for reporting carbon stock changes and/or emissions from Settlements are:

- Habitat/landscape surveys (see **Section 6.3.2**).
- Extent of settlement on organic soils (Evans et al. 2017 and further updates).
- Land-cover from satellite imagery classification (see **Section 6.3.2**).
- Data on deforestation areas from various sources;
 - Post-2000 deforestation areas are assessed from the NFI and administrative records of the conversion of areas in the public forest estate as part of habitat restoration and windfarm development.
 - Pre-2000 deforestation areas are estimated from unconditional felling licence data (felling licences granted without a requirement to restock), national forest estate administrative information and land conversion ratios from Countryside Survey. Details are given in **Annex 5.1.4.5**.

6.6.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Settlement is defined in accordance with the Agriculture, Forestry and Other Land Use Guidance (IPCC 2006).

The settlement land-cover types in the different data sources that contribute to the Settlement category are described in **Annex 5.1.4.3.1**.

6.6.4 Methodological Issues

6.6.4.1 Land-Use Change

Activity data for land-use change are estimated using a land-use change (LUC) matrix approach. Detailed descriptions of the methods, emission factors and data flows used for the Settlement activities are given in **Annex 5.1.4.3.1**.

Land use change on organic soils is split out from the land-use change matrices to produce a non-organic soil set of LUC change matrices. Emissions arising from land use and land-use change on organic soils are calculated using methodologies consistent with chapters 2 and 3 of the 2013 IPCC Wetlands Supplement (IPCC 2014a) described in **Annex 5.1.4.7**. The

dynamic model of soil carbon stock change is described in **Section 6.3.4**. Biomass carbon stock change is calculated using the LUC matrix and literature-derived Tier 2 stock change factors with all stock gains or losses assumed to occur in a single year. Detailed descriptions of the methods, emission factors and data flows used for the Settlement category are given in **Annex 5.1.4.7**.

Direct and indirect N₂O emissions associated with the non-organic soil disturbance from LUC are reported using the areas from the LUC matrices and the IPCC Tier 1 emission factors.

6.6.4.2 Drained organic soils

Emissions of carbon, CH₄ and N₂O from Settlements on drained organic soils are reported using Tier 2 and Tier 1 emission factors (**Annex 5.1.4.7**).

6.6.4.3 Biomass burning emissions

Emissions from controlled burning on settlement land are only reported for Forest Land conversion to Settlements and are estimated using Tier 1 emission factors and country-specific fuel densities.

6.6.5 Uncertainties and Time-Series Consistency

The uncertainty in 1990 and 2024 respectively are estimated at 45% and 50% for CO₂, 60% and 50% for CH₄, and 115 and 110% for N₂O. These uncertainties are based on an uncertainty analysis using the updated activity data and methodology for this submission. Details are provided in **Annex 5.1.4.12**. The areas undergoing land-use change are the biggest source of uncertainty in the LULUCF inventory (see **Annex 5.1.4.12**).

With regard to time series consistency:

- Drainage of organic soils: It is assumed that all existing Settlement areas on organic soils are drained. The only land use change from Settlement on organic soils is to and from Forest land and the areas involved are small (1.613 kha to Forest Land since 1990, and 4.671 kha from Forest Land since 1990) and all assumed to be drained.
- Changes in biomass and soil carbon due to LUC: the land-use change data assimilation methodology draws on multiple data-sources and takes account of random uncertainty and false positive rates. Estimated rates of change are lower and more gradual than in previous submissions, although the uncertainty bounds are larger.
- Controlled biomass burning after conversion of Forest Land to Settlement: there is good time series consistency as there has been continuity in the activity data source.

A significance analysis has been undertaken for key categories in the LULUCF sector. Carbon stock changes in mineral soils in 4E1 Settlements remaining Settlements and 4.E2.3 Grassland converted to Settlement are the most significant sub-categories/pools (**Table 6.11**).

Table 6.11 Significance analysis of the key sub-categories/pools in the Settlement category

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2024 total ¹
4(IV) Biomass burning		1%	4%
E.1. Settlements remaining Settlements		27%	38%
	Carbon stock change in biomass due to land use change	0%	0%
	Mineral Soils	27%	38%

Sub-category	Pool	Percentage contribution to 1990 total ¹	Percentage contribution to 2024 total ¹
	Organic Soils	0%	0%
E.2.a. Forest Land converted to Settlements		9%	20%
E.2.b. Cropland converted to Settlements		9%	8%
E.2.d. Grassland converted to Settlements		55% (mineral soils)	30% (mineral soils)

¹ Percentages may not sum to 100% due to rounding

6.6.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**.

6.6.7 Category-Specific Recalculations

The reported overall net GHG source in category 4.E has changed by -0.01 - 0.07 Mt CO₂e across the time series compared to the previous inventory (+/- 0.2%). The changes were mainly due to updates in deforestation activity data.

The changes and their justification are:

- **Updates to organic soil areas.** Minor changes to activity data for settlement to forest on organic soil has affected the total area of settlement on organic soil
- **Updates to deforestation activity data.** Updates to England deforestation estimates for 2023 are based on woodland removal figures from the Forestry Commission Key Performance Indicators 2024-2025 report. This value is rolled over to 2024.
- **Updates to the CARBINE model** – see section 6.2.7. These updates have affected biomass and dead organic matter losses following deforestation and controlled burning.

Table 6.12 4E Category specific recalculations since previous submission (UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.E.1	Net carbon stock change in soils - organic soils	3.14	2.98	3.15	2.99	Gg C	Updates to organic soil areas
4.E.2.a/4(IV)	Biomass burning - controlled burning	13.53	45.44	14.52	44.43	Gg C	Updates to deforestation activity data Updates to the CARBINE model
4.E.2.a	Carbon stock change in living biomass - losses	19.28	59.94	19.13	51.63	Gg C	
4.E.2.a	Net carbon stock change in dead organic matter	4.44	19.70	6.31	26.24	Gg C	
4.E.2.a	Net carbon stock change in soils - organic soils	0.01	0.69	0.01	0.71	Gg C	
4.E.1./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.53	0.50	0.53	0.50	Gg CH ₄	Updates to organic soil areas
4.E.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.00	0.12	0.00	0.12	Gg CH ₄	
4.E.2.a/4(IV)	Biomass burning - controlled burning	0.15	0.50	0.16	0.49	Gg CH ₄	Updates to deforestation activity data
4.E.1./4(II)	Emissions and removals from drainage and rewetting and other	0.002	0.002	0.002	0.002	Gg N ₂ O	Updates to organic soil areas

Land-Use, Land Use Change and Forestry (CRT Sector 4) **6**

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
	management of organic and mineral soils						
4.E.2.a./4(II)	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	0.000	0.000	0.000	0.000	Gg N ₂ O	Updates to deforestation activity data Updates to the CARBINE model
4.E.2.a/4(IV)	Biomass burning - controlled burning	0.008	0.028	0.009	0.027	Gg N ₂ O	Updates to deforestation activity data

6.6.8 Category-Specific Planned Improvements

See **Section 6.3.8** for planned improvements also affecting the Grassland and Settlement categories.

6.7 CATEGORY 4F – OTHER LAND

6.7.1 Description

Emissions sources	None
Gases Reported	None
Methods	NA
Emission Factors	NA
Key Categories	None identified
Key Categories (Qualitative)	None identified
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	None

No emissions or removals are reported in this category in the UK. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type. Therefore, the UK rows in Table 4.F. (Other Land) are completed with 'NO' (Not Occurring).

6.7.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 6.1.1**

6.7.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Other Land is defined as areas that do not fall into the other land use categories. The land-cover types in the different data sources that contribute to the Other Land category are described in **Annex 5.1.4.3.1**. As described in **Section 6.4**, areas of inland water exceeding 1km² are included in 4D Wetlands, but water bodies below this threshold would still be included under Other Land.

6.7.4 Category-specific recalculations

There are no emissions associated with Other Land and no recalculations.

6.7.5 Category-specific planned improvements

None planned.

6.8 CATEGORY 4G – HARVESTED WOOD PRODUCTS**6.8.1 Description**

Emissions sources	4G Harvested Wood Products
Gases Reported	CO ₂
Methods	Tier 3
Emission Factors	Country-specific
Key Categories	4G Harvested Wood Products – CO ₂ (L1)
Key Categories (Qualitative)	None identified
Completeness	No known omissions
Major improvements since last submission	No major improvements.

HWP stocks result from normal forest management processes (thinning and harvesting) in the Forest Land category and from conversion of Forest Land to Cropland, Grassland or Settlements (deforestation). Carbon stock gains and losses from HWP in use from the domestic UK harvest are reported in Table 4.Gs1. Production of UK HWP from 1961 is reported in Table 4.Gs2.

6.8.2 Methodological Issues

The UK has elected to use the production approach B2 as set out in the IPCC 2006 Guidelines for estimating HWP. The carbon accounting model (CARBINE) is used to calculate the net changes in carbon stocks of harvested wood products (at the product type level), in the same way as it is used to estimate carbon stock changes in 4.A Forest Land. Changes in carbon stocks from HWP arising from deforestation (conversion of Forest Land to Grassland, Cropland or Settlement) are also estimated using CARBINE. The estimated carbon in harvested wood is split in to harvested wood product classes based on information on wood use from Forestry Commission statistics and the FAO, producing a time series from 1961 to the latest inventory year. A description of the method is outlined in **Annex 5.1.4.10**. Data from the Forestry Statistics on consumption of wood products in the UK are then used to disaggregate the HWP into either consumed domestically or exported. This dataset exists from 2002 onwards and the 2002-2011 average values are used for 1990-2001.

6.8.3 Uncertainties and Time-Series Consistency

4G Harvested Wood Products is estimated to have a combined uncertainty of 15-20% for CO₂.

These uncertainties are based on an uncertainty analysis using the updated activity data and methodology for this submission. Details are provided in **Annex 5.1.4.12**.

Activity data for areas planted and consequently harvested are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals. Data on the total quantity of softwood and hardwood production are available from 1976 using Forestry Commission reported statistics and from 1961-1975 using FAO timber production data. Data on the relative proportions of wood from UK sources used for different harvested wood products is available from 1994 onwards, the proportions prior to 1994 are estimated from FAO data. Data on the export of products is also obtained from national forestry sources, however it is only available from 2002 onwards. The 1990-2001 values are based on the ten-year average of the 2002-2011 values.

A significance analysis has been undertaken for key categories in the LULUCF sector. In Harvested Wood Products HWP Produced and Consumed Domestically is the most significant sub-category (**Table 6.13**).

Table 6.13 **Significance analysis of the key sub-categories/pools in the Harvested Wood Products category**

Sub-category	Pool	Percentage contribution to 1990 total	Percentage contribution to 2024 total
HWP Produced and Consumed Domestically		85%	96%
	Paper and Paperboard	11%	-1%
	Sawn Wood	32%	51%
	Wood panels	42%	46%
HWP Produced and Exported		15%	4%

6.8.4 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.10**. The timber production predicted has been compared to the national timber production statistics produced by Forest Research based on timber sales data from the public forest estate, a private sector softwood removals survey, a survey of sawmills, a survey of round fencing manufacturers and a survey of pellet and briquette production.

6.8.5 Category-Specific Recalculations

The reported overall net GHG sink in category 4G has increased by between -0.1 and 0.1 Mt CO₂e (3.0 to 5.5%) across the time series compared to the previous inventory.

The changes resulted from:

- **Updated wood production estimates** and wood product trade statistics.
- **Updates to the CARBINE model** – see section 6.2.7

The changes are described in **Table 6.15**.

Table 6.14 4G Category specific recalculations to activity data since previous submission (UK only)

CRT Category	Source Name	Old 1990 value	Old 2023 value	New 1990 value	New 2023 value	Units	Comment / Justification
4.G	HWP produced and consumed domestically	-489.88	-566.31	-464.56	-549.82	Gg C	Updated wood production estimates. Updates to the CARBINE model.
4.G	HWP produced and exported	-84.14	-28.97	-79.73	-27.88	Gg C	

6.9 LULUCF EMISSIONS AND REMOVALS IN THE OVERSEAS TERRITORIES AND CROWN DEPENDENCIES

6.9.1 Description

Emissions sources	Carbon stock change: 4.A Forest Land, 4.B Cropland, 4.C Grassland, 4.D Wetlands, 4.E Settlements 4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils (4.A Forest Land, 4.B Cropland, 4.C Grassland) 4(III) Direct and indirect N ₂ O emissions from N mineralization (4.B Cropland, 4.C Grassland, 4.E Settlements) 4(IV) Biomass Burning (4.A Forest Land, 4.C Grassland)
Gases Reported	CO ₂ , CH ₄ , N ₂ O
Methods	Tier 1, T2 for organic soils
Emission Factors	T1 and T2 for direct CO ₂ , CH ₄ and N ₂ O emissions from organic soils, T1 for other emissions
Key Categories	None identified
Key Categories (Qualitative)	None identified
Completeness	No known omissions
Major improvements since last submission	No major improvements.

GHG emissions and removals from the UK Crown Dependencies (CD) and Overseas Territories (OT) are reported under the relevant categories for the LULUCF sector in the CRT GBR submission (**Table 6.15**). Emissions estimates are made for the CDs of Jersey, Guernsey and the Isle of Man and the OTs of the Falkland Islands, Cayman Islands and Bermuda. Gibraltar has only one land-use category of Settlement remaining Settlement, with no associated GHG emissions. **Annex 5.1.4.11** provides detailed descriptions of the methods and emission factors used.

Table 6.15 LULUCF net emissions in all Overseas Territories and Crown Dependencies (Mt CO₂e)

Crown Dependency/ Overseas Territory	1990, Mt CO ₂ e	2024, Mt CO ₂ e
Isle of Man	-0.032	-0.041
Jersey	0.000	0.000
Guernsey	-0.002	0.001
Cayman Islands	0.065	0.094
Bermuda	0.002	-0.000
Falkland Islands	0.012	0.010
Gibraltar	0.000	0.000

Total	0.046	0.065

The Forest Land and Grassland categories are net sinks in the OTs and CDs while other land use categories are net sources. The LULUCF sector in the OTs and CDs is a net source in all years. The individual territory trends are:

- Isle of Man: increasing net sink, with net sources in cropland and settlement counterbalanced by net sinks in forest and grassland
- Guernsey: small net sink, with net sources in cropland and settlement counterbalanced by net sinks in forest and grassland
- Jersey: moves between being a small net source to a small net sink across the time series, with net sources from cropland, settlements and wetlands and a net sink in grassland.
- Falkland Islands: stable net source 1990-2005, then variable slowly decreasing source due to reduced emissions from cropland
- Cayman Islands: stable net source 1990-2006, then a variable net source primarily due to conversion of mangrove (organic) soils to settlement and forest conversion to wetlands and grasslands.
- Bermuda: small stable net source 1990-2011 due to forest conversion to settlement, becoming a very small net sink from 2012 due to a net sink in settlement.

6.9.2 Land use areas

Land cover surveys and agricultural land statistics have been used to compile annual land-use change matrices for the OTs and CDs, which are converted into the UNFCCC land-use change matrices using the 20-year transitions (reported in CRT tables 4.A-4.E in the GBR submission). The total land area of the OTs and CDs is maintained at a constant area by including a small area of unmanaged wetland to account for land reclamation from the sea in Jersey.

The definition of each land category is in accordance with the Agriculture, Forestry and Other Land Use Guidance (IPCC 2006). The Grassland category is used as the 'buffer' category to ensure consistency in total land area.

6.9.3 Methodological Issues

There is incomplete information on annual land areas for all territories, so land areas have been interpolated between, or extrapolated from, land area surveys as required.

IPCC Tier 1 methods have been used to estimate carbon stock changes and emissions/removals. An emission factor review was undertaken in 2025. This identified that the IPCC 2019 Refinement contained more appropriate emission factors for the climate and ecosystem context of the CDs and OTs than the IPCC 2006 Guidelines in some cases. These updated emission factors are used in the latest inventory submission. Tier 1 default emission factors from the IPCC 2006 and 2013 Wetland Supplement guidance are also used as appropriate (**Annex 5.1.4.11**).

6.9.4 Recalculations

The net LULUCF emissions from the OTs and CDs changed compared to the previous inventory are shown in Table 6.6.16, with a reduction of -0.005 in 1990 and 0.049 Mt CO₂e in 2023. The main recalculations arose from updated area data on new forest planting and peatland in the Isle of Man and the implementation of IPCC 2019 Refinement emission factors.

Table 6.6.16: Recalculations in the LULUCF sector since the previous submission for the OTs and CDs, Mt CO₂e

LULUCF Categories	GBR Old 1990 value	GBR Old 2023 value	GBR New 1990 value	GBR New 2023 value
Total LULUCF	0.041	0.018	0.046	0.068
A. Forest Land	-0.041	-0.086	-0.043	-0.048
B. Cropland	0.013	0.030	0.013	0.027
C. Grassland	-0.010	-0.027	0.000	-0.013
D. Wetlands	0.000	0.001	0.000	0.001
E. Settlements	0.079	0.101	0.076	0.100
G. Harvested Wood Products	-	-	-	-

6.9.5 Planned improvements

The UK Government is funding longer-term research into organic soils and emissions in the Falkland Islands. There a new peatland map of the Isle of Man uplands⁹⁸ that could potentially be included in the inventory. Peat extent and depths have been mapped by the Darwin Plus project DPLUS083, and there are ongoing projects to map undisturbed reference habitats, estimate above-ground biomass stocks and measure CO₂ and CH₄ fluxes. The Falkland Islands have different peat-forming species to the Northern Hemisphere, and UK Tier 2 emission factors are an imperfect analogue for Falkland conditions, hence the need for additional research.

6.10 GENERAL COMMENTS ON QA/QC

UKCEH has adopted the quality assurance principles set out in the Joint Code of Practice for Research issued by the Biotechnology and Biological Sciences Research Council, the Department for Environment, Food and Rural Affairs, the Food Standards Agency and the Natural Environment Research Council. UKCEH is accredited to ISO9001, the internationally recognised standard for the quality management of businesses.

Forest Research are dedicated to delivering world-class scientific research which fully meets our customers' requirements for quality, timeliness and cost. The quality of science is supported by a Quality Management System (QMS) which ensures that appropriately-trained and qualified personnel use correctly maintained and calibrated equipment and appropriate techniques to produce reliable outputs. Our system of records management enables us to fully demonstrate the quality of our science. Forest Research applies the standards required by the Defra Joint Code of Practice for Research as described above for UKCEH. The Expert Committee on Forest Science provides guidance for the Forestry Commission on the quality and direction of their research.

In 2015 a review of the QA framework and procedures for the full UK inventory was carried out (Hartley McMaster Ltd, 2015). In 2016 all the LULUCF models based in Excel spread

⁹⁸ <https://www.iucn-uk-peatlandprogramme.org/projects/manx-peatland-project>

spreadsheets were reviewed by Hartley McMaster using a bespoke quality auditing tool developed in Excel. The outputs from this auditing tool resulted in improvements to model documentation and the correction of a few minor errors.

In addition to internal quality assurance procedures the submitted inventory data is also checked by Ricardo (the national inventory compilers) and the European Environment Agency, as part of the European Union Monitoring Mechanism.

A programme of upgrade to the LULUCF models ran from 2016 to 2020. This included verification of model calculations, improvement of documentation, addition of built in QA checks and storage in a version control repository. A Microsoft Access database is used to compile all the LULUCF inventory numbers and associated data. This database is used to produce consistent outputs for the CRT and other national and international reporting requirements, and for archiving purposes. In collaboration with Ricardo, UKCEH has developed a QA/QC plan to standardise and structure the way checks are carried out within the LULUCF inventory. The plan is implemented and revised as required in each inventory cycle. The QA/QC Plan is embedded into all planning, preparation and management activities of the Inventory. The plan sets out five key Data Quality Objectives (DQOs), covering Transparency, Consistency, Completeness, Comparability and Accuracy, which ensure consistency to the IPCC core QA/QC criteria during inventory preparation and checking.

7 Waste (CRT Sector 5)

7.1 OVERVIEW OF SECTOR

CRT Categories Included	5A: Solid Waste Disposal on Land 5B: Biological Treatment of Solid Waste 5C: Waste Incineration 5D: Wastewater Handling
Gases Reported	CO ₂ , CH ₄ , N ₂ O, NO _x , CO, NMVOC, SO ₂
Key Categories ('T' or 'L' indicates whether it's been identified in the trend or level assessment respectively and the number indicates which KCA approach it was identified in)	5A: Solid waste disposal – CH ₄ (L1, T1, L2, T2) 5B: Biological treatment of waste – CH ₄ (T1, L2, T2) 5B: Biological treatment of waste – N ₂ O (L2, T2) 5C: Waste incineration – CO ₂ (L2, T2) 5D: Wastewater handling – CH ₄ (L1, L2) 5D: Wastewater handling – N ₂ O (L2, T2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions from all sectors are included within UK CRT tables.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7
Major improvements since last submission	Revised estimates for 5A (landfill), changing the approach to extrapolating quantities of waste landfilled back to 1945. Removal of a double-count of emissions from chemical waste incineration. Complete overhaul of estimates for 5D1 (municipal wastewater) to use 2019 Refinement methodologies and other more recent literature. Inclusion of emissions from effluent in 5D2 where previously this was not estimated.

Emissions from the waste sector contributed 5.7% to greenhouse gas emissions in 2024. Emissions consist of CO₂, N₂O and CH₄ from waste incineration, CH₄ from solid waste disposal on land, and both CH₄ and N₂O from wastewater handling and biological treatment of solid waste. Overall emissions from the waste sector have decreased by 61% since 1990. This is mostly due to the implementation of methane recovery systems at UK landfill sites and reductions in the amount of waste disposed of at landfill sites

Table 7.1 gives an overview of the waste sector. The uncertainty estimate has been taken from Monte Carlo analysis. Emission trends are presented for 1990-2024 and 2023-2024. A description of the trends and the main drivers behind these can be found in **Chapter 2**.

Table 7.1 Waste Sector Overview

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Uncertainty	Latest year total (Mt CO ₂ e)	BY-Latest year trend	Last 2 yr trend	Recalculation:- 2023	Recalculation:- BY	Gases included	Methodology reference (NID Section)
Total waste		21.65	-61%	-4%	13%	-22%		
A. Solid Disposable Waste	52%	12.01	-76%	-8%	-10%	-26%	CH ₄ , NMVOC	5.2
B. Biological Treatment of Solid Waste	50%	2.19	6775%	1%	1%	0%	CH ₄ , N ₂ O	5.3
C. Incineration and Open Burning of Waste	53%	0.13	-88%	0%	-59%	-28%	CO ₂ , CH ₄ , N ₂ O, NO _x , CO, NMVOC, SO ₂	5.4
D. Wastewater Treatment and Discharge	45%	7.32	52%	1%	140%	77%	CO ₂ , CH ₄ , N ₂ O	5.5

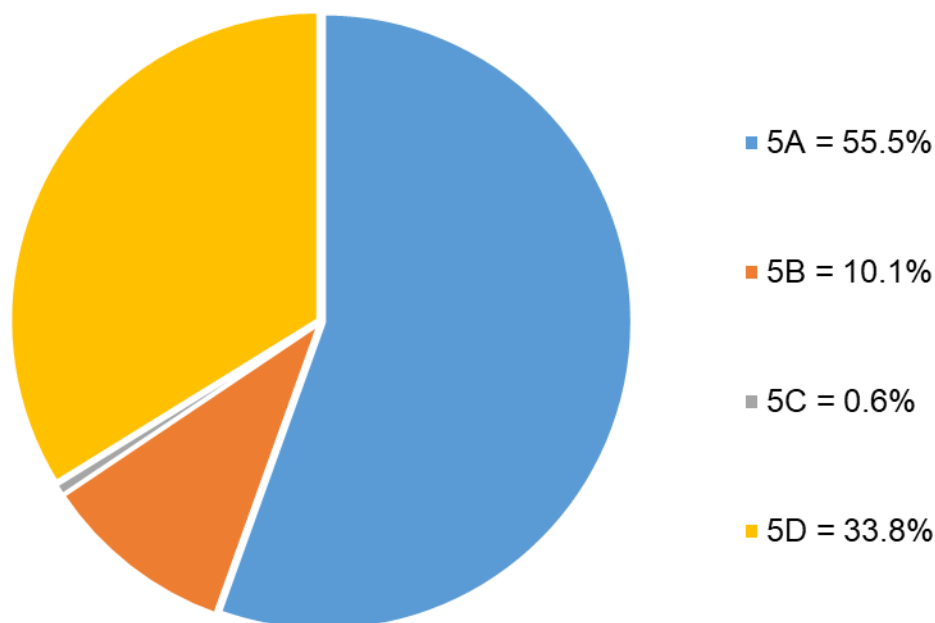
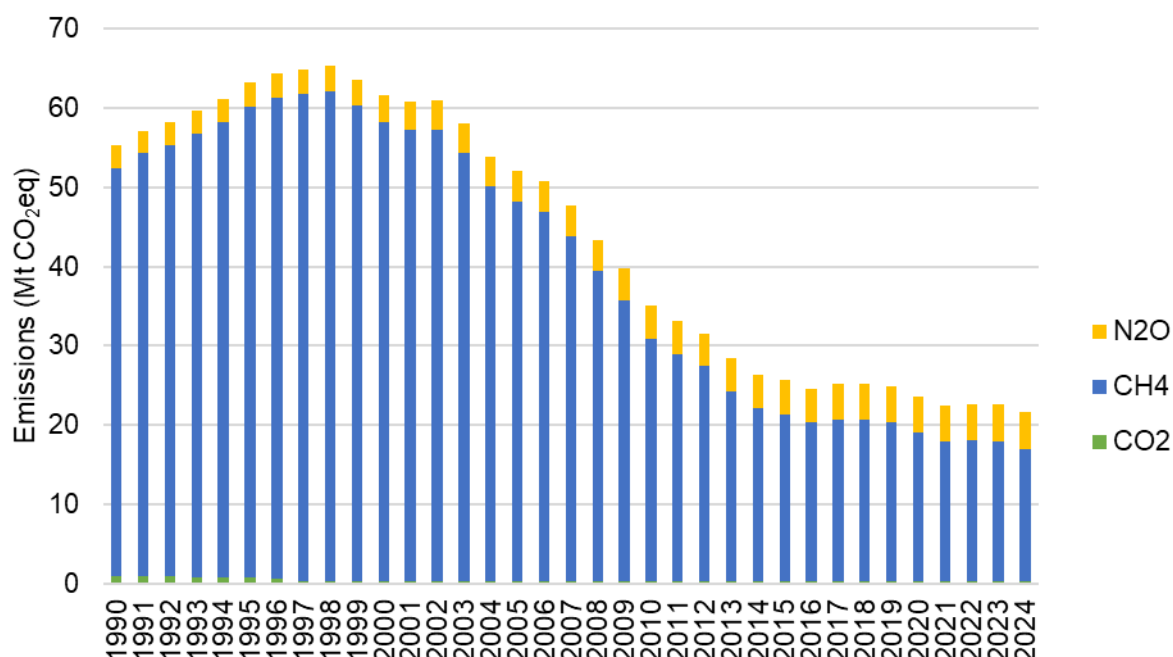
Figure 7.1 Breakdown of total GHG emissions from the Waste sector in 2024⁹⁹

⁹⁹ The categories in the Waste sector are explained in the CRT categories section

Figure 7.2 Trend in total GHG emissions in the Waste sector

7.1.1 Overview of UK waste management systems

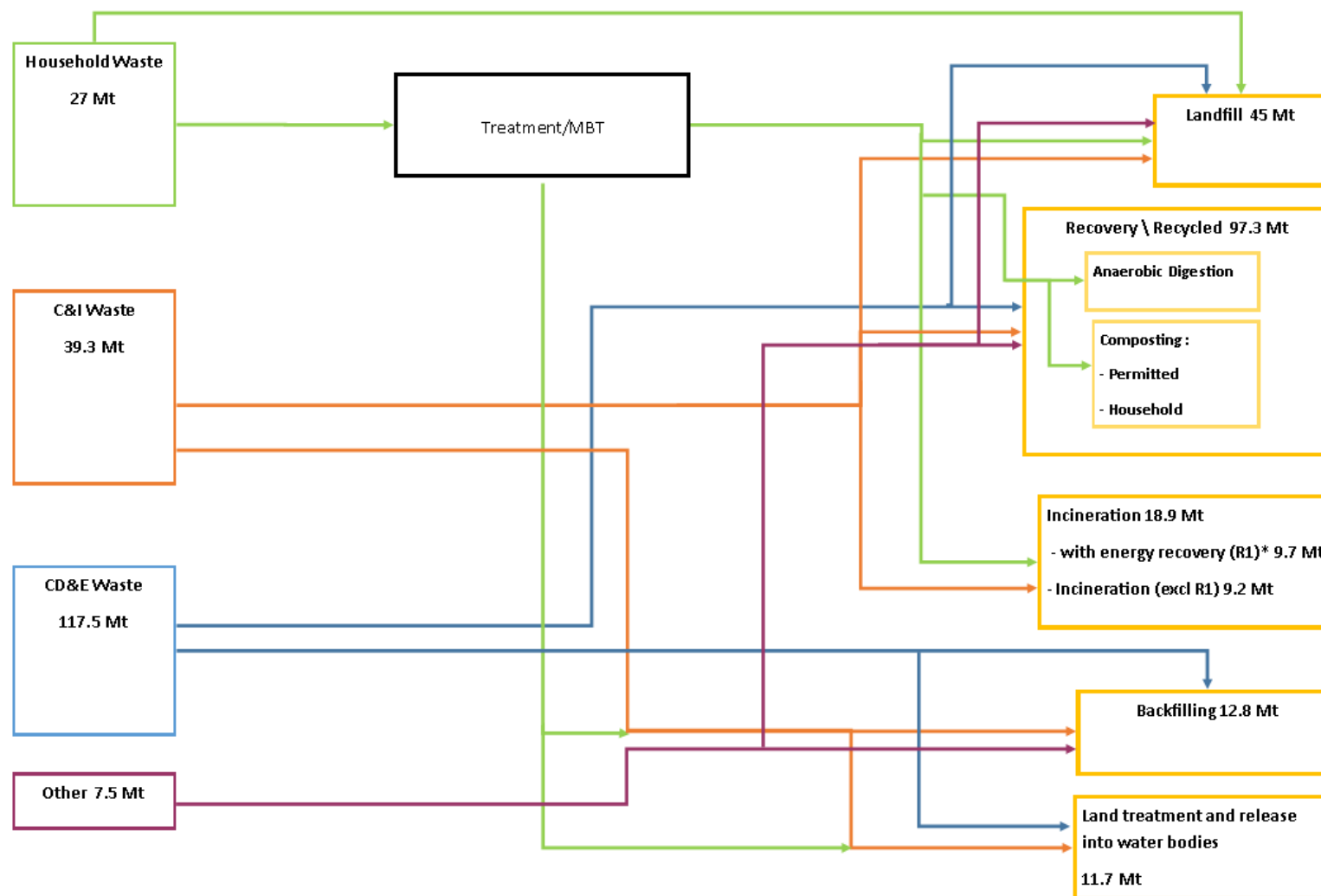
The waste datasets published by the Environmental Regulators of the Devolved Governments are the main source of activity data for solid waste for emissions estimates. However, the information collected and reported by each DG is often difficult to compare, which makes it challenging to use these datasets to map waste flows at the UK level within the NAEI. In contrast, the UK Waste Statistics (Defra, 2025e) published by Defra provide the most reliable dataset for mapping UK-wide waste flows. These statistics are designed to be as complete and internally consistent as possible, as they adjust reported waste data to reconcile differences between total waste generated and total waste treated. They cover the UK as a whole and include data on waste generation and management that support policy monitoring and development.

Wastewater, sewage sludge and septic tank sludge are managed under separate regulatory regimes and are therefore excluded from the official UK Waste Statistics, which focus on solid waste management (landfill, incineration, recycling). The Urban Waste Water Treatment Regulations (England and Wales) implements the requirements for the collection, treatment, and discharge of urban wastewater. The current regulatory regime for sludge treatment, storage and use sludge is under review¹⁰⁰. Sludge and septic tank sludge are expected to be regulated under the Environmental Permitting (England and Wales) Regulations (EPR), which will replace the need for the Sludge (Use in Agriculture) Regulations (SuiAR).

To improve information on activity data flows and source-categories reporting, a comprehensive global waste balance reflecting the generation and treatment of all types of solid waste, across all locations, is presented in **Figure 7.3**. This schematic depicts all solid waste categories, their sources, treatment processes, and final destinations. The UK dataset for the last complete reporting year, 2020, was used to generate the diagram.

¹⁰⁰ [Environment Agency strategy for safe and sustainable sludge use - GOV.UK](https://www.gov.uk/government/consultations/environment-agency-strategy-for-safe-and-sustainable-sludge-use)

For the purposes of the calculated total waste figures, sewage sludge is included within the UK 2020 C&I estimates (39.3 million tonnes). For the total waste generated and treated figures, sludges are converted from wet to dry weight to ensure consistency across waste categories.

Figure 7.3 UK waste generation and final treatment (2020)

* where formal R1 accreditation has been awarded

7.1.2 Waste Related Activities Reported in Other Sectors

The waste sector as defined in the 2006 IPCC guidelines relates to emissions from processes associated with the treatment and disposal of waste. However, if waste or waste-derived products are utilised for another process, emissions associated with this are reported according to the process and therefore excluded from waste sector reporting.

This section discusses such sources, where those sources are reported in the inventory, and how they relate to waste-sector processes and reporting. **Figure 7.4** presents at a high level how waste management, waste disposal and waste utilisation interact in the waste, energy and agriculture sectors, and where these are reported in the inventory.

Figure 7.4 Flow diagram of waste treatment and disposal route

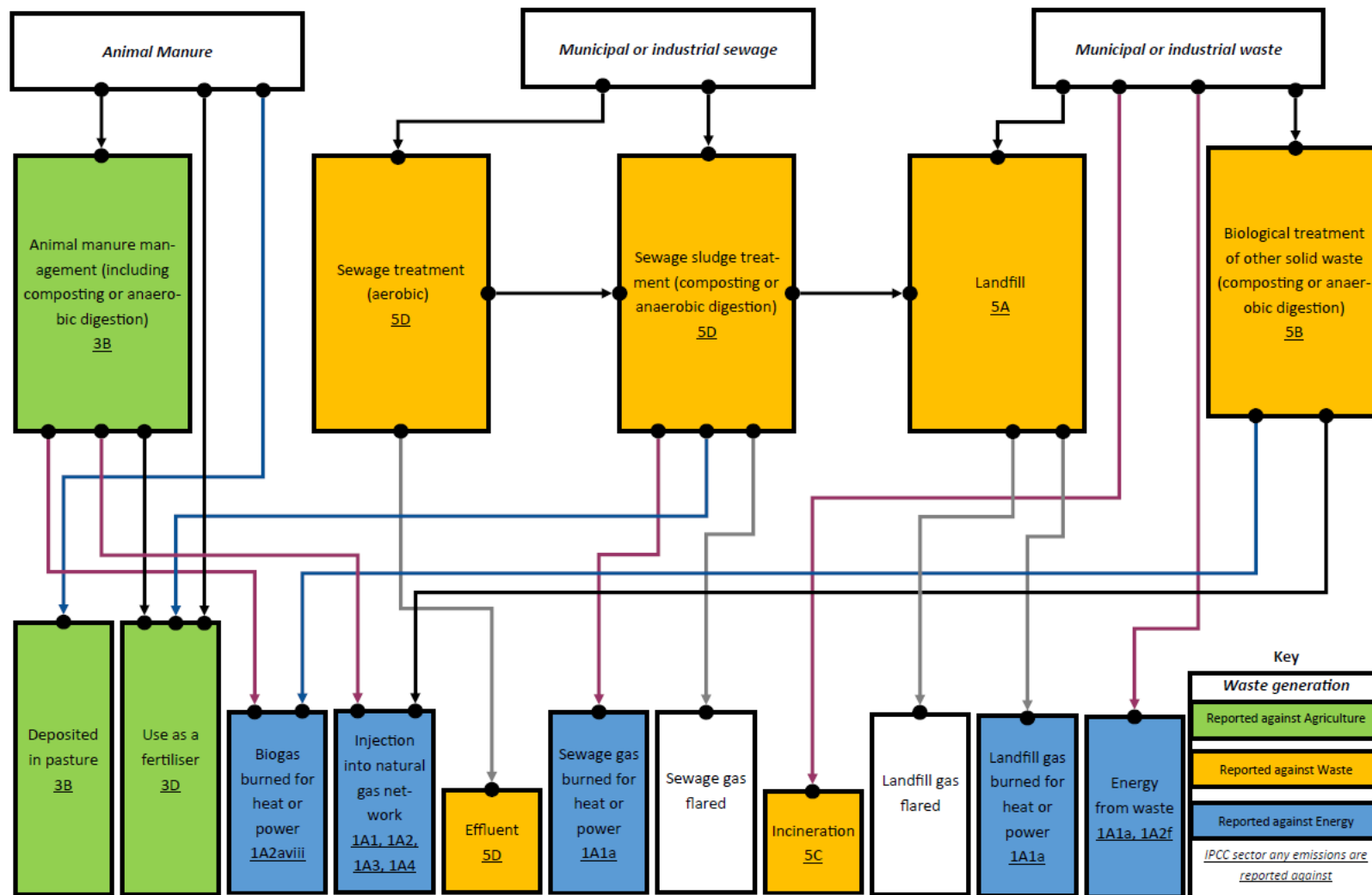


Figure 7.5 presents trends in solid waste disposal routes. It demonstrates a long-term trend of increasing redirecting of waste away from landfill and into either biological treatment of waste or energy from waste; this is further illustrated in the decline in digestible and combustible waste sent to landfill presented in **Figure 7.6**. What is not presented are trends in quantities of non-degradable waste recycling (such as plastics, glass, and metals) or exported from the UK, as within this context these do not directly generate emissions and therefore are not explicitly referred to in the inventory. It is expected that at least some of the decline in total waste presented will be due to increase in non-degradable recycling rates.

Figure 7.5 Trend in solid waste disposed by disposal route¹⁰¹

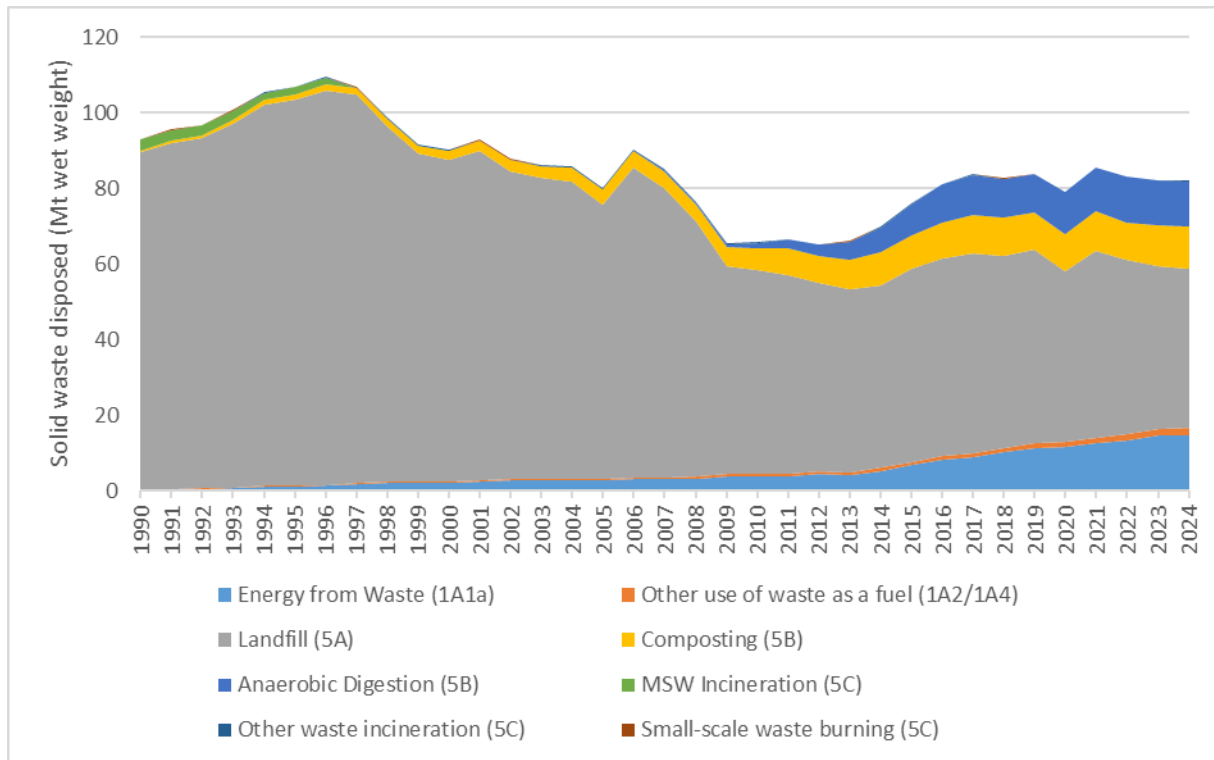
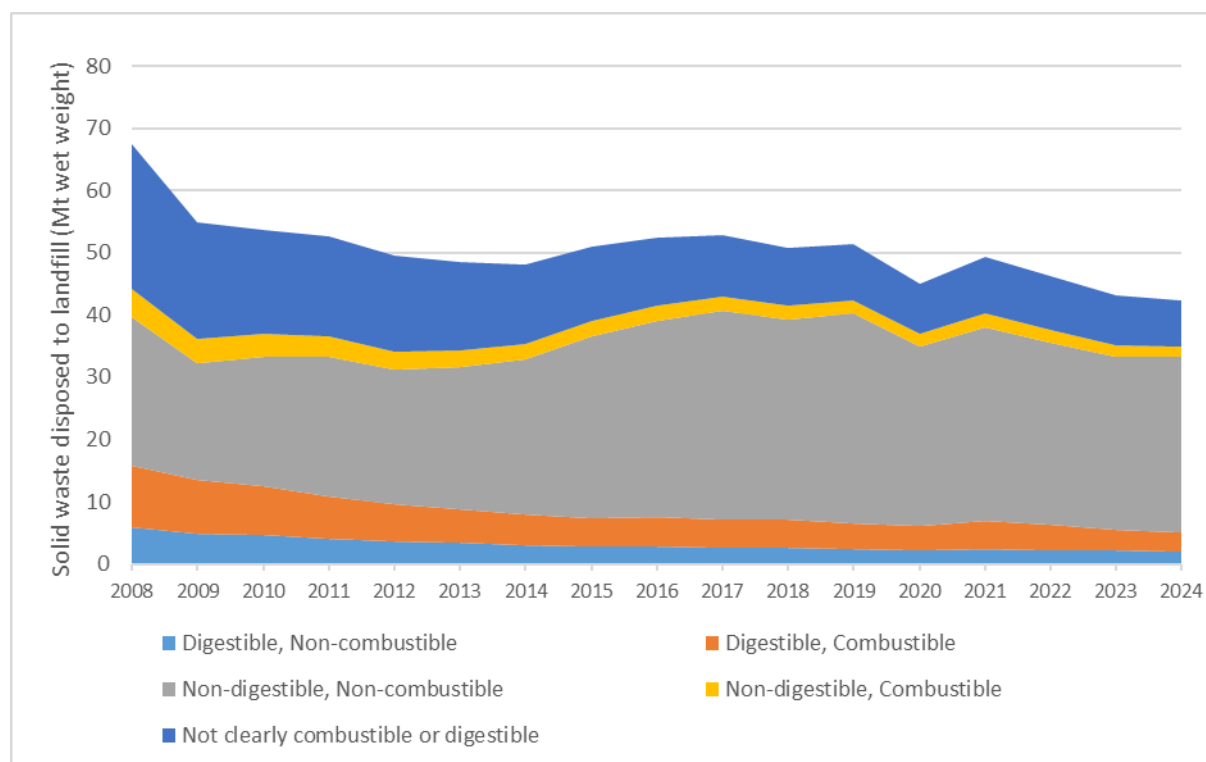


Figure 7.6 presents composition of solid waste disposed to landfill by general consideration of its combustibility and digestibility. Data are presented only for 2008 onwards as detailed breakdown of waste composition by European Waste Catalogue classification is available for these years only. Note that a large proportion of waste is classified as unspecified mixtures of waste, meaning that there is significant uncertainty as to the classification presented; the assumed composition of these categories is presented in **Table A 5.1.61**.

¹⁰¹ Recycling or waste exported are not included, as these do not result in direct emissions occurring in the UK, and therefore it has not been a priority for Inventory Agency to collect estimates of the quantities of waste disposed by these routes

Figure 7.6 Trend in landfill composition

7.1.2.1 Utilisation of Waste-Derived Biogas

A large proportion of methane generated in the anaerobic digestion of biodegradable material, occurring in sewage treatment plants, landfills and sites conducting biological treatment of solid wastes is captured and utilised as a fuel. Fuel use is typically on-site with the energy used for other activities on the site, or exported as electricity, but also increasingly, some methane is injected into the national natural gas distribution network for use as a fuel by any user of natural gas. Using methane as a fuel oxidises it, preventing it being released into the atmosphere as methane, instead releasing carbon dioxide and very small quantities of methane and nitrous oxide. The emissions as a result of combustion of biogases for energy is reported in sector 1A, including biogases that are injected into the national natural gas distribution network. The UK includes emissions from the utilisation of biogases for energy as follows:

- Sewage gas and landfill gas used to generate electricity or heat are reported in sector 1A1a, described in **MS 1**;
- Other biogases used for energy are reported in sector 1A2gviii, described in MS 3; and,
- Any biogases that are injected into the natural gas network are reported in energy statistics as a transfer from the renewables balance to the natural gas balance and are included in the inventory, mostly in various sub-sectors in 1A, described in various sub-sections in **Section 3** Data on the quantity of biogases transferred to natural gas are used to determine the proportion of CO₂ emissions from natural gas combustion which are of biogenic and fossil origin.

Note that for all sources of biogas, in the 2022 update of DUKES data reported for 2019 onwards has been reduced significantly compared to what DUKES reporting in 2021. In most cases this creates a divergence in the agreement between DUKES (and therefor the NAEI

energy sector estimates) and the NAEI waste sector estimates for recent years, and we are engaging with the UK energy stats team to understand how to interpret this.

Figure 7.7 presents an agreement within 9% for 2013-2018 between the municipal wastewater company reported estimates of sewage gas utilisation and UK energy statistics on sewage gas when noting that methane flaring is not a fuel use application, so is excluded from energy statistics. Data are only presented for 2013 onwards, as company reported data in this format is only available for these years; estimates of methane recovered for earlier years are extrapolated based on UK energy statistics. When capture is compared to emission rates, we see implied capture rates of 95-98% in these years, which is within the range suggested in the 2006 IPCC guidelines to expect.

Figure 7.7 Comparison of Estimates of Sewage Gas Utilisation

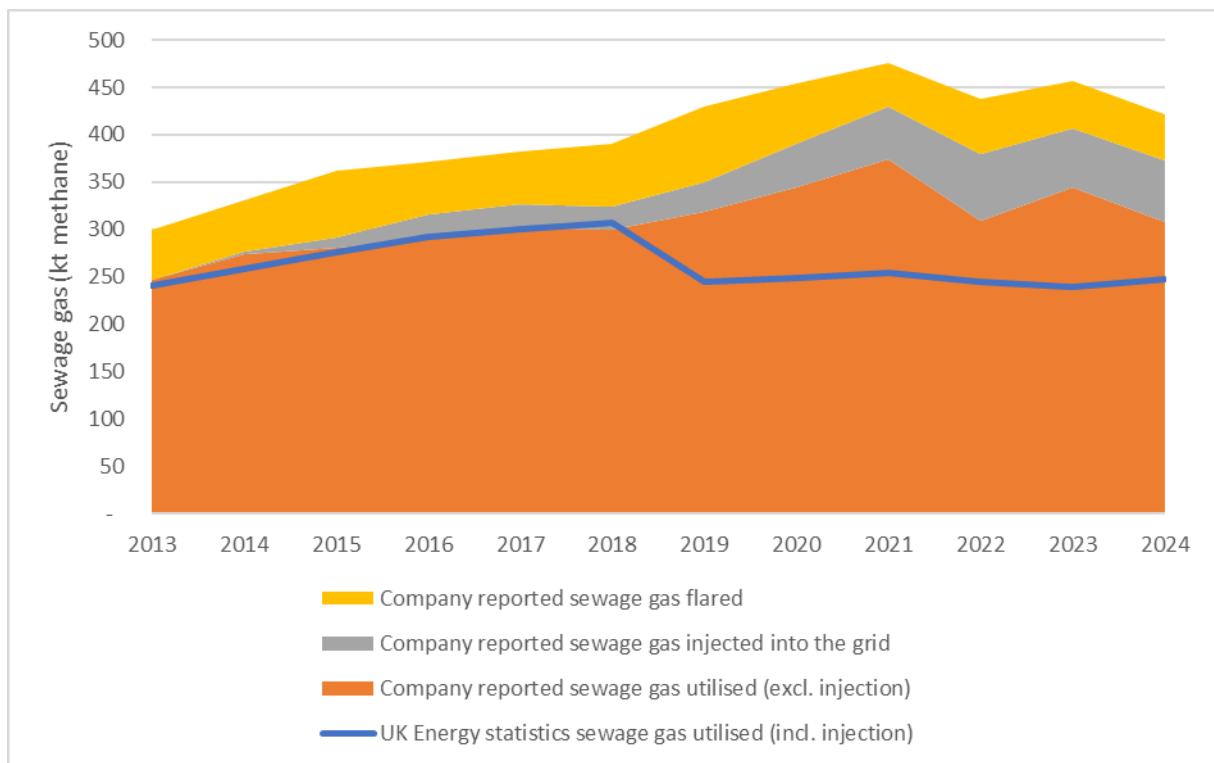


Figure 7.8 presents the strong agreement between the estimate of landfill gas captured for utilisation and UK energy statistics on landfill gas when noting that methane flaring is not a fuel use application, so is excluded from energy statistics. Both UK energy statistics and landfill gas capture estimates for landfill gas utilisation are based on data on electricity generated from engines consuming landfill gas, however, for landfill gas capture estimates, we estimate that these engines improve in efficiency in more recent years, reducing the landfill gas required to generate the electricity observed. The UK Inventory Agency and energy statistics team are aware of this difference and are considering whether these can be aligned.

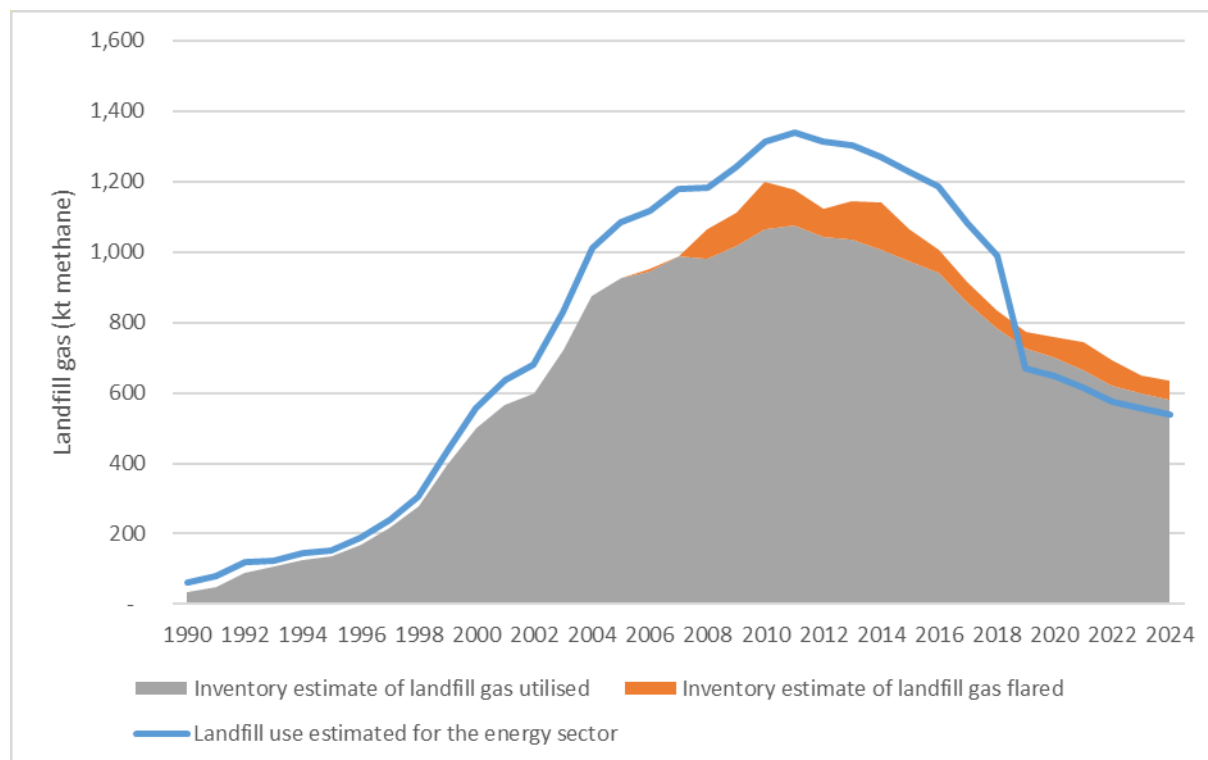
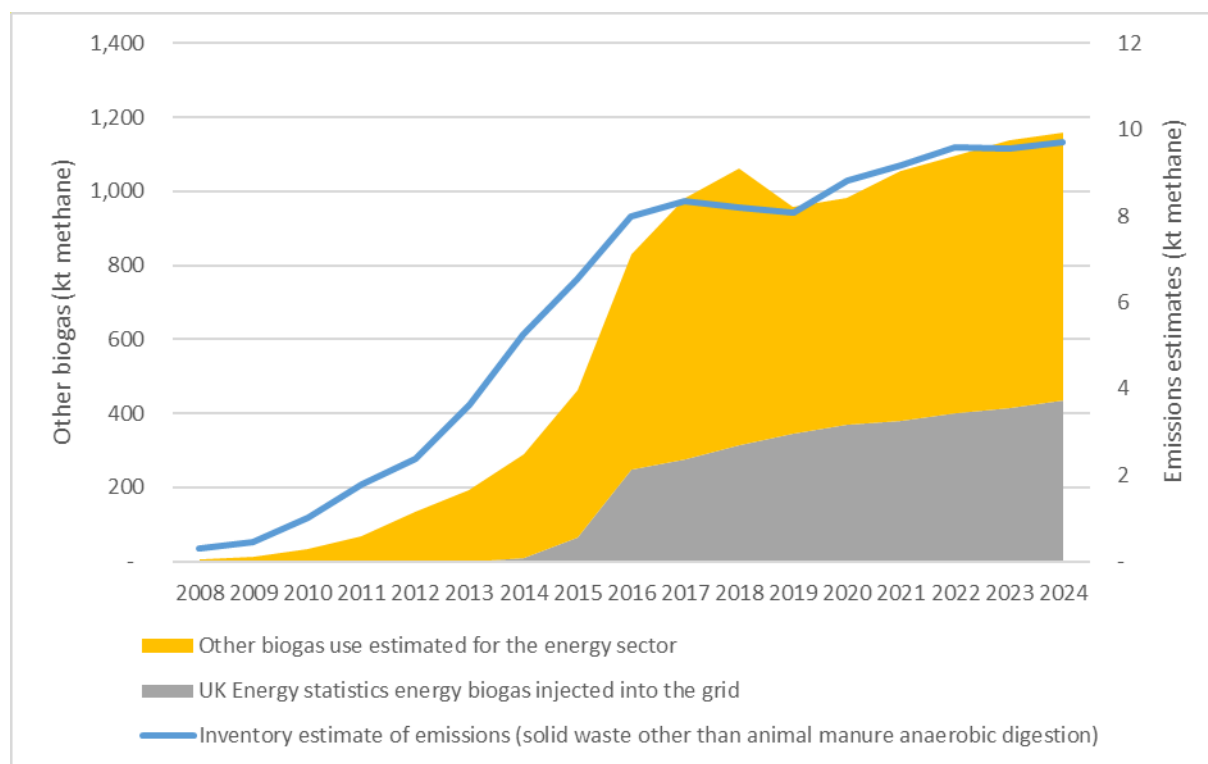
Figure 7.8 Comparison of Estimates of Landfill Gas Utilisation

Figure 7.9 presents the strong correlation between methane emissions from non-animal manure solid waste anaerobic digestion emissions estimates and UK energy statistics on other biogas use. Data are only presented for 2008 onwards, as all datasets present extremely low values in the early part of the time-series. It is not currently feasible to make more direct comparisons between the waste and energy sector due to the energy sector biogas including biogas derived from animal manures and the non-animal manures solid wastes estimates being a Tier 1 method.

If comparing non-animal manure solid waste anaerobic digestion emissions estimated to total biogas utilisation, the implied capture rate strictly increases from 95% in 2009 to over 99% since 2016. We suspect that the very high implied capture rate in recent years reflects an increasing contribution from manure anaerobic digestion biogas capture and utilisation, which will be included in the methane utilisation data, but not in the non-manure anaerobic digestion emissions data presented.

Figure 7.9 Comparison of Estimates of Other¹⁰² Biogas Utilisation

7.1.2.2 Energy from Waste

Information about the methods and data relating to waste incineration is reported under **Section 7.4** and emissions are reported under sector 5C. However, if useful energy is extracted from waste incineration, then for inventory reporting purposes, the activity is considered an energy sector process and emissions are reported under 1A. Due to a ban on the incineration of MSW without energy recovery in 1996, the quantity of emissions that are allocated to 5C fell significantly, as illustrated in **Figure 7.5**.

The UK includes emissions from the combustion of waste for energy as follows:

- Energy from Waste plants are reported in sector 1A1a, described in **MS 1**;
- A range of industries' use of waste are reported in sector 1A2, described in **MS 2** and,
- Commercial and public sector use of waste is reported in sector 1A4, described in **MS 5**.

7.1.2.3 Biological Treatment of Waste

The reporting of biological treatment (composting or anaerobic digestion) of waste depends on the nature of the waste treated. Specifically:

- For animal manure emissions are reported against 3B, described in **Section 5.3**;
- For sewage, industrial liquid wastes, or sludge derived from these wastes that are treated at a wastewater treatment plant emissions are reported against 5D, described in **Section 7.5**; and,
- For other solid wastes emissions are reported against 5B, described in **Section 7.3**.

¹⁰² i.e., not sewage gas or landfill gas

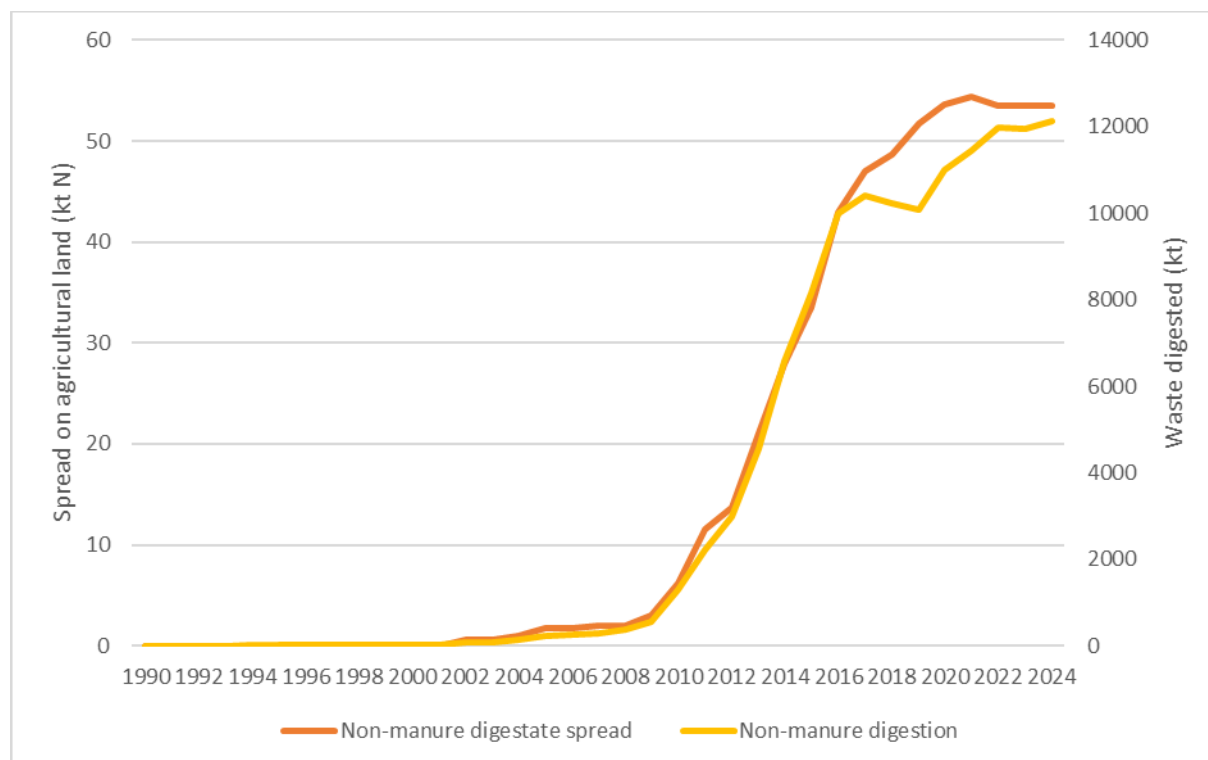
7.1.2.4 Utilisation of Digestates and Sewage Sludge

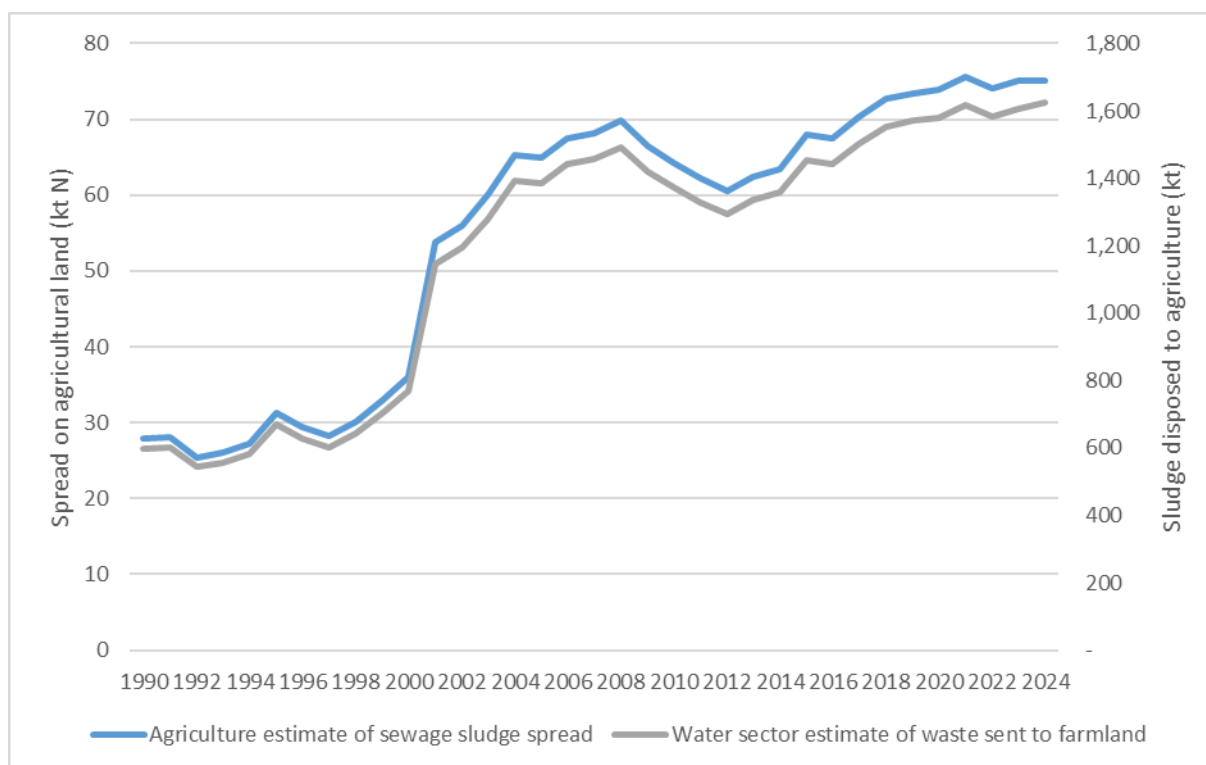
If digestates or sewage sludge are utilised as a fertiliser, then any emissions from the spreading of these products are reported as an agricultural soils emission, specifically:

- For digestates spread on agricultural land emissions are reported against 3D12c, described in **Section 5.5.2.3.2**; and,
- For sewage sludge spread on agricultural land emissions are reported against 3D12b, described in **Section 5.5.2.3.1**.

Figure 7.10 demonstrates the strong correlation between the Nitrogen content of wastes spread on agricultural land and waste digested or waste sector estimates of sewage sludge disposed to agricultural land. For agricultural waste spreading, a nitrogen balance approach is used to estimate N₂O emissions, and hence activity data for those sources are in terms of Nitrogen content instead of total mass.

Figure 7.10 Comparison of Estimates of Agriculture and Waste Sector Estimates for Digestates and Sewage Sludge





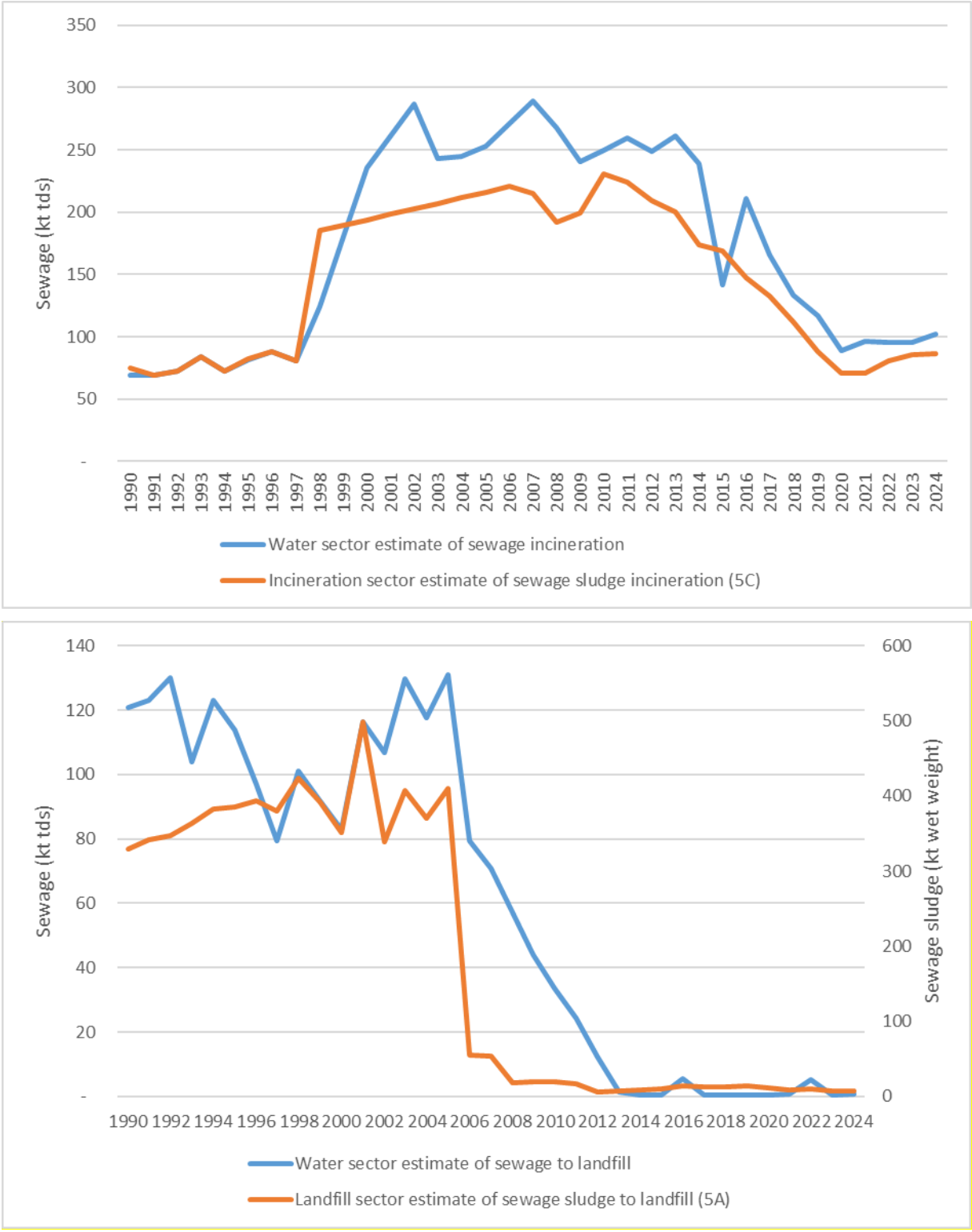
7.1.2.5 Disposal Routes of Sewage Sludge (Other than Utilisation)

The reporting of disposal emissions of biologically treated waste depends on the nature of the disposal route. Specifically:

- For sewage sludge disposed to landfill emissions are reported against 5A, described in **Section 7.2**; and,
- For sewage sludge incinerated without energy recovery emissions are reported against 5C, described in **Section 7.4**.

Figure 7.11 demonstrates the strong agreement between water sector estimates of sewage sludge disposal to landfill or incineration and the estimates of sewage sludge received at landfills and incineration plants. Note that data for sewage sludge received at landfills are the total weight of matter received, which means it includes a large proportion of water which would not be included in the wastewater data presented in kt tds.

Figure 7.11 Comparison of Estimates of Landfill/Incineration sector and Water Sector Estimates for Sewage Sludge disposal



7.2 SOURCE CATEGORY 5A – SOLID WASTE DISPOSAL ON LAND

7.2.1 Source category description

Emissions sources	Sources included	Method	Emission Factors
	5A: Landfill	T2/T3	CS
Gases Reported	CH ₄ , NMVOC		
Key Categories	5A: Solid waste disposal - CH ₄ (L1, T1, L2, T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	OT & CD emissions for 5A are included as a separate category within 5A.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	Major review of estimates of waste sent to landfill for 1945-1996. Some modest recalculations to activity data for 2006-10, 2020, 2022 and 2023.		

The NAEI category “Landfill” maps directly on to CRT category 5A (Solid Waste Disposal) for methane emissions. Emissions are reported from Solid Waste Disposal Sites (SWDS – also known as landfills) that started receiving waste in 1980, when legislative changes took effect to improve management of landfill sites, and old unmanaged waste disposal sites that closed prior to 1980. Emissions from the use of landfill gas to generate power are reported in CRT sector 1A1a and 1A2gviii (see **MS 1** and **MS 3**).

Estimated emissions from this sector in 2024 was 12.0 Mt CO₂e. Emissions have been on a downward trend in almost every year since 1999.

In addition to CH₄, anaerobic decomposition also produces an approximately equivalent amount of CO₂, and CO₂ is produced by other processes. However, as the decaying organic matter originates from biomass sources derived from contemporary crops and forests, we do not need to consider the greenhouse impacts of this carbon dioxide. For this reason, emissions of CO₂ from landfills are not estimated as they are considered to be entirely biogenic in origin and therefore not counted towards the national total as this would introduce a double count with net carbon losses reported in the LULUCF sector (this is also discussed in **Section 1.7.4.3**). Landfilled Solid Waste also contains fossil-derived organic matter, predominantly in the form of plastics, but it is assumed that these are essentially non-biodegradable under landfill conditions, and so emissions of fossil-derived CO₂ from SWDS are not considered further.

Non-methane volatile organic compounds (NMVOCs) are also released by SWDS. These are estimated using an emission factor relating the NMVOC to the amount of CH₄ emitted. The IPCC Guidelines do not provide emission factors for NMVOCs, therefore emission factors from the EMEP/EEA Air Pollutant Emission Inventory Guidebook are used. An emission factor of 0.0036 kg NMVOC/tonne landfill gas was used. This value quoted in the Guidebook is a UK a country -specific factor taken from the UK Informative Inventory Report (IIR) and is based on Broomfield & al. (2010).

The IPPC 2006 Guidelines confirm that nitrous oxide emissions from SWDS are not significant.

The amount of methane emitted from landfills depends primarily on the amount of carbon in biodegradable waste landfilled and how the sites are operated to reduce the escape of the methane produced from such wastes. Policy measures to reduce methane emissions from landfills have focused on both these aspects. Diverting biodegradable waste away from landfill avoids the future formation of methane, but landfills continue to produce CH₄ for many years from biodegradable waste that has already been deposited. Improving the efficiency of gas capture from landfills results in an immediate reduction in emissions, but is by nature an “end of pipe” solution, which does not itself prevent the formation of methane. In practice, a combination of measures based on both reducing the amount of biodegradable waste landfilled and improving the management of sites have, in the UK, provided the foundations for reducing emissions from this source. These two broad approaches are outlined below.

The most important legislative and regulatory measures which have reduced the emissions of methane from UK landfills derive from the 1999 Landfill Directive (1999/31/EC). The requirements of the Directive were transposed into national legislation through the Landfill (England and Wales) Regulations 2002, subsequently amended in 2004 and 2005 to transpose the requirements of Council Decision 2003/33/EC on Waste Acceptance Criteria. The provisions were re-transposed most recently as part of the Environmental Permitting (England and Wales) Regulations 2016, and their ongoing applicability confirmed through the Environmental Permitting (England and Wales) (Amendment) (EU Exit) Regulations 2018. In Scotland, the Landfill Directive is implemented through the Landfill (Scotland) Regulations 2003, as amended, and in Northern Ireland, through the Landfill Regulations (Northern Ireland) 2003. The provisions of the Landfill Directive require reduction of the amount of biodegradable waste landfilled to specific targets and improved landfill design, operation and management in order to reduce release of methane.

The EU Waste Framework Directive 2008/98/EC and Landfill Directive 1999/31/EC provides the legislative framework for collection, transport, recovery and disposal of waste. The Waste Framework Directive mandates management of waste according to the waste hierarchy – with the first and preferred method being prevention, followed by reuse, recycling, recovery, and lastly disposal. Defra’s Resources and Waste Strategy published in December 2018 set out how the Government intends to minimise waste, promote resource efficiency and move towards a circular economy in England. Similar approaches are being adopted in the Devolved Governments.

7.2.2 Methodological issues

The UK approach to calculating emissions of methane from landfills uses a “Tier 2/Tier3” methodology based on national data on waste quantities, composition, properties and disposal practices over several decades and on some country-specific key parameters. The equations for calculating methane generation use a first-order decay (FOD) methodology (IPCC, 2006). The IPCC FOD methodology is based on the premise that Decomposable Degradable Organic Carbon compounds (DDOC; those that can be converted to methane and carbon dioxide)¹⁰³ decay under the anaerobic conditions in landfills to form methane, carbon dioxide and a variety of stable decomposition products that remain in the landfill, and represent long-term storage of carbon. First order means that the rate of reaction is proportional to the amount of reactant

¹⁰³ DDOC is the amount of degradable organic carbon (DOC) that is converted (i.e. dissimilated) to methane and carbon dioxide under landfill conditions. $DDOC = DOC \times DOC_F$ where DOC_F is the fraction of DOC that dissimilates.

(i.e. DDOC) present at any given time. This means that as the reactant is used up, the rate of reaction slows down.

A spreadsheet model system, Methane Emissions from Landfill Model (MELMod) was used to carry out these calculations from 2008 (Brown et al., 2008). In the UK model, the various waste types are allocated to three pools (p) of DDOC that decompose according to their characteristic first order rate constant, k_p . This parameter defines the proportion of material decomposing per year in each year following disposal. The three pools are described as Rapidly, Moderately, and Slowly Decomposing Organics (RDO, MDO and SDO, respectively). Allocation of DDOC in waste materials to these pools was described in a report produced by Eunomia Consulting and Research (2011) and updated for the 2013 and 2014 inventories. Fats, sugars and proteins are assigned to the rapidly degrading pool (RDO), lignin to the slowly degrading pool (SDO) and cellulose, hemicelluloses and remaining compounds are allocated to the moderately degrading pool (MDO).

Methane generation is calculated using the methodology set out in the IPCC 2006 Equations 3.1 to 3.6. The equations set out below are copied directly from the IPCC 2006 Guideline.

Equation 3.1 represents the overall approach of calculating methane formation for each year, subtracting the quantity of methane collected (R_T), and allowing for the quantity of methane oxidised in the SWDS cover layer (OX_T). This equation is used explicitly in the UK inventory as set out in IPCC (2006).

EQUATION 3.1
CH₄ EMISSION FROM SWDS

$$CH_4 \text{ Emissions} = \left[\sum_x CH_4 \text{ generated}_{x,T} - R_T \right] \cdot (1 - OX_T)$$

The extent of oxidation in the upper aerobic layers of SWDS varies based on the thickness, properties, and moisture content of the cover. As outlined in the 2006 IPCC Guidelines (vol 5, chap 3), the default value for oxidation is zero, however an oxidation factor of 0.1 is justified for covered, well-managed landfills to reflect both diffusion through the cap and escape via cracks and fissures.

In previous submissions, the UK methane emission model employed the IPCC default oxidation factor of 0.1 for methane generated from waste, disposed in both unmanaged landfills and managed landfills. The assumption that all landfills being covered by soil coverings was based on the Brown et al (2008) report. This approach may not provide accurate estimates of methane emissions from landfill in the inventory, as there is insufficient evidence that all sites had effective soil cover systems. Therefore, landfills with insufficient covering should be assigned a methane oxidation factor of 0, whereas a factor of 0.1 should only be applied to well managed sites with effective cell coverings.

Due to limited information on the types of cover materials used in UK landfills, a revised approach to methane oxidation factors has been agreed for the 2026 submission, as follows:

- An oxidation factor of 0 has been applied to landfills operating before 1980, reflecting the likely absence of engineered cover systems.
- An oxidation factor of 0.1 has been maintained for landfills operating from 1980 onwards, consistent with improved landfill design and partial methane oxidation.

- An oxidation factor of 0.1 has been maintained for 1980 onwards for landfills that closed before 1980 on the expectation that such sites would be remediated with a cover layer.

This approach aligns with the methodology used in MELMod, which categorises landfills into two types:

- Old closed sites: Landfills and dumpsites that ceased receiving waste before 1980.
- Modern sites: Engineered landfills with comprehensive gas collection systems, operational from 1980 onwards.

The year 1980 was selected as a threshold to mark a shift in landfill design practices in the UK from the dilute and disperse method to more regulated and engineered systems. This transition was driven by the Control of Pollution Act 1974, which introduced regulatory oversight of landfill operations by local authorities.

Equation 3.2 enables the mass of DDOC deposited to be calculated from the mass of waste deposited, the fraction of Degradable Organic Carbon (DOC) in the waste, and the methane correction factor. This equation is applied to individual waste streams in the UK inventory based on their lignin and non-lignin carbon contents (rather than using an overall figure for the fraction of DOC in the waste) (Eunomia Consulting and Research, 2011). Separate Methane Correction Factors are applied to waste deposited in unmanaged sites prior to 1980, and waste deposited in managed sites from 1980 onwards (see below). These are taken from the IPCC 2006 Guidelines.

$$\text{EQUATION 3.2}$$

$$\text{DECOMPOSABLE DOC FROM WASTE DISPOSAL DATA}$$

$$DDOC_m = W \cdot DOC \cdot DOC_f \cdot MCF$$

The following values are used for DOC (derived from Eunomia Consulting and Research, 2011) (there is some overlap between categories because of historical definitions used to characterise residual waste landfilled):

Table 7.2 DOC values used to calculate landfill methane emissions (%dry matter)

	Lignin	Hemicellulose	Cellulose	Starch	Sugar	Fat	Proteins	Fibre	Readily soluble	Inert
Paper	8%	3%	21%	0%	0%	0%	0%	0%	0%	0%
Card	8%	3%	20%	0%	0%	0%	0%	0%	0%	0%
Nappies	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%
Textiles and footwear	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous combustible	0%	9%	8%	0%	0%	0%	0%	0%	0%	0%
Wood	14%	4%	14%	0%	0%	0%	0%	0%	0%	0%
Food	1%	1%	3%	2%	1%	3%	2%	2%	0%	0%
Garden	6%	3%	4%	0%	0%	1%	0%	0%	5%	0%
Soil and other organic	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Furniture	1%	4%	4%	0%	0%	0%	0%	0%	0%	0%

	Lignin	Hemicellulose	Cellulose	Starch	Sugar	Fat	Proteins	Fibre	Readily soluble	Inert
Mattresses	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%
Non-inert Fines	0%	7%	6%	0%	0%	0%	0%	0%	0%	0%
Inert	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Commercial ¹	0%	2%	19%	0%	0%	0%	0%	0%	0%	0%
Paper and Card	8%	3%	21%	0%	0%	0%	0%	0%	0%	0%
General industrial waste ¹	0%	2%	19%	0%	0%	0%	0%	0%	0%	0%
Food and Abattoir	1%	1%	1%	5%	1%	1%	2%	0%	0%	0%
Food effluent	0%	9%	1%	0%	0%	0%	0%	0%	0%	0%
Construction and Demolition	0%	3%	2%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous processes ¹	0%	4%	3%	0%	0%	0%	0%	0%	0%	0%
Other waste ¹	0%	9%	8%	0%	0%	0%	0%	0%	0%	0%
Sewage sludge	0%	2%	2%	0%	0%	0%	0%	0%	0%	0%
Textiles / Carpet and Underlay	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%
Sanitary	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%
Other ¹	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Note 1: This category no longer used in waste descriptions

These values are calculated by multiplying the dry matter content of each waste component by the organic component content and the carbon content of each organic component (**Table A 5.1.62** and below)

The following carbon content values are used to calculate the DOC data in **Table 7.2**.

- Lignin 65.1% dry matter
- Hemicellulose 44.6% dry matter
- Cellulose 40.0% dry matter
- Starch 44.4% dry matter
- Sugar 42.1% dry matter
- Fat 76.0% dry matter
- Proteins 40.0% dry matter
- Fibre 45.0% dry matter
- Readily soluble 45.0% dry matter
- Inert 0% dry matter

The following values are used for moisture content and DOC_f (Eunomia Consulting and Research, 2011):

Table 7.3 Moisture content and DOC_f values used to calculate landfill methane emissions

Component	Moisture content (% fresh matter)	Lignin bio-degradability DOC _f	Non-lignin bio-degradability DOC _f
Paper	15%	5.0%	65.0%
Card	20%	5.0%	65.0%
Nappies	65%	5.0%	65.0%

Component	Moisture content (% fresh matter)	Lignin bio-degradability DOC _f	Non-lignin bio-degradability DOC _f
Textiles and footwear	20%	5.0%	65.0%
Miscellaneous combustible	20%	5.0%	65.0%
Wood	17%	5.0%	65.0%
Food	70%	15.0%	70.0%
Garden	55%	10.0%	65.0%
Soil and other organic	30%	5.0%	65.0%
Furniture	12%	5.0%	65.0%
Mattresses	20%	5.0%	65.0%
Non-inert Fines	40%	0.0%	50.0%
Inert materials	0%	0.0%	0.0%
Commercial ¹	37%	5.0%	65.0%
Paper and Card	15%	5.0%	65.0%
General industrial waste ¹	37%	5.0%	65.0%
Food and Abattoir	70%	15.0%	70.0%
Food effluent	65%	15.0%	70.0%
Construction and demolition	30%	5.0%	65.0%
Miscellaneous processes ¹	20%	5.0%	65.0%
Other waste	20%	5.0%	65.0%
Sewage sludge	70%	5.0%	65.0%
Textiles / Carpet and Underlay	20%	5.0%	65.0%
Sanitary	65%	5.0%	65.0%
Other ¹		5.0%	65.0%

Note 1: This category no longer used in waste descriptions

There are no equivalent values to those set out in **Table 7.2** and **Table 7.3** in the IPCC 2006 Guidelines. However, the IPCC Tier 1 model contains default DOC values for some waste types. These are generally higher than the values used in the UK model, as shown in **Table 7.4**. However, the sensitivity test set out in **Section 7.2.5** indicates that the UK values are more representative of wastes landfilled in the UK

Table 7.4 DOC values used in UK model and IPCC default values

Component	Value used in UK model	Value in IPCC Tier 1 default model	UK value as % of IPCC Tier 1 value
Food waste	0.14	0.15	93%
Garden	0.18	0.20	90%
Paper	0.32	0.40	80%
Wood and straw	0.32	0.43	74%
Textiles	0.1	0.24	42%
Disposable nappies	0.07	0.24	29%
Sewage sludge	0.04	0.05	80%

The values used for the MCF are in accordance with the IPCC 2006 default values for managed and unmanaged sites (see below).

Equation 3.3 is a calculation of methane generation potential from the mass of DDOC deposited, and the fraction of methane in landfill gas. This equation is used in the UK inventory as set out in IPCC (2006). Following a review of data on the composition of landfill gas, the fraction of methane in landfill gas as formed in UK landfill sites is assumed to be 50%, the default value given in the 2006 IPCC Guidelines.

$$\begin{aligned} &\text{EQUATION 3.3} \\ &\text{TRANSFORMATION FROM DDOC}_{\text{m}} \text{ TO } L_0 \\ &L_0 = \text{DDOC}_{\text{m}} \cdot F \cdot 16/12 \end{aligned}$$

Equation 3.4 describes the accumulation of DDOC in the landfill site, accounting for new material deposited, and material which decomposes in each year. This equation is used in the UK inventory as described in IPCC (2006) Section 3A1.4, by carrying out a calculation of the mass of rapidly, medium and slowly-decaying carbon present in the landfill in each year, calculated as:

- The mass of DDOC remaining from the preceding year
- Plus the mass of DDOC landfilled in that year
- Minus the mass of DDOC removed due to decomposition in that year

The calculation has been amended to account for the commencement of decomposition during the year of deposition, as described in IPCC (2006) Equation 3A1.12.

$$\begin{aligned} &\text{EQUATION 3.4} \\ &\text{DDOC}_{\text{m}} \text{ ACCUMULATED IN THE SWDS AT THE END OF YEAR } T \\ &\text{DDOC}_{\text{m}T} = \text{DDOC}_{\text{md}T} + \left(\text{DDOC}_{\text{m}T-1} \cdot e^{-k} \right) \end{aligned}$$

Equation 3.5 describes the rate at which DDOC is removed from landfill sites in each year by decomposition and formation of methane and carbon dioxide in landfill gas. The calculation has been amended to account for the commencement of decomposition during the year of deposition, as described in IPCC (2006) Equation 3A1.13.

$$\begin{aligned} &\text{EQUATION 3.5} \\ &\text{DDOC}_{\text{m}} \text{ DECOMPOSED AT THE END OF YEAR } T \\ &\text{DDOC}_{\text{m decomp}T} = \text{DDOC}_{\text{m}T-1} \cdot \left(1 - e^{-k} \right) \end{aligned}$$

The decomposition rate constants used for rapidly, medium and slowly decaying wastes are the relevant default values given in the IPCC 2006 Guidelines Volume 5 Chapter 3 Table 3.3 for a wet boreal climate. The average of two default values for slowly decaying waste was used. These are allocated to the organic components of waste as follows:

- Rapidly decaying waste: Starch, Sugar, Fat, Proteins, Fibre, Readily soluble
- Medium decaying waste: Hemicellulose, Cellulose
- Slowly decaying waste: Lignin

Equation 3.6 is a calculation of methane generated from the mass of DDOC which decomposes during any given year, and the fraction of methane in landfill gas. This equation is used in the UK inventory as set out in IPCC (2006). As described for Equation 3.3, the fraction of methane in landfill gas as formed in UK landfill sites is assumed to be 50%.

EQUATION 3.6
CH₄ GENERATED FROM DECAYED DDOC_m

$$CH_4\ generated_T = DDOC_m\ decomp_T \bullet F \bullet 16/12$$

The values used for DOC and DOC_f for different material types, and the composition of different material types, are set out in **Table A5.1.62**.

The total methane generated in each inventory year is determined by summing the quantity of methane emitted over all waste types, all three decomposition pools, all landfill types, and all years in which the waste is landfilled.

A Methane Correction Factor (MCF) is used as a multiplier on methane formation to reflect the fact that shallow or unmanaged disposal sites do not develop extensive anaerobic conditions typical of modern landfills and hence a proportion of waste decays aerobically and does not produce methane. For modern landfills, the MCF term is given the value of 1 (IPCC 2006 Table 3.1), but the Guidelines allow the use of a lower figure for unmanaged dumpsites. All solid waste disposal sites in the UK that have received biodegradable wastes since 1980 have been required to adhere to a number of regulations are classed as landfills and assigned a MCF value of 1. MCF has been assigned a value of 0.6 for old, closed landfills that operated up to 1980 (IPCC 2006 Table 3.1).

Separate calculations are carried out for England, Scotland, Wales and Northern Ireland. In 2010, the UK government commissioned further work to update the activity data and emission factors for landfill methane (Eunomia Consulting and Research, 2011), which was peer reviewed by independent experts from academia, industry, regulators and consultants in 2010. Further details on data sources and rationale are given in Eunomia's report. The UK uses data from each of the Devolved Governments (Scotland, Wales and Northern Ireland) and England, in order to better-reflect differences in waste management around the UK, as it is an area of devolved policy.

7.2.2.1 Overseas Territories and Crown Dependencies

The IPCC landfill model is used for all landfill estimates for UK Overseas Territories and Crown Dependencies. Where available, country-specific waste generation and composition data have been applied and appropriate defaults have been chosen e.g. taking into account climatic variation. There are no landfill emissions for Gibraltar as waste is exported. Parameters used in these calculations are shown in **Section 5.1.5.1.1.3**.

7.2.3 Activity data

According to the IPCC Guidelines, the FOD method requires data on solid waste disposal, both quantities and composition, covering a default period of 50 years. When historical statistical data is not available, the missing information can be estimated using surrogate indicators, such as extrapolations based on population, economic trends, or other relevant drivers.

Records of individual waste consignments treated and disposed, together with European Waste Category (EWC) codes are compiled by the regulatory authorities in the Devolved Governments:

- Data on waste consignments landfilled in England for the period 2006 to 2024 are published by the Environment Agency (Environment Agency, 2025a).

- Data on waste consignments landfilled in Scotland for the period 2005 to 2024 are published by the Scottish Environmental Protection Agency (SEPA, 2025a).
- Data on waste consignments landfilled in Wales for the period 2006 to 2024 are published by Natural Resources Wales (NRW, 2025).
- Data on waste consignments landfilled in Northern Ireland for the period 2008 to 2024 were provided by the Northern Ireland Environment Agency (NIEA, 2025a).

This information is considered to be of good quality. The composition of waste landfilled was evaluated by allocating EWC codes to the categories used in the UK model, as set out in **Section A 5.1.5.1.1**.

For years prior to 2005-2008, the quantities of waste landfilled, and its composition were taken from a report compiled and peer-reviewed on behalf of the UK Government (Eunomia, 2011). The quantities of waste landfilled are set out in **Annex 5.1.5.1.1**.

For 1960-1997 landfill waste estimates, GDP is used as the proxy to extrapolate waste disposal data backward from 1996.

For pre-1960 biodegradable landfill waste disposal activity is estimated as zero. This is based on the assumption that during this period, most households burned their own waste at home, resulting primarily in dust and ash, which are biologically inert and do not generate methane.

7.2.3.1 Methane recovery from modern landfills

Landfill operators are required under their permit conditions to control the release of landfill gas. For large landfills containing biodegradable wastes, this requires the use of impermeable liners and cover material, and gas extraction systems. These typically consist of a system of gas wells (perforated pipes sunk into the waste) connected to a network of gas collection pipes. Suction is applied to the gas wells, resulting in a slight negative pressure sufficient to draw out the landfill gas but not enough to draw excessive air into the waste. Air ingress is avoided, as it can result in aerobic decomposition of the waste, which produces considerable heat, and may lead to the waste catching fire, as well as shutting off methane formation. The landfill gas collected is normally used to generate electricity on a commercial basis. Where this is not practicable, gas collected can be burnt in flares. In either case, the net effect of the combustion process is to convert the methane to carbon dioxide. The carbon dioxide so produced is not taken into further consideration for inventory purposes as it is considered to be entirely biogenic in origin. Small quantities of other GHGs (methane and nitrous oxide) are emitted from landfill gas use for energy and are included in Sector 1A1a and 1A2gvi.iii.

The key factors in determining methane emissions are estimates of the quantity of methane generated, and information on the amount of methane collected, either for utilisation or flaring. Data on utilisation is available and of good quality (see **Section 7.2.3.2**), but recent analysis indicates that data on flaring prior to 2009 is either unavailable or only accessible at disproportionate cost. The current inventory uses operator-provided data on the quantities of gas collected and burnt in landfill gas flares (see **Section 7.2.3.3**). No gas collection is assumed to be carried out at old pre-1980 closed sites. At sites and inventory years for which robust data on landfill gas flaring are not available, it is conservatively assumed that no landfill gas was flared.

Current estimates for methane recovered are given in **Annex 5.1.5.1.2**.

A high standard of gas collection and combustion efficiency is achieved by compliance with the Landfill Directive requirements for gas collection, and by implementing national guidance on landfill gas collection. This is enforced via the landfill permitting and regulatory processes. Large-scale passive venting of landfill gas is no longer accepted under permitting conditions

and impermeable barriers are required as best practice to prevent the migration of landfill gas off-site.

7.2.3.2 Gas Utilisation

Power generation is currently the dominant use for landfill gas in the UK and good data are available on this from official sources. The quantity of methane combusted was calculated as follows:

$$\begin{aligned} \text{Mass of methane combusted (kT)} = & \text{Electricity generated (GWh)} \\ & \times 3600 \text{ (GJ per GWh)} \\ & / \text{Net calorific value of methane (50,000 GJ/kT)} \\ & / \text{Engine efficiency (\%)} \end{aligned}$$

The assumed efficiency of landfill gas engines in these calculations was calculated in accordance with research carried out for the UK Government (Golder Associates, 2014). Engine efficiency was assumed to be 30% up to 1996, and 36% from 2012 onwards. Between 1996 and 2012, engine efficiency was assumed to increase linearly from 30% to 36%

Current data on the amount of methane used for power generation in England, Scotland, Wales and Northern Ireland, calculated from the electricity generated from landfill gas as reported in the Digest of UK Energy Statistics (DESNZ, 2025), is given in **Annex 5.1.5.1.2**. Carbon dioxide emitted from the combustion of landfill gas is biogenic in origin and is therefore not reported.

7.2.3.3 Flaring

Since 2009, operators of landfills in England and Wales permitted under the Integrated Pollution Prevention and Control (IPPC) Directive and subsequently the Industrial Emissions Directive (IED), have been required to report the annual quantity of methane flared at the regulated sites under the terms of their operating permits. As it has been obtained under the terms of IPPC operating permits, this data has documentation and quality control built in via the permitting procedures and operator obligations at an individual site level. The use of this dataset is therefore a robust and appropriate basis on which to evaluate the quantities of methane flared by operators.

Similarly, landfill site operators in Scotland have been required to compile a similar annual report on the quantity of landfill gas flared since 2013. This dataset was used to evaluate the quantity of methane flared by operators at landfill sites in Scotland from 2013 onwards.

Further work was commissioned by DESNZ (then DECC) to identify all reasonably available data on the quantities of methane flared at landfill sites in England, Scotland and Wales for other years (DECC, 2015a). This project identified some additional site-specific data which was also taken into account in compiling the inventory. Additionally, landfill operators voluntarily provided further site-specific data on the quantities of methane flared at older sites without a reporting requirement set in permit conditions since 2010. The amount of flared methane from these sites may not be complete, as operators are not required to report flare data, leading to potential underreporting of flaring quantities.

The landfill methane flaring data provided represents information for approximately 380 individual permitted sites in 2024. Data checking/validation therefore relies on the regulatory authorities and processes, rather than comprising additional checks on individual operators. The information on landfill gas flaring is provided via under the Environmental Permitting (England/Wales) and Pollution Prevention and Control (Scotland/Northern Ireland) regulatory processes. This information is consequently subject to quality obligations under these regulations, as with any other information reported to the regulatory authorities by regulated

process operators under the terms of their operating permits. The data is then forwarded to the compilation agency by each regulatory authority.

At all other sites and inventory years, robust data on landfill gas flaring was not available, and it was conservatively assumed that no landfill gas was flared.

The estimates shown in **Annex 5.1.5.1.2** are based on the estimate of methane used for power generation added to the estimated quantity of methane flared. The minor proportion of landfill gas used for non-electricity generation purposes such as direct use and as a vehicle fuel is neglected in these calculations due to a lack of data and assumed to be emitted to the atmosphere as a conservative assumption.

7.2.4 Uncertainties and time-series consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type. There are many uncertainties in estimating methane emissions from landfill sites. The model is sensitive to the values assumed for the degradable organic carbon (DOC) present in different fractions of waste, and the amount of this that is dissimilable (i.e. is converted to methane and carbon dioxide), as well as to the quantity of methane combusted in engines and flares, and the oxidation factor. The uncertainty estimates in **Annex 2** are intended to reflect the current uncertainties in data and model parameters.

The estimates for all years have been calculated from the MELMod model and thus the methodology is consistent throughout the time series. Estimates of waste composition and quantities have been taken from different sources as described in **Section 7.2.3**. The approach to calculating DDOC, the main driver behind methane formation, was reviewed and updated in 2011, and was endorsed by peer reviewers.

Uncertainty in the quantity of methane collected is also an important contributory factor to uncertainty in the calculation of overall landfill methane emissions. Uncertainties in the key components of this calculation are as follows.

- Current and historical combustion of methane in landfill gas engines: Reliable data on methane collected for power generation are available, based on official statistics for energy generated from landfill gas engines (DESNZ, 2025). Gas engine efficiency is assumed to be 30% up to 1996, increasing linearly to 36% in 2012 and thereafter, following peer review (Golder Associates, 2014). This is considered to be a reasonably reliable calculation of the quantity of methane combusted in landfill gas engines; and,
- Combustion of methane in flares. These data are based on site-specific records where available and are considered to be accurate for the sites where data exist. However, records of the quantity of landfill gas are incomplete, particularly for the years prior to 2008. In cases where records of landfill gas flaring are not available, the quantity of methane flared was assumed to be zero. This means that the landfill methane inventory is subject to greater uncertainty for the years prior to 2008, although because of the conservative approach adopted in respect of landfill gas flaring, it is considered that the inventory represents an over-estimate of methane emissions from landfill sites in the UK, particularly for the years prior to 2008. The methane to carbon dioxide ratio of gas burnt in landfill gas engines is assumed to be 50:50, following the IPCC default approach.

Landfill permit conditions are designed to deliver a high standard of gas collection and combustion efficiency. Requirements to design and operate landfills in order to minimise gas escape have strengthened considerably since the 1990s. In this context, the calculated

collection efficiencies of 46% to 57% for the period 2009 to 2024¹⁰⁴ derived in this analysis appear reasonable. Lower collection efficiencies in the years between 1990 and 2008 are likely to be more conservative.

Oxidation of methane in the surface layers of landfills is a further source of uncertainty in overall emissions. In the absence of better data, the IPCC oxidation default factor of 10% is applied to the estimated quantity of gas released as a fugitive emission (IPCC, 2006). A pilot survey carried out on behalf of the UK Government and Environment Agency included measurements of surface methane oxidation (Innocenti et al. 2012). This study did not support a move away from the IPCC default position. A particular challenge in deciding oxidation rates for use in a national landfill model is the high level of variability in field measurements, reflecting a wide range of factors such as nature and porosity of the surface layers, moisture content and temperature, along with methane production rates in the underlying waste.

7.2.5 Source-specific QA/QC and verification

This chapter provides the information described in IPCC (2006) Section 3.8 “QA/QC, Reporting and Documentation.”

Methodological data are described in **Section 7.2.2** above, with quantitative data in **Annex 5.1.5.1**. Activity data are described in **Section 7.2.3** above, with quantitative data on annual waste amounts and the quantities of landfill gas collected in **Annex 5.1.5.1**. A breakdown of waste composition for each year is available but as noted in IPCC (2006) Section 3.8, it is not practical to provide all documentation in the National Inventory Report.

In relation to specific recommendations of IPCC (2006) Section 3.8:

- “Countries using other methods or models should provide similar data (description of the method, key assumptions and parameters)” – this is provided in **Section 7.2.2**.
- “If country-specific data are used for any part of the time series, it should be documented.” – country-specific data on DOC, DOCf and MCF are used, as documented in **Section 7.2.2** and **Annex 5.1.5.1.1**.
- “The distribution of waste to managed and unmanaged sites for the purpose of MCF estimation should also be documented with supporting information.” This is documented in **Section 7.2.2**.
- “If CH₄ recovery is reported, an inventory of known recovery facilities is desirable. Flaring and energy recovery should be documented separately from each other.” Data on methane recovery for electricity generation is based on official statistics on electricity generation from landfill methane combustion, rather than reports of recovery at individual facilities. Data on methane recovery and flaring in 2019 is based on records from a total of 186 individual facilities in England, 40 in Scotland, 17 in Wales, and 3 in Northern Ireland: however, it is not practical to provide documentation for all these facilities in the National Inventory Report. Methane recovery for flaring and energy recovery are separately documented in **Section 7.2.3** and **Annex 5.1.5.1.2**.
- “Changes in parameters from year to year should be clearly explained and referenced.” Changes in parameters are documented each year in **Section 7.2.6**.

¹⁰⁴ See **Annex 5.1.5.1.2**

MELMod has been subject to peer review in 2011 and 2014 (see Eunomia Consulting and Research, 2011; Golder Associates 2014). The landfill methane model is subject to normal quality assurance procedures, as described in **Annex 4**.

IPCC (2006) guidelines, section 3.8 suggests that calculated emissions can be compared with those of similar countries. Relatively few countries have a similar history of landfill use to the UK, but in 2017 emissions for the period 1990-2015 were compared to data taken from NIRs recently produced by Ireland and Italy where landfill use has been extensive in the past, and continues to be a significant component of waste disposal to the present, as shown in **Table 7.5**.

Table 7.5 UK calculated emissions compared to Ireland and Italy

Year	Waste landfilled (Mt): UK	Waste landfilled (Mt): EI (approx.)	Waste landfilled (Mt): IT	Methane generated (kt): UK	Methane generated (kt) EI	Methane generated (kt) IT	Methane collected (%) UK	Methane collected (%) EI	Methane collected (%) IT
1990	93.3	1.9	25.2	2709	53	726	1%	0%	15%
1995	104.5	2.0	28.5	2939	64	677	5%	0%	21%
2000	84.9	2.1	27.4	3028	74	776	17%	32%	28%
2005	72.6	2.3	21.2	2870	90	787	32%	55%	40%
2010	51.4	1.6	19.1	2278	98	701	53%	89%	60%
2011	52.5	1.4	16.7	2159	96	678	55%	84%	65%
2012	49.6	1.2	14.4	2041	93	680	55%	87%	61%
2013	48.4	1.0	13.8	1929	89	612	60%	79%	76%
2014	48.2	0.8	12.6	1820	84	600	63%	69%	74%
2015	51.0	0.6	11.4	1716	80	565	62%	63%	81%

There is no more than a very approximate connection between the amount of waste landfilled in any year, and the amount of methane generated. The connection is stronger in cases where the quantities and composition are constant over a longer period of time. Nevertheless, for the majority of years, the reported quantity of methane generated in all three countries was in the range 24 to 50 kT methane per Mt waste landfilled. The UK was in the range 28 to 44 kt methane per Mt waste landfilled throughout the time series, with both higher and lower values exhibited by Italy and Ireland. This indicates that there are no causes for concern regarding any obvious inconsistency in the overall results for methane generation with the values reported by these other countries. Since 2013, the UK has reported an estimated methane collection efficiency of between 55% and 62%. This is comparable with, and, if anything, lower than the collection efficiencies reported by Ireland and Italy. This indicates that there are no causes for concern regarding any obvious inconsistency in the estimated methane collection efficiency with the values reported by these other countries.

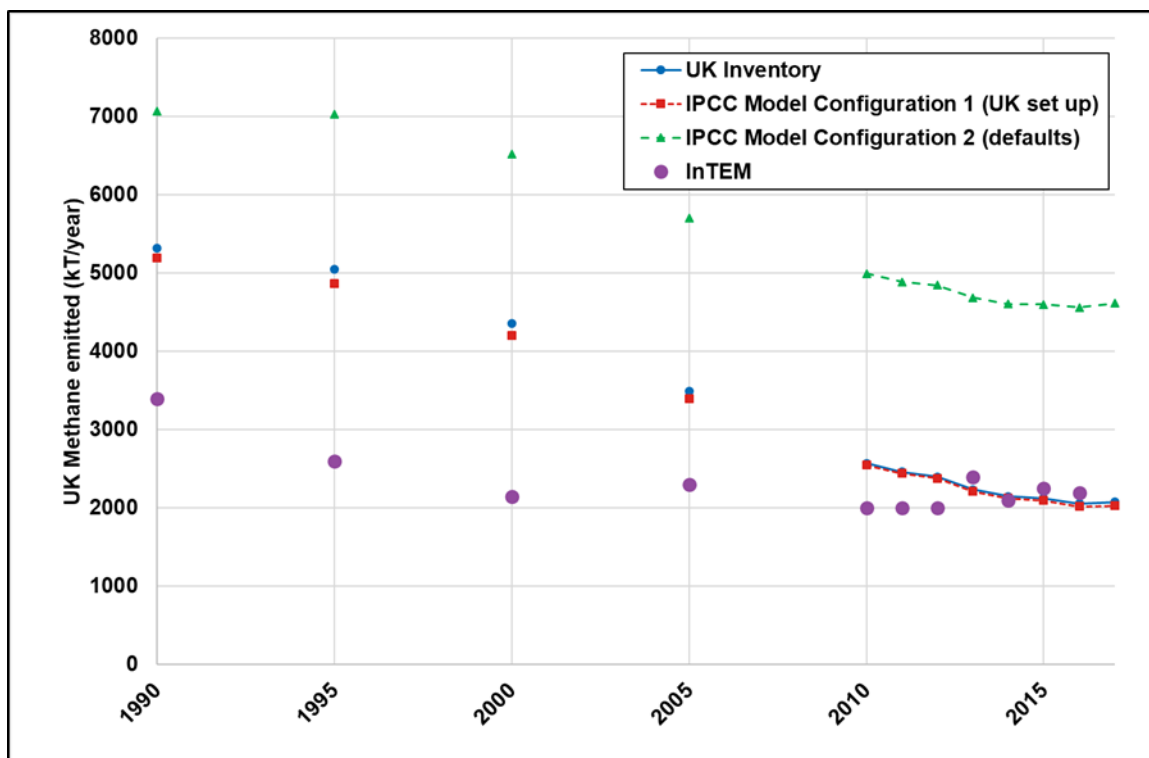
This onetime comparison was specifically performed to compare the methane collection efficiencies between the countries but was not carried out for the purposes of verification of MELMod model.

For the 2019 submission, an ad-hoc verification of the MELMod model was also carried out by comparing the estimation of emissions for 1990-2017 from the UK (Tier 2) model with the IPCC Tier 1 model. The IPCC model was set up in two ways: firstly, to reflect the UK Tier 1 model inputs so far as possible, and secondly, to reflect IPCC default inputs. The key methodological differences between MELMod and the IPCC-waste model with IPCC defaults are as follows:

- The MELMod model contains a more detailed breakdown of waste types with different categories to those used in the IPCC model. Hence it was not possible to accurately represent the MELMod inputs in the IPCC default model.
- The UK model allows for different waste types to have a range of rapidly, moderately and slowly decaying wastes, compared to the single value for each waste type used in the IPCC model.
- Additionally, the IPCC model includes a category of “Industrial waste” whereas the UK model is based on the EWC codes for every waste consignment, and so does not have an equivalent to the “industrial waste” category. This category was therefore not used in the IPCC model, further restricting the range of inputs available.

The model results are compared with each other, and with results derived from analysis of environmental methane measurements, in **Figure 7.12**.

Figure 7.12 Comparison of UK GHG inventory for Sector 5A with IPCC Tier 1 model results and estimates derived from environmental measurements (“InTEM”)



The following conclusions were drawn from this analysis:

- In view of the similarity between the UK model and the IPCC Model Configuration 1, the UK model does not appear to have significant errors in how it is set up.
- The results obtained using the UK Tier 2 model and IPCC Tier 1 Model set up to reflect UK waste and landfill management practices are more reliable than the results obtained using the IPCC Tier 1 Model default inputs.
- The UK landfill methane model provides a reliable calculation of landfill methane emissions for the period 2010 to 2016.

- d) The UK landfill methane model diverges from the estimated quantities calculated from environmental measurements for the period 1990 to 2005. This is currently under review via a separate initiative.
- e) The IPCC Tier 1 model using default inputs does not provide a robust estimate of UK landfill methane emissions.

The MELMod outputs have been compared to the outputs that would result from applying the IPCC Tier 1 methodology to the available data on UK waste receipts. This process indicated that the UK model does not have significant errors in how it is set up, and the use of UK-specific inputs to the UK Tier 2 model or the IPCC Tier 1 model gives more reliable results than the use of the IPCC Tier 1 model with IPCC default inputs. In conclusion, this analysis provides confidence in the UK greenhouse gas inventory for Sector 5.A.

The verification of MELMod has been described in the 2008 NIR. The update undertaken by Eunomia (Eunomia, 2011) in 2010 resulted in the updating of input data to the model only, with no changes implemented as to calculation methodology other than where indicated. The changes to the model input data recommended by Eunomia were peer reviewed by independent experts from academia, industry, regulators and consultants in late 2010, before their incorporation into the UK inventory.

MELMod was subject to a further peer review process in 2014 (Golder Associates, 2014). In the light of this peer review, changes were made to the assumed efficiency of landfill gas engines.

As described in **Annex 6.2**, the UK GHGI is verified against data measured from the InTEM network of measurement masts. These measurements indicate good agreement with the UK inventory for the period 2012 onwards, during which time there has been no strong trend in the landfill methane inventory, the total UK methane inventory, or the estimated inventory derived from the InTEM measurements. However, over the period 1990 – 1994, the InTEM measurements indicate a reduction of about 30% in the total UK methane emissions, whereas the GHGI indicates no strong trend in these years. The GHGI also indicates a consistent declining trend in methane emissions between 1996 and 2012 which is in contrast to almost no trend in InTEM measurements over this time. The trend in the UK GHGI methane estimates is driven mainly by reductions in landfill methane emissions. The reasons for this discrepancy are currently under review, as discussed in **Section 7.2.7**.

7.2.6 Source-specific recalculations

Changes to the UK landfill methane inventory for this submission are as follows:

- Revision to historical activity data. Waste reduction for 1960-1996 results in reduced methane generation in subsequent years, although this effect diminishes over time, as emissions become increasingly influenced by more recent landfill waste. d to enhance the accuracy of methane emission estimates from waste disposal sites. This change has a significant impact on methane emissions from SWDS.
- Revision of methane oxidation assumptions pre-1980, with a larger impact on methane emissions from SWDS in the first years on the timeseries.
- Updates to the material sent to landfill revisions in England for 2006 - 2010, 2020 and 2022. The changes for these years reflect the updated Waste Data Interrogator (WDI) statistics published in the WDI.
- Minor revisions to the material sent to landfill in 2022 and 2023 for Wales to include some waste codes that were not incorporated into the inventory.

- Revision of methane flaring data for England, Scotland, Wales and Northern Ireland for 2022 and 2023.
- Minor adjustments in landfill gas data in 2022 and 2023 regional statistics for England, Scotland, Wales and Northern Ireland

As a result, slight changes to the landfill methane inventory for England, Scotland, Wales and Northern Ireland were calculated.

7.2.7 Source-specific planned improvements

The Inventory Agency is working on improvements to the spatial distribution of landfill methane emissions data. This will enable verification of the calculated inventory against the InTEM field measurements to be carried out in more detail (InTEM is discussed in **Annex 6**).

An ongoing Defra project on municipal solid waste composition analysis is expected to provide updated data. Incorporating these new mixed-waste composition figures into MELMod will improve the accuracy of waste composition estimates and strengthen methane-generation modelling for landfills.

A number of programmes of research funded by the UK Government and regulatory agencies to improve estimates of emissions from landfill and into measurement and modelling of landfill methane emissions on a site-specific basis are currently being carried out. This may lead to future improvements in the solid waste treatment inventory.

7.3 SOURCE CATEGORY 5B – BIOLOGICAL TREATMENT OF SOLID WASTE

7.3.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	5B: Composting (non-household)	T1	D
	Composting (household)	T1	D
	Anaerobic digestion (non-agricultural)	T1	D
	Mechanical biological treatment	T1	D
Gases Reported	CH ₄ , N ₂ O		
Key Categories	5B: Biological treatment of solid waste – CH ₄ (T1, T2, L2) 5B: Biological treatment of solid waste – N ₂ O (T2)		
Key Categories (Qualitative)	None identified		
Overseas Territories (OT) and Crown Dependencies (CD) Reporting	Estimates have been made for OT and CD emissions from 5B1, composting of municipal solid waste, where data on the total amount of waste composted is available. In these cases, 2006 IPCC default EFs are applied. These estimates are included within 5B for CRT reporting.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7 .		
Major improvements since last submission	No major improvements have been made since the last submission.		

7.3.2 Methodological Issues

Emissions of methane and nitrous oxide from composting of MSW (Category 5.B.1) and anaerobic digestion and Mechanical Biological Treatment (MBT) (Category 5.B.2) are estimated using a Tier 1 methodology. This was identified as an appropriate approach in view of the scale of emissions from this sector (DECC, 2015b).

Activity data for composting and anaerobic digestion relies on the approaches used in the GHG and ammonia inventories. Activity data for composting was derived from Devolved Governments' data on organic waste fractions. Inputs to household composting were calculated by using population statistics and district level analysis for home composting in the UK (Parfitt, 2009).

Activity data for MBT and whether the MBT is aerobic or anaerobic is based on annual organics recycling reports, published between 1998 and 2013 by: The Waste and Resources Action Programme (WRAP, 2009 to 2014), The Association for Organics Recycling (2006 to 2008), The Composting Association (1998 to 2005). Some extrapolation and interpolation are required to generate a complete and consistent time series.

Activity data for anaerobic digestion was derived from the National Non-Food Crops Centre (NNFCC 2024) site information database. The NNFCC dataset provides annual facility-level data up to 2023. As no updated site-level dataset was obtained for 2025, the 2023 time series was used as the basis for this submission and the 2023 activity data were carried forward to 2024 to maintain time-series consistency. The reported inputs to each site in NNFCC reflect the actual tonnes inputted by feedstock category.

*[The UK activity data are summarised in **Annex 5.1.5.2**]*

Emissions from the anaerobic digestion of manure-based residues are not considered in the waste sector. These emissions are reported in the agriculture sector (CRT Sector 4), as it is suggested by the IPCC 2006 Guidelines.

Emission factors for source category 5.B.1 and the anaerobic digestion component of 5.B.2 were taken from IPCC (2006) default emission factors. IPCC 2006 Guidelines published an update for the waste sector in July 2015. This update is related to the default CH₄ and N₂O emission factors proposed for composting and anaerobic digestion and it has been applied to the complete time series. CO₂, in line with the IPCC methodology, is not included in the Inventory calculation as it comes from material of biogenic origin. The emission factors for the anaerobic digestion component of mechanical biological treatment were assumed to be the same as for anaerobic digestion.

7.3.2.1 Overseas Territories and Crown Dependencies

Emissions from 5.B.1 have been estimated, however due to data availability, only estimates for Guernsey and Bermuda can be derived. Within Guernsey, composting has only occurred on the Island since 2008, due to creation of a new national composting scheme. The total amount of waste composted within this scheme has been supplied by Guernsey. Official statistics provide the amount of waste composted in Bermuda. IPCC 2006 default emission factors for both CH₄ and N₂O have been applied.

7.3.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and fuel type.

Activity data for industrial activities over the time series were taken from relevant publications and are considered to provide robust and accurate data. Activity data for home composting is less reliable, but now represents a small proportion (approximately 3%) of total composting activity carried out in the UK.

IPCC Tier 1 default emission factors were used for this analysis. These are considered to be less reliable, and hence subject to greater uncertainty. This is the key source of uncertainty in emissions from the 5.B sector.

Time series consistency is based on activity data and is considered to be reasonably representative of activity in this sector.

7.3.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

7.3.5 Source Specific Recalculations

The inputs to permitted composting digestion plants and anaerobic digestion facilities have been revised and the historic timeline updated to use the latest available data (UKCEH 2025). This resulted in a small increase in the quantity of waste assumed to be processed at permitted composting facilities (less than 1 in 2022 and 2023), and corresponding changes in associated methane and nitrous oxides emissions.

The amount of waste assumed to be processed at anaerobic digestion facilities has been updated for 2023 using most recent dataset available (NNFCC 2024). It has also been revised to reflect small changes to number and capacity of MBT sites for years 2008-2011, resulting in corresponding changes to calculated emissions across the anaerobic digestion timeseries.

For information on the magnitude of recalculations, see **Section 10**.

7.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

7.4 SOURCE CATEGORY 5C – WASTE INCINERATION**7.4.1 Source Category Description**

Emissions sources	Sources included	Method	Emission Factors
	5C1: Incineration: MSW Incineration: sewage sludge Incineration: clinical Incineration: chemical Incineration: animal carcasses Crematoria 5C2: Accidental fires: dwellings Accidental fires: other buildings Accidental fires: vehicles Bonfire night Fireworks Small-scale waste burning	T2,T1 T1 T1 T2, T1 T1 CS CS CS CS CS CS CS CS	CS, D CR, D OTH, D CS, D CS CS OTH OTH OTH OTH OTH OTH OTH
Gases Reported	CO ₂ , CH ₄ , N ₂ O, NO _x , CO, NMVOC, SO ₂		
Key Categories	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Included in the CRT with the UK MSW incineration, since the same emission factors are applied, apart from 5C2.1b, incineration of waste from small scale burning, where estimates are now made for Guernsey using IPCC default method. Clinical waste incineration also occurs and is reported in many of the CDs and OTs.		
Completeness	A general assessment of completeness for the inventory is included in Section 1.7		
Major improvements since last submission	Removal of a double-count of emissions from the incineration of chemical waste (i.e. this source is now deleted from the inventory as already accounted for elsewhere).		

This source category covers the incineration of wastes (excluding waste-to-energy facilities which are reported in **MS 1**). The UK reports direct GHGs from: MSW incineration (UK, CDs), sewage sludge incineration (UK only), clinical waste (OTs, CDs only; UK emissions are IE), small-scale waste burning (UK, CDs, OTs), bonfire night and accidental fires (UK only). The UK reports GHG precursor emissions from the above and also from various other sources including crematoria and animal carcase incineration (UK only), chemical and clinical waste incineration (UK only; direct GHGs are IE), foot and mouth pyres (UK only) and fireworks (UK only).

In the UK, all MSW incineration plants have recovered energy since 1997, and so emissions are reported under CRT source category 1A1a. For the years 1990-1996, at least some MSW was incinerated at plants with no energy recovery, so emissions are split between 1A1a and 5C for those years, in proportion to the waste burnt with and without energy recovery respectively. All incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is reported under 5C1, since we have no information on any recovery of energy

from these processes. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 3F.

The numbers of chemical waste, clinical waste and sewage sludge incinerators in the UK are not known with certainty, although that number has almost certainly decreased significantly between 1990 and 2024. A total of 26 incinerators regulated under the Industrial Emissions Directive (IED) have been identified as operating in 2024 - 2 burning sewage sludge, 17 burning clinical wastes, and 7 burning chemical wastes. It is possible that a few very small incinerators, outside the scope of IED, may also exist. Approximately 2600 animal carcass incinerators were believed to be in use in the early 2002 (estimated in AEA Technology, 2002) and in the absence of updated data, we assume this is still the case. Animal carcass incinerators are typically much smaller than the incinerators used to burn other forms of waste. Numbers of crematoria are slowly increasing in the UK: there were 336 in 2024 compared with 241 in 1999 (based on statistics published by the Cremation Society of Great Britain, website at <http://www.cremation.org.uk/>).

This source category also includes emissions from the open burning of wood waste in Guernsey.

7.4.2 Methodological Issues

Emissions of direct GHGs from **chemical waste incinerators** are included elsewhere as the activity data for the method is combined in UK energy statistics with that for non-renewable MSW, and estimates are derived using emission factors. However, GHG precursors are estimated based on analysis of emissions data reported to the Pollution Inventory (Environment Agency, 2025), the Welsh Emissions Inventory (NRW, 2025) and the Northern Ireland Pollution Inventory (NIEA, 2025). There are no chemical waste plant in Scotland. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites occurs, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plants but the need for extrapolation of data may contribute to significant variations in the quality of the estimates.

Emissions of CH₄, CO, N₂O, SO₂ and NMVOC from **sewage sludge incineration** are estimated using literature-based emission factors, while emissions of NO_x are estimated using Pollution Inventory data. The factor for N₂O is the 2006 IPCC default for UK sewage sludge incineration on a dry matter basis (IPCC, 2006) and sewage sludge activity data are on a dry matter basis¹⁰⁵. Emission factors for other pollutants are taken from the EMEP/EEA Emission Inventory Guidebook. The quantity of waste burnt annually is estimated using data from various sources, specifically:

1990	RCEP, 1993
1991-1998	Digest of Environmental Statistics (Defra, 2004)
2006-2024	Environment Agency, waste disposal data for individual sites in England
2004-2024	Inventory Agency estimates for Northern Ireland, based on design capacity of incinerator plant at only site.
2013, 2015-2024	Scottish Environment Protection Agency, estimates of total sewage sludge incinerated in Scotland

¹⁰⁵ This is illustrated by the comparison to wastewater operator reporting in **Section 7.1.2.5** which is also on a dry matter basis, and aligns closely with incinerator reporting.

Interpolation between the various estimates is used to fill the gaps in the activity data time series.

Emissions of direct GHGs from **clinical waste incinerators** in the UK are included elsewhere as the activity data for the method is combined in UK energy statistics with that for non-renewable MSW, and estimates are derived using emission factors. However, GHG precursors are estimated based on analysis of emissions data reported to the Pollution Inventory (Environment Agency, 2025b), the Scottish Pollutant Release Inventory (SEPA, 2025b) and the Welsh Emissions Inventory (NRW, 2025). No clinical waste incinerators are evident in Northern Ireland. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites occurs, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plants but the need for extrapolation of data may contribute to significant variations in the quality of the estimates.

Emission estimates for **animal carcass incinerators** are taken directly from a Defra-funded study (AEA Technology, 2002) and are based on emissions monitoring carried out at a cross section of incineration plants. No activity data are available and so the emission estimates given in this report are assumed to apply for all years.

Emissions of CO, NO_x, SO₂ and NMVOC from **crematoria** are based on literature-based emission factors, expressed as emissions per corpse, and taken from EMEP/EEA (2023). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2024).

Emissions from **MSW incineration** for the period 1990-1996 are reported as a split between 1A1a and 5C, in proportion to the tonnages of waste burnt with and without waste recovery respectively. The same methodology is used to estimate emissions for both types. Emissions of direct GHGs from **chemical and clinical waste incineration** were previously estimated and reported separately in the UK inventory, based on operator-reported emissions data from the regulator inventories. However, through research into the scope of renewable and non-renewable wastes within the Digest of UK Energy Statistics, it was noted that activity data for the mass of annual chemical and clinical waste incinerated is included within the values presented for non-renewable wastes, and hence to make separate estimates for chemical waste incineration was a double count. Therefore, this has been removed from the 2026 UK submission; emissions of direct GHGs from chemical and clinical waste incineration are therefore Included Elsewhere, in-part within 5C estimates for municipal waste incineration up to 1996, and then within 1A1a via Energy-from-Waste plant across the rest of the time series.

Estimates for **accidental fires** are based on statistics from the Fire Service of Great Britain, available from the Department for Communities and Local Government (Home Office, 2024). These statistics give the number and severity of fires in dwellings and other buildings, and the number of fires in road vehicles by type. The statistics have then been converted into masses of material burnt by applying country-specific assumptions for each type of fire e.g. for the many fires in dwellings that are limited to just a single item, the mass of material combusted is assumed to be 1 kg. The total material burnt is then combined with emission factors to obtain emission estimates for methane, CO, NO_x and NMVOC. The methane factors are taken from AP 42 (US EPA) and relate to open burning of municipal waste (for dwellings and other buildings) and automobile parts (for vehicle fires). Factors for other pollutants are taken from the same source, or from UK-specific literature. The UK is not aware of any source of appropriate emission factors for carbon or nitrous oxide emissions from this source, but emissions of these pollutants from this source are expected to be small.

Emissions from **waste incineration in Jersey and the Isle of Man** are reported under 1A1a. Data are available for the amount of **waste open-burned in Guernsey**, so these are used to estimate emissions for 5C2 using IPCC 2006 default EFs. It is assumed that this source is not occurring in the remaining territories.

The inventory also includes estimates for emissions of:

- CO, NO_x & NMVOC from small-scale burning of domestic and garden waste, for example on domestic grates and on garden bonfires;
- CO from open fires lit as part of 'bonfire night' celebrations; and
- CO from fireworks.

All of these estimates are very uncertain, because of the need for expert judgements and assumptions in order to derive any activity data from waste arising data, and the need, because of a lack of suitable emission factors, to instead use factors that were designed for other types of emission source such as domestic fires.

Activity and emissions data for this sector can be found in **Annex 5.1, Table A 5.1.70** and **Table A 5.1.71**.

7.4.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 2** provides estimates of uncertainty according to CRT source category and gas.

7.4.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

7.4.5 Source Specific Recalculations

The following recalculations apply to the estimates submitted in this compilation cycle:

- Removal of the double-count of emissions from chemical waste incineration, as noted in **Section 7.4.2** above.
- Revised ONS death registration data and number of cremations for 2023 led to a minor revision in emissions.
- Small revision, within $\pm 1.5\%$, to the mean number of fillings and the proportion of dentate individuals based on the 2021 Adult Oral Health Survey (AOHS, 2024), affecting all years after 2009.
- Update to the Crown Dependency incineration data.
- Updates to site-level capacity and production data resulted in small changes to modelled emissions from clinical and chemical incineration (for GHG precursors only).

For information on the magnitude of recalculations to Source Category 5C, see **Section 10**.

7.4.6 Source Specific Planned improvements

The need to deal with significant gaps in the reported data means that estimates are quite uncertain. Emission estimates for animal carcass and sewage sludge incineration are also quite uncertain and ideally would be improved. The BTR review of 2025 identified a potential gap in UK evidence for the incineration of industrial organic sludge; no UK activity data are evident for such an emission source. Consultation with industry stakeholders will be considered to seek further information for this source.

Note that all incineration processes are relatively minor sources of greenhouse gases and further development of the methodology is not a high priority.

7.5 SOURCE CATEGORY 5D – WASTEWATER TREATMENT AND DISCHARGE

7.5.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	5D1: Domestic Waste-water treatment 5D2: Industrial Waste-water Treatment	T1, CS, OTH T1, CS	CS, D, OTH CS, D
Gases Reported	CH ₄ , N ₂ O, CO ₂		
Key Categories	5D: Wastewater Handling - N ₂ O (L2, T2) 5D: Wastewater treatment and discharge - CH ₄ (L1, L2)		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from wastewater handling within OTs and CDs are included in 5D1. Estimates are based on 2006 IPCC Guidelines and EFs with country-specific parameters applied, where available.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Section 1.7 .		
Major improvements since last submission	Revised estimates for 5D2, industrial wastewater treatment, based upon a new Tier 1 approach.		

Emissions reported in 5D2 arise from wastewater handling in a number of industry sectors in the UK where organic content of effluent is high.

Emissions reported in 5D1 arise from wastewater handling, sludge treatment and disposal¹⁰⁶ in the UK's municipal waste-water treatment system and private waste-water management systems. The UK's municipal waste-water treatment system encompasses the treatment of effluent and sludge from residential and commercial sectors as well as trade waste from many industrial sites in the UK.

Methane is released from handling of wastewater and its residual solid by-products (i.e. sludge) under anaerobic conditions, due to the decomposition of organic matter by microorganisms.

Nitrous oxide is released from human sewage during wastewater handling due to the release of nitrogenous material from proteins and from industrial wastewaters which contain nitrogen.

7.5.2 Methodological Issues

The emissions from 5D1 and 5D2 are estimated for the following sources in the UK:

¹⁰⁶ Where disposal isn't reported against another source, as discussed in **Section 7.1.2.5**; the main sewage sludge disposal route that remains in 5D1 is sludge to sea.

- **5D1 Domestic and Commercial Wastewater.** The following provides an overview of the main components:
 - **UK CH₄ emissions from the transport of wastewater volumes (gravity / rising-main sewers) to sewage treatment works.** Municipal wastewater volumes based on: UK specific consumption rate, population statistics, transfer rate to sewer, additional volume uplift (UK specific and IPCC 2006 guidelines) and gravity and rising-main sewer network split. Emission factor for Gravity and Rising-main sewers based on Song et al (2023);
 - **UK CH₄ and N₂O emissions from on-site sewage gas flaring.** Default IPCC methodology, using activity data from water operators reported statistics.
 - **UK CH₄ emissions from municipal wastewater treatment.** IPCC 2019 Refinement methodology, with Urban Waste Water Treatment Directive (UWWTD) Article 15 statistics used to provide a UK-specific treatment split. Emission factor applied on a treatment technology basis.
 - **UK N₂O emissions from municipal wastewater treatment.** IPCC 2019 methodology applied to UK time series of population, treatment technology (UWWTD Article 15 statistics), and protein intake estimates from food surveys and FAO statistics. Emission factor applied on a treatment technology basis;
 - **UK CH₄ and N₂O emissions composting of municipal sewage sludge.** Default IPCC methodology, using activity data from water operators reported statistics;
 - **UK CH₄ emissions from mechanical treatment of municipal sewage sludge.** Default IPCC methodology does not provide an emission factor for the process, with the literature values used from Song et al (2023). Activity data from water operators reported statistics;
 - **UK CH₄ emissions from the digestion or advanced digestion of municipal sewage sludge.** IPCC methodology, with the application of a UK-specific CH₄ emission capture rate. Activity data from water operators reported statistics;
 - **UK CO₂ emissions from liming of municipal sewage sludge.** UK-specific methodology. Activity data from water operators reported statistics. Emission factor based on required pH, carbon content of limestone, and required limestone vs target pH.
 - **UK CH₄ and N₂O emissions from municipal wastewater effluent discharged to waterways.** IPCC 2019 Refinement methodology. UK-specific methodology, with UWWTD Article 15 statistics used to provide a UK-specific receiving water body split, activity data disaggregation by treatment technology. IPCC 2019 Refinement guidelines emission factors for different types of receiving water bodies;
 - **UK CH₄ emissions from private wastewater management.** Default IPCC methodology using UK-specific per capita Biochemical Oxygen Demand (BOD) and estimated population using private waste-water management systems;
 - **UK CO₂ emissions from the oxidation of fossil carbon in municipal wastewater.** UK developed methodology utilising 2019 refinement to the 2006 IPCC guidelines, Appendix 6A.1 methodological development for fossil CO₂ emissions from wastewater treatment and discharge (Anagnostopoulos et al., 2022). Emission factor from Law et al (2013).
 - **OT and CD Sewage Treatment.** For the majority of overseas territories and crown dependencies, wastewater emissions are estimated using UK data and scaled by population. Data specific to Bermuda were provided by the territory and used within the time series, interpolating and extrapolating where necessary.

- **5D2 Industrial Wastewater Treatment.** Default IPCC methodology¹⁰⁷ applied to UK production data from a range of wastewater-generating industrial sectors.

7.5.2.1 5D1: UK municipal waste-water treatment overview

UK wastewater management systems are long established, even prior to 1990 almost the whole of the UK was connected to centralised sewer networks and wastewater treatment facilities. Over time, regulation has been setting higher expectations of wastewater management, extending the requirements of wastewater treatment, and leading to changes in wastewater and sludge management practices. For example, the Urban Wastewater Treatment Directive in the late 1990s / early 2000s banned the dumping of sewage sludge into the sea.

The UK water sector was previously publicly owned and is now comprised of over a dozen individual companies and a statutory cooperation that operate regional networks and infrastructure. There is a long history of UK-wide research and co-operation across these operators, and in response to the challenge to monitor and report environmental performance, all major UK water operators engage via a central body, UK Water Industry Research (UKWIR), through which common reporting frameworks and systems are researched, developed and updated to reflect latest science and industry practices.

In the UK, a typical Wastewater Treatment Plant (WWTP) involves a number of interrelated processes, each of which has different emissive behaviour. The different combinations of treatment options and the local wastewater arising characteristics (especially where high volumes of industrial waste are combined and treated together with municipal wastewater, altering the wastewater input characteristics away from “typical” municipal wastewater arisings) lead to a range of performance in the management of organic waste and the emission performance of the treatment works.

The UK tools to monitor WWTP performance, estimate the input water characteristics (which in the UK is linked to regulatory and charging regimes for industrial customers, often based on periodic sampling of industrial effluents that pass into the predominantly municipal system), and to estimate the GHG emissions from these activities have been developed through research focussed on the UK wastewater sector and the existing infrastructure.

The UK methodology for modelling the emissions from municipal wastewater has been split into three sections. These are the wastewater process, the sludge process, and the sewage gas treatment process, as summarised in **Figure 7.13**, **Figure 7.14**, and **Figure 7.15**, respectively. These flow diagrams show each step in these processes and where emissions can be estimated, and where they are both difficult to estimate and expected to be insignificant. Additionally, the sewage gas treatment, for which CH₄ capture can be estimated, is presented. The normal flows of the processes, as well as optional flows, are also presented.

This method also enables spatial assignment of emissions by integrating the UWWTD Article 15 dataset, ensuring that the methodology accurately reflects real-world UK wastewater treatment technologies.

¹⁰⁷ Note that in the case of N₂O this means a 2019 refinement to the 2006 IPCC guidelines default methodology, as there is no method presented in the 2006 IPCC guidelines.

Figure 7.13 Wastewater flow diagram

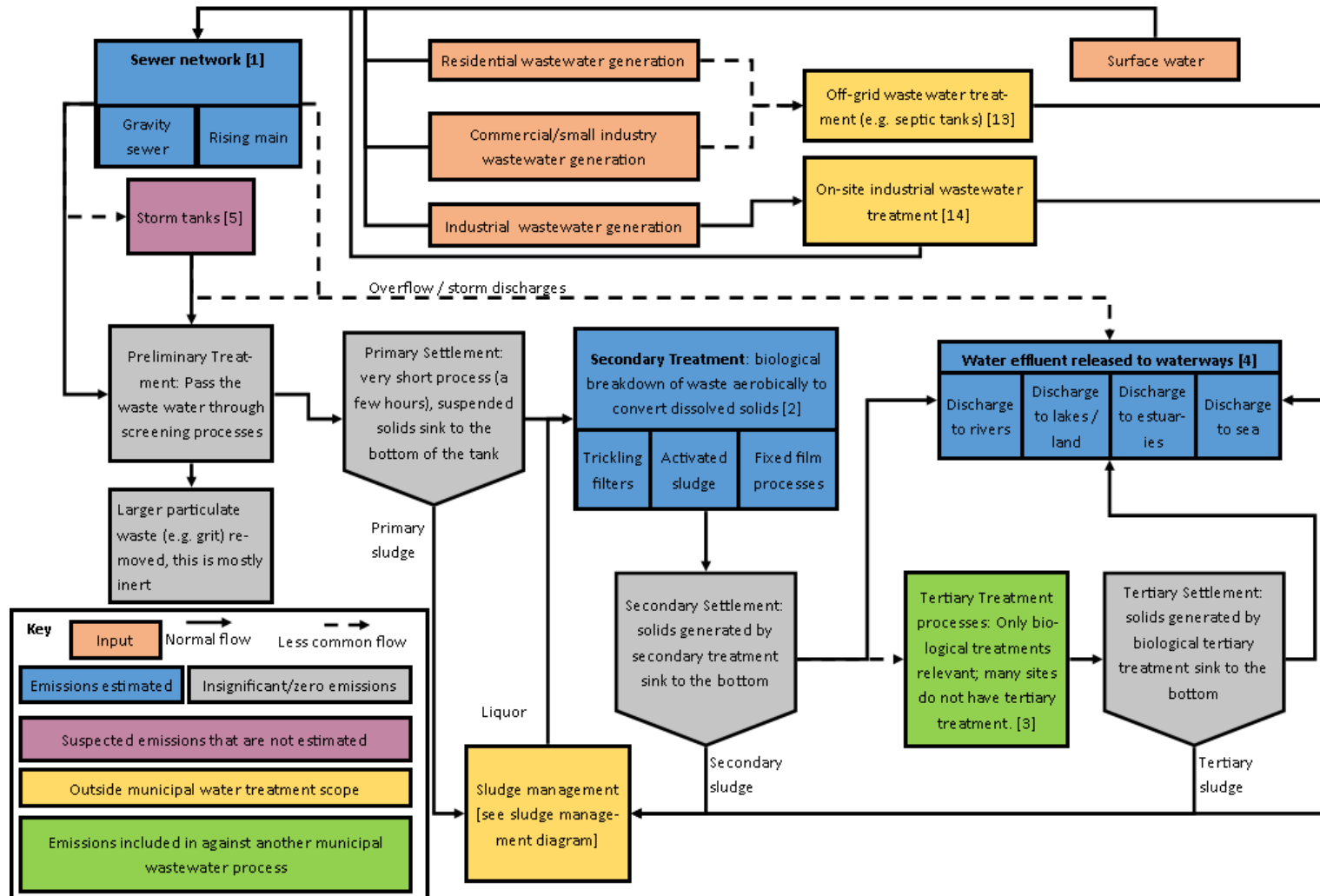


Figure 7.14 Sludge management flow diagram

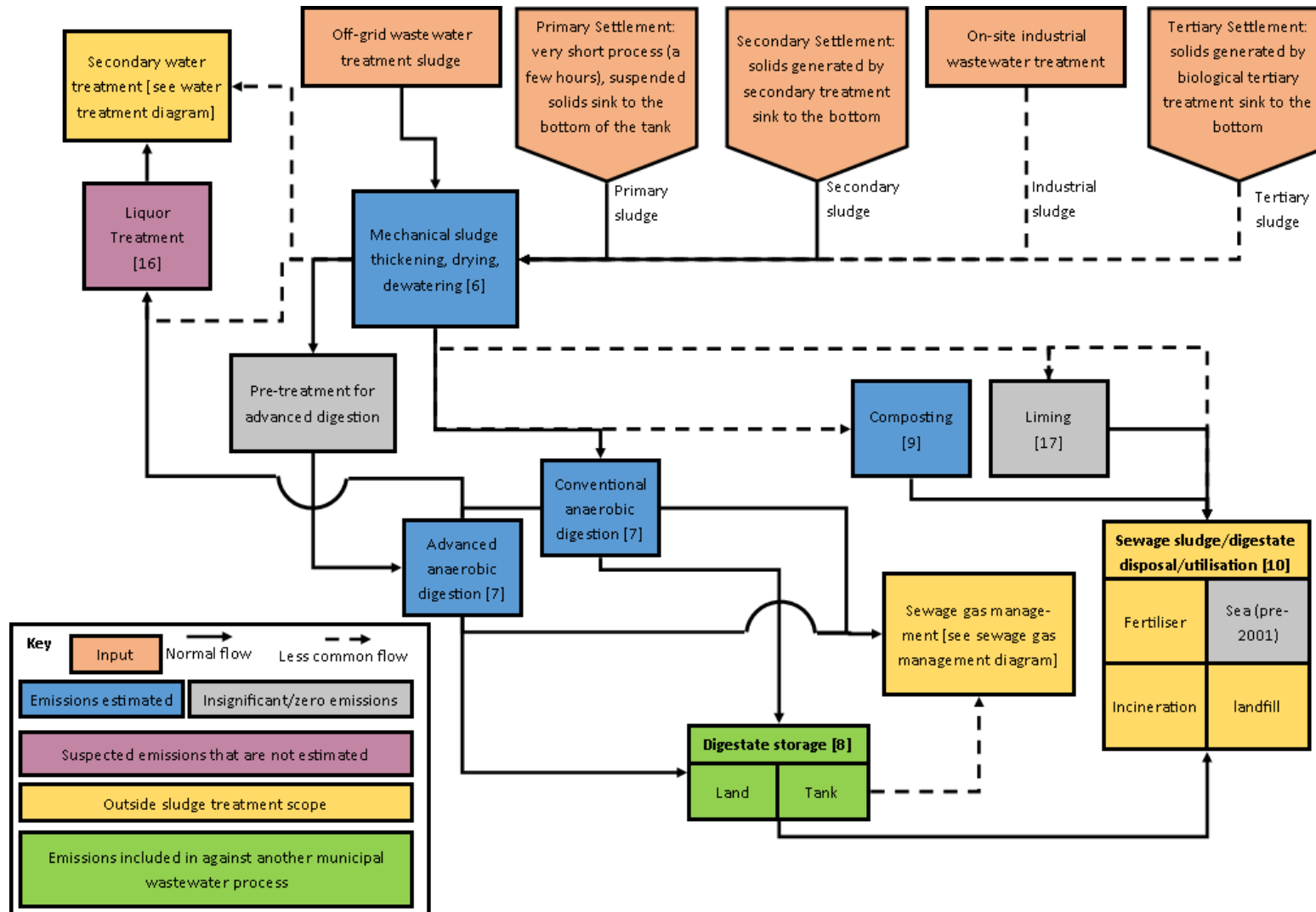
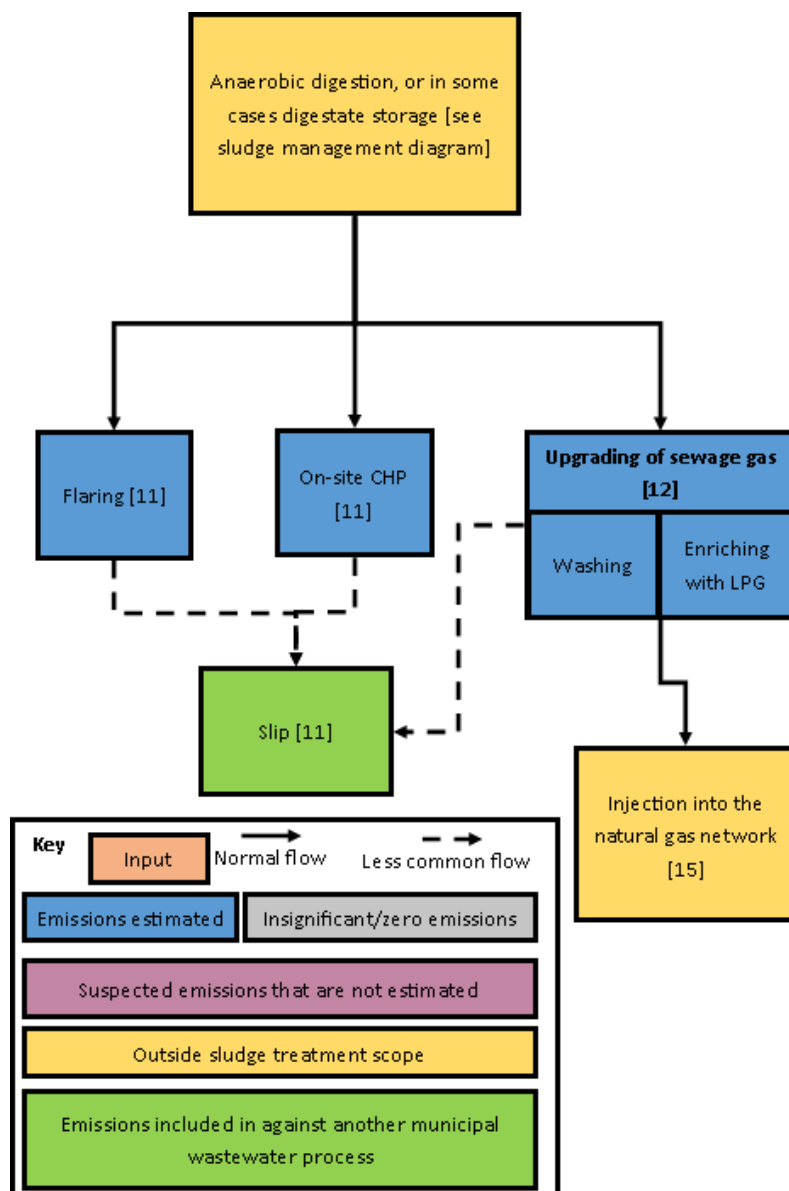


Figure 7.15 Sewage gas management flow diagram



7.5.2.1.1 Wastewater Process

The square brackets in the headings in this section relate to where in the flow diagrams in **Section 7.5.2.1** these processes appear.

7.5.2.1.1.1 Sewer network [1] – CH₄

The degradation of wastewater starts occurring as soon as it is generated, and therefore, CH₄ is generated as wastewater transitions through the sewer network. The CH₄ generation while in the sewer is sensitive to:

- Total time within the sewer;
- How ventilated the sewer is;
- The pipe diameter, and flow rate relative to pipe diameter;
- The gradient of the pipe;
- The temperature; and,

- Whether wastewater travels by gravity or is pumped.

Accounting for features would require significant information about the sewer network and a complex model. A more simplistic approach has been adopted that only accounts for whether wastewater travels through manhole (gravity) sewers and wet-well (pumped raising main) sewers. Analysis of two UK wastewater operators, from technical communication with Mott MacDonald (2024), has indicated that the proportion of sewers that are gravity sewers is >95%. Given the small sample size, a conservative assumption that only 95% of sewers are gravity sewers has been adopted.

The emission factors from Chaosakul et al. (2014) are based on sewer systems in Thailand and Australia, which are not representative of UK conditions, and no suitable method has been identified to adjust these factors for their impact on BOD arriving at treatment works—meaning their use could modestly double-count emissions. However, the IPCC default of zero emissions for closed, well-managed sewers is also unlikely to reflect UK practice, leaving a choice between using unrepresentative non-zero factors or leaving a methodological gap.

Although closed sewers may release CH₄ only upon arrival at treatment works—potentially causing some overlap with plant-level measurements—the risk of double-counting is considered low given that primary treatment, settlement, and storm-tank emissions are treated as insignificant, though this should be reconsidered if future measurement-based approaches are adopted.

N₂O emissions will also occur within the sewer; however, we have not identified an alternative method for estimate N₂O emissions from sewers. Similar to CH₄, the 2019 Refinement to the 2006 IPCC guidelines states that there is “insufficient data exist to quantify emission factors that address the variation in sewer type and operational conditions”, and there would be a risk of a partial double-count of emissions with existing method for estimating N₂O emissions downstream of the sewer network.

Calculation of CH₄ emissions uses **Equation 7.1** to estimate activity data and emission factors presented in **Table 7.6**, with activity calculated in litres, with *s* representing either - Gravity or Rising-main sewers.

Equation 7.1 Volume of wastewater transported in sewers

$$activity_s = (p * l * F_{ww} * (1 + F_{infiltr} + F_{com_{ind}}) * 365) * t_s$$

Where:

p is the population (ONS);

F_{ww} is the ratio of consumed water that becomes wastewater: 0.8, from World Health Organization (2023);

l is the Number of litres used per person per day: 137, from Environment Agency Water Resources (2024);

F_{infiltr} is the Ratio of water infiltration in relation to calculated domestic wastewater: 0.5, from Environment Agency (2020);

F_{com_ind} is the Ratio contribution of commercial/industrial wastewater discharges to the sewage network: 0.25; and,

t_s is the Ratio of sewer type (gravity or rising-main): 0.95 (Gravity), 0.05 (Rising main).

Table 7.6 Emission factors for methane emissions from sewers

Sewer type	Emission Factor	Reference
gravity sewers	0.7 mg CH ₄ / l	Song et al., (2023)
pumped rising main sewers	5.3 mg CH ₄ / l	Song et al., (2023)

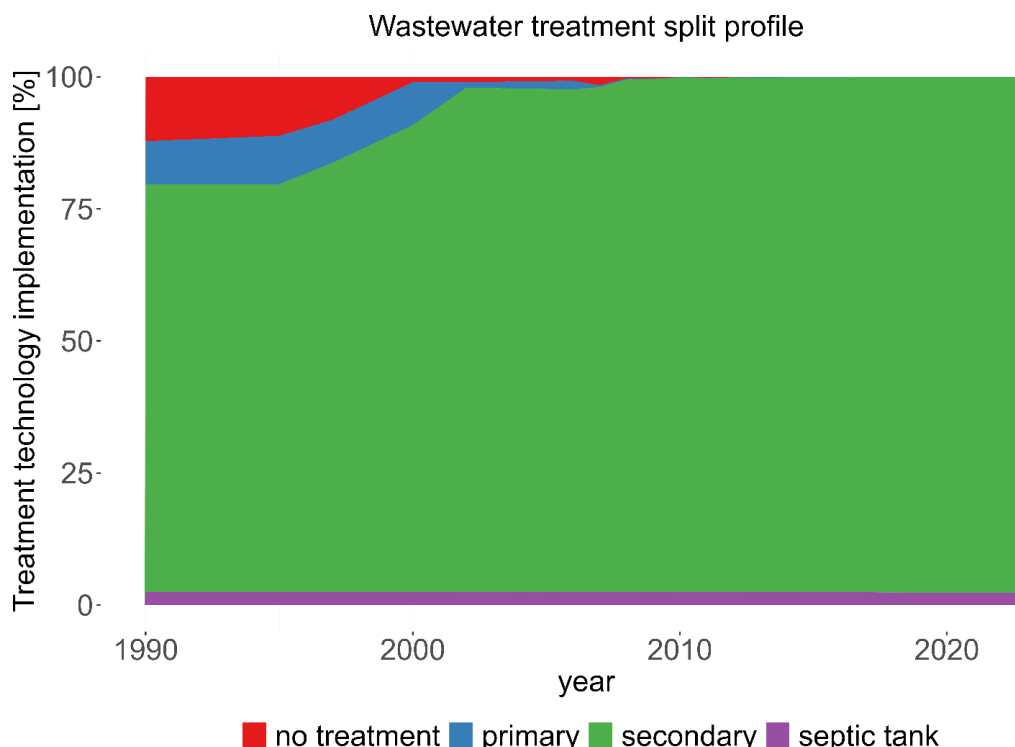
7.5.2.1.1.2 Wastewater Treatment Profile

A UK-specific wastewater treatment technology profile (treatment split) is utilised to calculate emissions from different activities per treatment type. The profile is shown in **Figure 7.16**, and is used to segment out the ONS population statistics across the UK. The profile is also used to back-cast the site treatment split for UWWTD Article 15 from 2005 to 1990 to provide a proxy for spatial estimates, Water UK (1998).

The profile has been developed using the following data inputs. The UWWTD Article 15 data returns have been used to inform the percentage breakdowns of the different wastewater treatment technologies (no treatment, primary, and secondary treatment; see **Section 7.5.2.1.1.8** on why we don't present tertiary treatment) connected to the sewer network. This dataset provided a detailed spatial breakdown from 2006 to 2018 (UK), European Environment Agency (2018), [Click or tap here to enter text.](#) and 2020 to 2022 (England Only), Defra (2024), [Click or tap here to enter text.](#) providing for each listed SWT site the level of treatment technology employed.

Due to no UWWTD Article 15 data returns being available from 1990 to 2005, Water Services Association (WSA)/Water UK reported technologies split information has been used to model these earlier years. From 2002 until 2005, linear interpolation was used to gap-fill the period between the last WSA/Water UK report available, the Defra report on Sewage Treatment in the UK, and the first UWWTD Article 15 data return.

For the total percentage contribution of Septic Tank systems, the model utilises the current approach adopted by the NAEI's existing (Excel-based) wastewater model. This approach uses 2013 Defra-reported statistics from each of the Devolved Governments (DGs) to model the number of households connected to septic tanks for each DG.

Figure 7.16 UK-specific Wastewater Treatment Technology Profile

7.5.2.1.1.3 Nitrogen content of wastewater received for treatment

The Nitrogen (N) content of wastewater entering the treatment process is calculated using Equation 6.10 (New) from Volume 5, Chapter 6 of the 2019 refinement to the 2006 IPCC guidelines (IPCC, 2019).

A key input to Equation 6.10 (New) is Protein consumption, and the 2019 refinement also present Equation 6.10A (New) for the calculation of protein consumed using data on protein supply (such as FAO reporting).

The UK GHGI estimate of protein consumption is derived from the Expenditure and Food Survey (Defra, 2020). This is a sample household survey in which households record the actual purchases of food they make. UK-specific conversion factors are then applied to these individual food items to estimate consumption of protein and other nutrients. The UK-specific conversion factors are based on a detailed analysis of the individual types of food purchased and therefore provides a country-specific alternative to using Equation 6.10A (New) with FAO data.

The following parameters have been applied to Equation 6.10 (NEW):

- i. F_{NPR} - The fraction of N in protein: 0.16 kg N/kg protein, the IPCC default (IPCC, 2006)
- ii. $transcript\ attached_{com}$ - Non-consumed protein factor: 1.09 kg N/kg N, the 2019 refinement recommended value for Europe (IPCC, 2019)
- iii. $F_{ind-com}$ - Industrial and commercial co-discharge protein factor: 1.25 kg N/kg N, the IPCC default (IPCC, 2006)
- iv. N_{HH} - Additional household product N factor: 1.08, the 2019 refinement recommended value for Europe (IPCC, 2019)

7.5.2.1.1.4 Total Organically Degradable Material of wastewater received for treatment

The calculation of the total amount of organically degradable material in the wastewater (TOW) entering SWT in units of BOD is conducted using Equation 6.3 (Updated), as outlined in Volume 5, Chapter 6 of the IPCC 2019 Refinement (IPCC 2019). The value of 60g/person/day for BOD (country-specific per capita BOD in inventory year) has been chosen from **Table 6.4**.

This estimate of TOW then feeds into Equation 6.3A (New) using:

- i. the degree of utilisation of treatment/discharge pathway or system discussed in **Section 7.5.2.1.1.2**; and,
- i. A correction factor of $I = 1.25$, the IPCC default (IPCC, 2006) which accounts for industrial wastewater co-discharge to municipal sewers.

The UK modifies Equation 6.3A (New) to account for sewage sludge generated at industrial wastewater treatment works that is delivered to municipal wastewater treatment plants. This is calculated as the ratio of estimated total BOD of wastewater and the company-reported statistics on sludge. This uplift represents a ratio increase in BOD of 1.03 to 1.23 and is applied on a year-specific basis.

7.5.2.1.1.5 Total Organically Degradable Material (TOW) removed as sludge

The total amount of organically degradable material that is removed as sludge from centralised municipal wastewater treatment works is calculated using Equation 6.3B (New) from the IPCC 2019 Refinement (IPCC, 2019). Statistics for S_{mass} , the amount of raw sludge removed during SWT as dry mass, are provided from the Wastewater company-reported data. The values of K_{rem} , the fraction of total water organic removed during wastewater treatment, are defined from Table 6.6A (New) - IPCC 2019 Refinement.

The following parameters have been applied to Equation 6.3B (New):

- i. S_{mass} , amount of raw sludge removed from wastewater treatment as dry mass: Company reported statistics of sludge removed (kg raw DM).
- ii. K_{rem} - sludge factor, kg BOD/kg sludge:
 - a. Mechanical treatment plants (primary sludge) – 0.5 kg BOD / kg dry mass sludge
 - b. Aerobic treatment plants with primary treatment (mixed primary and secondary sludge, untreated or treated aerobically) – 0.8 kg BOD / kg dry mass sludge.

The total amount of organically degradable material which is removed as sludge from homes connected to Private Septic Tank systems is calculated using Equation 6.3C (New) from the IPCC 2019 Refinement.

F , the fraction of the population managing their septic tank in compliance with the sludge removal instruction of their septic system, assume 50% in compliance. IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 6.

7.5.2.1.1.6 Secondary (aerobic) wastewater treatment [2] – CH₄

During intended operating conditions, aerobic treatment should lead to minimal CH₄ generation; this is illustrated in the 2006 IPCC default Methane Conversion Factor (MCF) of 0 for well-managed aerobic treatment. However, almost all wastewater undergoes aerobic treatment of some description in the UK, and any disruption to the process can lead to anaerobic pockets generating small quantities of CH₄, and some sites might see significant CH₄ emissions. The UK Carbon Accounting Workbook (CAW) includes an emission factor of 1.2 kg CH₄/t raw DS for typical wastewater treatment, and the 2019 refinement to the 2006 guidelines presents an MCF of 0.03, both alluding to a small, but significant CH₄ emission

source. As all of these emissions are subject to disruption to the intended functioning of the process, it is expected that these emissions will vary greatly between facilities.

The UK has adopted the MCF of 0.03 from the 2019 refinement (Table 6.3), and the maximum CH₄ producing capacity (B₀) of 0.25 kg CH₄/ kg BOD. The choice of B₀ value is discussed in **Section 7.5.2.1.6**.

CH₄ emissions from the wastewater treatment process are calculated using Equation 6.1 (Updated) from the IPCC 2019 Refinement. The method utilises Equation 6.1 calculated TOW_j, and S_j from **Sections 7.5.2.1.1.4** and **7.5.2.1.1.5** respectively. Activity data represents the BOD content of the wastewater (disaggregated per treatment type) after the sludge has been removed.

Emission factors have been chosen based on technology, as listed in Table 6.2, Table 6.3, and Equation 6.3 - IPCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 6.

Table 7.7 EFs, MCFs and B₀ values used for methane emissions from wastewater treatment

Parameter	Description	Value
B ₀	CH ₄ producing capacity for domestic wastewater	0.25 kg CH ₄ /kg
MCF _j	CH ₄ correction factor (fraction) – No treatment	0.0 kg CH ₄ / kg BOD
MCF _j	CH ₄ correction factor (fraction) – Primary Treatment	0.0
MCF _j	CH ₄ correction factor (fraction) – Secondary Treatment	0.03
MCF _j	CH ₄ correction factor (fraction) – Septic Tank Treatment	0.5
EF _j	CH ₄ emission factor – No treatment	0.0 kg CH ₄ / kg BOD
EF _j	CH ₄ emission factor – Primary Treatment	0.0 kg CH ₄ / kg BOD
EF _j	CH ₄ emission factor – Secondary Treatment	0.0075 kg CH ₄ / kg BOD
EF _j	CH ₄ emission factor – Septic Tank Treatment	0.125 kg CH ₄ / kg BOD

7.5.2.1.1.7 Secondary (aerobic) wastewater treatment [2] – N₂O

Secondary treatment uses aerobic biological processes to break down dissolved solid waste, primarily through trickling filters, activated sludge, and fixed-film systems, sometimes used in hybrid forms. Nitrous oxide (N₂O) emissions from these treatments vary widely and are highly sensitive to factors such as the specific process used, transit time, temperature, season, loading, and site-specific management practices. Evidence from the 2019 IPCC refinement highlights this variability, showing possible emissions ranging from –99% to +280% of the recommended emission factor. This project did not identify sufficient parameters or data to reliably capture such site-specific variation, and full representation would likely require direct monitoring.

Alternative emission factors from literature—such as Beyley et al. (2025), value of 0.0084 kg N₂O-N/kg N, based on Danish plants with extensive denitrification—were deemed unrepresentative of UK conditions, where intentional denitrification is less common. Other meta-analyses, like Haas and Andrews, suggest lower average emissions (1.1% vs. the IPCC refinement's 1.6%), but the relevance of their datasets to UK practices is uncertain and

underlying measurements still show wide variability. Given the lack of a more robust alternative, the 2019 IPCC refinement emission factor of 0.016 kg N₂O/kg N, with total nitrogen calculated according to Equation 6.9 (New) (IPCC, 2019).

Table 7.8 Emission factors used for N₂O emissions from wastewater treatment

Parameter	Description	Value
EF _j	N ₂ O emission factor – No treatment	0.00 kg N ₂ O-N/kg N
EF _j	N ₂ O emission factor – Primary Treatment	0.00 kg N ₂ O-N/kg N
EF _j	N ₂ O emission factor – Secondary Treatment	0.016 kg N ₂ O-N/kg N
EF _j	N ₂ O emission factor – Septic Tank Treatment	0.00 kg N ₂ O-N/kg N

7.5.2.1.1.8 Tertiary treatment [3]

Some biological tertiary treatments would be expected to result in further N₂O emissions and reduce N in effluent; however, many tertiary treatments are not relevant to either CH₄ or N₂O emissions (such as ultraviolet light treatment). It was also flagged to the UK Inventory Agency by an environmental regulator and wastewater consultants that in many cases, reported tertiary treatment can effectively mean an extension of secondary treatment where prior existing secondary treatment installed wasn't sufficient to comply with environmental standards required of effluents. This means that much of the tertiary treatment installed might be more representative of what the 2019 refinement describes as secondary treatment. Therefore, these emissions have been accounted for as part of the secondary treatment detailed above.

7.5.2.1.1.9 Water effluent [4] – CH₄

If any BOD remaining in effluent discharged to receiving waters decomposes under anaerobic conditions (e.g. if it is temporarily in stagnant water), then CH₄ emissions are expected. Most discharges are to running water, or to sea, and UK waters are relatively cold; therefore, in most cases, CH₄ emissions are expected to be limited.

The 2006 IPCC default emission factors do not account for the nature of receiving waters, but the 2019 refinement presents a Tier 2 methodology that accounts for the type of receiving waters; however, we have not identified a methodology that reflects UK-specific conditions. A study of wastewater discharges into Dutch rivers (Peterse et al., 2024) observed CH₄ emissions downstream of discharge points and showed that, even after treatment and in relatively cold, fast flowing receiving waters, CH₄ emissions remained clearly detectable. The observation of peak emissions occurring 2 km downstream of the discharge indicates that the methane measured was not generated at the treatment plant.

For CH₄ emissions, the activity represents the total BOD in the wastewater post-treatment (with BOD either removed in the sludge or breaking down and being released as an emission to air during treatment) based on Table 6.6b (fraction of total wastewater organics removed during wastewater treatment) in the 2019 Refinement (IPCC, 2019).

Table 7.9 **TOW_{REM} values used for estimating BOD in wastewater effluent**

Parameter	Description	Value
TOW _{REM}	Fraction of total wastewater organics removed – untreated system	0.00
TOW _{REM}	Fraction of total wastewater organics removed – primary treatment	0.40
TOW _{REM}	Fraction of total wastewater organics removed – secondary treatment	0.85
TOW _{REM}	Fraction of total wastewater organics removed – septic tanks	0.625

Emission factor for CH₄ emissions from wastewater discharged to aquatic systems have been assigned from Table 6.3 (Updated) in the IPCC 2019 Refinement. The application of an environment specific MCF is conducted by splitting up the effluent BOD data into individual water body types by applying the water discharge profile based on UWWTD Article 15 spatially resolved reporting. The emission factor is then calculated by multiplying the MCF by the B₀ value.

Table 7.10 **Parameters used for estimating methane emissions from wastewater effluent**

Parameter	Description	Value
B ₀	CH ₄ producing capacity for domestic wastewater	0.25 kg CH ₄ /kg ¹⁰⁸
MCF _j	Discharge to aquatic environments other than reservoirs, lakes, and estuaries (Tier 2)	0.035 kg CH ₄ / kg BOD
MCF _j	Discharge to reservoirs, lakes, and estuaries (Tier 2)	0.190 kg CH ₄ / kg BOD

7.5.2.1.1.10 Water effluent [4] – N₂O

Nitrogen that remains in the effluent after accounting for removal in sludge or treatment processes is assumed to contribute to N₂O emissions in receiving waters. The 2019 refinement to the 2006 IPCC guidelines (IPCC, 2019) approach presented in Volume 5, Chapter 6 is applied to this residual nitrogen. Activity Data is calculated by Equation 6.8 (Updated), which provides, per treatment type, an N removal fraction that accounts for N removed from wastewater through sludge removal or through nitrogen compounds being emitted to the atmosphere during treatment.

Table 7.11 **N_{REM} values used for estimating nitrogen in wastewater effluent**

Parameter	Description	Value
N _{REM}	Fraction of wastewater N removed – No treatment	0.00
N _{REM}	Fraction of wastewater N removed – Primary treatment	0.10
N _{REM}	Fraction of wastewater N removed – Secondary treatment	0.40

¹⁰⁸ The choice of B₀ value is discussed in **Section 7.5.2.1.6**.

Parameter	Description	Value
N _{REM}	Fraction of wastewater N removed – Septic Tank	0.15

N₂O emissions for residual N in effluent water are calculated through Equation 6.7 (Updated). Emission factors for N₂O emissions from wastewater discharged to aquatic systems are taken from IPCC guidelines, 2019 refinement (Table 6.8A). No methodology or data has been identified to assess nutrient-impacted or hypoxic conditions for marine, lake, or estuarine discharges, while river classifications were derived from UKCEH analysis. The river classifications only considered nutrient-impact, and we have not assessed the extent to which rivers are hypoxic. The selected emission factor is applied by allocating effluent nitrogen to specific receiving water types according to the discharge profile from the UWWTD Article 15 reporting and adjusting for the proportion of each water body type assessed as nutrient impacted.

Table 7.12 Emission Factors used for estimating N₂O emissions from wastewater effluent

Parameter	Description	Value
EF _{effluent}	Emission Factor for non-impacted water body, or water bodies where there is no assessment of whether they are nutrient-impacted and/or hypoxic	0.005 kg N ₂ O-N/kg N
EF _{effluent}	Emission Factor for a nutrient-impacted water body	0.019 kg N ₂ O-N/kg N

7.5.2.1.1.11 Storm tanks and storm discharges [5]

During periods of excessive rain, surface water can increase the quantities of wastewater received at wastewater treatment works beyond their capacity, and in these instances the excess water might be:

- discharged to waterways directly without treatment; or,
- the excess water might be sent to storm tanks where there is flow through treatment and settlement in the storm tank before either:
 - going through treatment when treatment plants have capacity to treat the additional load; or,
 - being discharged to waterways.

The UK has not identified suitable information to quantify how much degradable material that might be bypassing treatment due to storm discharges. However, it is expected that wastewater generated during these events would have a much lower BOD or N density than typical wastewater, as it is dominated by surface water, which will only include small quantities of material swept up with the rain (soil, leaves etc.). Note also that accounting for this would also lead to a reduction in estimated emissions from wastewater treatment, so the net impact on final emissions is expected to be limited.

Emissions might also occur while wastewater is stored in a storm tank, although again, we would expect emissions to be limited, but vary significantly per site, and data and methodologies on the quantity this is limited.

7.5.2.1.1.12 Off-grid wastewater treatment [13]

A small proportion of buildings in the UK are not connected to centralised municipal wastewater collection systems. While the flow diagram in **Figure 7.13** presents this as outside of the municipal wastewater system's scope, the UK's method for estimating emissions from these systems are presented alongside the calculations for municipal wastewater treatment (see **Sections 7.5.2.1.1.2, 7.5.2.1.1.5, 7.5.2.1.1.6, 7.5.2.1.1.7, 7.5.2.1.1.9, and 7.5.2.1.1.10**).

7.5.2.1.2 Sludge Management Processes

*The square brackets in the headings in this section relate to where in the flow diagrams in **Section 7.5.2.1** these processes appear.*

7.5.2.1.2.1 Mechanical treatment of sludge – thickening, drying, dewatering [6] – CH₄

CH₄ emissions from sludge processing are estimated using an emission factor of 0.9 g CH₄/m³ of sludge, adopted from Song et al. (2023), for mechanical sludge treatment steps such as thickening, dewatering, and storage. This factor is applied to the total quantity of sludge generated because all sewage sludge undergoes these processes regardless of whether anaerobic digestion is later used. Although previous UK CAW estimates applied a value of 1.5 kg CH₄ per tonne of raw dry solids, the Song et al factor is preferred due to its basis in a more recent and broader dataset.

To apply the volume-based emission factor, sludge quantities reported in dry weight units are converted to cubic metres using a density of 330 kg/m³, consistent with Environment Agency guidance (Environment Agency, 2014).

7.5.2.1.2.2 Mechanical treatment of sludge – thickening, drying, dewatering [6] – N₂O

N₂O emissions are not expected to be significant from this process, no methodology to estimate any emissions from this process has been identified.

7.5.2.1.2.3 Conventional and Advanced Digestion [7] – CH₄

Anaerobic digestion is treated as a controlled process in which sludge is decomposed under anaerobic conditions to maximise methane generation and enable methane capture. Most sewage sludge in the UK is treated using anaerobic digestion. The method distinguishes activity data between conventional and advanced digestion systems, however, the UK has not identified suitable information to reflect the impact of different digestion methods on methane emissions estimates in the UK's method.

The estimate of total organic component removed from wastewater (in the form of sludge), S_{aerobic}, is presented in **Section 7.5.2.1.1.5**. UK wastewater company reporting provides information on the proportion of sewage sludge that is digested.

Due to the high methane capture rates from anaerobic digestion, the UK finds that uncertainties in methane generation and methane content in captured sewage gas leads to implausible (e.g. negative values in some years) estimates of methane emissions when applying the Equation 6.1 from the 2006 IPCC guidelines (and the equivalent in the 2019 refinement). Because of this, the UK applies a modified version of this equation (**Equation 7.2**) which instead estimates emissions as a fraction of total methane generation expected when accounting for estimate methane capture rates.

A country-specific capture rate of 89.9% is applied, derived from the Howes et al. (2023) MEAD study. Although the sample did not include wastewater treatment works and was not designed to represent this sector, and although wastewater capture efficiency may be lower than that observed in the study, no alternative referenceable value is available. A comparative European study (Wechselberger et al., 2025) suggests a 93% capture rate but indicates strong sensitivity to whether digestate storage is gastight; UK sludge management commonly uses open storage, indicating that this higher capture rate is not suitable for UK conditions. Volume 5 Chapter 4 of the 2006 IPCC guidelines recommends a default of 5 percent leakage from

anaerobic digestion; however, it also indicates a range of 0-10 percent leakage can be expected, which the UK-specific values of 10.1% is only just outside.

Note that while this methane capture rate is used to calculate methane emissions, the UK uses company reported data on sewage gas flaring and utilisation when presenting methane capture in the CRT. This means that the implied methane capture rate when looking at these data will differ from the assumed methane capture rate used for methane emissions calculations.

Equation 7.2 Estimating methane emissions from anaerobic digestion of sewage sludge

$$Emission_{CH_4} = S_{aerobic} * B_0 * MCF * (1 - Cap_{rate})$$

Where:

- i. $S_{aerobic}$ = Organic component removed from wastewater (in the form of sludge) during aerobic treatment of wastewater
- ii. B_0 = CH_4 producing capacity for domestic wastewater
- iii. MCF = CH_4 correction factor
- iv. Cap_{rate} = Percentage of CH_4 captured

Table 7.13 Parameters used to estimate methane emissions from anaerobic digestion of sewage sludge

Parameter	Description	Value
B_0	CH_4 producing capacity for domestic wastewater	0.25 kg CH_4 /kg ¹⁰⁸
MCF	CH_4 correction factor	0.8
Cap_{rate}	Percentage of CH_4 captured (ratio)	0.899

7.5.2.1.2.4 Conventional and Advanced Digestion [7] – N_2O

The anaerobic conditions mean that there is insufficient oxygen to form N_2O , and emissions from this process are not expected.

7.5.2.1.2.5 Digestate storage [8]

In almost all cases, anaerobic digestion, and therefore CH_4 emissions continue after digestate has been removed from the digester, particularly when it is in temporary storage before disposal. The CH_4 generated by digestate is sensitive to how thorough the digestion of the sludge was, with longer retention reducing the potential for further CH_4 generation from digestate. Typically, this digestate would be stored on land, or in tanks, where we might expect CH_4 generation to be higher if stored in a tank, but also in some modern facilities tanks might be covered and CH_4 collected for oxidation. During this project we have not identified data on how much CH_4 is generated in digestate storage, or the proportion of each digestate storage practice.

These CH_4 emissions are accounted for as part of the anaerobic digestion emissions estimates (discussed in **Section 7.5.2.1.2.3**), where the Howes et al. CH_4 capture factor accounts for CH_4 losses in digestate storage, feedstock storage, and biogas management.

We have not identified a methodology to estimate N_2O from this process, however, we don't expect emissions to be significant from this process. Digestate continues to have depleted oxygen due to the anaerobic conditions during the digestion process, and digestate is

biologically decomposed material that reduces the opportunity for biological process to trigger N₂O emissions from occurring. Note also that the high N content of digestate makes it valuable as a fertiliser, indicating that most of the N is not being emitted as nitrogen compounds to air.

7.5.2.1.2.6 Composting [9] – CH₄ and N₂O

Composting is not widely used in UK sludge treatment, at <4% of total sludge treatment in all years, according to wastewater operators' reporting. While composting is an aerobic process, and therefore N₂O emissions are expected, CH₄ emissions can also occur if it is not well circulated. Note that, unlike anaerobic treatment, it is not routine to collect CH₄ from composting, and therefore, despite having lower CH₄ generation, final emissions from composting can be much higher than anaerobic digestion per unit of waste treated.

CH₄ and N₂O emissions from on-site composting are calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 4 Equations 4.1 and 4.2, and emission factors from Table 4.1. The estimate of total organic component removed from wastewater (in the form of sludge), is presented in **Section 7.5.2.1.1.5**. UK wastewater company reporting provides information on the proportion of sewage sludge that is composted.

Table 7.14 Emission factors used to estimate emissions from composting of sewage sludge

Parameter	Description	Value
EF _{CH₄}	CH ₄ emission factor for composting emissions.	10 g CH ₄ /kg waste
EF _{N₂O}	N ₂ O emission factor for composting emissions.	0.6 g N ₂ O/kg waste

7.5.2.1.2.7 Sludge disposal [10]

Most sewage sludge is sent for use as a fertiliser, and emissions from this use is reported as an agriculture source (See **Chapter 5**). Data on sludge used as a fertiliser will be delivered to the agriculture inventory team to ensure internal consistency, however the data are often not ready in time for use in agriculture estimates, so sometimes the data are updated the following year. The methodologies identified do not provide sufficient information for us to estimate the N content in sludge to help refine the agriculture emissions estimates. The N removal factors account for all types of N removal during treatment, notably including N released to the air as N₂, N₂O and other nitrogen compounds, meaning that the sludge doesn't retain all the N removed from wastewater.

Some sludge continues to be disposed to landfill or incineration, and emissions associated with those are reported in the NAEI as landfill (sector 5A) or incineration (section 5C) sources respectively.

In the 1990s, one of the main disposal routes for sludge was to be taken by barge out to sea and dumped. Emissions associated with this disposal route are not reported elsewhere, however, our understanding is that this settled sludge is expected to result in very low emissions, and we have not identified a methodology to quantify this.

UK sludge disposal reporting also suggests that some sludge is used for land reclamation and/or wetland restoration. These are relatively small quantities, and the reporting of this is limited (often these are included in 'other' disposal). This is not accounted for in the Land Use, Land Use Change and Forestry (LULUCF) team, and the IPCC guidelines doesn't provide guidance for this process. We have not identified any alternative methodologies to evaluate this potential source, and therefore have not made an estimate, however the small quantities

mean that it is likely a small source. We include this in the data on sewage sludge use as a fertiliser to be conservative.

7.5.2.1.2.8 Liquor treatment [16]

Sludge treatment generates a liquid by-product known as liquor, which contains substantially higher BOD and nitrogen concentrations than typical sewage. In most cases, this liquor is returned to the main treatment process, although some sites treat it separately prior to reintroduction. Because liquor has high pollutant loads, its treatment is expected to contribute additional emissions; however, no suitable data or methodological basis was identified to estimate these emissions, creating a gap in the current approach.

The method, therefore, assumes that any impacts arising from reintroducing liquor into the treatment stream are implicitly captured within existing IPCC wastewater treatment emission factors, while recognising that a more complete method may require explicit accounting for this process.

7.5.2.1.2.9 Liming [17] – CO₂

Liming involves adding limestone, dolomite or other alkaline materials to increase the pH of the sewage sludge, but this process causes the carbon in the alkaline material to be emitted as CO₂. This process is recognised as an emission source in the agriculture sector by the IPCC guidelines, as presented in Volume 4, Chapter 11.3.1, which provides an emission factor (CEF₀) of 0.12 kt CO₂ / kt limestone (IPCC, 2006).

The estimate of total organic component removed from wastewater (in the form of sludge), is presented in **Section 7.5.2.1.1.5**. UK wastewater company reporting provides information on the proportion of sewage sludge that is raw or limed. Wastewater company reported data does not distinguish between limed or raw sludge, so the Inventory Agency has assumed that any raw or limed sludge that isn't incinerated has been limed. It is expected that incinerated sludge would not benefit from liming and therefore would not be expected to be limed.

The UK has derived a sludge-specific limestone emission factor by combining parameters that determine how much limestone is needed to raise sludge pH, including horticultural guidance on the limestone application rate per unit of soil, and the difference between the initial sludge pH and the target pH. These parameters are converted into a factor representing the quantity of limestone required per unit mass of sludge. The default carbon emission factor for limestone application (kt C per kt limestone) is then multiplied by this sludge-specific limestone requirement, resulting in a final emission factor that quantifies the CO₂ emissions associated with liming sludge to the target pH.

Equation 7.3 presents how emissions are calculated for CO₂ emissions from liming.

Equation 7.3 Emissions calculation for liming of sewage sludge

$$\begin{aligned} \text{A) } \text{Emission Factor} \left(\frac{\text{kt C}}{\text{kt sludge}} \right) &= \text{CEF}_0 * L * \left(\frac{d}{p} \right) * \Delta pH \\ \text{B) } \text{Emissions}_{\text{CO}_2} (\text{kt CO}_2) &= \text{Activity} * \text{Emission Factor} \left(\frac{\text{kt C}}{\text{kt sludge}} \right) * \frac{44}{12} \end{aligned}$$

Where:

- i. ΔpH is the change in pH. The pH of sewage sludge of 7 (based on the Department for Environment 1996). Target pH of liming being 12 (based on Stehouwer 2023), making $\Delta pH = 5$;
- ii. L : limestone needed (kg m⁻²) to raise the pH by 1 in loam soil – 0.8 kg m⁻²;
- iii. d : Depth limed 0.2 m, based on Royal Horticultural Society guidance (RHS n.d.); and,

- iv. p : The density of soil, based on ‘Soils: an introduction to soils and plant growth of 1.5 kg m⁻³ (Donahue et al, 1977).

7.5.2.1.3 Sewage Gas Management Process

The square brackets in the headings in this section relate to where in the flow diagrams in Section 7.5.2.1 these processes appear.

7.5.2.1.3.1 Oxidation of sewage gas in on-site flares [11]

After biogas gas is captured from anaerobic digestion, as sewage gas mostly consists of CH₄, any leakage before oxidation will result in a CH₄ emission. However, CH₄ emissions are accounted for as part of the anaerobic digestion emissions estimates, where the Howes et al., CH₄ capture factor accounts for CH₄ losses in digestate storage, feedstock storage, and biogas management (discussed in Section 7.5.2.1.2.3).

CH₄ and N₂O emissions from on-site flaring of generated biogas are calculated using the following parameters. Activity data represents wastewater operator reporting statistics on biogas generation and emission factors from IPCC 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Stationary Combustion, Chapter 2: Stationary Combustion, Table 2.3 (Continued).

Table 7.15 Emission factors used to estimate emissions from sewage gas flaring

Parameter	Description	Value
EF _{CH4}	CH ₄ emission factor for flaring of biogas.	1 kg CH ₄ / TJ
EF _{N2O}	N ₂ O emission factor for flaring of biogas.	0.1 kg N ₂ O / TJ

7.5.2.1.3.2 Upgrading of sewage gas

As with the oxidation of sewage biogas, CH₄ losses can occur when sewage gas is upgraded to meet the standards required for injection into the UK’s natural gas distribution network. Because the standards required for injecting sewage gas into the grid are higher than those for use in sewage gas engines, this can lead to higher rates of flaring and venting of sewage gas, which may be less suitable for upgrading than at sites that do not upgrade sewage gas. Also similar to oxidation of sewage gas, CH₄ emissions are accounted for as part of the anaerobic digestion emissions estimates, where the Howes et al., CH₄ capture factor accounts for CH₄ losses in digestate storage, feedstock storage, and biogas management, including biogas upgrading (discussed in Section 7.5.2.1.2.3).

It is likely that the method of upgrading sewage gas would influence the CH₄ emissions (for example, as discussed in Hurtig et al., 2025)²³, however we have not identified suitable data to account for this.

7.5.2.1.4 Decomposition of fossil carbon to carbon dioxide in municipal wastewater

In the 2019 refinement to the 2006 IPCC guidelines (IPCC, 2019), Appendix 6A.1 presents a basis for future methodological development for estimating fossil CO₂ emissions from wastewater treatment and discharge. The 2019 refinement highlights that a potentially significant quantity of fossil carbon is co-discharged to sewers in the form of petroleum-derived products like “cosmetics; pharmaceuticals; surfactants; detergents and food additives (Law et al. 2013)”. While it would be expected that most petroleum products do not biodegrade, the 2019 refinement highlights research that indicates that at least some of these products do when co-discharged with wastewater, meaning that not all of the CO₂ emitted from wastewater and sewage sludge management, treatment, and discharge/disposal is of biogenic origin.

The UK has developed a methodology as presented in **Equation 7.4** to use the information in the 2019 refinement to calculate an estimate of emissions from this source.

Equation 7.4 Fossil CO₂ emissions calculation for decomposition of carbon in wastewater

$$fossil\ CO_2\ emissions = TOW * F_{TOC} * F_{fossilC} * CEF * \frac{44}{12}$$

Where:

- *TOW*: Total Organic Waste in units of BOD after the wastewater treatment process;
- *F_{TOC}*: Fraction of TOW that is Total Organic Carbon (TOC);
- *F_{fossilC}*: Fraction of TOC that is of fossil origin;
- *CEF*: Proportion of C in TOC emitted as CO₂; and,
- $\frac{44}{12}$: stoichiometric ratio of carbon to CO₂.

The values adopted for these parameters are:

- *TOW* is calculated as part of CH₄ emissions estimates and described in **Section 7.5.2.1.1.9**;
- *F_{TOC}* has been determined based on a CONCAWE (2022) report that COD = TOC * 3, and the IPCC default (IPCC, 2006) conversion between BOD and COD of 2.4, resulting in a final value of $1/(3 * 2.4) = 0.139$. Both the TOC/COD ratio and BOD/COD ratios were confirmed to be within the 'Medium' range presented in 'Biological Wastewater Treatment: Principles, Modelling and Design, Vazquez et al. (2023);
- For *F_{fossilC}*, a conservative value of 25% is used, which is towards the upper end of values presented in Table 6AP.1 in the 2019 refinement; and,
- For the *CEF*, the value of 0.43 was derived from the ratio of fossil C in TOC and proportion of TOC likely transformed to fossil CO₂ as presented in Law et al (2013).

7.5.2.1.5 Other Related Processes Outside of the Scope of the Municipal Wastewater Sector

The square brackets in the headings in this section relate to where in the flow diagrams in Section 7.5.2.1 these processes appear.

7.5.2.1.5.1 On-site industrial wastewater treatment [14]

Industries which generate significant quantities of wastewater often have on-site wastewater treatment, using many of the same processes as is used for municipal wastewater treatment. The extent of this treatment will vary by site, and in many cases treated industrial wastewater is still discharged to municipal sewers, or industrial sewage sludge collected for treatment at municipal wastewater treatment works; some industrial wastewater effluent is released directly to receiving waters without interacting with the municipal wastewater system at all.

Wastewater operators provide data on how much 'trade waste' is received, and this information is used to determine the industrial co-discharge treated in the municipal wastewater system (and therefore would be a double count if also included in industrial wastewater treatment).

Industrial wastewater emissions are reported in a separate category for UNFCCC reporting, and the NAEI have a separate model to estimate emissions from these processes (see **Section 7.5.2.2**). However, the estimates for centralised municipal wastewater treatment needs to account for the impact of industrial sources of wastewater and sludge that is received and treated in the municipal wastewater system. Note that this is additional to the

commercial/small industrial co-discharge that is accounted for in the IPCC guidelines equations (with a scaling factor of 1.25) for estimating municipal wastewater estimates.

7.5.2.1.5.2 Injection into the natural gas network [15]

As discussed in **Section 7.5.2.1.3.2**, some sewage biogas is upgraded and cleaned for injection into the natural gas distribution network. Any leaks from the natural gas network, and pre-ignition losses will result in CH₄ emissions, where a proportion of this CH₄ is ultimately derived from sewage gas.

Emissions from leakage from the natural gas distribution network and pre-ignition discharge are reported as a fugitive emission in the energy sector (see **Chapter 3**) and therefore excluded from municipal wastewater treatment emissions. It is useful for estimates of sewage gas injection to be tracked from the wastewater sector's perspective as a check against energy statistics reporting on this process.

7.5.2.1.6 Note on IPCC value for B₀

The 2006 IPCC guidelines present two values for the maximum CH₄ producing capacity (B₀):

- 0.6 kg CH₄/kg BOD
- 0.25 kg CH₄/kg COD

Our understanding was that the value on a COD basis is already the theoretical maximum, as stated in the 1996 IPCC guidelines (IPCC, 1997), and that the BOD value has been derived on the basis that typically there is a ratio of 2.4 between BOD and COD. However, the theoretical maximum on a COD basis would be if 100% of the COD is glucose, and this is also the case on a BOD basis, so in this case COD – BOD, and applying this conversion between *typical* COD and BOD leads to the 0.6 value not being theoretically possible.

This is discussed further in the 2019 refinement to the 2006 IPCC guidelines Volume 5, Chapter 6, Annex 6A.2.

Because of this, we have opted to deviate from the 2006 IPCC guidelines and adopt the theoretical maximum of 0.25 kg CH₄/kg BOD.

7.5.2.2 5D2: Industrial Waste-water Treatment

In the UK, a high proportion of industry trade wastewater is disposed to the municipal sewer system and treated by water operators together with the sewage and effluent from domestic and commercial sectors.

In the data reported by the water operators and used to generate methane emission estimates in 5D1 (see above), some of the annual reporting to water regulators includes explicit data on the COD from “trade waste” and the total COD treated (i.e. including domestic and commercial effluent) in the municipal systems. The share of total BOD that is attributable to the industry sector (i.e. “trade waste”, managed via contracts between water operators and industry operators) is variable across the UK and across years. This is removed from estimates of COD generated by industrial activity, to mitigate double-counting and leave only the COD treated through on-site treatment systems within the industrial sector. It is this source of emissions considered under CRT category 5D2.

In addition to the above, where large industrial sites that have on-site waste-water treatment plant are regulated under IPPC/EPR, the annual IPPC/EPR reporting to regulator inventories (PI/SPRI/NIPI) includes the requirement to report any methane emissions from the waste-water effluent plant. The PI/SPRI/NIPI data on methane emissions are used within the UK GHGI, and included within many CRT source categories, but the lack of source-specific detail in the PI/SPRI/NIPI reporting does not enable the waste-water treatment emission estimates from these industrial facilities to be split out and reported separately in the CRT.

In practice it is not straightforward to ascertain the extent to which emissions from waste-water treatment are consistently included in operator estimates across different industry sectors, as the IPPC/EPR data are not presented 'by source', but rather 'by installation'. Within sector-specific guidance to plant operators on pollution inventory data preparation, emissions of methane from wastewater treatment are not highlighted as a common source to be considered, whilst in guidance for several industrial sectors, wastewater treatment is singled out as a potentially significant source of ammonia and nitrous oxide emissions.

Therefore, some industrial waste-water treatment methane emissions are already reported within a range of CRT source categories, but cannot be quantified explicitly due to the lack of transparency of available source data from UK environmental regulatory reporting systems.

7.5.2.2.1 Summary of Estimation method for UK 5D2 Estimates

The UK uses the Tier 1¹⁰⁹ approach described in the 2019 refinement to the 2006 IPCC guidelines. This uses production data for each of the specific industries identified within the 2019 Refinement as wastewater intensive. Production data was sourced from Eurostat's 'Prodcom' database, which provides a detailed disaggregation of UK production by product. This enables a bottom-up approach to defining the coverage of each industry specified within the 2019 Refinement, by combining the production estimates for various products. In total, data for 476 individual products were sourced and allocated to industry sectors. As this data is used as the fundamental activity data for both Tier 1¹⁰⁹ estimates of CH₄ and N₂O emissions, this was a joint exercise for both pollutants. Industries highlighted as emissive for CH₄ emissions include:

- Alcohol refining
- Beer & malt
- Coffee
- Dairy products
- Fish processing
- Meat & Poultry
- Organic chemicals
- Petroleum refineries
- Soap & detergents
- Plastics & resins
- Pulp & Paper
- Starch production
- Sugar refining
- Vegetable oils
- Vegetables, fruits & juices
- Wine & vinegar

It should be noted that the Prodcom database typically includes production estimates for the UK from 1995 onwards, meaning production data prior to 1995, back to 1990, has been estimated using the 'splicing' techniques described in Section 5.3.3 of Volume 1, Chapter 5 of the 2006 IPCC Guidelines. A 'surrogate' approach is used, where a proxy dataset, related to the specific industry, is used to simulate the trend in activity data. Surrogates selected pertain to value indexes from the UK's Blue Book, an official dataset published by the ONS, describing

¹⁰⁹ Note that as reporting is done with respect to the 2006 IPCC guidelines as agreed by the UNFCCC, this means that as this is not the Tier 1 method from the 2006 guidelines, this will not be reported as a Tier 1 method in the UK's submission.

economic activity in the UK. Specific indexes were mapped onto specific industries above (e.g. the 'Manufacture of chemicals and chemical products' index was applied to the 'organic chemicals' sector) and the Blue Book dataset provides a timeseries back to 1990.

*[The UK activity data are summarised for selected years across the time series in **Annex 5.1.5.4**]*

In addition to the production data detailed above, the remainder of the estimation methodology for CH₄ is based on the combination of the following data and assumptions:

- Default values for Chemical Oxygen Demand (COD) per unit of wastewater, and amount of wastewater generated per tonne of industrial product, taken from Table 6.9 of Volume 5, Chapter 6, of the 2006 IPCC GLs or Table 6.12 of Volume 5, Chapter 6, of the 2019 Refinement to the 2006 IPCC GLs; complemented where possible by country-specific values derived from permits supporting the Industrial Emission Directive (IED) or values identified from literature research;
- The Factor B₀ (0.25 kg CH₄/kg COD), representing the IPCC COD-default factor for the maximum methane producing capacity of Industrial Wastewater;
- Default Methane Correction Factors for each type of treatment and discharge pathway or system, taken from Table 6.8 of Volume 5, Chapter 6, of the 2006 IPCC GLs;
- The percentage utilisation of treatment or discharge pathways sourced through analysing the Environment Agency's Discharge Consent Database. These are presented by industry, so that each industry has a specific treatment split, generating an industry specific weighted EF.
- There is no information currently available on how much sewage sludge is removed and sent to landfill or applied to agricultural land. Although it is likely that this activity does take place, due to the absence of information, the default value of zero has been used;
- There is no information on the amount of methane recovered, so the default value of zero has been used, although it is likely that this activity also takes place. There is some evidence from the UK and EU ETS dataset that several UK food and industry facilities collect methane from anaerobic digestion systems and use the gas as a fuel source.

CH₄ emissions from industrial wastewater treatment are calculated using the above data and assumptions in accordance with equations 6.4, 6.5 and 6.6 of Volume 5, Chapter 6, of the 2006 IPCC GLs.

N₂O emissions from industrial wastewater treatment are based on the same Prodcom data and wastewater generation factors detailed above, following equations 6.13 and 6.11 of Volume 5, Chapter 6, of the 2019 Refinement. The 2019 Refinement identifies the relevant industrial sectors as those listed in Table 6.12 of Volume 5, Chapter 6, including: alcohol refining, beer & malt, fish processing, iron and steel manufacturing, meat & poultry processing, nitrogen fertilisers, plastics and resins, and starch production. For these equations:

- Parameter TN_i, the total nitrogen in untreated wastewater for each industrial sector, uses the default factors presented in Table 6.12 of Volume 5, Chapter 6, of the 2019 Refinement;
- Emission factors for each treatment/discharge pathway or system are taken from Table 6.8A of Volume 5, Chapter 6, of the 2019 Refinement; and,
- The percentage utilisation of treatment or discharge pathways per industry, or parameter T_{ij} in equation 6.11, is the same as that used above for CH₄, for the purposes of consistency.

CH₄ and N₂O emissions from industrial wastewater from effluent discharge have been also estimated using the above data and the following assumptions in accordance with the equations in Vol. 5, Chapter 6 of the 2019 Refinement:

- The total nitrogen content in the industrial wastewater effluent discharged is calculated via Equation 6.11, which accounts for the fraction of nitrogen removed during treatment.
- The fraction of total wastewater nitrogen removed is taken from Table 6.10c. N₂O emissions from discharge of industrial wastewater is then estimated by combining $N_{\text{effluent,IND}}$ with the appropriate emission factors.
- Emission factors are taken from Table 6.8A of the 2019 Refinement and correspond to a Tier 1 approach, as this method relies on a single emission factor representing an average across nutrient-impacted aquatic environments (e.g. assumptions regarding denitrification rates in rivers or estuaries). A Tier 1 approach is considered appropriate given the level of data currently available.

7.5.2.3 Overseas Territories and Crown Dependencies

Estimates from the OTs and CDs are calculated using the Tier 1 approach from the 2006 IPCC Guidelines and default EFs. Country-specific parameters have been chosen based on information provided through a waste survey (distributed in 2014) and through expert judgement. Per capita protein consumption data were taken from FAOSTAT with data for Bermuda applied to all OTs other than Gibraltar, and data from the UK applied to all CDs and Gibraltar.

7.5.3 Uncertainties and Time-Series Consistency

As outlined in **Section 7.5.2**, the method for deriving methane emission estimates for 5D1 uses activity data from across the time series, and applies emission factors that are derived from reported emissions data from 2009 onwards. The method uses a published national set of activity statistics that reflect the changing fate of sewage sludge treatment and disposal; the UK water industry has undergone a marked shift in treatment and disposal practices since the Urban Waste-water Treatment Directive of 1999 banned the dumping of sewage to sea and in 2001 the same directive required all large WWTP to conduct secondary treatment; the sludge disposal trends are consistent with this regulatory change.

Not all UK water operators reported their emission estimates in all years since 2009, and the available dataset for deriving country-specific factors is limited in some cases to only around 50% coverage of UK water treatment and sludge treatment / disposal activity. The Inventory Agency has continued to develop working relationships with the 12 UK water operators and from 2013 onwards obtained activity and emissions data from all of the 12 water operators. Therefore, we have a much more complete, consistent set of activity and emissions data reported from across the UK. This helps to further develop the UK-specific dataset from which estimates can be derived, improving accuracy through accessing more complete, representative data which reflects the range of waste-water quality and the design / stock of waste-water treatment facilities across the UK.

The reported emissions and activity by UK water operators since 2013 has been used to derive country-specific emission factors for water treatment, methane capture, sludge treatment and most disposal routes, and these factors are applied to the activity dataset back to 1990. We are therefore using the best available data to estimate the emissions back to 1990. The use of the IPCC default for methane emissions from waste disposal to sea introduces a significant uncertainty to the early part of the time series where the activity is known to have taken place. This is because the IPCC default factor is for a wide range of situations including stagnant lakes with high organic loads in temperate climates, which would have very different emissive

behaviour to the cold, low organic load seas around the UK. Furthermore, the limited activity data time series for 5D1 due to changes in data reporting across the time series limits the accuracy and time series consistency of the estimates for the early part of the time series; however, it is observed that the overlaps in trend between the data sets typically show strong agreement.

The UK have included emissions estimates for sources where evidence is limited, such as methane emissions from sewers, mechanical treatment, and fossil CO₂ from the degradation of petroleum-based products disposed to municipal wastewater systems. Because of the limited information, there is very high uncertainty around the robustness of these methods for the UK inventory.

A major component of the UK wastewater emissions estimates relates to nitrous oxide emissions from secondary treatment of wastewater, where the uncertainty range given in the 2019 refinement is between -99% and +280% of the recommended emission factor. Our understanding is that emissions are extremely sensitive to individual site configuration and performance. This contributes to a significant overall uncertainty for municipal wastewater emissions, and additionally uncertainty to emissions trends, as it is possible that the significant changes to UK wastewater systems since 1990 would have resulted in changes to the N₂O intensity from UK wastewater treatment works over this time-period.

Another major component of the UK wastewater emissions estimates relates to methane emissions from anaerobic digestion of sewage sludge, where the intention is to capture methane. This means that a site operating perfectly might have nearly 100% lower emissions of a site with significant operating issues making emissions very sensitive to individual site configuration and performance. This contributes to a significant overall uncertainty for municipal wastewater emissions, and additionally uncertainty to emissions trends, as it is possible that the significant changes to UK wastewater systems since 1990 would have resulted in changes to the methane capture rates from UK wastewater treatment works over this time-period.

There is uncertainty within the approach for industrial wastewater owing to:

- Whether wastewater generation factors are appropriate, relative to wastewater practices in the UK. As a result, these should be periodically reviewed in compilation.
- The percentage utilisation of treatment or discharge pathways. This is currently based upon a one-off exercise and held constant for the timeseries but should be periodically updated when and if new data is made available. In addition, efforts should be made to determine changes in the percentage utilisation of treatment or discharge pathways over time, to represent improvement in treatment practice relative to legislation.
- The absence of data on methane capture likely leads to an overestimate of emissions.

See **Annex 5.1.5.4** for further details on the activity data, implied emissions factors and emissions estimates, and **Section 7.5.6** below for an insight into the planned improvements for this source method.

7.5.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Annex 4**.

During the development of the current Domestic Wastewater model, verification and comparison of the methodology was undertaken. Comparison of the parameters was conducted by comparing it with a Tier 1 default methodology set out in the 2006 IPCC guidelines. The comparisons between the base year of 1990 and 2023 for CH₄ and N₂O are

show in **Table 7.16** and **Table 7.17** respectively. The UK also investigated how the methodology compared to the water industry's Carbon Accounting Workbook (CAW).

7.5.4.1 Methane

The UK methodology for estimating methane emissions from wastewater significantly diverges from the 2006 IPCC default approach by adopting parameters from the 2019 IPCC refinement and integrating several UK-specific emission sources. While some core elements—such as per-capita BOD and industrial BOD correction factors—remain aligned with the IPCC defaults, the UK method introduces organics-removal fractions for different treatment stages (primary, secondary, septic) and includes quantification of organic material diverted into sludge during treatment. These parameters do not appear in the 2006 IPCC guidelines and allow for a more nuanced characterisation of treatment processes presented in the 2019 refinement. The UK approach also applies country-specific data for methane capture efficiency in anaerobic digestion, producing a slightly lower capture rate and therefore a correspondingly higher un-captured fraction when compared to the 2006 IPCC assumption.

A further difference arises from the inclusion of several methane-generating sources that are either absent from, or assumed to be negligible in, the 2006 IPCC guidelines. These include emissions from closed, flowing sewer networks (both gravity and rising mains), methane generation during mechanical sludge treatment, and updated methane correction factors for effluent based on recent literature. Additionally, the UK adopts a substantially lower value for the maximum methane-producing potential (B_0), justified in **Section 7.5.2.1.6**. Collectively, these updates result in significantly higher estimated UK emissions for 1990 compared with the IPCC range, as the UK method captures a wider range of emission pathways and applies more a detailed methodology.

Table 7.16 Comparison of IPCC and UK CH₄ parameters by source

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Degradable Organic component - BOD	60 g/person/day	60 g/person/day	Adopted method values are from the 2019 IPCC refinement. This feature is no different in the 2006 IPCC guidelines.
Correction factor for industrial BOD discharged in sewers	For collected the default is 1.25, for uncollected the default is 1.00	1.25	Adopted method values are from the 2019 IPCC refinement. This feature is no different in the 2006 IPCC guidelines.
Wastewater treatment organics removal fractions (towrem) - No Treatment	0	0.00	Adopted method values are from the 2019 IPCC refinement. This feature does not appear in the 2006 IPCC guidelines.

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Wastewater treatment organics removal fractions (towrem) - Primary Treatment	0	0.40	Adopted method values are from the 2019 IPCC refinement. This feature does not appear in the 2006 IPCC guidelines.
Wastewater treatment organics removal fractions (towrem) - Secondary Treatment	0	0.85	Adopted method values are from the 2019 IPCC refinement. This feature does not appear in the 2006 IPCC guidelines.
Wastewater treatment organics removal fractions (towrem) - Septic Tanks	0	0.625	Adopted method values are from the 2019 IPCC refinement. This feature does not appear in the 2006 IPCC guidelines.
Removal of organic component from wastewater as sludge - primary	Not applicable	0.5 kg BOD/kg dry mass sludge	Adopted method values are from the 2019 IPCC refinement. This feature does not appear in the 2006 IPCC guidelines.
Removal of organic component from wastewater as sludge - secondary.	Not applicable	0.8 kg BOD/kg dry mass sludge	
Fraction of generated CH ₄ that is captured.	0.95	0.899	Country specific - CH ₄ Emissions from Anaerobic Digestion (MEAD) study. 2006 IPCC guidelines suggested that 90-100% of CH ₄ from anaerobic digestion CH ₄ is captured in Volume 5 Chapter 4, with a suggested default of 95%. The value adopted is only just outside the range but is considered to be more accurate for the UK due to it being a UK-specific study.
Fraction of generated CH ₄ that is lost to the Atmosphere.	0.05	0.101	

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Maximum CH ₄ producing capacity (B ₀)	0.6	0.25	The 2006 IPCC guidelines present two values for the maximum methane-producing capacity (B₀): 0.6 kg CH₄/kg BOD and 0.25 kg CH₄/kg COD. The COD-based value represents the theoretical maximum, as noted in the 1996 guidelines, whereas the higher BOD-based value appears to result from applying a typical COD:BOD ratio of 2.4. However, because the theoretical maximum is the same on both a COD and BOD basis when assuming complete conversion of glucose, the 0.6 kg CH₄/kg BOD value is not theoretically achievable. This issue is discussed in a 2016 technical note for a European working group and in the 2019 refinement (Volume 5, Chapter 6, Annex 6A.2). On this basis, the UK methodology departs from the 2006 IPCC default and adopts 0.25 kg CH₄/kg BOD as the appropriate theoretical maximum for B₀.
MCF - no treatment	0	0	Adopted method values are from the 2019 IPCC refinement.
MCF - primary	0	0	
MCF - secondary	0 or 0.3 (centralized, aerobic treatment plant – well managed vs not well managed)	0.03	We consider that there should be small, but non-zero emissions from well-managed aerobic treatment, and hence the 2019 refinement value addresses this.
MCF - septic tank	0.5	0.5	
MCF – anaerobic digestion	0.8	0.8	Note that Volume 5 Chapter 4 of the 2006 IPCC guidelines presents an alternative method for anaerobic digestion which results in dramatically lower estimates of CH ₄ emissions, than using this MCF-based approach.
MCF – effluent	0.1	0.035-0.19	

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
CH ₄ emission factor for CH ₄ generation during gravity sewer network use	0	0.7 mg/L	Adopted method uses values from Song et al. Mechanical treatment of sludge not explicitly accounted for in the 2006 IPCC guidelines, or the 2019 refinement. Both the 2006 IPCC guidelines and the 2019 refinement treat flowing closed sewers as having zero CH₄ emissions (although it is acknowledged that emissions can occur).
CH ₄ emission factor for CH ₄ generation during rising main sewer network use	0	5.6 mg/L	
CH ₄ emission factor for emissions from mechanical treatment of sewage sludge	0	0.9 g CH ₄ /m ³	
Total Emissions for 1990	1.38 to 552 kt CO₂e	843 kt CO₂e	The wide range in the 2006 IPCC guidelines approach is driven by the choice of whether to use Chapter 4 or Chapter 6 methods for estimating anaerobic digestion emissions. This illustrates how sensitive overall CH₄ emissions are to anaerobic digestion emissions and/or assumed CH₄ capture rates. The adopted method is higher in the base year than even the higher 2006 IPCC approach due to including sources which are not captured in the 2006 IPCC guidelines (treated effluent and mechanical treatment of sludge), or that were presented as zero emissions in the 2006 IPCC guidelines (closed flowing sewers and well-managed aerobic treatment).

7.5.4.2 Nitrous Oxide

For N₂O emissions, the UK methodology also draws heavily on the 2019 IPCC refinement to develop a more comprehensive representation of nitrogen flows and emission processes than is provided in the 2006 IPCC guidelines. Several parameters are consistent between the two approaches—such as the nitrogen content of protein—but the UK method incorporates nitrogen added from household products (NHH), and nitrogen-removal fractions for primary, secondary, and septic treatment, which does not appear in the 2006 IPCC method. The UK method also bases its activity data on protein consumption that already reflects the proportion

of protein actually reaching wastewater systems, meaning that the UK implicitly accounts for a reduction relative to supply that doesn't appear in the IPCC default methodology.

Another major difference lies in how emissions from aerobic treatment is accounted for. The 2006 IPCC guidelines presents a modest emission factor for this source, but also recommends removing these emissions from effluent emissions to avoid double-counting, effectively making net emissions from this source zero. The 2019 refinement method adopted by the UK results in a modestly smaller estimated N in effluent (due to removal during aerobic treatment), but a much larger estimated N₂O emissions from aerobic treatment due to the treatment emission factors in the 2019 refinement being much higher than the 2006 IPCC default emission factor for effluent.

The UK also applies distinct emission factors for effluent discharged into nutrient-impacted versus non-impacted receiving waters. This reflects more recent scientific understanding of how nitrogen transformations differ depending on treatment and environmental context.

As a result, UK estimates for 1990 N₂O emissions are roughly three to four times higher than those generated under the 2006 IPCC approach. This increase is driven by the fact that most UK wastewater undergoes aerobic treatment, which has a higher emission potential than effluent-only pathways, and by the large proportion of nitrogen that continues to be released in treated effluent, even after accounting for removal within treatment processes.

Table 7.17 Comparison of IPCC and UK N₂O parameters by source

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Per capita protein consumption (kg/person/year)	Country-specific	27.1 to 30.0 kg protein/person/year	The UK range for 1990-2023
Fraction of N in protein (kg N/kg protein)	0.16	0.16	Adopted method values are from the 2019 IPCC refinement. This feature is no different in the 2006 IPCC guidelines.
Fraction of protein consumed	1	0.85	The UK value is not explicitly applied – as activity data is based on consumption which already reflected this parameter This parameter is not presented in the 2006 IPCC Guidelines, but effectively the value would be 1 as this is a scaling factor.

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Factor to adjust for non-consumed protein	1.1 for countries with no garbage disposals, 1.4 for countries with garbage disposals	1.09	Adopted method values are from the 2019 IPCC refinement. This value is lower than the 2006 IPCC parameter, however there is an additional parameter (N_{HH} below) in the 2019 refinement compared to the 2006 IPCC guidelines.
Factor to allow for co-discharge of industrial N into sewers	1.25 (For countries with significant fish processing plants, this factor may be higher. Expert judgment is recommended.)	1.25	Adopted method values are from the 2019 IPCC refinement. This feature is no different in the 2006 IPCC guidelines.
Additional N from household products added to the wastewater (N_{HH})	1	1.08	Adopted method values are from the 2019 IPCC refinement. This parameter is not presented in the 2006 IPCC Guidelines, but effectively the value would be 1 as this is a scaling factor.
Wastewater treatment N removal fractions (N_{rem}) - No treatment	0	0.00	Adopted method values are from the 2019 IPCC refinement. This feature is not present in the 2006 IPCC guidelines.
Wastewater treatment N removal fractions (N_{rem}) - Primary treatment	0	0.10	Adopted method values are from the 2019 IPCC refinement. This feature is not present in the 2006 IPCC guidelines.
Wastewater treatment N removal fractions (N_{rem}) - Secondary treatment	0	0.40	Adopted method values are from the 2019 IPCC refinement. This feature is not present in the 2006 IPCC guidelines.

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Wastewater treatment N removal fractions (Nrem) - Septic tank treatment	0	0.15	Adopted method values are from the 2019 IPCC refinement. This feature is not present in the 2006 IPCC guidelines.
Emission factor for secondary treatment	0	0.016 kg N ₂ O-N/kg N	Adopted method values are from the 2019 IPCC refinement. Note that while the 2006 IPCC guidelines presented a method for emissions from wastewater treatment, the method for accounting for the reduction in N in effluent was crude, and effectively led to no change in final total emissions, and hence for this exercise it is presented as 0.
Emission factor used to calculate the emission of N ₂ O from effluent water post treatment activity, non-nutrient-impacted	0.005	0.005 kg N ₂ O-N/kg N	Adopted method values are from the 2019 IPCC refinement. This feature is no different in the 2006 IPCC guidelines.
N ₂ O emission factor for N ₂ O emissions from effluent water, primary treatment, Nutrient-impacted	0.005	0.019 kg N ₂ O-N/kg N	Adopted method values are from the 2019 IPCC refinement. The 2006 IPCC guidelines did not present emission factors depending on the nature of receiving waters.
Total Emissions for 1990	732 kt CO₂e	2,474 kt CO₂e	

Source/Parameter	2006 IPCC Default Parameter	UK Parameter	Comments
Total Emissions for 2023	856 kt CO _{2e}	3,422 kt CO _{2e}	N₂O emissions are dominated by aerobic treatment and N in effluent. We would expect the adopted method's emissions to be 3-4 times higher than the 2006 IPCC guidelines approach given that: The 2006 IPCC default is dominated by N in effluent; the emission factor adopted for aerobic treatment is roughly triple the emission factor for N in effluent; almost all water goes through aerobic treatment in the UK; even accounting for N removal in treatment, a very large proportion of N is still released in effluent.

7.5.5 Source Specific Recalculations

The following recalculations apply to the estimates submitted in this compilation cycle:

- Implementation of the new municipal wastewater model where the largest changes are:
 - Increase to N₂O emissions in all years due to estimating emissions from aerobic treatment, which has a much higher emission factor than the emission factor for N discharged to receiving waters and represents an almost tripling in N₂O emissions estimates from this sector;
 - Decrease to CH₄ emissions in the 1990s due to using a lower value for the maximum CH₄ producing capacity;
 - Increase to CH₄ emissions after ~2000 due to estimating emissions associated with Biological Oxygen Demand (BOD) remaining in effluent discharged to receiving waters; Increase to CH₄ emissions in all years, but more in later years than the 1990s due to the 2019 methodology combined with UK-specific CH₄ capture rates resulting in higher emissions than the previous CAW-based method;

- Increase to CH₄ emissions in all years due to introducing an estimate of emissions from sewers;
 - New estimates of CO₂ emissions from liming and decomposition of materials with fossil Carbon content where previously no estimate was made; and,
 - A number of further changes with smaller impacts.
- Estimates for CH₄ and N₂O emissions from industrial wastewater discharges have been included in this submission where previously emissions were not estimated.
- Use of ONS population statistics for 2024.
- Estimates for CH₄ and N₂O emissions from industrial wastewater treatment for 5D2 have been revised in this submission. This is primarily due to the adjustment to the activity data (e.g. the industrial production estimates for various products allocated to industry) revision to the approach to splicing and gap-filling of various datasets used.

For information on the magnitude of recalculations, see **Section 10**.

7.5.6 Source Specific Planned improvements

During the development of the current wastewater model, recommendations for further improvements were collated and will be considered in any future further development of emissions estimates. Many of these recommendations are likely to require additional research and/or monitoring.

8 Other (CRT Sector 6)

8.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 6.

9 Indirect CO₂ and Nitrous Oxide Emissions

9.1 DESCRIPTION OF SOURCES OF INDIRECT EMISSIONS IN GHG INVENTORY

The calculation of indirect CO₂ and N₂O is not mandatory. The UK calculates indirect emissions of N₂O from emissions of NO_x and NH₃ from non-AFOLU sources. These are reported as a memo item.

The methods and data sources for the calculation of NO_x and NH₃ emissions are described in the UK's Informative Inventory Report (IIR), as submitted under the Convention on Long Range Transboundary Air Pollution.

9.2 METHODOLOGICAL ISSUES

Emissions of indirect N₂O are calculated using Equation 7.1 of Volume 1 of IPCC, 2006. EF₄ within the equation is the IPCC default of 0.01 kg N₂O-N/kg NH₃-N or NO_x-N emitted.

9.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

No formal uncertainty or trend analysis for indirect N₂O emissions has been carried out. Uncertainties and trends for NO_x and NH₃ are described in the IIR.

9.4 CATEGORY-SPECIFIC QA/QC AND VERIFICATION

Emissions of NO_x and NH₃ reported under the GHG inventory are cross checked with those reported under CLRTAP and are consistent.

9.5 CATEGORY-SPECIFIC RECALCULATIONS

Indirect nitrous oxide emissions will change in line with changes made to the NO_x and NH₃ inventories. These are described in the IIR.

9.6 CATEGORY-SPECIFIC PLANNED IMPROVEMENTS

Indirect nitrous oxide emissions will change in line with changes made to the NO_x and NH₃ inventories. Air quality pollutants are subject to a separate improvement programme to the GHG inventory, this is described in the IIR

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2025 NID submission (1990-2023 inventory), including responses to the review of the UK inventory via the in-country review of the UK's First Biennial Transparency Report (BTR1) during summer 2025. It summarises material that has already been presented and discussed in more detail in **Chapter 3** to **Chapter 7**.

Each year, the UK greenhouse gas inventory is updated, extended, and may be expanded.

Updating the inventory includes revision of emission estimates, often due to updates to UK activity data, for example, due to revisions to historic data within UK statistics such as the Digest of UK Energy Statistics (DUKES) or other key data inputs (see Table 1.4 for more examples). Updates to the inventory may also include the adoption of revised methodologies, the use of new emissions data and/or emission factors, or revisions to assumptions to improve the representation of the inventory to reflect UK circumstances, for example, to address UK data gaps.

Inventory revisions must be implemented such that the time series consistency of the UK inventory is maintained, and hence a UK inventory update may affect the whole time series; therefore, estimates of emissions from a given source/sink and for a given year may differ from estimates of emissions for the same year reported previously.

In this chapter, we present comparisons between emission estimates from the latest submission and from previous submissions and summarise the key reasons for recalculations, which may include changes to:

- the emission estimation methodology, including revisions to emission factors, assumptions, or conversion factors;
- UK emissions data (e.g. from operator-reported emission measurements) and/or activity data; and /or
- the inventory compilation and reporting guidelines under which the submissions are made. For example, UK methods in this submission primarily align with methods from the 2006 IPCC Guidelines, the 2013 Wetlands Supplement, and the 2019 Refinement to the 2006 Guidelines (for details, see individual method descriptions in Chapters 3 to 7). This UK submission also aligns with the Modalities, Procedures and Guidelines (MPGs) to the Enhanced Transparency Framework (ETF) under the Paris Agreement.

The time series of the UK inventory is **extended** by including a new inventory year. For example, the previous report covered years up to and including 2023. This report gives emission estimates for 2023 and also includes estimates for the year 2024.

The scope of the UK inventory may also be **expanded** to include emissions from additional sources/sinks, where a new source/sink is found to be occurring within the UK, where activity data and emission factors are available to implement an appropriate inventory methodology, and where a method can be implemented and reported that aligns with the prevailing IPCC methodological guidelines, the UNFCCC Reporting Guidelines and Paris Agreement ETF MPGs. In these cases, new emission estimates are compiled and reported for the full time series, i.e. from the Base Year to the latest year.

10.1

EXPLANATIONS AND JUSTIFICATIONS FOR RE-CALCULATIONS, INCLUDING IN RESPONSE TO THE REVIEW PROCESS

Table 10.1 R to

Table 10.14 summarise the recalculations that have occurred in estimates of CO₂, CH₄, N₂O and F-gases since the 2025 NID submission (1990-2023 inventory). The changes in emissions are net changes (the sum of any increases and decreases) in the source category, for each GHG in the Base Year (1990) (1995 for F-gases) and latest recalculated year (2023).

Table 10.15 summarises where changes to methodological descriptions have been made and where these descriptions can be found in the main text of this document.

All revisions to source data and methods, and all recalculations that are reported in the latest UK GHG inventory are conducted by the Inventory Agency in agreement with the DESNZ GHG inventory management team; all major recalculations and systematic improvements to the UK GHG inventory are approved and managed via the National Inventory Steering Committee (NISC), with new outputs approved through the UK's system for pre-submission review. The inventory improvement process that manages the prioritisation and implementation of revisions to inventory data and methods uses the guiding principles of the 2006 IPCC Guidelines to govern the decisions over whether to implement changes to inventory estimates or not. The most common justifications for implementing changes that lead to recalculations are aligned to IPCC good practice data quality objectives, including

- ✓ Improved **transparency** of the inventory estimates, e.g. the restructuring of inventory data reporting to improve the level of detail of the UK inventory (e.g. the reporting of F-gas estimates by species wherever this is achievable);
- ✓ Improved **comparability** of the inventory estimates, e.g. the restructuring of inventory data reporting to enable UK estimates to align more closely with IPCC Guidelines and Good Practice Guidance and to match the data resolution as defined within the Common Reporting Tables that are mandated under the Paris Agreement ETF.;
- ✓ Improved **completeness** of the inventory estimates, e.g. the addition of emission estimates for new sources/sinks that occur in the UK, or where new data for an existing source indicates that the activity data previously used in the method omitted some portion of the source/sink emissions.
- ✓ Improved **consistency** of the inventory estimates, e.g. to implement new or revised methods that deliver estimates based on more consistent underlying data or assumptions across the time series;
- ✓ Improved **accuracy** of the estimates, e.g. where underlying data from data providers has been revised (e.g. revisions to energy statistics), where less uncertain data are now available (e.g. use of ETS activity data to inform energy allocations, in preference to UK energy statistics data sources), or where the Inventory Agency has applied more representative (ideally country-specific) EFs in estimation methods.

Table 10.1 Recalculations to CO₂ in 1990 (kt CO₂)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					
A. Fuel combustion activities	551,015.40	547,310.01	-3,705.39	-0.67%	See explanations below in individual categories
1. Energy Industries	238,063.89	237,966.64	-97.25	-0.04%	No significant recalculations
2. Manufacturing industries and construction	72,657.49	72,770.54	113.05	0.16%	Recalculation due to the Gas Oil time-series improvement work, which has recalculated the time-series based on how the reconciliation assigns Gas Oil to Other Industry
3. Transport	121,107.11	118,009.46	-3,097.64	-2.56%	Implementation of new methodology for shipping, incorporating 2019 international AIS data, revised emission factors and assumptions from the DfT's MEM and a fundamental shift from a "fuel used" to "fuel sold" approach.
4. Other sectors	113,893.48	113,270.09	-623.39	-0.55%	Recalculations due to: Gas Oil time-series improvement work, revisions to estimates for fishing vessels due to the shipping model improvements, and revisions to parameters for peat in the residential sector
5. Other	5,293.44	5,293.28	-0.16	0.00%	No significant recalculations
B. Fugitive emissions from fuels	6,787.07	6,787.07	0.00	0.00%	See explanations below in individual categories
1. Solid fuels	1,698.56	1,698.56	0.00	0.00%	No significant recalculations
2. Oil and natural gas	5,088.51	5,088.51	0.00	0.00%	No significant recalculations

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial Processes and product use					
A. Mineral industry	10,234.92	10,234.86	-0.06	0.00%	No significant recalculations
B. Chemical industry	6,975.59	6,975.59	0.00	0.00%	No significant recalculations
C. Metal industry	25,445.62	25,447.75	2.13	0.01%	No significant recalculations
D. Non-energy products from fuels and solvent use	552.78	552.78	0.00	0.00%	No significant recalculations
G. Other product manufacture and use	0.00	NO			
H. Other	0.00	IE,NE,NO			
3. Agriculture					
G. Liming	1,023.85	1,023.85	0.00	0.00%	No significant recalculations
H. Urea application	294.01	293.63	-0.38	-0.13%	No significant recalculations
4. Land use, Land-use change and forestry					
A. Forest land	-14,302.91	-14,755.14	-452.23	3.16%	The main cause of this change was updates to activity data and to the CARBINE model.
B. Cropland	14,234.69	14,239.28	4.59	0.03%	No significant recalculations
C. Grassland	-636.54	-620.99	15.56	-2.44%	Changes are due to carbon stock change as a result of changes in deforestation activity data and new peatland restoration data.
D. Wetlands	573.06	525.84	-47.22	-8.24%	Changes in domestic peat extraction activity data
E. Settlements	5,409.58	5,417.36	7.78	0.14%	Changes are due to updates to deforestation activity data and

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
					updates to the CARBINE modelling of the impact the biomass and dead organic matter losses following deforestation.
G. Harvested wood products	-2,104.72	-1,995.72	109.00	-5.18%	Changes are due to updated wood production estimates, and updates to the CARBINE model providing a closer alignment to total wood production.
5. Waste					
C. Incineration and open burning of waste	1,222.81	791.49	-431.32	-35.27%	Research into DUKES data on non-renewable wastes highlighted that chemical waste was accounted for there. Hence, separate estimates of chemical waste incineration emissions from operator reporting have been removed as they were a double-count.
D. Wastewater treatment and discharge	0	129.29	129.29		New methodology developed and implemented for the estimation of fossil CO ₂ emissions from wastewater treatment and discharge

Table 10.2 Recalculations to CO₂ in 2023 (kt CO₂)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
A. Fuel combustion activities	289,717.33	289,353.02	-364.31	-0.13%	See explanations below in individual categories
1. Energy Industries	67,819.14	69,265.54	1,446.40	2.13%	Recalculation due to DUKES revisions affecting Natural Gas; Municipal solid waste: biomass fraction and Municipal solid waste: non-biomass fraction.
2. Manufacturing industries and construction	33,062.26	32,277.72	-784.54	-2.37%	Recalculation due to revised DUKES statistics for Gas and Oil.
3. Transport	108,298.63	107,587.38	-711.25	-0.66%	Recalculation due to the Road Transport model using actual ANPR data for 2023, implementation of the DfT Maritime Emissions Model, with fuel use constrained to DUKES.
4. Other sectors	79,078.52	78,763.59	-314.93	-0.40%	Recalculation mostly due to DUKES revisions; which is then further split into biogas from the natural gas based on data from DUKES on the quantity of biogas injected into the grid.
5. Other	1,458.79	1,458.79	0.00	0.00%	No significant recalculations
B. Fugitive emissions from fuels	2,580.20	2,271.96	-308.23	-11.95%	See explanations below in individual categories
1. Solid fuels	123.97	123.32	-0.65	-0.52%	Method change to use 5-year average values from 2017-2021, in place of carbon balance approach
2. Oil and natural gas	2,456.22	2,148.64	-307.59	-12.52%	Revisions to "other fugitives" emissions to fully utilise ETS statistics
2. Industrial processes and product use					
A. Mineral industry	5,203.67	5,197.36	-6.31	-0.12%	Replacement of extrapolated statistics with updated data from

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
					latest BGS Yearbook, replacing activity data for 2023
B. Chemical industry	1,514.93	1,665.80	150.87	9.96%	Revision to allocations of the ETS dataset for petrochemical sites where “fuel gas” was previously allocated to “natural gas” from the gas supply grid (1A2c: chemical sector gas use) but now allocated to process off-gases and reported as OPG use in 2B8.
C. Metal industry	10,765.35	8,700.90	-2,064.45	-19.18%	Method change to use 5-year average values from 2017-2021, in place of carbon balance approach. See Energy chapter, Method Statement 4, for more details.
D. Non-energy products from fuels and solvent use	466.08	434.02	-32.06	-6.88%	Revisions to DUKES petroleum coke data, and revision to estimate for petroleum coke in the residential sector, which impacts the amount allocated to non-energy use.
G. Other product manufacture and use	0.00	0.00	0.00	0.00%	No significant recalculations
H. Other	0.00	0.00	0.00	0.00%	No significant recalculations
3. Agriculture					
G. Liming	1,190.41	1,190.41	0.00	0.00%	No significant recalculations
H. Urea application	401.55	405.99	4.44	1.10%	Update to data for quantity of fertiliser spread
4. Land use, land-use change and forestry					

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
A. Forest land	-18,049.50	-18,691.33	-641.82	3.56%	Updates to the CARBINE model, wildfire activity data and forest land activity data.
B. Cropland	12,497.08	12,533.05	35.97	0.29%	No significant recalculations
C. Grassland	-2,878.71	-3,002.94	-124.23	4.32%	Updates to organic soil areas and deforestation activity data and CARBINE model.
D. Wetlands	725.26	662.78	-62.47	-8.61%	Updates to organic soil areas, domestic peat extraction activity data, forest rewetting activity data and CARBINE model.
E. Settlements	3,953.35	3,942.85	-10.51	-0.27%	No significant recalculations
G. Harvested wood products	-2,182.70	-2,118.23	64.48	-2.95%	Updates to wood production estimates and CARBINE model.
5. Waste					
C. Incineration and open burning of waste	251.75	47.77	-203.98	-81.03%	Research into DUKES data on non-renewable wastes highlighted that chemical waste was accounted for there. Hence, separate estimates of chemical waste incineration emissions from operator reporting have been removed as they were a double-count.
D. Wastewater treatment and discharge	0	140.02	140.02		New methodology developed and implemented for the estimation of fossil CO ₂ emissions from wastewater treatment and discharge

Table 10.3 Recalculations to CH₄ in 1990 (kt CO₂ eq)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					
A. Fuel combustion activities	3,596.33	3,605.85	9.52	0.26%	See explanations below in individual categories
1. Energy Industries	244.72	243.34	-1.38	-0.56%	No significant recalculations
2. Manufacturing industries and construction	96.83	96.96	0.12	0.13%	Recalculation due to gas oil time series improvement
3. Transport	1,275.35	1,278.25	2.89	0.23%	Application of emission factors from DfT Maritime Emissions model, and fuel use data now constrained to DUKES
4. Other sectors	1,975.44	1,982.73	7.28	0.37%	Peat calculations were revised to use consistent parameters, including updated assumptions on calorific value, moisture, and carbon content
5. Other	3.98	4.59	0.61	15.25%	Recalculation due to the DfT shipping model providing a higher emission factor for naval shipping
B. Fugitive emissions from fuels	38,268.27	38,268.33	0.06	0.00%	See explanations below in individual categories
1. Solid fuels	24,446.08	24,446.08	0.00	0.00%	No significant recalculations
2. Oil and natural gas	13,822.19	13,822.25	0.06	0.00%	No significant recalculations
2. Industrial processes and product use					
A. Mineral industry	34.84	34.84	0.00	0.00%	No significant recalculations
B. Chemical industry	248.23	248.23	0.00	0.00%	No significant recalculations
C. Metal industry	43.92	43.92	0.00	0.00%	No significant recalculations

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
3 Agriculture					
A. Enteric fermentation	27,691.74	28,042.42	350.68	1.27%	Re-parameterisation of the dairy cattle growth curve using slaughter-weight data, leading to an increase in liveweight of dairy animals and enteric CH ₄ emissions. Update to the metabolisable energy content of grass in preferential grazing areas for rapidly growing lambs and lactating ewes in the sheep sector, leading to increased enteric CH ₄ emissions
B. Manure management	4,642.94	4,692.76	49.82	1.07%	Re-parameterisation of the dairy cattle growth curve using slaughter-weight data, leading to an increase in the liveweight of dairy animals and manure management CH ₄ emissions. A downward adjustment to the assumed metabolisable energy density of grazed grass for rapidly growing lambs and lactating ewes, leading to an increase in total dry matter intake to meet the energy requirements of an animal
F. Field burning of agricultural residues	209.71	209.71	0.00	0.00%	No significant recalculations

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
4. Land use, land-use change and forestry					
A. Forest land	99.38	99.62	0.25	0.25%	Updates to the CARBINE model, wildfire activity data, and forest land activity data.
B. Cropland	332.60	332.62	0.02	0.01%	No significant recalculations
C. Grassland	2,811.73	2,820.94	9.21	0.33%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
D. Wetlands	2,309.21	2,306.48	-2.73	-0.12%	Updates to organic soil areas, domestic peat extraction activity data, forest rewetting activity data and CARBINE model.
E. Settlements	19.03	19.36	0.33	1.72%	Updates to organic soil areas, deforestation activity data and CARBINE model.
5. Waste					
A. Solid waste disposal	66,245.17	49,336.43	-16,908.73	-25.52%	The landfill model now uses gross GDP to estimate solid waste disposal where data is missing, replacing the previous method based on household and employment statistics. This change improves consistency with IPCC guidelines, especially for pre-1997 data where reliable records aren't available.
B. Biological treatment of solid waste	20.31	20.31	0.00	0.00%	no significant recalculations
C. Incineration and open burning of waste	243.98	253.79	9.81	4.02%	Revisions to bonfire activity data by adding 11 th night data from Northern Ireland

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
D. Wastewater treatment and discharge	1,924.00	1,933.69	9.69	0.50%	Implementation of the new domestic wastewater model developed during the GHGIIP Programme. Inclusion of industrial wastewater CH ₄ emissions from discharge

Table 10.4 Recalculations to CH₄ in 2023 (kt CO₂ eq)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					
A. Fuel combustion activities	1,414.30	1,423.22	8.92	0.63%	See explanations below in individual categories
1. Energy Industries	350.15	356.77	6.62	1.89%	Recalculation due to DUKES revisions to Natural Gas; Municipal solid waste: biomass fraction and Municipal solid waste: non-biomass fraction
2. Manufacturing industries and construction	103.62	104.85	1.23	1.19%	Reallocations within 1A2 to align biofuel reporting with other fuels. Overall emissions impacted by DUKES revisions
3. Transport	85.01	91.26	6.25	7.36%	Recalculation is due to the implementation of the DfT Maritime Emissions model, with fuel use now constrained to DUKES totals
4. Other sectors	874.49	869.13	-5.36	-0.61%	Multiple interconnected changes for residential combustion, overall recalculation is largely due to DUKES revisions and an updated ECUK split

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
5. Other	1.04	1.21	0.18	17.10%	Recalculation due to the application of emission factors from the DfT Maritime Emissions model for naval shipping and update activity statistics
B. Fugitive emissions from fuels	4,658.88	4,554.35	-104.54	-2.24%	See explanations below in individual categories
1. Solid fuels	676.10	676.10	0.00	0.00%	No significant recalculations
2. Oil and natural gas	3,982.79	3,878.25	-104.53	-2.62%	Minor recalculations in 2021-2023 to estimates of Northern Ireland gas leakage
2. Industrial processes and product use					
A. Mineral industry	4.84	4.84	0.00	0.00%	No significant recalculations
B. Chemical industry	16.51	15.67	-0.84	-5.09%	Update to correct closure dates for two UK chemical sites (acrylonitrile and acrylics) removing process emissions that were previously estimated for 2023, via extrapolation of historic PI data.
C. Metal industry	10.05	10.03	-0.01	-0.13%	Revision to data for a single site, based on stakeholder consultation.
3 Agriculture					
A. Enteric fermentation	23,041.58	23,339.59	298.00	1.29%	Re-parameterisation of the dairy cattle growth curve using slaughter-weight data, leading to an increase in liveweight of dairy animals and enteric CH ₄ emissions. Update to the

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
					metabolisable energy content of grass in preferential grazing areas for the rapidly growing lamb and lactating ewes in the sheep sector, leading to an increase in enteric CH ₄ emissions.
B. Manure management	4,134.06	4,156.66	22.59	0.55%	Re-parameterisation of the dairy cattle growth curve using slaughter-weight data, leading to an increase in liveweight of dairy animals and manure management CH ₄ emissions. Updated data on amount of manure destined for anaerobic digestion. A downward adjustment to the assumed metabolisable energy density of grazed grass for rapidly growing lambs and lactating ewes leading to an increase in total dry matter intake to meet the energy requirements of an animal.
4. Land use, land-use change and forestry					
A. Forest land	123.54	131.07	7.53	6.10%	Updates to the CARBINE model, wildfire activity data and forest land activity data.
B. Cropland	316.84	317.98	1.14	0.36%	Updates to organic soil areas, wildfire activity data and CARBINE model.
C. Grassland	2,876.34	2,881.37	5.03	0.17%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
D. Wetlands	2,405.31	2,399.09	-6.22	-0.26%	Updates to organic soil areas, domestic peat extraction activity

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
					data, forest rewetting activity data and CARBINE model.
E. Settlements	31.30	31.11	-0.19	-0.61%	Updates to organic soil areas, deforestation activity data and CARBINE model.
5. Waste					
A. Solid waste disposal	14,587.85	13,109.80	-1,478.05	-10.13%	Revision due to Solid Waste improvement – reductions to landfilled waste in the early part of the time series continue to impact on methane generation in later years, plus revisions to data for landfill gas captured for electricity production in 2023
B. Biological treatment of solid waste	1,457.69	1,475.93	18.24	1.25%	Correction of formula for number and capacity of MBT sites
C. Incineration and open burning of waste	39.39	51.86	12.47	31.66%	Revisions to bonfire activity data by adding 11th night data from Northern Ireland
D. Wastewater treatment and discharge	2,083.65	3,143.59	1,059.94	50.87%	Recalculation due to the GHGIIP incorporation of the wastewater model.

Table 10.5 Recalculations to N₂O in 1990 (kt CO₂ eq)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					
A. Fuel combustion activities	3,131.92	3,069.61	-62.32	-1.99%	See explanations below in individual categories
1. Energy Industries	1,277.61	1,275.87	-1.74	-0.14%	No significant recalculations
2. Manufacturing industries and construction	222.37	222.60	0.23	0.10%	Recalculations due to implementation of gas oil time series improvements

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
3. Transport	1,196.33	1,145.31	-51.02	-4.26%	Recalculation is due to the implementation of the DfT Maritime Emissions model, with fuel use now constrained to DUKES totals.
4. Other sectors	385.71	377.08	-8.63	-2.24%	Impacted by the implementation of gas oil time series improvements, and the implementation of the DfT Maritime Emissions model, with fuel use now constrained to DUKES totals
5. Other	49.91	48.75	-1.16	-2.33%	Recalculation due to the application of emission factors from DfT Maritime Emissions model for naval shipping
B. Fugitive emissions from fuels	39.82	39.82	0.00	0.00%	See explanations below in individual categories
1. Solid fuels	0.08	0.08	0.00	0.00%	No significant recalculations
2. Oil and natural gas	39.74	39.74	0.00	0.00%	No significant recalculations
2. Industrial processes and product use					
B. Chemical industry	21,162.10	21,162.10	0.00	0.00%	No significant recalculations
C. Metal industry	18.43	18.43	0.00	0.00%	No significant recalculations
G. Other product manufacture and use	645.73	880.24	234.51	36.32%	Time series consistent data now provided for one site which had a method change for 2023. Impacts all years except for 2023, as assumption to uplift time series is removed and replaced with actual data.

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
3 Agriculture					
B. Manure management	3,105.70	3,130.40	24.70	0.80%	Updates in N excretion associated with updating slaughter weight timeseries and re-parameterisation of the dairy cow mature liveweight (growth curve for followers/calves based on cow mature weight). Revision to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations (sheep sector). Changes in N excretion and manure management result in changes in the quantity of nitrate leached and the indirect nitrous oxide emitted from leached nitrate and from re-deposition of NH ₃ and NO _x .
D. Agricultural soils	13,175.34	13,212.08	36.74	0.28%	Emissions from urine and dung affected by the changes detailed for 'Manure management: Nitrous Oxide emissions', i.e. changes in cattle N excretion associated with changes to slaughter weights. Addition of a new source of NH ₃ emissions from decomposing plant residues from grass on the soil surface which resulted in an increase in NH ₃ and indirect N ₂ O emissions. Update to long-term trend in improved grass yield and nitrogen uptake resulting in increased N ₂ O emissions from residues decomposition and decreased indirect from leaching.
F. Field burning of agricultural residues	51.46	51.46	-	0.00%	No significant recalculations

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
4. Land use, land-use change and forestry					
A. Forest land	484.41	488.22	3.81	0.79%	Updates to the CARBINE model and forest land activity data.
B. Cropland	800.29	800.28	-0.01	0.00%	No significant recalculations
C. Grassland	136.47	136.83	0.36	0.27%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
D. Wetlands	18.87	18.45	-0.41	-2.19%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
E. Settlements	479.63	479.61	-0.02	0.00%	Updates to organic soil areas, deforestation activity data and CARBINE model.
5. Waste					
B. Biological treatment of solid waste	11.53	11.53	0.00	0.00%	No significant recalculations
C. Incineration and open burning of waste	49.14	50.88	1.74	3.54%	Revisions to bonfire activity data by adding 11th night data from Northern Ireland
D. Wastewater treatment and discharge	798.58	2,745.92	1,947.34	243.85%	Recalculation due to the inclusion of a new source "Municipal wastewater aerobic/secondary treatment"

Table 10.6 Recalculations to N₂O in 2023 (kt CO₂ eq)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
1. Energy					
A. Fuel combustion activities	1,845.33	1,844.85	-0.49	-0.03%	See explanations below in individual categories
1. Energy Industries	556.99	582.65	25.66	4.61%	Revisions to DUKES, plus correction of underestimation for emissions from one site
2. Manufacturing industries and construction	172.14	174.68	2.54	1.48%	Gas Oil and Biodiesel DUKES revisions, and source re-allocation (source reallocation within 1A2, does not impact recalculation for the total)
3. Transport	884.86	866.95	-17.92	-2.02%	Recalculation is due to the implementation of the DfT Maritime Emissions model, with fuel use now constrained to DUKES totals.
4. Other sectors	217.40	206.75	-10.65	-4.90%	Recalculation is due to the implementation of the DfT Maritime Emissions model for fishing vessels, with fuel use now constrained to DUKES totals.
5. Other	13.94	13.82	-0.12	-0.87%	Application of emission factors from the DfT's Maritime Emissions Model for naval shipping
B. Fugitive emissions from fuels	24.00	23.21	-0.80	-3.32%	See explanations below in individual categories
1. Solid fuels	0.01	0.01	0.00	0.00%	No significant recalculations
2. Oil and natural gas	24.00	23.20	-0.80	-3.32%	Revisions to Upstream Oil Production – flaring emissions
2. Industrial processes and product use					

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
B. Chemical industry	21.20	21.28	0.07	0.34%	Reallocation of one chemical site between source codes within the ETS data processing
C. Metal industry	5.02	4.97	-0.06	-1.15%	Revision to activity data for a single site based on stakeholder consultation
G. Other product manufacture and use	816.34	793.64	-22.70	-2.78%	Recalculation due to new data replacing rolled data for 2023 for recreational drug use
3 Agriculture					
B. Manure management	2,497.75	2,516.49	18.74	0.75%	Updates in N excretion associated with updating slaughter weight timeseries and re-parameterisation of the dairy cow mature liveweight (growth curve for followers/calves based on cow mature weight). Revision to the calculations of forage fresh-weight weighted estimates of the metabolisable energy content of mixed feed rations (sheep sector). Changes in N excretion and manure management result in changes in the quantity of nitrate leached and the indirect nitrous oxide emitted from leached nitrate and from re-deposition of NH ₃ and NO _x .

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
D. Agricultural soils	9,959.94	10,099.95	140.01	1.41%	Emissions from urine and dung affected by the changes detailed for 'Manure management: Nitrous Oxide emissions', i.e. changes in cattle N excretion associated with changes to milk yield and slaughter weights. Addition of a new source of NH ₃ emissions from decomposing plant residues from grass on the soil surface which resulted in an increase in NH ₃ and indirect N ₂ O emissions. Update to long-term trend in improved grass yield and nitrogen uptake resulting in increased N ₂ O emissions from residues decomposition and decreased indirect from leaching.
4. Land use, land-use change and forestry					
A. Forest land	405.22	409.32	4.11	1.01%	Updates to the CARBINE model and forest land activity data.
B. Cropland	437.33	437.05	-0.28	-0.06%	No significant recalculations
C. Grassland	130.90	127.55	-3.34	-2.56%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
D. Wetlands	27.01	26.37	-0.64	-2.37%	Updates to organic soil areas, wildfire activity data, deforestation activity data and CARBINE model.
E. Settlements	319.47	319.21	-0.26	-0.08%	Updates to organic soil areas, deforestation activity data and CARBINE model.

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
5. Waste					
B. Biological treatment of solid waste	683.69	686.01	2.32	0.34%	Revisions to the compost AD time series from 2007-2023
C. Incineration and open burning of waste	28.29	29.95	1.66	5.87%	Revisions to bonfire activity data by adding 11th night data from Northern Ireland
D. Wastewater treatment and discharge	941.90	3,964.81	3,022.91	320.94%	The domestic wastewater model has been updated to align with IPCC guidelines and reflect UK-specific treatment practices. It now uses parameters from the 2019 Refinement to the 2006 IPCC Guidelines, along with new UK-specific assumptions and academic evidence to address areas not covered by the IPCC.

Table 10.7 Recalculations to SF₆ in base year (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.C.4. Magnesium production	399.06	399.06	-	0.00%	no significant recalculations
2.G.1. Electrical equipment	829.01	829.01	-0.00	0.00%	no significant recalculations
2.G.2. SF ₆ and PFCs from other product use	62.92	62.92	-	0.00%	no significant recalculations

Table 10.8 Recalculations to SF₆ in 2023 (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.C.4. Magnesium production	1.12	1.12	-	0.00%	no significant recalculations
2.G.1. Electrical equipment	266.55	284.25	17.70	6.64%	Revisions to Ofgem emissions data for SF ₆
2.G.2. SF ₆ and PFCs from other product use	34.13	34.19	0.06	0.19%	Revisions to ONS UK GDP timeseries

Table 10.9 Recalculations to HFCs in base year (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.B.9. Fluorochemical production	14,807.32	14,807.32	0.00	0.00%	No significant recalculations
2.E.1. Integrated circuit or semiconductor	10.84	10.84	0.00	0.00%	No significant recalculations
2.F.1. Refrigeration and air conditioning	72.17	72.17	0.00	0.00%	No significant recalculations
2.F.2. Foam blowing agents	168.40	168.28	-0.11	-0.07%	No significant recalculations

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2.F.3. Fire protection	1.01	1.01	-0.00	-0.07%	No significant recalculations
2.F.4. Aerosols	407.73	407.73	0.00	0.00%	No significant recalculations
2.F.6. Other applications	23.60	23.58	-0.02	-0.07%	No significant recalculations

Table 10.10 Recalculations to HFCs in 2023 (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.B.9. Fluorochemical production	-	23.97	23.97		New source: Fluoropolymer manufacture - Undefined activity data
2.C.4. Magnesium production	3.04	3.04	-	0.00%	No significant recalculations
2.E.1. Integrated circuit or semiconductor	5.59	5.59	-	0.00%	No significant recalculations
2.F.1. Refrigeration and air conditioning	5,587.10	5,585.85	-1.25	-0.02%	No significant recalculations
2.F.2. Foam blowing agents	282.63	282.35	-0.28	-0.10%	No significant recalculations
2.F.3. Fire protection	138.95	135.69	-3.26	-2.35%	Correction to the underlying EU GDP timeseries used in calculations
2.F.4. Aerosols	893.89	893.72	-0.16	-0.02%	No significant recalculations
2.F.5. Solvents	12.58	12.70	0.12	0.96%	Correction to the underlying EU GDP data
2.F.6. Other applications	24.62	24.56	-0.06	-0.25%	No significant recalculations

Table 10.11 Recalculations to PFCs in base year (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.B.9. Flurochemical production	104.34	104.34	-0.00	0.00%	No significant recalculations
2.C.3. Aluminium production	299.84	299.84	-	0.00%	No significant recalculations
2.F.3. Fire protection	0.46	0.46	-0.00	-0.07%	No significant recalculations
2.G.2. SF ₆ and PFCs from other product use	128.63	128.63	-	0.00%	No significant recalculations

Table 10.12 Recalculations to PFCs in 2023 (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.B.9. Flurochemical production	84.55	84.55	0.00	0.00%	No significant recalculations
2.C.3. Aluminium production	2.84	2.84	0.00	0.00%	No significant recalculations
2.G.2. SF ₆ and PFCs from other product use	57.93	57.93	0.00	0.00%	No significant recalculations

Table 10.13 Recalculations to NF₃ in base year (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.E.1. Integrated circuit or semiconductor	0.26	0.26	0.00	0.00%	No significant recalculations

Table 10.14 Recalculations to NF₃ in 2023 (CO₂ eq., kt)

CRT Category	Previous submission (CO ₂ eq., kt)	Latest submission (CO ₂ eq., kt)	Difference (CO ₂ eq., kt)	Difference %	Explanation for recalculations
2. Industrial processes and product use					
2.E.1. Integrated circuit or semiconductor	0.06	0.06	0.00	0.00%	No significant recalculations

Table 10.15 Changes in Methodological Descriptions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
Total (Net Emissions)	Y	Y	
1. Energy	Y	Y	Chapter 3
A. Fuel Combustion (sectoral approach)	Y	Y	Chapter 3
1. Energy industries	Y	Y	Chapter 3
2. Manufacturing industries and construction	Y	Y	Chapter 3
3. Transport	Y	Y	Chapter 3
4. Other sector	Y	Y	Chapter 3
5. Other	Y	Y	Chapter 3
B. Fugitive emissions from fuels	Y	Y	Chapter 3
1. Solid fuels	Y	Y	Chapter 3
2. Oil and natural gas and other emissions from energy production	Y	Y	Chapter 3
C. CO ₂ transport and storage	N	N	
2. Industrial processes and product use	Y	Y	Chapter 4
A. Mineral industry	Y	Y	Chapter 4
B. Chemical industry	Y	Y	Chapter 4
C. Metal industry	Y	Y	Chapter 4
D. Non-energy products from fuels and solvent use	Y	Y	Chapter 4
E. Electronic industry	Y	Y	Chapter 4
F. Product uses as substitutes for ODS	Y	Y	Chapter 4

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
G. Other product manufacture and use	Y	Y	Chapter 4
H. Other	Y	Y	Chapter 4
3. Agriculture	Y	Y	Chapter 5
A. Enteric fermentation	Y	Y	Chapter 5
B. Manure management	Y	Y	Chapter 5
C. Rice cultivation	N	N	Chapter 5
D. Agricultural soils	Y	Y	Chapter 5
E. Prescribed burning of savannahs	N	N	Chapter 5
F. Field burning of agricultural residues	Y	N	Chapter 5
G. Liming	Y	Y	Chapter 5
H. Urea application	Y	Y	Chapter 5
I. Other carbon containing fertilisers	Y	Y	Chapter 5
J. Other	Y	Y	Chapter 5
4. Land use, land-use change and forestry	Y	Y	Chapter 6
A. Forest land	Y	Y	Chapter 6
B. Cropland	Y	Y	Chapter 6
C. Grassland	Y	Y	Chapter 6
D. Wetlands	Y	Y	Chapter 6
E. Settlements	Y	Y	Chapter 6
F. Other land	Y	Y	Chapter 6

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
G. Harvested wood products	Y	Y	Chapter 6
H. Other	Y	Y	Chapter 6
5. Waste	Y	Y	Chapter 7
A. Solid waste disposal	Y	Y	Chapter 7
B. Biological treatment of solid waste	Y	Y	Chapter 7
C. Incineration and open burning of waste	Y	Y	Chapter 7
D. Wastewater treatment and discharge	Y	Y	Chapter 7
E. Other	N	N	
6. Other (as specified in Summary 1.A)	N	N	

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

Information at sector level is summarised in **Table 10.1 R** to

Table 10.14. The overall impact of all recalculations is a decrease of 18.7 Mt CO₂ equivalent in 1990, and a decrease of 0.6 Mt CO₂ equivalent in 2023.

An overview chart showing the sector level changes is presented below.

Figure 10.1 Time series of changes in GWP emissions between the inventory presented in the current and the previous NID, according to CRT source sector.

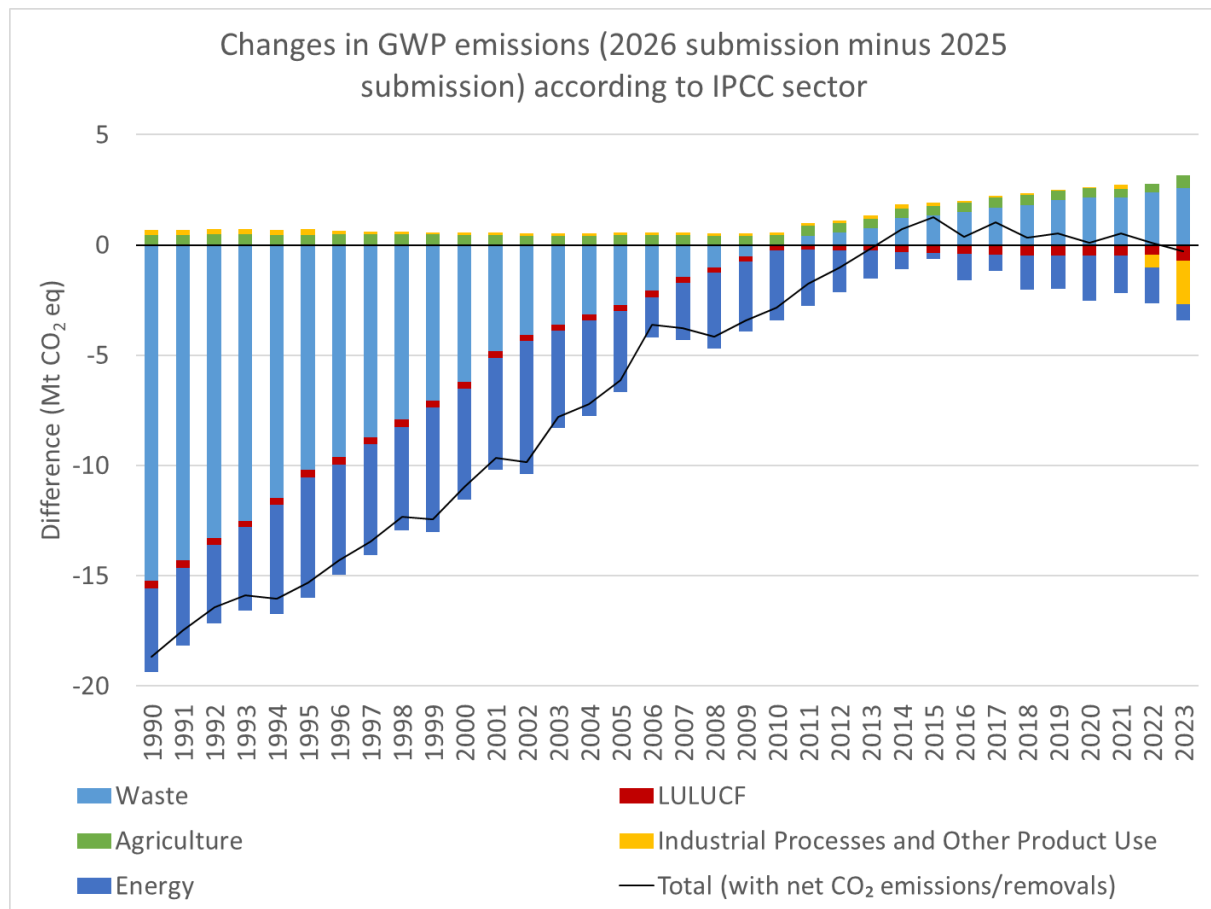
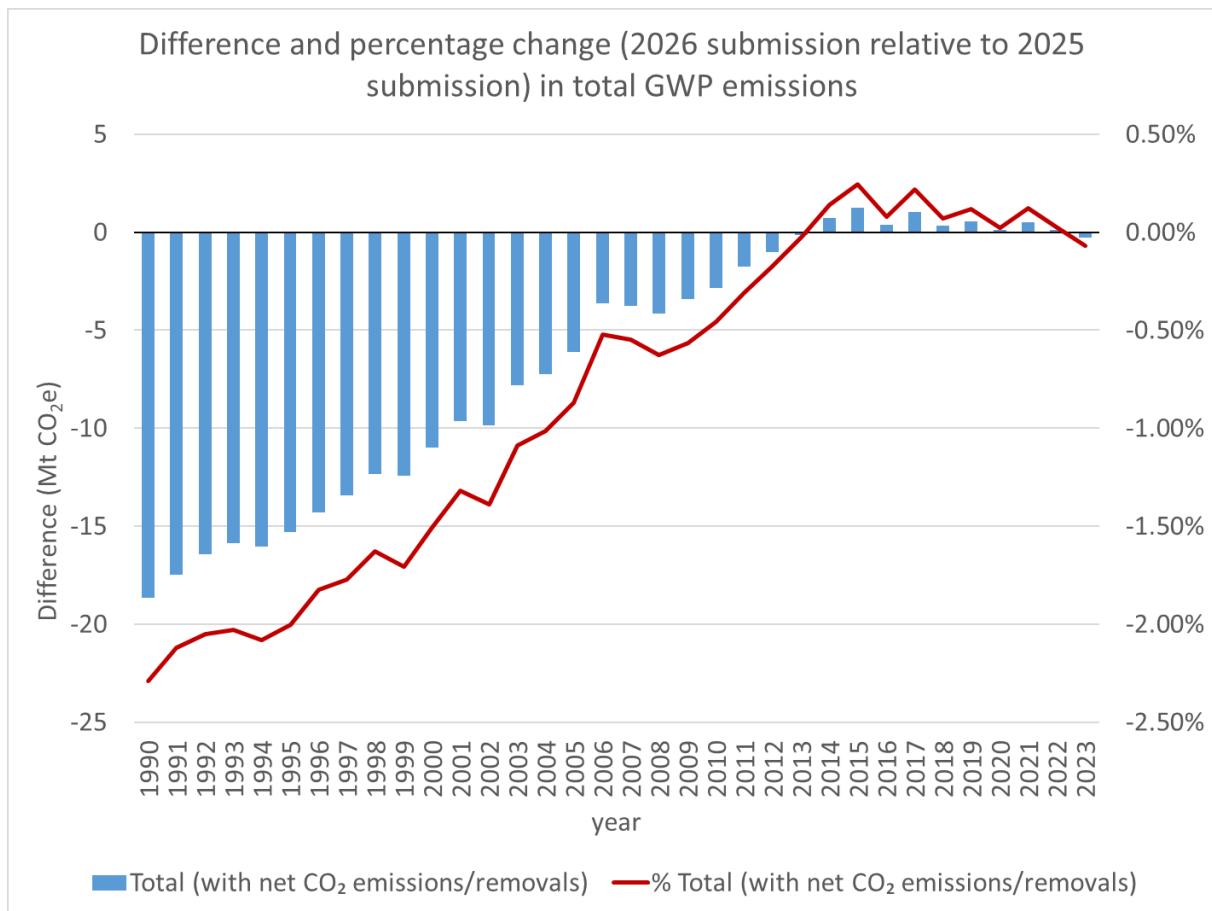


Figure 10.2 shows the net impact of all recalculations in absolute and percentage terms.

Figure 10.2 Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NID.



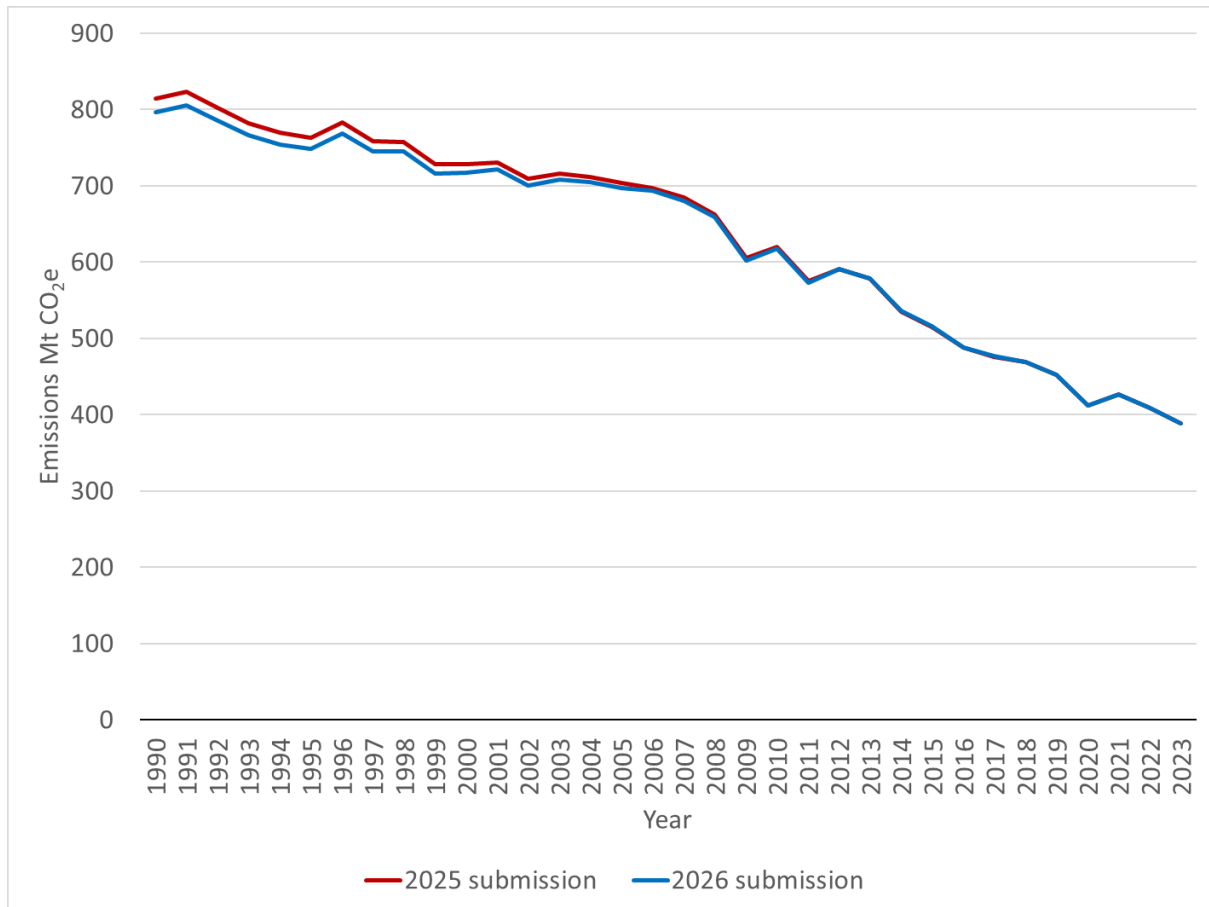
10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

There has been a very minor change in the reported trend in emissions. The reported trend from 1990 to 2023 in the 2024 inventory submission was a decrease of 52.2%. The recalculated trend from 1990 to 2022, as presented in the 2025 submission is a decrease of 51.2%.

The chart below displays the trend from both the 2025 and 2026 submissions.

Figure 10.3 Reported trends from the current and previous inventory submissions



10.4 RECALCULATIONS, INCLUDING IN RESPONSE TO THE REVIEW PROCESS, AND PLANNED IMPROVEMENTS TO THE INVENTORY

All recalculations to the inventory, including those made in response to the review process and other recalculations e.g. due to data revisions are described in detail within Chapters 3 to 8, and are summarised in **Table 10.1 R** to

Table 10.14. This section of the report summarises all recommendations from the review process, including where these have led to:

- Recalculations;
- changes in reporting in the NID;
- changes in reporting in the CRT; and
- planned improvements for future submissions.

The UNFCCC conducted an in-country review of the 2024 UK greenhouse gas inventory submission and the UK's First Biennial Transparency Report (BTR1) from the 19th of May to the 23rd of May 2025 in accordance with Article 13 of the Paris Agreement. The final output of this review, the 2025 Technical Expert Review Report, was published on the 17th of October 2025.

Table 10.16 details the responses to the BTR1 review recommendations, as part of the 2026 inventory submission.

10.4.1 Responses to BTR1 Review Recommendations**Table 10.16 Improvements to the UK GHG Inventory Submissions in response to UNFCCC Review Findings of the BTR**

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
1.A Fuel combustion – sectoral approach – CO ₂ Specified in paragraph 39 of the MPGs	3.E.1	The TERT recommends that the United Kingdom provide in the NID explicit justification for retaining and using historical carbon EFs in cases where no up-to date values are available, and clearly document the sources of all country-specific EFs used for estimating emissions, particularly where multiple sources are used for EFs for different time periods, and/or explain whether new sources of EFs or information were used in the compilation of the NIR.	Resolved in the 2026 submission. The UK has added a new section 3.2.5 to outline the evidence available that informs CS CEFs and to justify the approach. We note that the full detail of CEFs and the data source references are provided in the supplementary files appended to the NID, and that further details on specific data selection per source are documented in the Method Statements, whilst details of key CEF resources are also provided in Annex 5.1.	Section 3.2.5 Annex 5.1 Supplementary file on CEFs
1.A Fuel combustion – sectoral approach – NA Specified in paragraph 40 of the MPGs	3.E.2	The TERT recommends that the United Kingdom provide in the NID information on how fuel consumption data for each Crown dependency and overseas territory were integrated by the Party into the estimation of emissions from fuel combustion, at the category or subcategory level, to the extent possible, and for all years of the time series.	Addressing in the 2026 submission. The UK has added some clarifications within sections of the NID including Section 1.1.2.2 and has provided explanatory text and data tables in Annex 5.1.6.	Section 1.1.2.2 Annex 5.1.6

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
2.A.4 Other process uses of carbonates – CO ₂ Specified in paragraphs 21 and 39 of the MPGs	4.I.1	The TERT recommends that the Party use a more precise atomic mass for determining its country-specific CO ₂ EF for estimating emissions for subcategory 2.A.4.b or, if this is not possible, use the 2006 IPCC Guidelines default CO ₂ EF (0.41492 t CO ₂ /t soda ash), as it was determined using a more precise atomic mass, and include relevant information on the determination and use of the CO ₂ EF in the NID.	Resolved in the 2026 submission. The UK method has been improved to apply the atomic mass at full precision and the text in the NID has been updated to reflect this.	Section 4.5.2 and 4.5.5
2.B.8 Petrochemical and carbon black production – CO ₂ Specified in paragraph 39 of the MPGs	4.I.2	The TERT recommends that the Party report a clear description of the method used to estimate and report CO ₂ emissions for subcategory 2.B.8.d ethylene oxide, including information on the circumstances that prevented it from reporting CO ₂ emissions for 1990–1994 using emission estimates from the pollution inventory, as explained during the review.	Resolved in the 2026 submission. Additional text has been added to the NID, within the IPPU 2B8 method description and also within the Annex 5, to explain the approach to using operator-reported data and IPCC good practice gap-filling approaches to derive least-uncertain time series consistent estimates back to 1990. We note that there were no regulatory requirements for operator reporting of GHG emissions in the early 1990s and that these methods have been implemented and subject to reviews for many years, as explained during the BTR review.	Section 4.13.2, Table 4.14 and Annex A5.1.1.2.2

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
3.A.1; transparency of national methods (paragraphs 22, 39 of the MPGs)	5.A.1 (a) in ETF/TERR.1/2024/GBR/Add.1	Enhance the description of methodologies, parameters and data for CS methods including for the UK industry frameworks applied to derive cattle energy allowances, where year-specific data on animal weight and productivity are applied to ensure that the method is time-series consistent and accurately tracks changes in the UK herd.	Resolved in the 2026 submission. Additional text included in the NID to describe the UK industry frameworks and the annual data updates to ensure that the method remains representative of the UK herd.	Sections 5.3.2.1, 5.3.2.2 and 5.4.2.2.2.
3.B.1; transparency of national methods (paragraphs 22, 39 of the MPGs)	5.A.1 (b) in ETF/TERR.1/2024/GBR/Add.1	Enhance the description of methodologies, parameters and data for CS methods including for the proportions of cattle manure management systems to present additional information pertaining to farm survey data from recent years.	Addressing in the 2026 submission. Additional text included in the NID to describe the UK method and available data on cattle manure management from annual farm surveys. A peer review of cattle MM system assumptions is ongoing.	Sections 5.3.2.1, 5.3.2.2 and 5.4.2.2.2.
3.B.1; transparency of national methods (paragraphs 22, 39 of the MPGs)	5.A.1 (c) in ETF/TERR.1/2024/GBR/Add.1	Enhance the description of methodologies, parameters and data for CS methods including for the housing period for beef cattle, to present additional information pertaining to farm survey data from recent years.	Addressing in the 2026 submission. Additional text included in the NID to describe the UK method and available data on cattle housing from research across the time series. A peer review of cattle housing assumptions is ongoing.	Sections 5.3.2.1, 5.3.2.2 and 5.4.2.2.2.

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
3.B.1; reporting of information on QA/QC processes implemented (paragraph 46 of the MPGs)	5.A.2 in ETF/TERR.1/2024/GBR/Add.1	Enhance the reporting of the category-specific QC procedures undertaken, including a description of such procedures, including the specific QC procedures applied to the methods for estimating emissions for category 3.B, such as the establishment of management systems for nitrogen flow, the development of mass balance tables for accuracy and consistency checks, the comparison of calculated animal nitrogen excretion rates with reference values and the comparison of calculated nitrogen content in consumed grass and animal feeds with independent inventory calculations of nitrogen intake	Resolved in the 2026 submission. Additional text included in the NID to set out the category-specific QC procedures in 3.B, per the exchanges with the TERT and as listed in the TERR.	Section 5.4.4.
3; reporting of the results and methodology for the uncertainty analysis (paragraph 44 of the MPGs)	5.A.4 in ETF/TERR.1/2024/GBR/Add.1	Enhance the description of the uncertainty analysis by clearly specifying when a Monte Carlo simulation was performed and for which categories.	Resolved in the 2026 submission. Additional text provided in the NID Annex to describe the approach to update the agriculture sector uncertainties, both in years when a full Monte Carlo analysis is conducted and in other years where a simpler approach is taken.	Annex A5.1.6.20

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
3.B Manure management – CH ₄ and N ₂ O Specified in paragraphs 32 and 47 of the MPGs	5.A.5	The TERT recommends that the Party report CH ₄ and N ₂ O emissions from composting of manure under category 3.B manure management.	Not resolved. The UK continues to seek activity data for this minor source in the UK farming sector.	
4. General (LULUCF) – CO ₂ , CH ₄ and N ₂ O Specified in paragraph 55 of the MPGs	6.L.1	The TERT recommends that the Party provide clear information in the NID on the approach taken to address natural disturbances and how it is consistent with IPCC guidance, as appropriate, and clearly indicate if the estimates are included in national totals.	Resolved in the 2026 submission. Additional text has been provided in the NID to state that natural disturbances are not explicitly modelled in the UK greenhouse gas inventory and the surrounding assumptions.	Section 6.2.1
4.A Forest land – CO ₂ Specified in paragraph 40 of the MPGs	6.L.2	The TERT recommends that the Party add clear information to the NID on the disaggregation level of the AD and parameters used for estimating CSCs for category 4.A, including the information presented in figure 3.1 of the document on the National Forestry Accounting Plan for 2021–2025 (p.27).	Resolved in the 2026 submission. Additional text has been included in the NID Annex and additional supplementary files describing the approach and parameters of the CARBINE model.	Annex A5.1.4.2
4.A Forest land and 4.G HWP – CO ₂ Specified in paragraph 40 of the MPGs	6.L.3	The TERT recommends that the Party provide in the NID information that supports the use of a single value for wood carbon content for its calculations and a table with the values for oven-dried wood density for each tree species used to estimate the CSCs in forest land and HWP.	Resolved in the 2026 submission. Justification for the single carbon fraction value and further details of the modelling process has been included in the NID Annex.	Annex A5.1.4.1.1

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
4.B Cropland – CO ₂ Specified in paragraphs 39–40 of the MPGs	6.L.4	The TERT recommends that the Party provide in the NID detailed information on the methodology, parameters and assumptions used in estimating CSCs in biomass for land conversions from annual crops to perennial crops or perennial crops to annual crops, as provided during the review.	Resolved in the 2026 submission. Further details of the methodology for calculating carbon stock changes for cropland management has been included in the NID Annex.	Annex A5.1.4.4.1
4.B Cropland – CO ₂ Specified in paragraph 40 of the MPGs	6.L.5	The TERT recommends that the Party provide information on harvest cycles and maturity ages for each perennial crop type in the NID, as presented in Moxley et al. (2014).	Addressing in the 2026 submission, details have been added to the NID Annex outlining that there is currently limited information on harvest cycles/maturity ages for each perennial crop type in the UK and that improving this is on the GHG inventory improvement list for future development.	Annex 5.1.4.4.1
5. General (waste) – CH ₄ and N ₂ O Specified in paragraphs 21 and 39 of the MPGs	7.W.1	The TERT recommends that the Party describe in the NID the methodology, assumptions, EFs and AD used for estimating CH ₄ and N ₂ O emissions from industrial organic sludge treatment. The TERT also recommends that the Party revise the estimate of N ₂ O emissions from incineration of industrial organic sludge by assessing the amount of industrial organic sludge and applying an appropriate N ₂ O EF, such as the default N ₂ O EF of 450 g N ₂ O/t, in the estimation.	Not addressed in the 2026 submission. The UK has no activity data for this source, if it occurs in the UK at all.	

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
5.C.1 Waste incineration – CO ₂ Specified in paragraphs 40 and 47 of the MPGs	7.W.2	The TERT recommends that the Party collect necessary data and use relevant methodologies for estimating fossil- and biogenic-origin CO ₂ emissions from incineration of waste plastics, ensuring that bio-based plastics are included, and update the estimation of CO ₂ emissions for categories 1.A fuel combustion and 5.C incineration and open burning of waste.	Not addressed in the 2026 submission. The combustion of fossil and biogenic waste materials is already accounted for within the existing MSW incineration and EfW methodology, via the use of DUKES data on renewable and non-renewable waste. To identify specifically the contribution of fossil- and bio-plastics is not a requirement of the IPCC guidelines. In future, EfW facilities will be included within the UK's Emission Trading Scheme (ETS), introducing a requirement for operators to actively track and report on the biogenic and non-biogenic carbon in material combusted at such sites. The UK expects that in future this will provide the UK with a robust Tier 3 estimate of CO₂ emissions (including the biogenic/fossil ratio) from EfW.	

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
5.C.1 Waste incineration – CO ₂ Specified in paragraphs 40 and 47 of the MPGs	7.W.3	The TERT recommends that the United Kingdom clearly explain in the NID the reasons for the decrease in estimated CO ₂ emissions from liquid waste incineration under categories 1.A and 5.C between 2005 and 2006 and the trend after 2006 and ensure that emissions from all uses of waste oils are included in the estimates of CO ₂ emissions under the relevant categories of the energy, industrial processes and product use, and waste sectors.	Resolved in the 2026 submission. The chemical waste incineration activity data have been noted as a double-count, as they are already included within MSW statistics in DUKES. Hence this emission source has been removed from the UK inventory. In response to the specific trend noted by the TERT, the UK was undergoing a reduction in chemical waste incineration capacity during the early 2000s and this was hastened by the Hazardous Waste (England and Wales) Regulations 2005 (SI 2005/894) which imposed new restrictions on the handling, management and disposal of hazardous waste.	Section 7.4.2 and this table entry

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
5.C.1 Waste incineration – CO ₂ Specified in paragraphs 22, 39 and 47 of the MPGs	7.W.4	The TERT recommends that the Party explain in the NID how the methodology for estimating CO ₂ emissions from incineration of chemical waste reported by operators is consistent with the 2006 IPCC Guidelines, including information on the content and composition of the chemical waste. If this methodology is not consistent with the 2006 IPCC Guidelines, the TERT recommends that the Party update the estimates of CO ₂ emissions from incineration of chemical waste using an appropriate CO ₂ EF, such as the IPCC default CO ₂ EF (2,933 kg CO ₂ /t), and the amount of incinerated chemical waste.	Resolved in the 2026 Submission. Emissions from chemical waste incineration were previously estimated and reported separately in the UK inventory, based on operator-reported emissions data from the regulator inventories. However, through research into the scope of renewable and non-renewable wastes within the Digest of UK Energy Statistics, it was noted that activity data for the mass of annual chemical waste incinerated is included within the values presented for non-renewable wastes, and hence to make separate estimates for chemical waste incineration was a double count. Therefore, this has been removed from the 2026 UK submission; emissions from chemical waste incineration are therefore Included Elsewhere, in-part within 5C estimates for municipal waste incineration up to 1996, and then within 1A1a via Energy-from-Waste plant across the rest of the time series.	Section 7.4.2

CRT category/issue	Review Report / paragraph	Recommendation	Response	Chapter / section in the NID
5.C.1 Waste incineration – N ₂ O Specified in paragraph 40 of the MPGs	7.W.5	The TERT recommends that the Party revise table A 5.72 to correct the errors and inconsistent trends reported for the amount of incinerated sewage sludge in tables A 5.70 and A 5.72 of the NID. The TERT also recommends that the Party provide in the NID the N ₂ O EF used for estimating emissions from incineration of sewage sludge, as well as proper justification for its use and the amount of incinerated sewage sludge on a dry weight basis.	Resolved in the 2026 submission. The UK has revised the tables presented in the Annex 5 to present consistent data on activity and emissions from waste incineration. Clarification has been added to the methodology description in the main NID chapter to set out the N ₂ O EF applied to the UK AD.	Section 7.4.2 and Annex 5, tables A5.1.68 and A5.1.69

11 References

References for the main chapters and the annexes are listed here and are organised by chapter and annex. References in this document refer to correct name at the time of original publication.

11.1 CHAPTER 1 [BACKGROUND AND CROSS-CUTTING INFORMATION]

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11.2 CHAPTER 2 [TRENDS IN GREENHOUSE GAS EMISSIONS]

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11.3 CHAPTER 3 [ENERGY (CRT SECTOR 1)]

Baggott SL, Lelland A, Passant NP, and Watterson J (2004) Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. AEA Energy and Environment, The Gemini Building, Fermi Avenue, Didcot, Oxfordshire, OX11 0QR, UK. November 2004. AEA report number AEAT/ENV/R/2347. Report prepared for UK Defra under contract RMP/2106.

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11.4 CHAPTER 4 [INDUSTRIAL PROCESSES (CRT SECTOR 2)]

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11.7 CHAPTER 7 [WASTE (CRT SECTOR 5)]

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11.12 ANNEX 5.1, SECTOR 3

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12 Acknowledgements

We are grateful for the contributions, advice and support from the following people listed in **Table 12.1** during the compilation of this National Inventory Document (NID). The Key Data Providers are listed in **Table 12.2**.

Table 12.1 Contributors to this National Inventory Report and the CRT

Person	Technical work area and responsibility
<i>Main authors</i>	
Brown, Peter	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NID and the CRT ¹¹⁰ . Lead Author. Author of the key category analysis annex. Reviewed F-gas sections. Contributions to many chapters.
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Del Vento, Sabino	Lead author of Chapter 7 and Annex 5.1.5
Karagianni, Eirini	Sector expert and NID text author for road transport and off-road machinery.
MacCarthy, Joanna	Contributions to many chapters.
Mullen, Paddy	Lead author of Chapter 10. Contribution to many chapters.
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Richmond, Ben	Contributions to Annex 5.2 and Annex 8. Development of UK GHGI quality checking models.
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Thomson, Amanda ¹¹²	Sector expert for LULUCF. Main author of LULUCF Chapters 6, Annex 5.1.4 and LULUCF sections in Chapters 1 and 2. Contributor to compilation of Sector 4.
Wakeling, Daniel	Transport sector lead compiler and NID text author, including for: road transport, off-road machinery, shipping and fishing.

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Aston, Clare	Data acquisition
Bahou, Jack ¹¹⁴	Author of MS 9
Barber, Rosie	Inventory compilation. Contribution to Annex 1 and Annex 2
Broomfield, Mark	Sector expert for solid waste disposal on land.
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Carnell, Ed ¹¹²	Agriculture sector expert, including pre-processing of June Agricultural Census data, derivation of RFT dataset and high-definition mapping of Agriculture sector estimates.
Carswell, A. ¹¹¹	Agriculture sector expert with focus on NH ₃ emissions
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Gibbs, Mark ¹¹⁴	Compilation of rail emissions estimates and text for this sector.
Gilhespy, Sarah ¹¹¹	Inventory compilation for Dairy, Pig, Poultry, Other Livestock sectors. Contributions to agriculture sector NID text.
Gluckman, Ray ¹¹⁵	Author of the section on f-gases in Cpt 4.
Hamilton, Neve	Contribution to Annex 2. Inventory and GIS compilation
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Hows, Sian	Inventory and GIS compilation
Ingledew, Dominic	Inventory compilation
Kelsall, Alex	Author of MS2, MS18, Source Categories 2B6, 2C3, 2G2A, 2G2B, 2G2E, and Uncertainties Annex.
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Matthews, Robert ¹¹²	CARBINE modelling for LULUCF inventory for 4A Forestry, 4G Harvested Wood Products, contributions to text sections in chapter 6 and Annex 5.1.4
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Vaughan, Adam	NAEI QA/QC Manager. Author of Annex 4.
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Watterson, John	Review of LULUCF chapters and Annex. Contribution to chapter 10.
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Esegbue, Onoriode	DESNZ GHGI Science Lead
Hayes, William	DESNZ GHGI Statistician
Ren, Antonia	DESNZ GHGI Statistician
Rose, Jake	DESNZ GHGI Statistician
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Szanto, Courtney	DESNZ GHGI Scientist
Waite, Christopher	DESNZ GHGI Statistician
Wright, Ken	DESNZ Head of GHGI science and improvement
National Inventory Steering Committee	Review of the draft versions of the NID; feedback on inventory improvements; scrutiny of GHGI updates.

Table 12.2 Key Data Providers to the Greenhouse Gas Inventory

Organisation	Summary of Data Provided
DESNZ	Energy statistics (DUKES) including fuel activity, NCVs and GCVs; Oil and gas production; upstream oil and gas emissions (EEMS).
Defra	Solid waste disposal / fate statistics; Waste-water treatment activity data; Food and protein survey data; Agricultural survey data, activity statistics (livestock, crops).
DfT	Road traffic statistics; Marine transport statistics; Rail activity and emission estimates (REM); Aviation movement statistics.
OGA	Petroleum Production Reporting System data, including: oil and gas production per field, throughput per terminal; gas density and NCV per field or terminal. Wells Operations Notification System, wellbore database on number of wells drilled and their status (e.g. suspended, abandoned).
ONS	PRODCOM statistics (industrial production data); Housing and population data; Economic activity statistics (GDP, GVA);
Environment Agency SEPA NIEA NRW	Industrial activity and emissions data (EU ETS); Industrial emissions data from IPPC/EPR regulation; Waste management and disposal statistics, including incineration data, landfill gas flaring data;
Fuels Industry UK	Refinery emissions data by source; Oil products characteristics (RVP, sulphur content)
Mineral Products Association	Mineral processing activity and emissions data; fuel quality data;
National Grid Gas	National Transmission System (NTS) operator, providing gas leakage and natural gas compositional data for the NTS.
Cadent Gas, Northern Gas Networks, Scotland Gas Networks, Southern Gas Networks, Wales & West Utilities.	Gas Distribution Network operators, each providing: Natural gas compositional analysis provided annually per Local Distribution Zone (LDZ); Gas leakage estimates from the UK distribution network per LDZ.
ISSB	Iron and steel production statistics, by technology; Iron and steel fuel use, by fuel, by source;
Tata Steel British Steel	Iron and steel facility emissions by source for integrated works; Fuel quality data and other raw material parameters;

Organisation	Summary of Data Provided
Rio Tinto Alcan	Aluminium production data, facility emissions data, supporting data on plant performance and controls.
British Glass	Glass production data.
Ineos BP Chemicals Kemira GrowHow SABIC Shell	Facility emissions data by source, aligned to specific inventory reporting requirements for the chemicals and petrochemicals sectors.
ICOS PIs, Atmospheric Thematic Centre Carbon Portal	Data and facilities involved in the production of the CH ₄ , N ₂ O and SF ₆ datasets used in Annex 6.