IRELAND

NATIONAL INVENTORY REPORT 2014

GREENHOUSE GAS EMISSIONS 1990 - 2012 REPORTED TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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EXECUTIVE SUMMARY

ES.1 Background

The present report constitutes Ireland's National Inventory Report for 2014 and refers to the inventory time-series for the years 1990-2012.

The reporting guidelines on annual inventories adopted by the United Nations Framework Convention on Climate Change (UNFCCC), describe the scope and reporting of greenhouse gas emission inventories by Parties included in Annex I to the Convention. The guidelines set out the methodologies and procedures to be followed for submitting consistent and comparable data on an annual basis in a timely, efficient and transparent manner to meet the needs of the Convention. The UNFCCC guidelines require that Parties prepare a National Inventory Report (NIR) as one of the key components of their annual submissions to the UNFCCC secretariat. The purpose of the NIR is to describe the input data, methodologies, emission factors, quality assurance and quality control procedures and other information underlying the inventory compilation for greenhouse gases and to give details of any recalculations of inventories previously submitted. It is needed to assess the transparency, completeness and overall quality of the inventories as part of the rigorous on-going technical review of submissions from Annex I Parties.

Ireland's submission under the UNFCCC in 2014 is also its submission under the Kyoto Protocol, with 2012 being the fifth and final year of the first commitment period 2008-2012. The NIR is compiled according to the structure adopted by Decision 18/CP.8. Part I includes sections describing the national system for inventory preparation and management, emission trends, key emission categories, recalculations and on-going improvements. In addition, detailed documentation of methods, activity data and emission factors used for each of the six source categories, as defined by the Intergovernmental Panel on Climate Change (IPCC), are included. Part II contains the supplementary information required under Article 7.1 of the Kyoto Protocol, which refers mainly to the reporting and accounting of emissions and removals for activities under Article 3.3 of the Protocol. The report contains several annexes, which include calculation sheets, activity data, emission factors and other appropriate reference material to support the descriptions of inventory calculation methods given in both Part I and Part II and to provide adequate transparency for review purposes, as required by the UNFCCC Reporting Guidelines.

The Environmental Protection Agency has overall responsibility for the national greenhouse gas inventory in Ireland's national system, which was established in 2007 under Article 5 of the Kyoto Protocol. The EPA Office of Climate, Licensing and Resource Use (OCLR) performs the role of inventory agency in Ireland and undertakes all aspects of inventory preparation and management as well as the reporting of Ireland's submissions annually in accordance with the requirements of Decision 280/2004/EC and the UNFCCC. In addition to complying with the UNFCCC reporting guidelines, the 2014 NIR is intended to inform Irish Government departments and institutions involved in the national system, as well as other relevant stakeholders in Ireland, of the level of emissions and the state-of-the-art of Irish greenhouse gas inventories. The in-depth analysis of key categories and the up-to-date data on emissions trends provides essential information for the implementation of the National Climate Change Strategy and the development of emissions projections. The detailed NIR, together with activities provided for in the national system, allows data suppliers to become fully aware of the importance of their contributions to the inventory process and it serves to identify areas where improvements in input data can be achieved.

Ireland's commitment on greenhouse gases under the Kyoto Protocol, as determined by Decision 2005/166/EC, is to limit the increase in emissions in the 2008-2012 commitment period to 13 per cent above base year emissions. The baseline emissions total for Ireland is calculated as the sum of CO_2, CH_4 and N_2O emissions in 1990 and the contribution from fluorinated gases in 1995. The baseline value was established at 55.607 Mt CO_2eq and results in total allowable emissions of 314.184272 Mt CO_2eq in the commitment period, which equates to the average of 62.837 Mt CO_2eq per annum. This value remains fixed for the commitment period even though methodological improvements may change the estimates of emissions in the base year. Compliance with the Kyoto Protocol limit is achieved by ensuring that Ireland's total emissions in the period 2008-2012, adjusted for any offsets from activities under Article 3.3 and the surrender of any purchased Kyoto Protocol credits, are below 314.184272 Mt CO_2eq at the end of the five-year period.

ES.2 Emissions Trends and Key Categories

In 2012, total emissions of greenhouse gases (excluding the *LULUCF* sector) in Ireland were 58,531.24 Gigagrams (Gg) CO_2 equivalent, which is 5.9 per cent higher than emissions in 1990. The total for 2012 is 16.6 per cent lower than the peak of 70,207.50 Gg CO_2 equivalent in 2001 when emissions reached a maximum following a period of unprecedented economic growth. The *Energy* sector accounted for 63.3 per cent of total emissions in 2012, *Agriculture* contributed 30.7 per cent while a further 4.1 per cent emanated from *Industrial Processes*, 1.7 per cent was due to *Waste* and 0.1 per cent was due to *Solvents*. Emissions of CO_2 accounted for 64.9 per cent of the national total in 2012, with CH_4 and N_2O contributing 20.6 per cent and 12.7 per cent, respectively. The combined emissions of HFCs, PFCs and SF_6 accounted for 1.8 per cent of total emissions in 2012.

Tier 1 level assessment of emission source categories (ranking on the basis of their contribution to total emissions) identified 24 key categories in 2012 (excluding the *LULUCF* sector). There were 13 key categories of CO_2, accounting for 62.8 per cent of total emissions. There were seven key categories of CH_4, three key categories of N_2O and 1 key category of HFC in level assessment, which accounted for 19.8 per cent, 11.0 per cent and 1.7 per cent of total emissions, respectively. The results of the Tier 1 key category analysis clearly show the impact of CO_2 emissions from energy consumption on total emissions in Ireland. These combustion sources of CO_2 emissions accounted for 12 out of 24 key categories identified by level assessment in 2012 and for two-thirds (60.8 per cent) of total emissions. The top ten key categories contributed 72.8 per cent of total emissions in 2012 with emissions of CO_2 from the combustion of liquid fuels (petrol and diesel) by road traffic being the single largest source, accounting for 17.6 per cent of the total national emissions.

The application of uncertainty analysis for Irish greenhouse gas inventories using the IPCC approach indicates an overall level uncertainty of 6.8 per cent in the 2012 inventory (excluding the LULUCF sector) and a trend uncertainty of 2.7 per cent for the period 1990 to 2012. These values are determined largely by the low uncertainty in the estimates of CO_2 emissions from the energy sector, which is the major source category in Ireland and for which the input data and methodologies are most reliable. The 64.9 per cent of emissions contributed by CO_2 are estimated to have an uncertainty of 1.12 per cent. Emissions of N_2O from the agriculture sector account for over 95 per cent of the level uncertainty in the 2012 inventory. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2012 is negligible (0.4 per cent) because they account for only 1.8 per cent of total emissions.

Ireland has reported net greenhouse gas removals amounting to 17,901.30 Gg CO_2 eq. for 2008 to 2012 under Article 3.3 of the Kyoto Protocol in respect of 292.91 kha of lands subject to afforestation since 1990 while there were net emissions of 1,610.15 Gg CO_2 for a deforested area of 16.51 kha for the same 5 year period. Ireland has elected not to account for any of the activities under Article 3.4 of the Kyoto Protocol in the first commitment period.

ES.3 Overview of Source Category Emissions Estimates and Trends

Chapter 2 of the NIR describes the trends in Ireland's time-series of greenhouse gas inventories for the years 1990 through 2012. The emissions time-series is available as a complete set of Common Reporting Format files, generated by the CRF Reporter tool, the electronic reporting protocol adopted for annual data submissions to the UNFCCC secretariat. The annual inventories are complete with respect to both the coverage of the six greenhouse gases for which information is required and the coverage of the six IPCC source categories. Some recalculations have again been undertaken for the purposes of the 2014 submission and the latest inventories for the years 1990-2012 indicate revisions and improvements in some areas due to these recalculations.

Fuel combustion in the Energy sector is the principal source of emissions in Ireland and major increases in fuel use have driven the increase in emissions up to 2012. The largest increase took place in transport with an increase of 112.8 per cent on 1990 levels, while there were increases of 13.0 per cent and 7.9 per cent in the emissions from electricity production and the industrial sectors, respectively. The emissions from Agriculture sector, the other main source category, increased during the 1990s but have decreased to 8.5 per cent below 1990 levels in 2012. As the emissions from energy increased, the contribution of agriculture to total national emissions decreased from 35.5 per cent in 1990 to 30.7 per cent in 2012. This is primarily as a result of falling livestock numbers since 1998 due to reform of the Common Agricultural Policy (CAP).

ES.4 Indirect Greenhouse Gases

The inventory reporting process requires the inclusion of a number of gases whose indirect effects are also relevant to the assessment of human-induced impacts on climate. They include sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO) and volatile organic compounds (VOC). Emissions of SO_2 contribute to the formation of aerosols, which may offset the effects of greenhouse gases, while CO, NO_X and VOC are precursors of ozone, another naturally occurring greenhouse gas. This NIR does not describe the methods used to estimate emissions of SO_2, NO_X, CO and VOC but the annual emissions estimates over the period 1990-2012 are included in the submission.

The emissions of most of the indirect gases have decreased substantially in the period 1990-2012 under various forms of control legislation emanating from the European Commission and the Convention on Long Range Transboundary Air Pollution. The reductions achieved between 1990 and 2012 in Ireland are of the order of 87.3 per cent in the case of SO_2, 70.6 per cent for CO and 46.5 per cent for NMVOC and 39.8 per cent for $NO_{x.}$

PART I

ANNUAL INVENTORY SUBMISSION 2014

Chapter One

Introduction

1.1 Background and Context

This report constitutes Ireland's National Inventory Report (NIR), for the years 1990-2012, as required under the United Nations Framework Convention on Climate Change. Ireland's submission under the UNFCCC in 2014 is also its submission under the Kyoto Protocol, with 2012 being the fifth and final year of the Kyoto commitment period 2008-2012.

The objective of the NIR is to describe the methodologies, input data, background information and the entire process of inventory compilation for greenhouse gases and to give explanations for any improvements and recalculations of the inventories reported in previous submissions. The report is a key component of the UN review process which assesses the transparency, completeness and overall quality of the inventories from Annex I Parties.

1.1.1 Introduction and Reporting Requirements under the UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) (Articles 4 and 12), hereafter referred to as the Convention, requires Annex I Parties to develop, publish and make available to the Conference of the Parties (COP), the Convention's implementation body, their national inventories of emissions and removals of all greenhouse gases not controlled by the Montreal Protocol. The UNFCCC Reporting Guidelines on Annual Inventories (SBSTA, 1999 and SBSTA, 2002), hereafter referred to as the UNFCCC reporting guidelines, describe the scope and reporting of the emissions inventories. They specify the methodologies and procedures to be followed for submitting consistent and comparable data on an annual basis in a timely, efficient and transparent manner to meet the needs of the Convention. Under the UNFCCC reporting guidelines, Parties are required to compile a National Inventory Report (NIR) and up-to-date annual inventories in an electronic Common Reporting Format (CRF) as the key components of their annual submissions.

The NIR is compiled according to the structure adopted by Decision 18/CP.8.

- Part I includes sections describing the national system for inventory preparation and management, emission trends, key emission categories, recalculations and on-going improvements. In addition, detailed documentation of methods, activity data and emission factors used for each of the six source categories as defined by the Intergovernmental Panel on Climate Change (IPCC) is provided.
- Part II contains the supplementary information required under Article 7.1 of the Kyoto Protocol, which refers mainly to the reporting and accounting of emissions and removals for activities under Article 3.3 and any elected activities under Article 3.4 of the Protocol (i.e. emissions by sources and removals by sinks of GHGs resulting from LULUCF activities).

The NIR addresses the full range of reporting requirements related to annual inventories set down in the UNFCCC reporting guidelines and responds to issues identified in the UNFCCC annual review process. Furthermore, the report captures the cyclical nature of the reporting process and clarifies the chronology of changes and revisions that are part of normal inventory development, including those that are implemented in response to the UNFCCC review process. In this way, the report continues to improve the basis for technical assessment and expert review of Irish greenhouse gas inventories. An attempt has been made to provide all the primary inventory information, including calculation sheets as appropriate, to facilitate replication of the emission estimates for the most recent year of the inventory time-series so that the annual submission is fully transparent.

In addition to complying with the UNFCCC reporting guidelines, the report is intended to inform Government Departments, national institutions and other stakeholders of the state of the art of Irish greenhouse gas inventories as they address the challenges to comply with commitments under the Kyoto Protocol. In this context, it provides some additional background on relevant emission sources in Ireland, the standard reporting format and other issues for the benefit of those not entirely familiar with the agreed content of the NIR or the general reporting requirements under the Convention and the Kyoto Protocol. The report is also aimed at all the key data providers, with a view to making them fully aware of the importance of their contributions to the inventory process and to provide a means of identifying areas where improvements in input data may be possible. The in-depth analysis of key categories and the up-to-date data on emissions trends provides essential information for the implementation of the National Climate Change Strategy and the development of emissions projections.

The NIR is updated annually in accordance with the UNFCCC guidelines and is published on the web site of the EPA [http://erc.epa.ie/ghg/nirdownloads.jsp]. Such updating is necessary to keep the UNFCCC secretariat and other interested parties informed of the status of Irish greenhouse gas inventories and to document on-going improvements, recalculations and other developments affecting the estimates of emissions. The structure of the report is designed to facilitate year-on-year revision in a manner that allows for systematic and efficient assessment of progress towards the achievement of greenhouse gas emission inventories that meet the guiding principles of transparency, consistency, comparability, completeness and accuracy. Ireland's submission under the UNFCCC in 2014 is also its submission under the Kyoto Protocol.

Ireland's commitment on greenhouse gases under the Kyoto Protocol, as determined by Decision 2005/166/EC, is to limit the increase in emissions in the 2008-2012 commitment period to 13 per cent above base year emissions. The baseline emissions total for Ireland is calculated as the sum of CO_2, CH_4 and N_2O emissions in 1990 and the contribution from fluorinated gases in 1995. The baseline value was established at 55.607 Mt CO_2 eq and results in total allowable emissions of 314.184272 Mt CO_2 eq in the commitment period, which equates to the average of 62.837 Mt CO_2 eq per annum. This value remains fixed for the commitment period even though methodological improvements may change the estimates of emissions in the base year. Compliance with the Kyoto Protocol limit is achieved by ensuring that Ireland's total emissions in the period 2008-2012, adjusted for any offsets from activities under Article 3.3 and the surrender of any purchased Kyoto Protocol credits, are below 314.184272 Mt CO_2 eq at the end of the five-year period. The annual inventory submissions for the years 2008-2012 will determine compliance under the Kyoto Protocol.

1.1.2 Scope of Greenhouse Gas Inventories

1.1.2.1 Greenhouse Gases and Global Warming Potential

The full range of greenhouse gases for which emissions data are required under the Convention is given in Table A.1 of Annex A. It includes carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), the most widely known and most ubiquitous of the anthropogenic greenhouse gases, along with 13 hydrofluorocarbons (HFCs), seven perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The global warming potentials (GWP) of the various greenhouse gases vary enormously, as shown on Table A.1 of Annex A. The GWP of a gas is a measure of the cumulative warming over a specified time period, e.g. 100 years, resulting from a unit mass of the gas emitted at the beginning of that time period, expressed relative to an absolute GWP of 1 for the reference gas carbon dioxide (IUCC, 1998). The mass emission of any gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide. Therefore, while CO_2, CH_4 and N_2O are important because they are normally emitted in large amounts, HFCs, PFCs and SF_6 are included in the inventory process mainly because of their comparatively much larger GWP values.

The inventory reporting process allows for the inclusion of a number of additional gases whose indirect effects are also relevant to the assessment of human-induced impacts on climate. These include sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO) and volatile organic compounds (VOC). Emissions of SO_2 contribute to the formation of aerosols, which may offset the effects of greenhouse gases, while CO, NO_X and VOC are precursors of ozone formation, another naturally occurring greenhouse gas. This NIR does not describe the methods used to estimate emissions of SO_2, NO_X, CO and VOC but up-to-date estimates of total emissions are included for information purposes. These estimates are taken from Ireland's submission to the Convention on Long Range Transboundary Air Pollution (CLRTAP), which are produced annually in a manner that is fully consistent with the inventory for greenhouse gases.

1.1.2.2 IPCC Reporting Format

Greenhouse gas emissions are reported under the Convention in a multi-level reporting format adopted by the Intergovernmental Panel on Climate Change (IPCC). This is a standard table format that forms the basis of the Common Reporting Format (CRF) which assigns all potential sources of emissions and removals of a Party's national total to six Level 1 broad source categories. A further category is provided for the reporting of any additional sources that may be specific to individual Parties. The Level 1 source categories are each divided into as many as seven sub-categories, giving a total of 36 Level 2 source/sink categories, which in turn are further sub-divided to give the 126 standard sub-categories disaggregated at Level 3 in the CRF. Table A.2 of Annex A lists the Level 1 and Level 2 source/sink categories. The Level 3 categories are detailed in the description of category coverage and inventory methods and data in the respective sectoral chapters of this NIR. The computation of emissions is usually undertaken at Level 3 or lower, using further appropriate disaggregation (for example, by using fuel type in the case of combustion sources under *1.A Energy-Fuel Combustion*) while summary results are normally published at Level 2.

The reporting format was extended to accommodate the reporting of emissions and removals under Articles 3.3 and 3.4 of the Kyoto Protocol (i.e. emissions by sources and removals by sinks of GHGs resulting from LULUCF activities) for the years 2008-2012. The additional tables use a hierarchical system similar to that for reporting under the Convention, with flexibility for Parties to provide as much disaggregation as is necessary to reflect the variation in the parameters underlying the estimates of emissions and removals for the Articles 3.3 and 3.4 activities applicable in their territories. The Kyoto reporting tables also include the accounting quantity for each relevant activity i.e. the quantity of units to be added or subtracted from a Party's assigned amount in accordance with the provisions of Article 7.4 of the Protocol.

The IPCC reporting format also includes a number of *Memo Item* entries. These items refer to sources of emissions whose contributions are not included in a Party's national total but which are to be reported because of their importance in relation to the overall assessment of emissions and for comparisons among Parties.

The national total of emissions that is commonly used under the Convention excludes the estimates for the Land Use Land-Use Change and Forestry (LULUCF) sector in Table A.2 of Annex A, this total being consistent with that for the categories included in Annex A of the Kyoto Protocol.

1.1.2.3 Supplementary Information

For a Party to the Kyoto Protocol, the annual inventory submission under the Convention is also its annual inventory submission under the Protocol. Supplementary information required under Article 7.1 of the Kyoto Protocol comprises the GHG emissions and removals under Articles 3.3 and 3.4 of the Kyoto Protocol, details of all Kyoto units for the year subsequent to the inventory year as generated by the national registry and compiled in the Standard Electronic Format, changes in the national system and national registry and information on the minimization of adverse impacts of climate change and response measures on developing countries in accordance with Article 3.14.

1.2 Institutional and Procedural Arrangements

1.2.1 Overview

The Environmental Protection Agency is required to establish and maintain databases of information on the environment and to disseminate such information to interested parties (Section 52 of the Environmental Protection Agency Act of 1992 (DOE, 1992)). The Act states that the Agency must provide, of its own volition or upon request, information and advice to Ministers of the Government in the performance of their duties (Section 55). This includes making available such data and materials as are necessary to comply with Ireland's reporting obligations and commitments within the framework of international agreements. These requirements are the regulatory basis on which the EPA prepares annual inventories of greenhouse gases and other important emissions to air in Ireland. It is in this context that in 1995 the Department of the Environment, Community and Local Government (DECLG) designated the EPA as the inventory agency with responsibility for the submission of emissions data to the UNFCCC Secretariat and to the Secretariat for the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

The establishment of Ireland's national inventory system was completed by Government Decision in early 2007, building on the framework that had been applied for many years. The EPA's Office of Climate, Licensing, Resource and Research (OCLR) was designated the inventory agency and the EPA was also designated as the single national entity with overall responsibility for the annual greenhouse gas inventory. Within the OCLR, the Climate Resource and Research Programme (CRRP), compiles the national greenhouse gas emission inventories for submission on behalf of DECLG under the Framework Convention on Climate Change and Decision 280/2004/EC (EP and CEU, 2004a), the latter being the basis for EU Member States' reporting under the Convention and the Kyoto Protocol. All formal mechanisms together with the QA/QC procedures are fully operational since they were established in the 2007 reporting cycle.

Following establishment of the national system, institutional arrangements directed towards national inventory reporting that involve the EPA, DECLG and other stakeholders were reorganised, extended and legally consolidated across all participating institutions to strengthen inventory capacity within the EPA. This ensured that more formal and comprehensive mechanisms of data collection and processing were established and maintained for long term implementation. In particular, the system puts in place formal procedures for the planning, preparation and management of the national atmospheric inventory and identifies the roles and responsibilities of all the organisations involved in its compilation. This was achieved through extensive discussions with all key data providers leading to the adoption of Memoranda of Understanding (MOU) between the key data providers and the inventory agency. These MOUs stipulate the scope, timing and quality of the inputs necessary for inventory compilation in accordance with the guidelines for national systems. Secondary MOUs are, in turn, used by some key data providers to formalise the receipt of data from their own particular sources. Table 1.1 lists the key data providers and indicates the range of data covered by MOU in the national system. A QA/QC plan is an integral part of the national system.

Figure 1.1 provides a schematic overview of the institutions, procedures and information flows involved in the national system. In addition to the primary data received from the key data providers, the inventory team draws on various other data streams available within the EPA, such as the National Waste Database, reports on wastewater treatment, Annual Environmental Reports from companies subject to Integrated Pollution Prevention Control and submissions prepared under the European Pollutant Release and Transfer Register and also obtains information from other diverse sources to prepare the inventories for fluorinated gases and solvent use. The inventory team also draws on national research related to greenhouse gas emissions and special studies undertaken from time to time to acquire the information needed to improve the estimates for particular categories and gases.

The Emissions Trading Unit (ETU), also within the Climate Resource and Research Programme of the OCLR, is a key component of the national system. The ETU are responsible for administering the European Union Emissions Trading Scheme (ETS), under Directive 2003/87/EC (EP and CEU, 2003), in Ireland and, as such, provide annual verified emissions data to the inventory team.

The estimates of emissions and removals for forest lands under the Convention, as well as those in respect of Article 3.3 activities under the Kyoto Protocol, are prepared by consultants contracted to the Department of Agriculture, Food and Marine (DAFM). These are delivered to the inventory agency under a Memorandum of Understanding between DAFM and OCLR. Research fellows contracted directly to OCLR are responsible for completion of the annual inventory for all other land categories in LULUCF for the annual inventory under the Convention. The deliverables received by OCLR from DAFM and the research fellows include the completed CRF tables and draft NIR sections for their respective areas of responsibility.

The approval of the completed annual inventory involves sign-off by the QA/QC manager and the inventory manager before it is transmitted to the Board of the EPA via the Programme Manager of the Climate Resource and Research Programme in OCLR. Any issues arising from the Board’s examination of the estimates are communicated to the inventory experts for resolution before final adoption of the inventory. The results for the inventory year are normally released at national level in autumn of the following year. This is in advance of their official submission to the European Commission in accordance with Decision 280/2004/EC in January of the reporting year and subsequently to the UNFCCC secretariat.

The national system is also exploited for the purpose of parallel inventory preparation and reporting under the LRTAP Convention ensuring efficiency and consistency in the compilation of emission inventories for a wide range of substances using common datasets and inputs.

Table 1.1. Key Data Providers and Information covered by MOU

Key Data Provider	Data Supplied	Deadline	Sector in which data are used
Sustainable Energy Authority of Ireland	National Energy Balance; Detailed national energy consumption disaggregated by economic sector and fuel	30 September	Energy, Waste
Department of Agriculture, Food and Marine	**Table 1.1-1.4** Statistical data for cattle compiled under the Animal Identification and Movement (AIM) scheme Fertiliser and lime statistics Poultry statistics Sheep statistics	30 September	Agriculture
Department of Agriculture, Food and Marine (Forest Sector Development Division)	**Table 2.1** GHG emission/removal estimates from all pools for forest lands under the Convention Statistical data on Afforestation, Reforestation, Deforestation and harvesting for forest land lands under Article 3.3 of KP GHG emission/removal estimates from all biomass pools for KP Article 3.3	30 September	LULUCF and Article 3.3 of the Kyoto Protocol
Central Statistics Office	Annual population, livestock populations, crop statistics, housing survey data	30 September	Agriculture, Industrial Processes, Waste
Bord Gáis	Analysis results for indigenous and imported natural gas	30 September	Energy
Marine Institute	Annual Report on Discharges, Spills and Emissions from Offshore Gas Production Installations	30 October	Energy
Emissions Trading Unit	Verified CO_2 estimates and related fuel and production data for installations covered by the EU ETS[1]	30 April	Energy, Industrial Processes
*Department of Communications, Energy and Natural Resources	National Oil Balance (as a component of the energy balance)	30 September	Energy
*Road Safety Authority	Road transport statistics from the National Car Test (NCT)	30 April	Energy
**Forest Service	(i) GIS data base on premiums and grants afforestation areas (iFORIS) with associated attributes (II) NFI database	30 September 2007, 2012	LULUCF and Article 3.3 activities
**Coillte	GIS data base of intersected of NFI permanent sample plot points (Coillte-NFI plots) with sub-compartment and management unit data.	30 September	LULUCF and Article 3.3 activities

[1]ETS – Emissions Trading Scheme
*These bodies have MOUs with SEAI rather than with OCLR
**These bodies have MOUs with the Department of Agriculture, Food and Marine rather than with OCLR

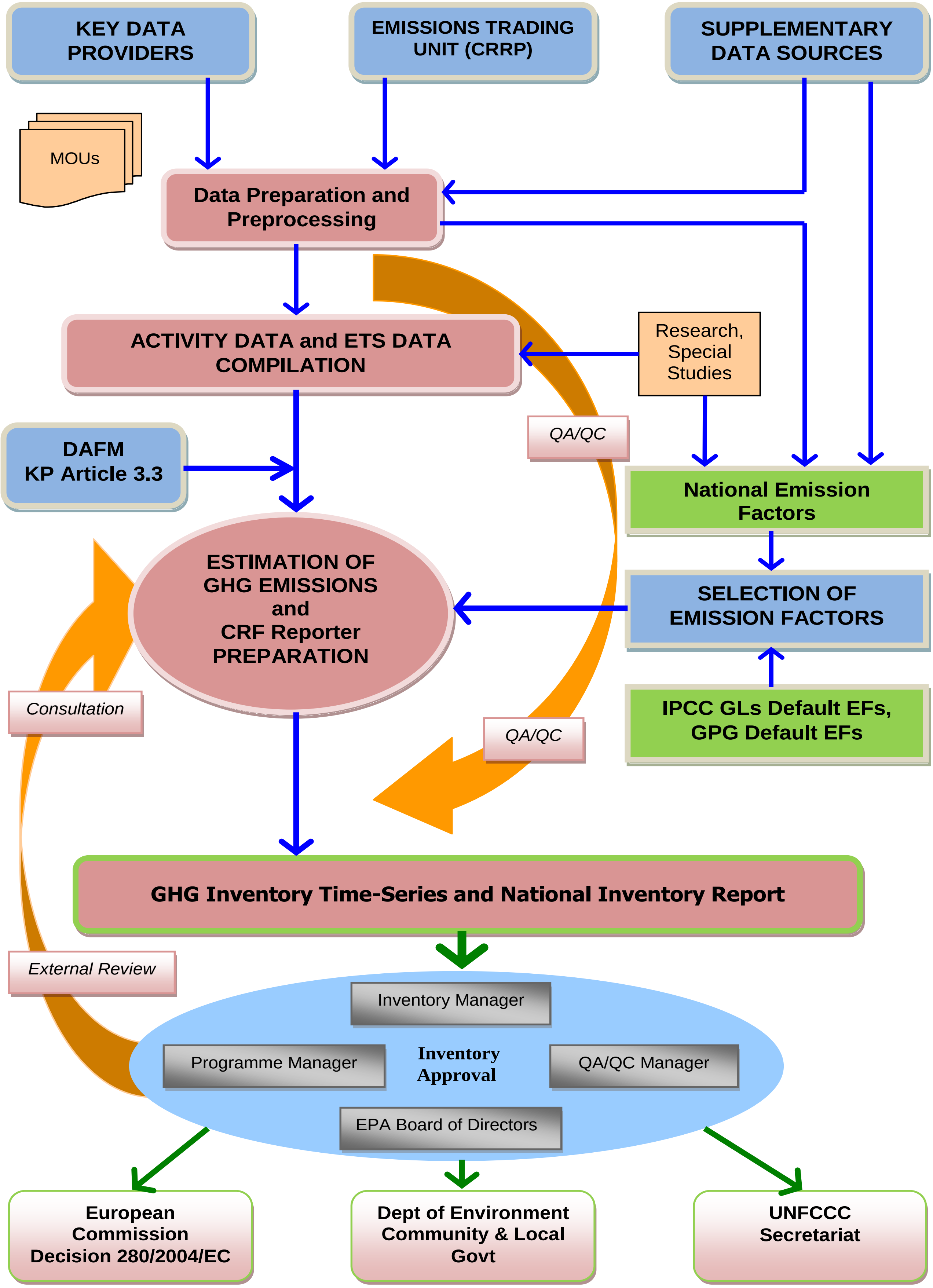


Figure 1.1. National Inventory System Overview

1.2.2 Inventory Planning

The inventory agency plans for preparation of the annual inventory as soon as possible after completion of the annual reporting cycle in April following submission to the UNFCCC secretariat. Planning largely involves the identification of improvements to be undertaken by way of revised methodologies and updated activity data or emission factors as well as addressing the issues and recommendations in the review of the previous inventory submission.

Planning also considers the further development of inventory reporting for the LULUCF sector and for activities under Article 3.3 as new data becomes available through national research and development of the forest inventory.

In addition, any changes required by the outcome of review activities conducted among the Member States of the European Union, or by the need to report in a manner consistent with other Member States for the purposes of Decision 280/2004/EC, are taken into account in inventory planning.

1.2.3 Overview of Inventory Preparation and Management

The first version of the latest annual inventory, produced in autumn of the following year, and a short National Inventory Report are used to comply with the subsequent 15 January deadline prescribed by Decision 280/2004/EC, which governs the reporting of greenhouse gases and implementation of the Kyoto Protocol by the European Union and its EU Member States.

The inventory preparation and management process thereafter involves making any revisions subsequent to the receipt of updated or outstanding information nationally. In addition, any observations or amendments following initial assessment at EU level of the 15 January submission by Member States to the European Commission are incorporated into the inventory between 15 January and 15 March.

The complete and final inventory submission, including the National Inventory Report, is submitted to the European Commission by 15 March as required under Decision 280/2004/EC. This version of the latest inventory is fixed and retained for submission to the UNFCCC secretariat by 15 April to complete the reporting cycle. Ireland’s national system is operating very successfully and the timeliness of inventory preparation has benefited from the implementation of more formal arrangements and enhanced engagement among the various institutions and contributors.

1.3 Inventory Preparation

1.3.1 GHG Inventory and KP-LULUCF Inventory

An emissions inventory database normally contains information on measured emission quantities, activity statistics (populations, fuel consumption, vehicle/kilometres of travel, industrial production and land areas), emission factors and the associated emission estimates for a specified list of source categories. In practice, very few measured data are available for greenhouse gases and, consequently, the emissions from most activities are estimated by applying emission factors for each source/gas combination to appropriate activity data for the activity concerned. Virtually all emissions and removals estimates may be ultimately derived on the basis of such simple product of activity data and emission factor. However, a certain amount of data analysis and preparatory calculations are generally needed in order to make available suitable combinations of activity data and emission factors at the level of disaggregation that gives the best estimates of emissions and removals. In the case of some source/gas combinations, such as methane emissions from solid waste landfills and CO_2 sequestration by forest biomass, it may be necessary to apply sophisticated models to generate the activity data, the emission factors or the emissions. The methods recommended by the Revised 1996 IPCC Guidelines (IPCC, 1997), IPCC Good Practice Guidance (IPCC, 2000) and IPCC Good Practice Guidance on LULUCF (IPCC, 2003) use a tier system to take account of these issues and other factors, such as data availability, technical expertise, inventory capacity and other circumstances, which may vary considerably across countries.

1.3.2 Data Collection, Processing and Storage

Preparation for the annual GHG inventory takes place in an Excel spread sheet system where activity data stored in *Source Data* files are linked to calculation sheets in *Data Processing* files that produce the emissions estimates at the lowest possible level of disaggregation. These are combined and allocated according to IPCC requirements for direct transmission into the CRF Reporter utility for the generation of the CRF tables. These results are stored in *Outputs* files while supporting QA/QC sheets, extracted from *Data Processing* files, are held in summary *QA/QC* record files. The *Data Processing* files hold the emission factors and they are structured on a time-series basis, which facilitates efficient recalculation and output to the CRF Reporter. This procedure applies to all IPCC sectors of the GHG inventory for which the calculations are made by the inventory team and the full set of files applicable to each year under the four headings is stored using appropriate version control on the OCLR servers.

Table 1.1 lists the principal data suppliers and the information that they are required to deliver to the inventory agency annually under MOU for the preparation of the GHG inventory. In some cases, e.g. the national energy balance, the input file received from the data supplier may be linked directly to the *Data Processing* files, but generally some degree of preparation and pre-processing is needed before the activity data are used in inventory preparation. In collating and compiling the activity data, the inventory team collects data from the various data streams e.g. Annual Environmental Report and submissions under the European Pollutant Release and Transfer Register.

A national model called CARBWARE is used to derive the estimates of emissions and removals for forest lands, which are incorporated in the overall scheme for LULUCF reporting under the Convention following the procedure outlined above. A variety of databases related to land cover, soil type and forest areas are applied for the LULUCF inventory under the Convention. These include the National Forest Inventory (NFI), the Forest Inventory and Planning System (FIPS), the Land Parcels Information System (LPIS), CORINE Land Cover Maps and the General Soil Map of Ireland. These are supported by statistical information from Bord na Móna and the National Roads Authority.

The static national model, CARBWARE has been extensively developed to a dynamic version to provide the necessary estimates for Article 3.3 activities under the Kyoto Protocol. This work was undertaken by FERs Ltd, the consultants working to Department of Agriculture, Food and Marine, who supply the Article 3.3 results to OCLR under an agreed MOU (Table 1.1). Secondary MOUs between Department of Agriculture, Food and Marine and its data suppliers formalise annual data collection for this area of the inventory. The model contains a multitude of component modules needed to produce estimates of the carbon stock changes for the various carbon pools under afforestation and deforestation areas and for reporting any relevant emissions of CH_4 and N_2O. The model processes detailed spatially explicit data on forest species and soil type obtained from the NFI, FIPS, soils maps, supported by the Grants and Premiums Administration System (GPAS), and felling license records. The model uses complex pre-processing functions, growth models, allometric equations and pool allocation and transfers to produce the results required for Article 3.3 activities.

The annual ETS compilation serves as an important source of activity-specific and company-specific data on CO_2 emissions, fuel use and emission factors for major combustion sources and industrial processes. The emissions trading scheme covers approximately 100 installations in Ireland with combined CO_2 emissions of 16,852 Gg in 2012, accounting for 28.8 per cent of total greenhouse gas emissions (58,531.24 Gg CO_2 equivalent). Guidance provided under the associated Decision 2004/156/EC (EP and CEU, 2004) on methodologies for estimating and reporting greenhouse gas emissions to support Directive 2003/87/EC, together with monitoring and verification mechanisms administered by the ETU, consolidates and improves the information in relation to a substantial proportion of CO_2 emissions for the purposes of reporting national GHG inventories under the Convention and the Protocol.

All of the data used in the compilation of the national GHG inventory submission is stored on an EPA data server located in the Monaghan Regional Inspectorate of the EPA where key staff involved in inventory compilation is located. All background data for recent years are available in electronic format, with a transparent file structure. All data (emission estimates, AD, inventory submissions, references, QA/QC) on the data server are backed up daily.

1.3.3 Quality Assurance and Quality Control

In early 2005, the inventory agency in Ireland commissioned a project with UK consultants NETCEN to establish formal QA/QC procedures that would meet the needs of the UNFCCC reporting requirements. The project developed a QA/QC system including a documented QA/QC plan and procedures along with a QA/QC manual.

The manual provides a general overview of the QA/QC system. In addition, the manual provides guidance and templates for appropriate quality checking, documentation and traceability. The selection of source data, calculation methodologies, peer and expert review of inventory data and the annual requirements for continuous improvement for the inventory are also outlined in the manual.

The QA/QC plan identifies the specific data quality objectives related to the principles of transparency, consistency, completeness, comparability and accuracy required for Ireland's national inventory and provides specific guidance and documentation forms and templates for the practical implementation of QA/QC procedures. The QA/QC procedures cover such elements as data selection and acquisition, data processing and reporting.

1.4 Methodologies and Emission Factors

Table 1.2 and Table 1.3 present summaries of the methodologies and emission factors used by Ireland to estimate GHG emissions reported for the years 1990-2012. More than 80 per cent of the total emissions (excluding LULUCF) are covered by Tier 2 methods or higher in Ireland’s GHG inventory under the Convention and a Tier 3 model is applied for carbon stock changes for Article 3.3 activities under the Kyoto Protocol.

Carbon dioxide (CO_2)

Tier 2 or Tier 3 methods are used for the majority of CO_2 combustion source categories and country-specific emission factors are used for all fuels. Even for those combustion categories where data limitations dictate the use of Tier 1 methods, such as *1.A.2 Manufacturing Industries and Construction* and *1.A.4 Other Sectors*, the CO_2 emissions obtained using the energy balance fuel data and country-specific emission factors are reliable. Tier 2 methods also apply to important process sources of CO_2 emissions, such as cement and lime production, where country-specific circumstances are again taken fully into account.

The national model used to estimate carbon stock change in the various carbon pools for forest lands in respect of both Convention reporting and Article 3.3 activities is a Tier 3 methodology. The methods for CO_2 in other LULUCF categories and for relevant CH_4 and N_2O emissions in this sector are invariably Tier 1.

Methane (CH_4)

Ireland's national circumstances are well captured in the Tier 2 methods applied for the major sources of CH_4 in the inventory, which are *enteric fermentation* and *manure management* associated with cattle and the CH_4 emissions from *solid waste disposal* sites.

Tier 2 and Tier 3 methods are used for CH_4 emissions from *1.A.1 Energy Industries* and *1.A.3.b Road Transport*, respectively, while Tier 1 methods and IPCC default emission factors are used for other CH_4 emissions.

Nitrous oxide (N_2O)

Ireland relies on the simplified IPCC Tier 1 methodologies and default emission factors to estimate all N_2O emissions in agriculture, which is the main source of N_2O in the inventory.

Tier 2 and Tier 3 methods are used for N_2O emissions from *1.A.1 Energy Industries* and *1.A.3.b Road Transport*, respectively, while Tier 1 methods and IPCC default emission factors are used for other N_2O emissions.

1.5 Overview of Key Categories

The IPCC good practice guidance defines a key category as one that is prioritised within the national inventory system because its emission estimate has a significant influence on the Party's total inventory in terms of the absolute level of emissions, the trend in emissions or both. Information about key categories is considered to be crucial to the choice of methodology for individual sources and to the management and reduction of overall inventory uncertainty. The identification of such categories is recommended in order that inventory agencies can give them priority in the preparation of annual inventories, especially in cases where resources may be limited. Information on key categories is clearly also vital for the development of policies and measures for emissions reduction. The IPCC good practice guidance provides several methods for undertaking the analysis of key categories that can be applied at any appropriate level of source aggregation, depending on the information available. The simplest Tier 1 approach is again used for 2012 to further highlight which sources of emissions are the most important in Ireland.

The IPCC good practice guidance encourages inventory agencies to perform a Tier 2 Key Category Analysis, and this has also been suggested in previous annual inventory review reports. In response to this, initial work on the Tier 2 Key Category Analysis was carried out, which highlighted differences between the level of disaggregation found in the Tier 1 Key Category Analysis compared to the Tier 1 Uncertainty Assessment. Some sub-categories are reported at a more detailed level in the Key Category Analysis compared to the Uncertainty Analysis (such as transport). Due to resource constraints, it was not possible to complete this work for this year's submission so the finalisation of the Tier 2 Key Category Analysis and the disaggregation of the Tier 1 Uncertainty Analysis are planned improvements for the 2015 submission.

1.5.1 Key Categories at IPCC Level 2

As inventories of CO_2, CH_4 and N_2O were developed in Ireland during the 1990s, it was quickly established that CO_2 emissions from fuel combustion was by far the largest contributor to the combined national total for these three primary greenhouse gases. It was also evident that CH_4 emissions produced by large cattle herds and the N_2O emissions from agricultural soils, associated with intensive farming practices and large inputs of nitrogen to agricultural soils, were also major sources, even if the estimates were more uncertain than those for CO_2. A preliminary estimate of key categories is therefore provided by considering the emissions aggregated at the IPCC Level 2 source category classification, which clearly indicates the importance of CO_2 emissions from fuel combustion and CH_4 and N_2O emissions from agriculture.

The results at the IPCC Level 2 source category classification may be readily drawn from the CRF Summary 2. Those for 1990 and 2012 are shown in Table 1.2 and Table 1.3, respectively. It can be seen that there are seven highly significant key categories of emissions in Ireland in the 1990-2012 trend.

They are the CO_2 combustion sources in *1.A.1 Energy Industries, 1.A.2 Manufacturing Industries and Construction 1.A.3 Transport and 1.A.4 Other Sectors,* along with the CH_4 emissions from categories *4.A Enteric Fermentation* and *4.B Manure Management*, N_2O emissions from *4.B Manure Management* and *4.D Agricultural Soils* and HFC emissions from category *2.F Consumption of F Gas and* SF_6. These seven categories accounted for 89.3 per cent and 92.3 per cent of total emissions in 1990 and 2012, respectively. In the case of 2012 emissions, two additional Level 2 source categories are needed to reach the cumulative 95 per cent threshold that defines a key category: *2.A.1 Cement Production* with CO_2 emissions and *2.F Consumption of F Gas and* SF_6 with HFC emissions and CH_4 emissions from *Solid Waste Disposal on land (6.A)* are no longer a key category. The increase in the contribution of CO_2 emissions from category *1.A.3 Transport* from 9.1 per cent in 1990 to 18.4 per cent in 2012 is notable, along with the corresponding reductions in the contributions from the four categories: three in *Agriculture (4.A, 4B* and *4.D)* and one in *Energy (1.A.4)*. This simple analysis of key categories continues to prove useful to the formulation of abatement strategies and for prioritising work on inventories in Ireland. When LULUCF is accounted for in the Level 2 analysis, additional CO_2 emissions in *5.A Forest land* and *2.A.1 Cement production* become key categories in 1990, and additional CO_2 emissions in *5.A Forest land* plus CH_4 emissions in *Solid Waste Disposal on land (6.A)* become key categories in 2012 (as compared to those excluding LULUCF).

Table 1.2. Key Categories at IPCC Level 2 in 1990

IPCC Level 2 Source Category		GHG	Emissions in 1990 (Gg CO2 eq)	1990 Level Assessment (%)	Cumulative Total of Level (%)
1.A.1.	Energy Industries	CO2	11,158.61	20.20	20.20
1.A.4	Other Sectors(Comm/Resid/Agric)	CO2	10,031.09	18.16	38.36
4.A	Enteric Fermentation	CH4	9,574.12	17.33	55.68
4.D.	Agricultural Soils	N2O	7,271.20	13.16	68.85
1.A.3	Transport	CO2	5,021.69	9.09	77.94
1.A.2.	Manufacturing Industries and Construction	CO2	3,942.64	7.14	85.07
4.B	Manure Management	CH4	2,353.63	4.26	89.33
6.A	Solid Waste Disposal on land	CH4	1,173.05	2.12	91.46
2.B.2	Nitric Acid Production *	N2O	1,035.40	1.87	93.33
2.B.1	Ammonia Production *	CO2	990.23	1.79	95.12

* Nitric acid and Ammonia plants ceased operation in 2002 and 2001, respectively

Table 1.3. Key Categories at IPCC Level 2 in 2012

IPCC Level 2 Source Category		GHG	Emissions in 2012 (Gg CO2 eq)	2012 Level Assessment (%)	Cumulative Total of Level (%)
1.A.1.	Energy Industries	CO2	12,646.87	21.61	21.61
1.A.3	Transport	CO2	10,775.86	18.41	40.02
1.A.4	Other Sectors(Comm/Resid/Agric)	CO2	8,829.73	15.09	55.10
4.A	Enteric Fermentation	CH4	8,811.21	15.05	70.16
4.D.	Agricultural Soils	N2O	6,453.69	11.03	81.18
1.A.2.	Manufacturing Industries and Construction	CO2	4,254.97	7.27	88.45
4.B	Manure Management	CH4	2,238.46	3.82	92.28
2.A.1	Cement Production	CO2	1,177.02	2.01	94.29
2.F.	Consumption of F Gas and SF6	HFC	982.01	1.68	95.97

Table 1.4. Summary of Methods

IPCC SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	PFC	SF_6
1. Energy						
A. Fuel Combustion (Sectoral Approach)						
1. Energy Industries	T1, T3	T1, T2	T1, T2	NA	NA	NA
2. Manufacturing Industries and Construction	T1, T3	T1	T1	NA	NA	NA
3. Transport	T1, T2	T1, T2, T3	T1, T2, T3	NA	NA	NA
4. Other Sectors	T1	T1	T1	NA	NA	NA
5. Other	NA	NA	NA	NA	NA	NA
B. Fugitive Emissions from Fuels						
1. Solid Fuels	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas	NA	CS, T1	NA	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	T2	NA	NA	NA	NA	NA
B. Chemical Industry	T1	NA	T1	NA	NA	NA
C. Metal Production	NA	NA	NA	NA	NA	NA
D. Other Production	NA	NA	NA	NA	NA	NA
E. Production of Halocarbons and SF_6	NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF_6	NA	NA	NA	T1, T2, T3	T1a	T1, T1a
G. Other	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CR, CS	NA	NA	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	CS, T1, T2	NA	NA	NA	NA
B. Manure Management	NA	T1, T2	T1	NA	NA	NA
C. Rice Cultivation	NA	NA	NA	NA	NA	NA
D. Agricultural Soils	NA	NA	T1a, T1b	NA	NA	NA
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	NA
F. Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
5. Land-Use Land-Use Change Change and Forestry						
A. Forest Land	D, T1, T3	D, T1	D, T1	NA	NA	NA
B. Cropland	T1	NA	D, T1	NA	NA	NA
C. Grassland	T1, T3	NA	NA	NA	NA	NA
D. Wetlands	CS, T1	NA	D, T1	NA	NA	NA
E. Settlements	T1, T2	NA	NA	NA	NA	NA
F. Other Land	D, T1, T2	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NA	T2	NA	NA	NA	NA
B. Wastewater Handling	NA	T1	T1	NA	NA	NA
C. Waste Incineration	T1	T1	T1	NA	NA	NA
D. Other	NA	NA	NA	NA	NA	NA
7. Other	NA	NA	NA	NA	NA	NA
Article 3.3 Afforestation and Deforestation	Tier 3	Tier 1	Tier 1	NA	NA	NA
International Bunkers						
Aviation	Tier 1	D	D	NA	NA	NA
Marine	Tier 1	D	D	NA	NA	NA
Multilateral Operations	NA	NA	NA	NA	NA	NA
CO_2 Emissions from Biomass	Tier 1	Tier 1	Tier 1	NA	NA	NA

T1: IPCC Tier 1 or equivalent
T2: IPCC Tier 2 or equivalent
T3: IPCC Tier 3 or equivalent

CS: Country specific
CR: CORINAIR
D: IPCC Default

Table 1.5. Summary of Emission Factors

IPCC SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	PFC	SF_6
1. Energy						
A. Fuel Combustion (Sectoral Approach)						
1. Energy Industries	CS, PS	D	D	NA	NA	NA
2. Manufacturing Industries and Construction	CS, D, PS	D	D	NA	NA	NA
3. Transport	CS	CR, D, M	CR, D, M	NA	NA	NA
4. Other Sectors	CS	D	D	NA	NA	NA
5. Other	NA	NA	NA	NA	NA	NA
B. Fugitive Emissions from Fuels						
1. Solid Fuels	NA	NA	NA	NA	NA	NA
2. Oil and Natural Gas	NA	CS, D	NA	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	D, PS	NA	NA	NA	NA	NA
B. Chemical Industry	CS	NA	PS	NA	NA	NA
C. Metal Production	NA	NA	NA	NA	NA	NA
D. Other Production	NA	NA	NA	NA	NA	NA
E. Production of Halocarbons and SF_6	NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF_6	NA	NA	NA	CS	CS	CS
G. Other	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CR	NA	NA	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	CS, D	NA	NA	NA	NA
B. Manure Management	NA	CS, D	D	NA	NA	NA
C. Rice Cultivation	NA	NA	NA	NA	NA	NA
D. Agricultural Soils	NA	NA	CS, D	NA	NA	NA
E. Prescribed Burning of Savannas	NA	NA	NA	NA	NA	NA
F. Field Burning of Agricultural Residues	NA	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
5. Land-Use Land-Use Change and Forestry						
A. Forest Land	CS, D	D	D	NA	NA	NA
B. Cropland	D	NA	D	NA	NA	NA
C. Grassland	CS, D	NA	NA	NA	NA	NA
D. Wetlands	CS, D	NA	D	NA	NA	NA
E. Settlements	CS, D	NA	NA	NA	NA	NA
F. Other Land	CS, D	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NA	CS, D	NA	NA	NA	NA
B. Wastewater Handling	NA	D	D	NA	NA	NA
C. Waste Incineration	D	D	D	NA	NA	NA
D. Other	NA	NA	NA	NA	NA	NA
7. Other	NA	NA	NA	NA	NA	NA
Article 3.3 Afforestation and Deforestation	CS	D	D	NA	NA	NA
International Bunkers						
Aviation	CS	CR	CR	NA	NA	NA
Marine	CS	D	D	NA	NA	NA
Multilateral Operations	NA	NA	NA	NA	NA	NA
CO_2 Emissions from Biomass	CS, D	D, M, CR	D, M, CR	NA	NA	NA

PS: Plant specific   D: Default
CS: Country specific   M: Model
CR: CORINAIR

1.5.2 Disaggregated Key Categories

Ireland uses the Tier 1 method provided in the IPCC good practice guidance to extend the analysis above to identify key categories that may be treated separately at a more disaggregated level. This gives more information about the individual sources or combination of sources and gases that are of most importance within a Level 2 category. The disaggregation corresponds generally to that at which the emissions are calculated and to that used for estimating uncertainty. The results of the analysis for the Tier 1 level assessment in relation to emissions excluding LULUCF in both 1990 and 2012 are presented in Table 1.6 and Table 1.7, respectively. Tables 1.8 and 1.9 present the Tier 1 level assessment including LULUCF. Ranking in this way identifies those categories that should be prioritised in the inventory process itself and also the individual components of emissions that could be targeted by specific abatement measures. Results for Tier 1 trend assessment for 1990-2012 excluding LULUCF are shown in Table 1.10 and the trend assessment including LULUCF is presented in Table 1.11. The complete table of ranked sources for 2012 key category analysis is provided in Tables B.1-4 in Annex B.

The results of the level and trend assessments for 2012 excluding LULUCF categories may be summarised as follows:

(i) The level assessment identifies 24 key categories, all of which but four (CO_2 emissions in *1.A.4.c. Agriculture/Forestry/Fisheries* - Liquid Fuels, plus CH_4 emissions in *Manure Management: 4.B.1. Non-Dairy Cattle, 4.B.1 Dairy Cattle* and *4.B.8. Pigs*) are also key categories by trend assessment;
(ii) there are 13 key categories of CO_2 in level assessment, accounting for 62.8 per cent of total emissions;
(iii) there are 7 key categories of CH_4, three key categories of N_2O and one category of HFC in level assessment, which account for 19.8 per cent, 11.0 per cent and 1.7 per cent, respectively, of total emissions;
(iv) *Energy* accounts for 12 key categories, *Agriculture* for 9, while *Industrial Processes* contributes two and *Waste* contributes one;
(v) The trend assessment identifies 22 key categories, all of which but two (solid fuels CH_4 emissions in *1.A.4.b. Residential* and solid fuels CO_2 emissions in *1.A.2. Manufacturing Industries & Construction*) are also key categories for 2012 level assessment;
(vi) there are 13 key categories of CO_2 in trend assessment, accounting for 79.3 per cent of the total trend;
(vii) there are 5 key categories of CH_4, three key categories of N_2O and one key category of HFC in trend assessment, which account for 7.6 per cent, 4.6 per cent and 3.6 per cent, respectively, of the total trend.

The results of the level and trend assessment for 2012 including LULUCF categories may be summarised as follows:

(i) The level assessment identifies 28 key categories, 16 of these are sources of CO_2 emissions, accounting for 64.8 per cent of total emissions;
(ii) there are 4 additional categories that are not present in the assessment excluding LULUCF, of which 3 are *LULUCF* and the remaining one is N_2O emissions from *4.B.13 Manure Management - solid storage*;
(iii) the three additional *LULUCF* categories are CO_2 emissions from *5.A.2 Land converted to Forest Land*, *5.B.2 Land converted to Cropland* and *5.C.2 Land converted to Grassland*.
(iv) there are 7 key categories from sources of CH_4, 4 key *categories* from N_2O and 1 category of HFC, which account for 18.2 per cent, 10.7 per cent and 1.5 per cent, respectively, of total emissions;

(v) *Energy* accounts for 12 key categories, *Agriculture* for 10, *LULUCF* for 3, while *Industrial Processes* contributes 2 and *Waste* contributes 1;

(vi) The trend assessment identifies 28 key categories, six of which were not present in the assessment excluding LULUCF: CO_2 emissions from *LULUCF*: *5.A.2 Land converted to Forest Land, 5.A.1 Forest land Remaining Forest Land, 5.E.2 Land converted to Settlements, 5.C.2 Land converted to Grassland, 5.B.2 Land converted to Cropland* and *5.C.1 Grassland Remaining Grassland;*

(vii) there are 19 key categories of CO_2 in the trend assessment, accounting for 81.8 per cent of the total trend;

(viii) there are 5 key categories of CH_4, three key categories of N_2O and one key category of HFC in the trend assessment, which account for 6.9 per cent, 3.7 per cent and 2.6 per cent, respectively, of the total trend.

The list of key categories given by level assessment in 2012 is very similar to that for 1990. However, the higher ranking of the main CO_2 sources in *Energy,* at the expense of CH_4 and N_2O sources in *Agriculture*, is notable in 2012. The top ten key categories (excluding LULUCF) were in a different order but identical apart from two (*1.A.4.a Commercial/Institutional* and *1.A.2. Manufacturing Industries & Construction* with CO_2 emissions both from liquid fuels in 1990 were replaced by *1.A.4.b. Residential* with CO_2 emissions from liquid fuels and *1.A.2. Manufacturing Industries & Construction* CO_2 emissions from gaseous fuels) and contributed 70.1 and 72.8 per cent, of total emissions in 1990 and 2012, respectively. The emissions of CO_2 from the use of petrol and diesel *by road traffic (1.A.3.b)* and from solid fuel combustion in *1.A.1 Energy Industries* were the largest source categories of greenhouse gas emissions in Ireland in 2012, accounting for 17.6 and 12.5 per cent of the total, respectively.

The CO_2 removals in three categories: *5.A.2 Land converted to Forest Land, 5.B.2 Land converted to Cropland* and *5.C.2 Land converted to Grassland* are key categories in level assessment when the LULUCF sector is included in the detailed analysis. CO_2 removals in category KP *A.1 Afforestation (*which are determined largely by *5.A.1 Forest Land Remaining Forest Land* under LULUCF) is a key category (as well as *5.A.2 Land converted to Forest Land*) in 2012 when Article 3.3 activities are included in the analysis.

1.5.3 Use of Key Category Analysis

The Tier 1 approach to the determination of key categories is based on the principle that the cumulative uncertainty in their emissions represents 90 per cent of the total inventory uncertainty and that 95 per cent of total emissions account for this cumulative fraction of uncertainty. This quantitative approach may therefore result in a much larger number of key categories than might be expected using simpler qualitative criteria. In effect, an inventory with only a small number of major emission sources will require the inclusion of many source categories in order to reach the 95 per cent emissions threshold.

This is well shown by the results of key category determination for Ireland, based on Tier 1 level assessment, in Table 1.9. The results including LULUCF indicate that 18 of the 28 key categories in 2012 each accounted for less than 3 per cent of the total emissions and that only five key categories contributed more than 5 per cent each to the total. The Tier 1 analysis adequately identifies the specific sources of emissions that are significant in terms of the overall uncertainty of the inventory but it provides little direction on where to focus priority when the number is large. In these circumstances, information on the uncertainty in the individual source categories and other factors must be taken into account in making decisions regarding the most cost-effective use of inventory capacity related to key categories.

The results of the Tier 1 key category analysis in Table 1.7 and 1.9 clearly show the impact of CO_2 emissions from energy consumption on total emissions in Ireland. These emissions (CO_2 from energy) account for 12 of the key categories listed in Table 1.10 and for 62.2 per cent of total emissions in 2012. While key categories determined by CO_2 emissions from energy consumption have a major bearing on total emissions in Ireland, the remaining potential for significant reduction in the uncertainties associated with these sources is rather limited. The activity data and CO_2 emission factors for *Energy* source categories in general are among the most reliable items of input data in the inventory and there is consequently little scope for improving the accuracy of the emission estimates. The application of a robust Tier 2 methodology for emissions of CH_4 from *enteric fermentation* in *cattle* (*non-dairy* and *dairy*) and the use of verified estimates for CO_2 process emissions from *cement production* means that the contributions from three additional key categories (ranked 17, 18 and 21 in Table 1.10, respectively), making up a further 15.9 per cent of the total, are also known with probably the highest certainty now achievable. The N_2O emissions from *4.D Agricultural Soils*, F-gas emissions from *2.F Consumption of Halocarbons & SF_6* and CH_4 emissions from *6.A Solid Waste Disposal on Land* account for most of the remaining important key categories in Table 1.10. The uncertainties in the estimates for these complex sources (section 1.7) will remain high due to the large number of factors that influence their emissions and the relatively simple methods that continue to be used.

1.6 Quality Assurance and Quality Control

The inventory agency initiated a new approach to QA/QC in the 2006 reporting cycle. Its application was completed and consolidated in delivering the submissions up to 2012. This involved the allocation of responsibilities linked to the national system mentioned in section 1.3.2 and the use of a template spread sheet system to record the establishment and maintenance of general inventory checking and management activities covering the overall compilation process, as well as the undertaking of specific annual activities and any necessary periodic activities in response to specific events or outcomes in inventory reporting and review. The system facilitates record keeping related to the chain of activities from data capture, through emissions calculations and checking, to archiving and the identification of improvements. The system has been carried forward for use in completing the 2014 submission.

Ireland's calculation spread sheets in all sectors are structured and organised to facilitate the QA/QC process and more efficient time-series analysis and also to ensure ease of transfer of the outputs to the CRF Reporter Tool. This facilitates rapid year-on-year extension of the time-series, rapid inter-annual comparisons and efficient updating and recalculation, where appropriate, in the annual reporting cycle. Internal aggregation to various levels corresponding to the CRF tables provides immediate and complete checks on the results.

External reviews of the agriculture sector and of the entire ETS results for 2005 were conducted as important new components of quality assurance at the beginning of 2007. The review for the agriculture sector was performed by a Technical Inspector in the Department of Agriculture, Food and Marine. This review used the new calculation files to assess the consistency of the time series which had been subject to considerable improvement and recalculation in the 2006 reporting cycle. These improvements and recalculations were part of a move to higher tier methods for enteric fermentation in cattle as well as advice from the Department on various aspects of input data and calculation parameters. The detailed external review has not been repeated as there have not been any further changes to the methodologies in the agriculture sector. However, the inventory agency continues to work closely with the Department of Agriculture, Food and Marine and seeks advice and guidance from experts in Teagasc, an Agency of the Department of Agriculture, Food and Marine.

The ETS returns to the ETU provide for the complete coverage of CO_2 estimates in a number of sub-categories under *1.A.1 Energy Industries* and *2.A. Mineral Products*. When the allocation to these categories from the ETS raw data is completed, the output is returned to the ETS administrator in OCLR for final checking against the source data. This ensures the efficient and consistent transfer of the verified ETS emissions estimates into the national inventory. Inventory development continues to benefit from the internal review procedures that are on-going with regard to the EU and its Member States.

The inventory team contracted an external service provider, Aether, to assist in aspects of inventory compilation in 2013 for this submission. The transparency, robustness and accessibility of the inventory data within the electronic filing structures were assessed by Aether, who concluded that the system is very well organised.

1.7 Uncertainty Assessment

The Tier 1 method provided by the IPCC good practice guidance has been used to make an assessment of uncertainty in the emissions inventory data for 2012 in the same way as for previous years. This method estimates uncertainties for the entire inventory in a particular year and the uncertainty in the trend over time by combining the uncertainties in activity data and emission factors for each source category. The analysis for 2012 data is presented in Table 1.12 (excluding LULUCF) and Table 1.13 (including LULUCF), using emissions on a GWP basis and a level of source category disaggregation that corresponds closely to the level used for emissions calculation and for key category analysis. This disaggregation level limits the likely dependency and correlation between source categories.

The input values of uncertainty for activity data and emission factors in the GHG inventory have been assigned largely on the basis of general information related to the methodological descriptions in the IPCC good practice guidance, supported by opinions elicited from the principal data suppliers, such as statistical offices, energy agencies, Government Departments and individual experts who contributed to certain parts of the inventory.

Where higher tier methods are used for combustion sources, such as those covered by ETS and road transport, the activity data uncertainty estimates are those indicated for the tier concerned. Accordingly, low estimates of uncertainty apply to the activity data for categories such as *1.A.1 Energy Industries* and *1.A.3 Transport*, as shown on Table 1.12. Slightly higher uncertainty levels are used for energy activity data in sub-categories under *1.A.2 Manufacturing Industries and Constructio*n and *1.A.4 Other Sectors*, where the end use of fuels is not as well quantified in the top-down methods used. Low activity data uncertainties are justified in respect of CO_2 emissions sources in *Industrial Processes*, for which bottom-up data are applied in most cases and the major sources of emissions are covered by ETS. Country-specific CO_2 emission factors are used for all combustion sources, which gives a basis for assigning the uncertainties for emission factors while again taking into account the applicable tiers. Uncertainties in the emission factors for CH_4 and N_2O released from combustion sources are high and not well established quantitatively. For CH_4 and N_2O emission factors for combustion categories, the most up-to-date IPCC publications are used and an indicative uncertainty of 50 per cent is used for both gases.

The *Agriculture* sector is the second most important sector in Ireland's GHG inventory and has a major influence on overall uncertainty due to its large contribution in terms of CH_4 and N_2O emissions. Ireland has long-established and robust statistical data collection procedures in place for agriculture in general, which guides the selection of 1 per cent as the activity data uncertainty for all agriculture sub-categories. The IPCC good practice guidance indicates that the emission factor estimates for the Tier 2 approach to determine CH_4 emissions from enteric fermentation in cattle are likely to have an uncertainty of 20 per cent.

Following the opinion of national agriculture experts, a value of 15 per cent has been adopted for these emissions to take into account Ireland's detailed Tier 2 method and use of reliable data. In some of the other important emissions sources in *Agriculture* (such as manure management and agricultural soils) the activity data or emission factors ultimately used are determined by several specific component inputs, which are individually subject to varying degrees of uncertainty. The uncertainty estimates used for emission factors for these sources have been derived by assigning uncertainties to the key component parameters and combining them at the level of activity data or emission factors, as appropriate, using equation 6.4 in section 6.3 of the IPCC good practice guidance for each activity to obtain the input to the Tier 1 uncertainty assessment. The footnotes to Table 1.12 show how some of these uncertainty inputs are obtained.

Category *6.A Solid Waste* is the principal source of CH_4 emissions outside *Agriculture*. Under the revised methodology used for category 6.A in this submission, the component uncertainties for both activity data and emission factor for CH_4 generation are derived using equation 6.4 of the IPCC good practice guidance and as shown in the footnotes to Table 1.12. These are combined with uncertainties of 30 per cent and 10 per cent for flaring and utilisation respectively to obtain the overall uncertainty using equation 6.3 of the IPCC good practice guidance.

Equations 6.3 and 6.4 are both applied as appropriate in a hierarchical approach to derive uncertainty for *LULUCF* under both the Convention inventory and Article 3.3 activities. This is achieved by developing uncertainties for carbon pools, which are combined to give the values for the individual land-use categories, which are then combined with uncertainties for other reported activities to give the totals for *LULUCF* and Article 3.3 separately. Additional information on uncertainties for *LULUCF* is provided in chapters 7 and 11.

The F-gas inventory has been substantially revised following work by consultants in 2013, and new data sources were established. The uncertainties associated with the F-gas emission estimates were reviewed, and still considered to be appropriate.

The Tier 1 uncertainty analysis (excluding LULUCF) for Ireland's 2012 inventory under the Convention gives an overall uncertainty of 6.79 per cent in total emissions and a trend uncertainty of 2.71 per cent for the period 1990 to 2012 similar to the values reported in 2013 of 7.09 and 2.30 per cent, respectively.

These relatively low estimates are determined largely by the low uncertainties in the estimate of CO_2 emissions, which accounts for 64.9 per cent of total Irish emissions in 2012 and which are estimated to have a level uncertainty of 1.12 per cent (excluding LULUCF). When CH_4 is included, bringing the proportion of total emissions up to 85.6 per cent, the total uncertainty estimate is 2.06 per cent (excluding LULUCF), even though there are large uncertainties assigned to the CH_4 emission factors in some source categories. However, it is the influence of N_2O that leads to a substantial uncertainty in total emissions. This influence is not as large in the case of the trend, due to the modest change in emissions of N_2O from 1990 to 2012 and the relatively small share of this gas in total emissions. The impact of HFC, PFC and SF_6 on inventory uncertainty remains negligible because these gases account for only 1.8 per cent of total emissions in Ireland.

The Tier 1 uncertainty analysis (including LULUCF) for Ireland's 2012 inventory under the Convention (Table 1.13) gives an overall uncertainty of 11.34 per cent in total emissions and a trend uncertainty of 6.23 per cent for the period 1990 to 2012.

The overall uncertainly (including LULUCF) of the inventory in 2012 is a decrease on the last submission. The corresponding value in 2011 was 12.51 per cent. The reason for the decrease from 2011 to 2012 is due to a reduction in the amount of CO_2 sequestration from

Forestland in the LULUCF sector and the corresponding impact on the overall uncertainty from this sector on national total emission including LULUCF. The overall trend uncertainty decreased in 2012 when compared to 2011 to a value of 6.23 per cent compared to 6.62 per cent, for the same reason as above.

The overall uncertainty estimate for Article 3.3 activities in 2012 is 17.08 per cent, which is determined largely by an uncertainty of 16.11 per cent calculated for CO_2 removals in the category 5(KP-I)A.1.1.

1.8 Completeness and Time-Series Consistency

Table 1.14 gives an overview of the level of completeness of the 2014 GHG inventory submission with respect to the six greenhouse gases covered by the UNFCCC reporting guidelines, the IPCC Level 2 source-category split in operation since 2005 for reporting under the Convention and Article 3.3 activities under the Kyoto Protocol. Further detail on source/gas coverage at IPCC Level 3 is provided in the individual chapters describing the inventory methods and data for each Level 1 source-category.

The availability of new, more detailed, input data has allowed some emission calculations to be undertaken at a more detailed level. This has improved the accuracy of the emission estimates, and in some cases the completeness of the inventory has been improved – although not at the sectoral level:

- More detailed information on the use of some fuels has been used in the inventory for the first time, including the allocation of milled peat in *1.A.2*.
- A review of the F-gas emission estimates was undertaken, and more detailed activity data obtained. The use of this more comprehensive data has resulted in improved completeness in the 2014 emissions estimates of HFCs.
- A revision to CH_4 estimates from sludge from *waste water handling (6.B)* based on revised population equivalent data and biogas recovered at waste water treatment plants from 2003 to 2012.

The work done for the current reporting cycle serves to maintain a complete and consistent emissions time-series by improving the inventories for the years 1990-2011 to bring them fully into line with that for 2012. The opportunity has also been taken in this current cycle to improve, wherever possible, the estimates of emissions and removals for all years for LULUCF reported under the Convention in accordance with the requirements of Decision 13/CP.9 in order to achieve consistency with the reporting on Article 3.3 activities under the Kyoto Protocol.

Table 1.6. Key Category Analysis Level Assessment 1990 (excluding LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions exclud. LULUCF (Gg CO_2 eq)	1990 Level assessment exclud. LULUCF (%)	Cumulative Total (%)
1	1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	14.50	14.50
2	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,630.17	10.19	24.69
3	1.A.4.b	Residential - Solid Fuels	CO2	5,606.94	10.15	34.84
4	1.A.3.b	Road Transport - Liquid Fuels	CO2	4,690.42	8.49	43.33
5	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.84	5.47	48.80
6	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35	5.19	53.99
7	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99	5.17	59.16
8	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2,198.38	3.98	63.14
9	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00	3.54	66.68
10	1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	3.40	70.08
11	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,381.01	2.50	72.58
12	4.B.1	Manure Management - Non-Dairy cattle	CH4	1,279.75	2.32	74.90
13	1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	2.30	77.20
14	1.A.4.b	Residential - Liquid Fuels	CO2	1,175.35	2.13	79.32
15	6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05	2.12	81.45
16	2.B	Chemical Industry	N2O	1,035.40	1.87	83.32
17	4.A.3	Enteric Fermentation - Sheep	CH4	1,032.48	1.87	85.19
18	2.B	Chemical Industry	CO2	990.23	1.79	86.98
19	2.A.1	Cement Production	CO2	884.00	1.60	88.58
20	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	1.58	90.16
21	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	1.58	91.74
22	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	1.20	92.93
23	4.B.1	Manure Management - Dairy Cattle	CH4	608.23	1.10	94.03
24	4.B.13	Manure Management - Solid Storage	N2O	371.24	0.67	94.71
25	1.A.4.b	Residential - Solid Fuels	CH4	356.29	0.64	95.35

Table 1.7. Key Category Analysis Level Assessment 2012(excluding LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	2012 Emissions exclud. LULUCF (Gg CO_2 eq)	2012 Level assessment exclud. LULUCF (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10,322.82	17.64	17.64
2	1.A.1	Energy Industries - Solid Fuels	CO2	7,332.86	12.53	30.16
3	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,513.55	9.42	39.58
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	4,771.00	8.15	47.74
5	1.A.4.b	Residential - Liquid Fuels	CO2	2,734.28	4.67	52.41
6	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,686.52	4.59	57.00
7	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,606.20	4.45	61.45
8	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2,516.45	4.30	65.75
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2,239.71	3.83	69.58
10	1.A.4.b	Residential - Solid Fuels	CO2	1,874.34	3.20	72.78
11	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1,619.42	2.77	75.54
12	1.A.4.b	Residential - Gaseous Fuels	CO2	1,429.72	2.44	77.99
13	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,250.72	2.14	80.12
14	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,183.90	2.02	82.15
15	2.A.1	Cement Production	CO2	1,177.02	2.01	84.16
16	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,101.99	1.88	86.04
17	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	999.40	1.71	87.75
18	6.A	Waste - Solid Waste Disposal on land	CH4	803.62	1.37	90.80
19	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	690.01	1.18	91.98
20	4.A.3	Enteric Fermentation - Sheep	CH4	612.22	1.05	93.02
21	2.F	Consumption of Halocarbons & SF6	HFC	982.01	1.68	89.43
22	4.B.1	Manure Management - Dairy Cattle	CH4	481.09	0.82	93.85
23	1.A.1	Energy Industries - Liquid Fuels	CO2	449.46	0.77	94.61
24	4.B.8	Manure Management - Pigs	CH4	408.91	0.70	95.31

Table 1.8. Key Category Analysis Level Assessment 1990 (including LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions exclud. LULUCF (Gg CO_2 eq)	1990 Emissions for LULUCF (Gg CO_2 eq)	Absolute Values (Gg CO_2 eq)	1990 Level assessment includ. LULUCF (%)	Cumulative Total (%)
1	1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44		8,009.44	13.54	13.54
2	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,630.17		5,630.17	9.52	23.05
3	1.A.4.b	Residential - Solid Fuels	CO2	5,606.94		5,606.94	9.48	32.53
4	1.A.3.b	Road Transport - Liquid Fuels	CO2	4,690.42		4,690.42	7.93	40.46
5	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.84		3,021.84	5.11	45.57
6	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2		-3,007.68	3,007.68	5.08	50.65
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35		2,868.35	4.85	55.50
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99		2,854.99	4.83	60.33
9	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2,198.38		2,198.38	3.72	64.04
10	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00		1,957.00	3.31	67.35
11	1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66		1,880.66	3.18	70.53
12	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,381.01		1,381.01	2.33	72.86
13	4.B.1	Manure Management - Non-Dairy cattle	CH4	1,279.75		1,279.75	2.16	75.03
14	1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51		1,268.51	2.14	77.17
15	1.A.4.b	Residential - Liquid Fuels	CO2	1,175.35		1,175.35	1.99	79.16
16	6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05		1,173.05	1.98	81.14
17	2.B	Chemical Industry	N2O	1,035.40		1,035.40	1.75	82.89
18	4.A.3	Enteric Fermentation - Sheep	CH4	1,032.48		1,032.48	1.75	84.63
19	2.B	Chemical Industry	CO2	990.23		990.23	1.67	86.31
20	2.A.1	Cement Production	CO2	884.00		884.00	1.49	87.80
21	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02		873.02	1.48	89.28
22	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24		871.24	1.47	90.75
23	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30		660.30	1.12	91.87
24	4.B.1	Manure Management - Dairy Cattle	CH4	608.23		608.23	1.03	92.90
25	5.C.1	LULUCF - Grassland Remaining Grassland	CO2		600.29	600.29	1.01	93.91
26	4.B.13	Manure Management - Solid Storage	N2O	371.24		371.24	0.63	94.54
27	1.A.4.b	Residential - Solid Fuels	CH4	356.29		356.29	0.60	95.14

Table 1.9. Key Category Analysis Level Assessment 2012 (including LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	2012 Emissions exclud. LULUCF (Gg CO_2 eq)	2012 Emissions for LULUCF (Gg CO_2 eq)	Absolute Values (Gg CO_2 eq)	2012 Level assessment includ. LULUCF (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10,322.82		10,322.82	16.18	16.18
2	1.A.1	Energy Industries - Solid Fuels	CO2	7,332.86		7,332.86	11.49	27.67
3	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,513.55		5,513.55	8.64	36.31
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	4,771.00		4,771.00	7.48	43.78
5	5.A.2	LULUCF - Land converted to Forest Land	CO2		-3,847.33	3,847.33	6.03	49.81
6	1.A.4.b	Residential - Liquid Fuels	CO2	2,734.28		2,734.28	4.28	54.10
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,686.52		2,686.52	4.21	58.31
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,606.20		2,606.20	4.08	62.39
9	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2,516.45		2,516.45	3.94	66.34
10	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2,239.71		2,239.71	3.51	69.85
11	1.A.4.b	Residential - Solid Fuels	CO2	1,874.34		1,874.34	2.94	72.78
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1,619.42		1,619.42	2.54	75.32
13	1.A.4.b	Residential - Gaseous Fuels	CO2	1,429.72		1,429.72	2.24	77.56
14	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,250.72		1,250.72	1.96	79.52
15	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,183.90		1,183.90	1.86	81.38
16	2.A.1	Cement Production	CO2	1,177.02		1,177.02	1.84	83.22
17	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,101.99		1,101.99	1.73	84.95
18	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	999.40		999.40	1.57	86.51
19	6.A	Waste - Solid Waste Disposal on land	CH4	803.62		803.62	1.26	89.31
20	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	690.01		690.01	1.08	90.39
21	4.A.3	Enteric Fermentation - Sheep	CH4	612.22		612.22	0.96	91.35
22	2.F	Consumption of Halocarbons & SF6	HFC	982.01		982.01	1.54	88.05
23	4.B.1	Manure Management - Dairy Cattle	CH4	481.09		481.09	0.75	92.11
24	1.A.1	Energy Industries - Liquid Fuels	CO2	449.46		449.46	0.70	92.81
25	4.B.8	Manure Management - Pigs	CH4	408.91		408.91	0.64	93.45
26	4.B.13	Manure Management - Solid Storage	N2O	398.52		398.52	0.62	94.08
27	5.B.2	LULUCF - Land converted to Cropland	CO2		377.75	377.75	0.59	94.67
28	5.C.2	LULUCF - Land converted to Grassland	CO2		-354.97	354.97	0.56	95.23

Table 1.10. Key Category Analysis Trend Assessment 1990-2012 (excluding LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions exclud. LULUCF (Gg CO_2 eq)	2012 Emissions exclud. LULUCF (Gg CO_2 eq)	2012 Level assessment exclud. LULUCF (%)	2012 Trend assessment exclud. LULUCF (%)	Contribution to Trend (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4690.42	10322.82	17.64	8.63	19.78	19.78
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	1874.34	3.20	6.56	15.02	34.80
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	1880.66	4771.00	8.15	4.48	10.27	45.07
4	1.A.4.b	Residential - Liquid Fuels	CO2	1175.35	2734.28	4.67	2.40	5.50	50.57
5	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2239.71	3.83	2.12	4.86	55.43
6	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1429.72	2.44	1.84	4.23	63.91
7	1.A.1	Energy Industries - Solid Fuels	CO2	8009.44	7332.86	12.53	1.86	4.26	59.69
8	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1957.00	1101.99	1.88	1.57	3.59	71.13
9	1.A.1	Energy Industries - Liquid Fuels	CO2	1268.51	449.46	0.77	1.44	3.30	74.43
10	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	999.40	1.71	1.23	2.82	77.25
11	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.38	1619.42	2.77	1.14	2.62	79.87
12	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3021.84	2516.45	4.30	1.10	2.53	82.40
13	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	338.89	0.58	0.94	2.16	84.56
14	2.F	Consumption of Halocarbons & SF6	HFC	0.47	982.01	1.68	1.58	3.63	67.54
15	4.A.3	Enteric Fermentation - Sheep	CH4	1032.48	612.22	1.05	0.78	1.78	86.34
16	6.A	Waste - Solid Waste Disposal on land	CH4	1173.05	803.62	1.37	0.71	1.62	89.63
17	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5630.17	5513.55	9.42	0.73	1.67	88.01
18	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2854.99	2606.20	4.45	0.67	1.55	91.18
19	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2868.35	2686.52	4.59	0.57	1.30	92.48
20	1.A.4.b	Residential - Solid Fuels	CH4	356.29	119.55	0.20	0.42	0.95	93.43
21	2.A.1	Cement Production	CO2	884.00	1177.02	2.01	0.39	0.89	94.32
22	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1381.01	1250.72	2.14	0.34	0.78	95.11

Table 1.11. Key Category Analysis Trend Assessment 2012 (including LULUCF)

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions includ. LULUCF (Gg CO2 eq)	2012 Emissions includ. LULUCF (Gg CO2 eq)	2012 Level assessment includ. LULUCF (%)	2012 Trend assessment includ. LULUCF (%)	Contribution to Trend (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4690.42	10322.82	16.18	7.63	14.03	14.03
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	1874.34	2.94	6.07	11.16	25.19
3	5.A.2	LULUCF - Land converted to Forest Land	CO2	17.64	3847.33	6.03	5.55	10.22	35.41
4	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	3007.68	9.02	0.01	4.70	8.65	44.06
5	1.A.1	Energy Industries - Gaseous Fuels	CO2	1880.66	4771.00	7.48	3.97	7.31	51.37
6	1.A.4.b	Residential - Liquid Fuels	CO2	1175.35	2734.28	4.28	2.13	3.91	55.28
7	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2239.71	3.51	1.88	3.46	62.26
8	1.A.1	Energy Industries - Solid Fuels	CO2	8009.44	7332.86	11.49	1.91	3.52	58.80
9	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1429.72	2.24	1.65	3.04	65.30
10	5.E.2	LULUCF - Land converted to Settlements	CO2	1173.05	256.47	0.40	1.47	2.70	70.70
11	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1957.00	1101.99	1.73	1.47	2.70	68.00
12	1.A.1	Energy Industries - Liquid Fuels	CO2	1268.51	449.46	0.70	1.34	2.46	75.77
13	6.A	Waste - Solid Waste Disposal on land	CH4	14.68	803.62	1.26	1.14	2.10	77.88
14	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	999.40	1.57	1.10	2.02	79.90
15	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.38	1619.42	2.54	1.10	2.02	81.91
16	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3021.84	2516.45	3.94	1.08	2.00	83.91
17	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5630.17	5513.55	8.64	0.82	1.52	85.52
18	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	338.89	0.53	0.87	1.61	87.03
19	2.F	Consumption of Halocarbons & SF6	HFC	0.47	982.01	1.54	1.42	2.62	73.32
20	4.A.3	Enteric Fermentation - Sheep	CH4	1032.48	612.22	0.96	0.73	1.34	88.38
21	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2854.99	2606.20	4.08	0.69	1.27	89.65
22	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2868.35	2686.52	4.21	0.60	1.10	90.75
23	5.C.2	LULUCF - Land converted to Grassland	CO2	0.00	354.97	0.56	0.52	0.95	91.70
24	5.B.2	LULUCF - Land converted to Cropland	CO2	600.29	377.75	0.59	0.39	0.72	92.42
25	1.A.4.b	Residential - Solid Fuels	CH4	356.29	119.55	0.19	0.38	0.71	93.13
26	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	47.10	302.80	0.47	0.37	0.67	93.80
27	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1381.01	1250.72	1.96	0.35	0.64	94.44
28	2.A.1	Cement Production	CO2	884.00	1177.02	1.84	0.32	0.59	95.04

Table 1.12. Tier 1 Uncertainty Estimates 2012 excluding LULUCF (continued on following pages)

	IPCC Source Category	Gas	Emissions in 1990 Gg CO_2eq	Emissions in 2012 Gg CO_2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	449.46	1.00	2.50	2.69	0.02	0.00	-0.02	0.01	0.01	-0.04	0.04	0.00
1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	7,332.86	1.00	5.00	5.10	0.64	0.41	-0.02	0.13	0.19	-0.10	0.21	0.05
1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	4,771.00	1.00	2.50	2.69	0.22	0.05	0.05	0.09	0.12	0.13	0.18	0.03
1.A.1	Energy Industries - Non-Renewable Waste	CO2	0.00	93.55	1.00	5.00	5.10	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.2	Industry - Liquid Fuels exc Pet Coke	CO2	2,013.71	1,266.53	10.00	2.50	10.31	0.22	0.05	-0.02	0.02	0.32	-0.04	0.33	0.11
1.A.2	Industry - Coal	CO2	871.24	338.89	2.00	5.00	5.39	0.03	0.00	-0.01	0.01	0.02	-0.05	0.06	0.00
1.A.2	Industry - Pet Coke	CO2	184.67	352.88	5.00	5.00	7.07	0.04	0.00	0.00	0.01	0.05	0.01	0.05	0.00
1.A.2	Industry - Gaseous Fuels	CO2	873.02	2,239.71	2.50	2.50	3.54	0.14	0.02	0.02	0.04	0.14	0.06	0.16	0.02
1.A.2	Industry - Non-Renewable Waste	CO2	0.00	56.96	1.00	5.00	5.10	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.3	Transport - Oil	CO2	4,959.65	10,633.86	1.00	2.50	2.69	0.49	0.24	0.10	0.19	0.27	0.24	0.37	0.13
1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	142.00	1.00	2.50	2.69	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.A.4.a	Commercial - Liquid Fuels	CO2	1,957.00	1,101.99	10.00	5.00	11.18	0.21	0.04	-0.02	0.02	0.28	-0.09	0.30	0.09
1.A.4.a	Commercial - Coal	CO2	0.00	0.00	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Peat	CO2	138.29	0.00	10.00	20.00	22.36	0.00	0.00	0.00	0.00	0.00	-0.05	0.05	0.00
1.A.4.a	Commercial - Gaseous Fuels	CO2	223.49	999.40	2.50	2.50	3.54	0.06	0.00	0.01	0.02	0.06	0.03	0.07	0.01
1.A.4.b	Residential - Liquid Fuels	CO2	1,099.66	2,694.55	10.00	5.00	11.18	0.51	0.26	0.03	0.05	0.69	0.14	0.70	0.49
1.A.4.b	Residential - Coal	CO2	2,483.57	958.89	5.00	10.00	11.18	0.18	0.03	-0.03	0.02	0.12	-0.30	0.33	0.11
1.A.4.b	Residential - Pet coke	CO2	75.68	39.73	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
1.A.4.b	Residential - Peat	CO2	3,123.37	915.45	10.00	20.00	22.36	0.35	0.12	-0.04	0.02	0.23	-0.87	0.90	0.80
1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,429.72	2.50	2.50	3.54	0.09	0.01	0.02	0.03	0.09	0.05	0.11	0.01
1.A.4.c	Agri/Forest/Fisheries - Liquid Fuels	CO2	660.30	690.01	10.00	5.00	11.18	0.13	0.02	0.00	0.01	0.18	0.00	0.18	0.03
2.A.1	Cement Production	CO2	884.00	1,177.02	1.50	1.50	2.12	0.04	0.00	0.00	0.02	0.05	0.01	0.05	0.00
2.A.2	Lime Production	CO2	214.08	214.39	5.00	5.00	7.07	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00
2.A.3	Limestone Use	CO2	0.15	0.44	5.00	2.50	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4	Soda Ash Production and Use	CO2	0.10	0.09	5.00	2.50	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Glass Production	CO2	13.33	0.00	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Bricks & Ceramics	CO2	5.07	0.03	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO2	990.23	0.00	1.00	5.00	5.10	0.00	0.00	-0.02	0.00	0.00	-0.09	0.09	0.01
3	Solvent and Other Product Use	CO2	80.03	72.72	30.00	5.00	30.41	0.04	0.00	0.00	0.00	0.06	0.00	0.06	0.00
6.C	Waste - Waste Incineration	CO2	82.97	39.26	10.00	5.00	11.18	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	Total CO2		**32,423.99**	**38,011.39**	**0.65**			**1.12**	**1.26**					**1.38**	**1.91**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.13	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Solid Fuels	CH4	2.36	2.20	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	1.95	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Non-Renewable Waste	CH4	0.00	0.48	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Liquid Fuels exc Pet Coke	CH4	1.60	0.95	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Coal	CH4	1.93	0.75	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Pet Coke	CH4	0.12	0.24	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Gaseous Fuels	CH4	0.33	0.83	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Non-Renewable Waste	CH4	0.00	0.07	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	CH4	37.17	16.00	1.00	50.00	50.01	0.01	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.26	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Liquid Fuels	CH4	5.53	3.13	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Coal	CH4	0.00	0.00	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Peat	CH4	0.29	0.00	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Gaseous Fuels	CH4	0.43	1.85	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Liquid Fuels	CH4	2.95	7.77	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Coal	CH4	165.07	62.96	5.00	50.00	50.25	0.05	0.00	0.00	0.00	0.01	-0.10	0.10	0.01
1.A.4.b	Residential - Pet coke	CH4	0.17	0.09	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Peat	CH4	191.22	56.59	10.00	50.00	50.99	0.05	0.00	0.00	0.00	0.01	-0.13	0.13	0.02
1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.64	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Charcoal	CH4	0.04	0.09	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.c	Agri/Forest/Fisheries - Liquid Fuels	CH4	0.90	0.98	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A	Biomass (excl. charcoal)	CH4	13.39	17.34	10.00	50.00	50.99	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.B	Fugitive Emissions	CH4	131.26	24.00	2.50	10.00	10.31	0.00	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
4.A.1	Enteric - Dairy Cattle	CH4	2,854.99	2,606.20	1.00	15.00	15.03	0.67	0.45	-0.01	0.05	0.07	-0.11	0.13	0.02
4.A.1	Enteric - Non-dairy Cattle	CH4	5,630.17	5,513.55	1.00	15.00	15.03	1.42	2.01	-0.01	0.10	0.14	-0.12	0.19	0.03
4.A	Enteric - Other Livestock	CH4	1,088.95	691.46	1.00	30.00	30.02	0.35	0.13	-0.01	0.01	0.02	-0.25	0.25	0.06
4.B.1	Manure Mgt - Dairy Cattle	CH4	608.23	481.09	1.00	15.00	15.03	0.12	0.02	0.00	0.01	0.01	-0.04	0.05	0.00
4.B.1	Manure Mgt - Non-dairy Cattle	CH4	1,279.75	1,183.90	1.00	15.00	15.03	0.30	0.09	0.00	0.02	0.03	-0.05	0.06	0.00
4.B	Manure Mgt - Other Livestock	CH4	465.65	573.47	1.00	30.00	30.02	0.29	0.09	0.00	0.01	0.01	0.04	0.05	0.00
6.A	Waste - Solid Waste Disposal abc	CH4	1,173.05	803.62	34.64	34.64	31.13	0.43	0.18	-0.01	0.01	0.71	-0.28	0.76	0.58
6.B	Waste - Waste Water Handling	CH4	14.68	19.42	10.00	30.00	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
6.C	Waste - Waste Incineration	CH4	0.01	0.00	10.00	30.00	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total CH4		**13,674.09**	**12,074.01**				**1.72**	**2.96**					**0.86**	**0.74**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Solid Fuels	N2O	62.22	57.90	1.00	50.00	50.01	0.05	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	75.73	1.00	50.00	50.01	0.06	0.00	0.00	0.00	0.00	0.06	0.06	0.00
1.A.1	Energy Industries - Non-Renewable Waste	N2O	0.00	0.95	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Liquid Fuels exc Pet Coke	N2O	4.65	2.67	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Coal	N2O	4.28	1.67	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Pet Coke	N2O	0.37	0.71	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Gaseous Fuels	N2O	0.00	0.20	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Industry - Non-Renewable Waste	N2O	0.49	1.22	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	N2O	61.77	106.75	1.00	25.00	25.02	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.00
1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.55	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Liquid Fuels	N2O	4.87	2.75	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial - Coal	N2O	792.28	0.00	5.00	50.00	50.25	0.00	0.00	-0.02	0.00	0.00	-0.76	0.76	0.58
1.A.4.a	Commercial - Peat	N2O	-791.69	0.00	10.00	50.00	50.99	0.00	0.00	0.02	0.00	0.00	0.76	0.76	0.58
1.A.4.a	Commercial - Gaseous Fuels	N2O	0.13	0.54	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Liquid Fuels	N2O	2.43	6.79	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Coal	N2O	12.18	4.65	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.4.b	Residential - Pet coke	N2O	0.15	0.08	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Peat	N2O	13.17	3.90	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.78	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Charcoal	N2O	0.00	0.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.c	Agri/Forest/Fisheries - Liquid Fuels	N2O	72.05	68.33	10.00	50.00	50.99	0.06	0.00	0.00	0.00	0.02	-0.01	0.02	0.00
1.A	Biomass (excl. charcoal)	N2O	5.48	16.40	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
2.B	Nitric Acid	N2O	1,035.40	0.00	1.00	10.00	10.05	0.00	0.00	-0.02	0.00	0.00	-0.20	0.20	0.04
4.B.12	Manure Mgt - Liquid Systems d	N2O	63.87	65.51	11.22	100.00	100.63	0.11	0.01	0.00	0.00	0.02	0.00	0.02	0.00
4.B.13	Manure Mgt - Solid Storage d	N2O	371.24	398.52	11.22	100.00	100.63	0.69	0.47	0.00	0.01	0.11	0.01	0.11	0.01
4.D.1	Agri Soils - Direct Soil Emissions d	N2O	3,021.84	2,516.45	11.22	100.00	100.63	4.33	18.72	-0.01	0.05	0.72	-1.24	1.43	2.06
4.D.2	Agri Soils - Pasture, Range & Pdk d	N2O	2,868.35	2,686.52	11.22	100.00	100.63	4.62	21.33	-0.01	0.05	0.77	-0.64	1.00	1.00
4.D.3	Agri Soils - Indirect Emissions d	N2O	1,381.01	1,250.72	11.22	50.00	51.24	1.10	1.20	0.00	0.02	0.36	-0.19	0.41	0.17
6.B	Waste - Waste Water Handling	N2O	111.71	144.54	10.00	10.00	14.14	0.03	0.00	0.00	0.00	0.04	0.00	0.04	0.00
6.C	Waste - Waste Incineration	N2O	0.86	0.41	10.00	10.00	14.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total N2O		**9,112.12**	**7,416.59**				**6.46**	**41.74**					**2.11**	**4.44**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
2.F	Consumptn of Halocarbons & SF6	HFC	0.47	982.01	20.00	10.00	22.36	0.38	0.14	0.02	0.02	0.50	0.18	0.53	0.28
2.F	Consumptn of Halocarbons & SF6	PFC	0.09	8.03	10.00	2.50	10.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F	Consumptn of Halocarbons & SF6	SF6	35.51	39.21	15.00	5.00	15.81	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	Total HFC, PFC & SF6		**36.07**	**1,029.25**				**0.38**	**0.14**					**0.53**	**0.28**
	Total all gases		**55,246.27**	**58,531.24**					**46.11**						**7.37**
					Overall Uncertainty in Emissions			**6.79**				**Trend Uncertainty**		**2.71**	

a AD uncertainty for CH4 generation based on equation 6.4 of GPG with uncertainties of 20%, 20% and 20% for MSW quantity, MSW composition and DOC, respectively
b EF uncertainty for CH4 generation based on equation 6.4 of GPG with uncertainties of 20%, 20% and 20% for fraction of DOC dissimilated, MCF and decay rate constant, respectively
c Combined uncertainty based on equation 6.3 of GPG using a and b above and assuming 30% and 10% uncertainties for CH4 flaring and utilisation, respectively
d AD uncertainty based on Equation 6.4 of IPCC GPG with uncertainties of 5%, 1% and 10% for AWMS proportion, livestock/fertiliser numbers and nitrogen excretion

Table 1.13. Tier 1 Uncertainty Estimates 2012 including LULUCF (continued on following pages)

	IPCC Source Category	Gas	Emissions 1990 in Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	449.46	1.00	2.50	2.69	0.02	0.00	-0.02	0.01	0.01	-0.04	0.04	0.00
1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	7,332.86	1.00	5.00	5.10	0.68	0.46	-0.02	0.14	0.20	-0.10	0.22	0.05
1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	4,771.00	1.00	2.50	2.69	0.23	0.05	0.05	0.09	0.13	0.13	0.18	0.03
1.A.1	Energy Industries - Non-Renewable Waste	CO2	0.00	93.55	1.00	5.00	5.10	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	CO2	2,013.71	1,266.53	10.00	2.50	10.31	0.24	0.06	-0.02	0.02	0.34	-0.04	0.34	0.12
1.A.2	Manufacturing Industries & Construction - Coal	CO2	871.24	338.89	2.00	5.00	5.39	0.03	0.00	-0.01	0.01	0.02	-0.05	0.06	0.00
1.A.2	Manufacturing Industries & Construction - Pet Coke	CO2	184.67	352.88	5.00	5.00	7.07	0.05	0.00	0.00	0.01	0.05	0.02	0.05	0.00
1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2,239.71	2.50	2.50	3.54	0.14	0.02	0.03	0.04	0.15	0.06	0.16	0.03
1.A.2	Manufacturing Industries & Construction - Non-Renewable Waste	CO2	0.00	56.96	1.00	5.00	5.10	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.3	Transport - Oil	CO2	4,959.65	10,633.86	1.00	2.50	2.69	0.52	0.27	0.10	0.20	0.28	0.26	0.38	0.15
1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	142.00	1.00	2.50	2.69	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00	1,101.99	10.00	5.00	11.18	0.22	0.05	-0.02	0.02	0.29	-0.09	0.31	0.09
1.A.4.a	Commercial/Institutional - Coal	CO2	0.00	0.00	5.00	10.00	11.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Peat	CO2	138.29	0.00	10.00	20.00	22.36	0.00	0.00	0.00	0.00	0.00	-0.05	0.05	0.00
1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	999.40	2.50	2.50	3.54	0.06	0.00	0.01	0.02	0.07	0.04	0.08	0.01
1.A.4.b	Residential - Liquid Fuels	CO2	1,099.66	2,694.55	10.00	5.00	11.18	0.54	0.30	0.03	0.05	0.72	0.15	0.73	0.54
1.A.4.b	Residential - Coal	CO2	2,483.57	958.89	5.00	10.00	11.18	0.19	0.04	-0.03	0.02	0.13	-0.31	0.34	0.11
1.A.4.b	Residential - Pet coke	CO2	75.68	39.73	5.00	5.00	7.07	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
1.A.4.b	Residential - Peat	CO2	3,123.37	915.45	10.00	20.00	22.36	0.37	0.14	-0.04	0.02	0.24	-0.89	0.92	0.85
1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,429.72	2.50	2.50	3.54	0.09	0.01	0.02	0.03	0.10	0.05	0.11	0.01
1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	690.01	10.00	5.00	11.18	0.14	0.02	0.00	0.01	0.18	0.00	0.18	0.03
2.A.1	Cement Production	CO2	884.00	1,177.02	1.50	1.50	2.12	0.05	0.00	0.00	0.02	0.05	0.01	0.05	0.00
2.A.2	Lime Production	CO2	214.08	214.39	5.00	5.00	7.07	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00
2.A.3	Limestone Use	CO2	0.15	0.44	5.00	2.50	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4	Soda Ash Production and Use	CO2	0.10	0.09	5.00	2.50	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Glass Production	CO2	13.33	0.00	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Bricks & Ceramics	CO2	5.07	0.03	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO2	990.23	0.00	1.00	5.00	5.10	0.00	0.00	-0.02	0.00	0.00	-0.10	0.10	0.01
3	Solvent and Other Product Use	CO2	80.03	72.72	30.00	5.00	30.41	0.04	0.00	0.00	0.00	0.06	0.00	0.06	0.00
5.A	LULUCF - Forest Land	CO2	-2,990.04	-3,856.35	51.00	114.00	124.89	-8.70	75.61	-0.01	-0.07	-5.25	-1.57	5.48	30.07
5.B.1	LULUCF - Cropland remaining Cropland	CO2	20.00	9.60	22.57	69.15	72.74	0.01	0.00	0.00	0.00	0.01	-0.01	0.02	0.00
5.B.2	LULUCF - Total Land converted to Cropland	CO2	0.00	377.75	18.61	69.15	71.61	0.49	0.24	0.01	0.01	0.19	0.49	0.53	0.28
5.C.1	LULUCF - Grassland Remaining Grassland	CO2	600.29	302.80	12.22	90.00	90.83	0.50	0.25	-0.01	0.01	0.10	-0.55	0.56	0.32
5.C.2	LULUCF - Grassland in Transition	CO2	-106.41	-354.97	43.95	101.11	110.24	-0.71	0.50	0.00	-0.01	-0.42	-0.47	0.62	0.39
5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	47.10	34.14	21.49	101.45	103.70	0.06	0.00	0.00	0.00	0.02	-0.03	0.04	0.00
5.D.2	LULUCF - Total Land converted to Wetland	CO2	0.00	-1.76	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.E.1	LULUCF - Settlement remaing Settlement	CO2	0.00	0.00	39.97	75.00	84.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.E.2	LULUCF - Lands converted to Settlement	CO2	77.94	256.47	39.97	81.83	91.07	0.42	0.18	0.00	0.00	0.27	0.27	0.38	0.15
5.F.1	LULUCF - Other Land remaining Other Land	CO2	0.00	0.00	30.91	90.00	95.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.F.2	LULUCF - Lands converted to Other Land	CO2	0.89	9.32	51.93	75.00	91.23	0.02	0.00	0.00	0.00	0.01	0.01	0.02	0.00
6.C	Waste - Waste Incineration	CO2	82.97	39.26	10.00	5.00	11.18	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	Total CO2		**30,073.75**	**34,788.40**	**0.63**			**8.84**	**78.19**					**5.77**	**33.25**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to AD %	Uncertainty in Trend in Total Emissions due to EF %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.13	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Solid Fuels	CH4	2.36	2.20	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	1.95	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Non-Renewable Waste	CH4	0.00	0.48	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	CH4	1.60	0.95	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Coal	CH4	1.93	0.75	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Pet Coke	CH4	0.12	0.24	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.33	0.83	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Non-Renewable Waste	CH4	0.00	0.07	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	CH4	37.17	16.00	1.00	50.00	50.01	0.01	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.26	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	5.53	3.13	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Coal	CH4	0.00	0.00	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Peat	CH4	0.29	0.00	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	0.43	1.85	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Liquid Fuels	CH4	2.95	7.77	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Coal	CH4	165.07	62.96	5.00	50.00	50.25	0.06	0.00	0.00	0.00	0.01	-0.10	0.10	0.01
1.A.4.b	Residential - Pet coke	CH4	0.17	0.09	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Peat	CH4	191.22	56.59	10.00	50.00	50.99	0.05	0.00	0.00	0.00	0.02	-0.14	0.14	0.02
1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.64	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Charcoal	CH4	0.04	0.09	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	0.98	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A	Biomass (excl. charcoal)	CH4	13.39	17.34	10.00	50.00	50.99	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.B	Fugitive Emissions	CH4	131.26	24.00	2.50	10.00	10.31	0.00	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99	2,606.20	1.00	15.00	15.03	0.71	0.50	-0.01	0.05	0.07	-0.11	0.13	0.02
4.A.1	Enteric Fermentation - Non-dairy Cattle	CH4	5,630.17	5,513.55	1.00	15.00	15.03	1.50	2.24	-0.01	0.10	0.15	-0.11	0.18	0.03
4.A	Enteric Fermentation - Other Livestock	CH4	1,088.95	691.46	1.00	30.00	30.02	0.37	0.14	-0.01	0.01	0.02	-0.25	0.25	0.06
4.B.1	Manure Management - Dairy Cattle	CH4	608.23	481.09	1.00	15.00	15.03	0.13	0.02	0.00	0.01	0.01	-0.04	0.05	0.00
4.B.1	Manure Management - Non-dairy Cattle	CH4	1,279.75	1,183.90	1.00	15.00	15.03	0.32	0.10	0.00	0.02	0.03	-0.04	0.05	0.00
4.B	Manure Management - Other Livestock	CH4	465.65	573.47	1.00	30.00	30.02	0.31	0.10	0.00	0.01	0.02	0.05	0.05	0.00
5.A	LULUCF - Forest Land	CH4	9.29	1.92	30.00	100.00	104.40	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05	803.62	34.64	34.64	48.99	0.71	0.51	-0.01	0.02	0.74	-0.28	0.79	0.63
6.B	Waste - Waste Water Handling	CH4	14.68	19.42	10.00	30.00	31.62	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
6.C	Waste - Waste Incineration	CH4	0.01	0.00	10.00	30.00	31.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total CH4		**13,683.38**	**12,075.93**				**1.90**	**3.61**					**0.88**	**0.78**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2012 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2012 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Uncertainty in Trend in Total Emissions due to EF %	Uncertainty in Trend in Total Emissions due to AD %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared
1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.1	Energy Industries - Solid Fuels	N2O	62.22	57.90	1.00	50.00	50.01	0.05	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	75.73	1.00	50.00	50.01	0.07	0.00	0.00	0.00	0.00	0.06	0.06	0.00
1.A.1	Energy Industries - Non-Renewable Waste	N2O	0.00	0.95	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	N2O	4.65	2.67	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Coal	N2O	4.28	1.67	2.00	50.00	50.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Pet Coke	N2O	0.37	0.71	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	0.00	0.20	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2	Manufacturing Industries & Construction - Non-Renewable Waste	N2O	0.49	1.22	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	N2O	61.77	106.75	1.00	25.00	25.02	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.00
1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.55	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	4.87	2.75	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.a	Commercial/Institutional - Coal	N2O	792.28	0.00	5.00	50.00	50.25	0.00	0.00	-0.02	0.00	0.00	-0.78	0.78	0.61
1.A.4.a	Commercial/Institutional - Peat	N2O	-791.69	0.00	10.00	50.00	50.99	0.00	0.00	0.02	0.00	0.00	0.78	0.78	0.61
1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.13	0.54	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Liquid Fuels	N2O	2.43	6.79	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Coal	N2O	12.18	4.65	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.4.b	Residential - Pet coke	N2O	0.15	0.08	5.00	50.00	50.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Peat	N2O	13.17	3.90	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.78	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.b	Residential - Charcoal	N2O	0.00	0.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	68.33	10.00	50.00	50.99	0.06	0.00	0.00	0.00	0.02	-0.01	0.02	0.00
1.A	Biomass (excl. charcoal)	N2O	5.48	16.40	10.00	50.00	50.99	0.02	0.00	0.00	0.00	0.00	0.01	0.01	0.00
2.B	Nitric Acid	N2O	1,035.40	0.00	1.00	10.00	10.05	0.00	0.00	-0.02	0.00	0.00	-0.20	0.20	0.04
4.B.12	Manure Management - Liquid Systems	N2O	63.87	65.51	11.22	100.00	100.63	0.12	0.01	0.00	0.00	0.02	0.00	0.02	0.00
4.B.13	Manure Management - Solid Storage	N2O	371.24	398.52	11.22	100.00	100.63	0.72	0.52	0.00	0.01	0.12	0.02	0.12	0.01
4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.84	2,516.45	11.22	100.00	100.63	4.57	20.90	-0.01	0.05	0.75	-1.22	1.43	2.05
4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35	2,686.52	11.22	100.00	100.63	4.88	23.82	-0.01	0.05	0.81	-0.59	1.00	1.00
4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,381.01	1,250.72	11.22	50.00	51.24	1.16	1.34	0.00	0.02	0.38	-0.18	0.42	0.17
5.A	LULUCF - Forest Land	N2O	24.78	38.61	30.00	100.00	104.40	0.07	0.01	0.00	0.00	0.03	0.02	0.04	0.00
5.B.2	LULUCF - Land converted to Cropland	N2O	0.00	35.07	30.00	100.00	104.40	0.07	0.00	0.00	0.00	0.03	0.07	0.07	0.01
5.C.1	LULUCF - Grassland Remaining Grassland	N2O	0.00	0.00	91.02	100.00	135.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.C.2	LULUCF - Land converted to Grassland	N2O	0.00	0.00	91.02	100.00	135.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.D.2	LULUCF - Land Converted to Wetlands	N2O	3.59	2.54	92.16	100.00	135.99	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
6.B	Waste - Waste Water Handling	N2O	111.71	144.54	10.00	10.00	14.14	0.04	0.00	0.00	0.00	0.04	0.01	0.04	0.00
6.C	Waste - Waste Incineration	N2O	0.86	0.41	10.00	10.00	14.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total N2O		**9,140.49**	**7,492.81**				**6.83**	**46.63**					**2.13**	**4.53**

	IPCC Source Category	Gas	Emissions in 1990	Emissions in 2012	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2012	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions due to AD	Uncertainty in Trend in Total Emissions due to EF	Combined Uncertainty in Trend in Total Emissions	Combined Trend Uncertainty Squared
			Gg CO2eq	**Gg CO2eq**	**%**	**%**	**%**	**%**		**%**	**%**	**%**	**%**	**%**	
2.F	Consumption of Halocarbons & SF6	HFC	0.47	982.01	20.00	10.00	22.36	0.38	0.14	0.02	0.02	0.50	0.18	0.53	0.28
2.F	Consumption of Halocarbons & SF6	PFC	0.09	8.03	10.00	2.50	10.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F	Consumption of Halocarbons & SF6	SF6	35.51	39.21	15.00	5.00	15.81	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	Total HFC, PFC & SF6		**36.07**	**1,029.25**				**0.38**	**0.14**					**0.53**	**0.28**
	Total all gases		**52,933.69**	**55,386.39**					**128.57**						**38.84**
					Overall Uncertainty in Emissions			**11.34**				**Trend Uncertainty**		**6.23**	

a AD uncertainty for CH4 generation based on equation 6.4 of GPG with uncertainties of 20%, 20% and 20% for MSW quantity, MSW composition and DOC, respectively
b EF uncertainty for CH4 generation based on equation 6.4 of GPG with uncertainties of 20%, 20% and 20% for fraction of DOC dissimilated, MCF and decay rate constant, respectively
c Combined uncertainty based on equation 6.3 of GPG using a and b above and assuming 30% and 10% uncertainties for CH4 flaring and utilisation, respectively
d AD uncertainty based on Equation 6.4 of IPCC GPG with uncertainties of 5%, 1% and 10% for AWMS proportion, livestock/fertiliser numbers and nitrogen excretion

Table 1.14. Summary of Completeness

IPCC SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	PFC	SF_6
1. Energy						
A. Fuel Combustion (Sectoral Approach)	All	All	All	NA	NA	NA
1. Energy Industries	All	All	All	NA	NA	NA
2. Manufacturing Industries and Construction	All	All	All	NA	NA	NA
3. Transport	All	All	All	NA	NA	NA
4. Other Sectors	All	All	All	NA	NA	NA
5. Other	NO	NO	NO	NA	NA	NA
B. Fugitive Emissions from Fuels						
1. Solid Fuels	NO	NO	NO	NA	NA	NA
2. Oil and Natural Gas	All	All	Part	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	All	Part	Part	NA	NA	NA
B. Chemical Industry	NO	NO	NO	NO	NO	NO
C. Metal Production	NO	NO	NO	NO	NO	NO
D. Other Production	NE	NA	NA	NA	NA	NA
E. Production of Halocarbons and SF_6	NA	NA	NA	NO	NO	NO
F. Consumption of Halocarbons and SF_6	NA	NA	NA	All	All	All
G. Other	NO	NO	NO	NO	NO	NO
3. Solvent and Other Product Use	All	NA	NE	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	All	NA	NA	NA	NA
B. Manure Management	NA	All	All	NA	NA	NA
C. Rice Cultivation	NA	NO	NA	NA	NA	NA
D. Agricultural Soils	NA	NE	All	NA	NA	NA
E. Prescribed Burning of Savannas	NO	NO	NO	NA	NA	NA
F. Field Burning of Agricultural Residues	NO	NO	NO	NA	NA	NA
G. Other	NO	NO	NO	NA	NA	NA
5. Land-Use Land-Use Change and Forestry						
A. Forest Land	All	Part	Part	NA	NA	NA
B. Cropland	All	NO	All	NA	NA	NA
C. Grassland	All	NO	IE	NA	NA	NA
D. Wetlands	All	NE	All	NA	NA	NA
E. Settlements	Part	NO	NO	NA	NA	NA
F. Other Land	All	NE	NE	NA	NA	NA
G. Other	NO	NO	NO	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NO	All	NA	NA	NA	NA
B. Wastewater Handling	NA	All	All	NA	NA	NA
C. Waste Incineration	NE	NE	NE	NA	NA	NA
D. Other	NO	NO	NO	NA	NA	NA
7. Other	NO	NO	NO	NA	NA	NA
Article 3.3 Afforestation and Deforestation	All	All	All	NA	NA	NA
Memo Items:						
International Bunkers						
Aviation	All	All	All	NA	NA	NA
Marine	All	All	All	NA	NA	NA
Multilateral Operations	NO	NO	NO	NA	NA	NA
CO_2 Emissions from Biomass	All	NA	NA	NA	NA	NA

All : Emissions of the gas are covered for all sources under the source category/memo item
NA : Emissions of the gas not applicable to the source category/memo item
NO : Emissions of the gas does not occur in Ireland for the source category/memo item
NE : Emissions on the gas not estimated for the source category/memo item
Part : Emissions of the gas estimated for some activities in the source category

Chapter Two

Emission Trends

2.1 Trends in Total Emissions

The trends in emissions of the six greenhouse gases in Ireland over the period 1990-2012 are shown in Table 2.1. The estimates reported here show some changes on those reported in the 2013 submission, which reflect recalculations that are fully described in subsequent chapters. The trends in the principal emission components, shown as CO_2 equivalents, within the six IPCC sectors are shown on Figure 2.2 through Figure 2.12. Total emissions of the six greenhouse gases in Ireland (excluding net emissions from *Land Use Land Use Change and Forestry*) increased steadily from 55,246.27 Gg CO_2 eq in 1990 to 70,207.50 Gg CO_2 eq in 2001 and then decreased slightly to 68,184.47 Gg CO_2 eq in 2004. Total emissions increased again in 2005 to 69,655.66 Gg CO_2 eq and then decreased for six consecutive years to 57,749.96 in 2011, but increased in 2012 to 58,531.24 Gg CO_2 eq. The largest annual change occurred from 2008 to 2009 when emissions decreased by 5,708.23 Gg CO_2 eq from 68,020.49 to 62,312.26 Gg CO_2 equivalent, a reduction of 8.4 per cent. Total emissions in 2012 were 5.9 per cent lower than in 1990 and 16.6 per cent lower than the peak level in 2001. The estimated total for 2012 is 58,531.24 Gg CO_2 eq, equating to 781.28 Gg CO_2 eq or 1.4 per cent higher than that for 2011. Inter annual changes to national total emission estimates are shown in Figure 2.1.

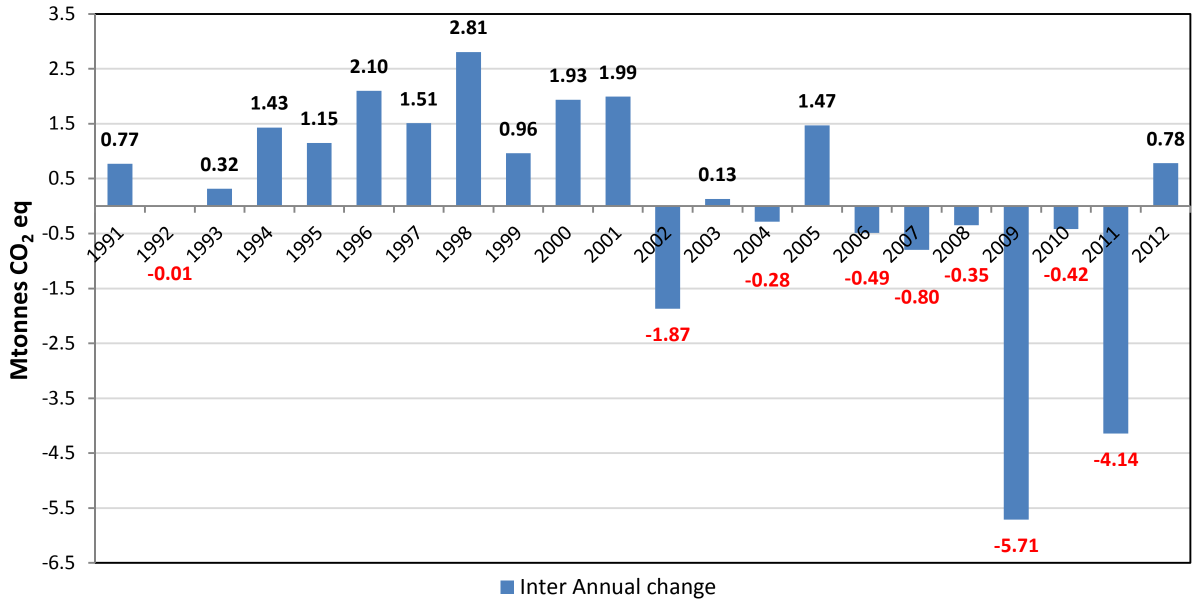


Figure 2.1 Inter annual change in national total emissions 1990-2012

In 2012, the total *Energy* sector accounted for 63.3 per cent of total emissions, *Agriculture* contributed 30.7 per cent while a further 4.1 per cent emanated from *Industrial Processes*, 1.7 per cent was due to *Waste* and 0.1 per cent was due to *Solvents and Other Product Use*.

The *Energy* and *Industrial Processes* sectors accounted for the bulk of the CO_2 emissions in 2012 (96.0 per cent and 3.4 per cent), CH_4 emissions are produced mainly in the *Agriculture* (91.5 per cent) and *Waste* (6.8 per cent) sectors and most of the N_2O emissions are generated in *Agriculture* and *Energy* (93.3 per cent and 4.8 per cent, respectively).

The large increase in emissions during the period 1990-2001 was clearly driven by the growth in CO_2 emissions from energy use. CO_2 from energy use increased its share of national total emissions from 54.6 per cent in 1990 to 62.5 per cent share in 2001. The bulk of this increase occurred in the years between 1994 and 2001, during which Ireland experienced a period of unprecedented economic growth with energy CO_2 emissions increasing by an average of 4.6 per cent annually. The rate of economic growth slowed down from 2002 to 2004, which together with the closure of ammonia and nitric acid production plants and the continued decline in cattle populations and fertiliser use resulted in a reduction in the emission levels in the period 2002 to 2004. The increase in 2005 to 64.5 per cent share was due largely to increased emissions from road transport and from electricity generation from two new peat-fired stations. The trend was growing to reach the maximum share at 65.5 per cent in 2008 and was a result of growing Irish economy. The sustained increase in transport emissions, the major contributor to the trend, came to an end in 2008 and together with the recent economic downturn caused a major decrease in emissions in 2009 to 2011, before rising in 2012. However, CO_2 from energy use continued to decline since 2008 and at 62.2 per cent share reached pre-2004 level.

Table 2.1. Greenhouse Gas Emissions 1990, 1995, 2000-2012 (Gg CO_2 equivalent)

(a) Emissions by Gas

GREENHOUSE GAS EMISSIONS	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Change from base to latest reported year
CO_2 emissions including net CO_2 from LULUCF	30,073.75	33,806.53	43,798.05	46,408.28	45,020.15	44,107.67	43,345.73	45,351.56	45,861.83	44,450.41	42,799.99	37,182.31	37,343.69	33,997.72	34,788.40	15.68%
CO_2 emissions excluding net CO_2 from LULUCF	32,423.99	35,232.54	44,689.18	47,098.33	45,676.12	45,151.23	45,805.48	47,626.85	47,227.19	47,213.62	47,005.72	41,749.65	41,292.13	37,716.34	38,011.39	17.23%
CH_4 emissions including CH_4 from LULUCF	13,683.38	13,932.12	13,419.75	13,473.39	13,398.74	13,959.87	13,165.79	12,825.87	12,895.47	12,369.48	12,243.51	11,950.79	11,741.06	11,699.63	12,075.93	-11.75%
CH_4 emissions excluding CH_4 from LULUCF	13,674.09	13,919.99	13,411.77	13,457.48	13,395.08	13,937.33	13,152.65	12,821.10	12,890.70	12,364.11	12,237.97	11,947.66	11,720.62	11,692.05	12,074.01	-11.70%
N_2O emissions including N_2O from LULUCF	9,140.49	9,595.22	9,530.12	9,025.28	8,653.98	8,578.59	8,397.74	8,180.62	8,047.82	7,801.57	7,708.48	7,619.52	7,907.25	7,360.86	7,492.81	-18.03%
N_2O emissions excluding N_2O from LULUCF	9,112.12	9,555.24	9,484.81	8,974.22	8,604.38	8,519.35	8,339.64	8,123.93	7,991.52	7,745.36	7,640.05	7,551.09	7,837.02	7,288.43	7,416.59	-18.61%
HFCs	0.47	37.13	270.82	313.65	381.97	514.99	635.44	813.46	844.63	850.89	973.06	957.12	973.37	992.28	982.01	209730.85%
PFCs	0.09	75.38	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20	8.03	8525.51%
SF_6	35.51	82.93	54.35	67.84	67.74	115.43	68.83	101.98	63.40	66.18	57.50	41.17	34.74	47.66	39.21	10.41%
Total (including LULUCF)	**52,933.69**	**57,529.32**	**67,378.49**	**69,584.42**	**67,734.98**	**67,505.36**	**65,795.96**	**67,441.84**	**67,861.47**	**65,669.11**	**63,888.74**	**57,816.48**	**58,037.12**	**54,111.36**	**55,386.39**	**4.63%**
Total (excluding LULUCF)	**55,246.27**	**58,903.21**	**68,216.34**	**70,207.50**	**68,337.70**	**68,467.13**	**68,184.47**	**69,655.66**	**69,165.75**	**68,370.74**	**68,020.49**	**62,312.26**	**61,894.90**	**57,749.96**	**58,531.24**	**5.95%**

(b) Emissions by IPCC Source Category

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Change from base to latest reported year
1. Energy	30,970.48	33,779.89	42,459.41	44,572.60	43,360.07	43,893.17	43,792.23	45,586.61	45,193.15	45,159.51	45,240.08	40,761.57	40,482.32	37,008.94	37,062.65	19.67%
2. Industrial Processes	3,178.43	3,065.51	4,234.11	4,364.45	3,828.57	3,201.84	3,393.76	3,636.58	3,595.10	3,628.08	3,438.34	2,549.19	2,344.17	2,220.41	2,421.22	-23.82%
3. Solvent and Other Product Use	80.03	85.39	78.99	77.84	75.51	74.28	73.78	73.92	74.89	75.45	73.94	71.37	71.16	72.07	72.72	-9.13%
4. Agriculture	19,634.06	20,314.39	19,970.38	19,594.76	19,378.81	19,511.03	19,315.01	18,857.31	18,721.86	18,283.22	18,150.58	17,937.38	18,004.52	17,380.55	17,967.39	-8.49%
5. LULUCF	-2,312.58	-1,373.89	-837.85	-623.08	-602.73	-961.77	-2,388.51	-2,213.83	-1,304.28	-2,701.63	-4,131.75	-4,495.78	-3,857.78	-3,638.60	-3,144.85	35.99%
6. Waste	1,383.27	1,658.03	1,473.45	1,597.85	1,694.74	1,786.81	1,609.69	1,501.24	1,580.76	1,224.48	1,117.56	992.75	992.73	1,067.99	1,007.26	-27.18%
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (including LULUCF)	**52,933.69**	**57,529.32**	**67,378.49**	**69,584.42**	**67,734.98**	**67,505.36**	**65,795.96**	**67,441.84**	**67,861.47**	**65,669.11**	**63,888.74**	**57,816.48**	**58,037.12**	**54,111.36**	**55,386.39**	**4.63%**

2.2 Trends by Gas

Emissions of CO_2 accounted for 64.9 per cent of the total (excluding LULUCF) of 58,531.24 Gg CO_2 equivalent in 2012, with CH_4 and N_2O contributing 20.6 per cent and 12.7 per cent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for approximately 1.8 per cent of total emissions in 2012. In 1990 emissions of CO_2, CH_4, N_2O and the combined emissions of HFCs, PFCs and SF_6 accounted for 58.7, 24.8, 16.5 and less than 0.01 per cent, respectively of total emissions of 55,246.27 Gg CO_2 equivalent.

CO_2 is the most significant contributor to the greenhouse gas emissions with *1.A.1 Energy Industries* responsible for 33.3 per cent of total CO_2 emissions in 2012. *1.A.3 Transport* represents a share of 28.3 per cent, *1.A.4 Other Sectors* has a share of 23.2 per cent, *1.A.2 Manufacturing Industries and Construction* has an 11.2 per cent share and the remainder of CO_2 emissions (4.0 per cent share) fall into other sectors. Emissions of CO_2 increased from 32,423.99 Gg in 1990 to 38,011.39 Gg in 2012, which equates to an increase of 17.2 per cent. The main driver behind this increase in emissions is primarily fuel combustion in *Transport* followed by *Energy Industries*. Over the period 1990-2012, emissions of CO_2 from transport, predominantly road traffic in Ireland, increased by 114.6 per cent. This trend is exaggerated somewhat in later years by so-called fuel-tourism. In 2012 it is estimated that approximately 8.5 per cent of automotive fuel sold in Ireland is used in vehicles in the UK and other countries. Over the time-series, emissions of CO_2 from *1.A.1 Energy Industries* increased by 13.3 per cent, further adding to the increase in CO_2 emissions over the 1990-2012 period. In addition, even though Ireland has only a small number of energy intensive industries, CO_2 emissions from combustion in the industrial sector *1.A.2 Manufacturing Industries and Construction* increased by 7.9 per cent between 1990 and 2012.

Methane is the second most significant contributor to greenhouse gas emissions in Ireland which is due to the large population of cattle. In 2012 emissions of CH_4 were 12,074.01 Gg CO_2 equivalent, indicating a decrease of 11.7 per cent on the 1990 level of 13,674.09 Gg CO_2 equivalent. Emissions of CH_4 increased progressively from 1990, reaching a peak in 1998 of 14,417.35 Gg CO_2 equivalent, which reflects an increase in livestock numbers and therefore increased emissions from source categories *4.A Enteric Fermentation and 4.B Manure Management*. Between 1998 and 2011 CH_4 emissions decreased as a result of falling livestock numbers due to reform of the Common Agricultural Policy (CAP). However, total CH_4 emissions in the period 2001-2011 fluctuated to some extent on a yearly basis. This trend is a direct result of fluctuating CH_4 emissions from *1.A.4 Other Sectors* and *1.B.Fugitive Emissions from Fuels.* The main contributor to the CH_4 trend has been *Agriculture* and in 2012 the sector accounted for 91.5 per cent of the total methane emissions (compared to 87.2 per cent share in 1990 when emissions from Waste had a larger share in the methane trend). Nevertheless, the sectoral methane emissions from *Agriculture* decreased by 7.4 per cent between 1990 (11,927.75 Gg CO_2 equivalent) and 2012 (11,049.67 Gg CO_2 equivalent). Another significant source of methane emissions is *Waste* sector, especially from landfill gas in category *6.A Solid Waste Disposal on Land*. CH_4 emissions from *Waste* decreased from 8.7 per cent share of total methane emissions (1,187.73 Gg CO_2 equivalent) in 1990 to 6.8 per cent share (823.04 Gg CO_2 equivalent) in 2012. This decrease is a result of improved management of landfill facilities, including increased recovery of landfill gas utilised for electricity generation and flaring.

Emissions of N_2O decreased by 18.6 per cent from their 1990 level of 9,112.12 Gg CO_2 equivalent in 1990 to 7,416.59 Gg CO_2 equivalent in 2012. Similar to CH_4, emissions of N_2O increased during the 1990s to reach peak level of 10,267.45 Gg CO_2 equivalent in 1998 reflecting increased use of synthetic fertilisers and increased amounts of animal manures associated with increasing animal numbers over that period. Emissions of N_2O subsequently show a clear downward trend following reductions in synthetic fertiliser use and organic nitrogen applications on land as a result of the effect of CAP reform on animal numbers as well the closure of Ireland's only nitric acid plant in 2002. The biggest contributor to the trend is Agriculture sector with 93.3 per cent share of the total N_2O emissions (6,917.72 Gg CO_2 equivalent) in 2012. This reflects an increase from 84.6 per cent share (7,706.30 Gg CO_2 equivalent) in 1990 despite being a lower absolute number. Emissions from *Industrial Processes* in chemical industry used to be the second largest contributor to the trend contributing 11.4 per cent to total N_2O emissions in 1990 and an average of 8.8 per cent share to the trend between 1990 and 2000, before falling to 3.4 per cent share in 2002 – the year of nitric acid plant closure. *Energy* and *Waste* sectors contribute 4.8 per cent and 2.0 per cent respectively to the rest of the N_2O trend.

Emissions of the F-gases (HFCs, PFCs and SF_6) were 1,029.25 Gg CO_2 equivalent in 2012 compared to 36.07 Gg CO_2 equivalent in 1990, a 27.5-fold increase over the time series. However, F-gas emissions only account for 1.8 per cent of the national total. F-gases include a wide range of substances that are used in a diverse range of products and manufacturing processes. Therefore it can be difficult to identify the factors contributing to actual trends in emissions over time. However, it is possible to establish the main contributory sub-categories underlying these trends.

The main causative factor of the increase in F-gas emissions has been the growth in HFC emissions from *2.F.1 Refrigeration and Air Conditioning* through their use as replacement refrigerants across virtually all refrigeration sub-categories since 1991. Increased use of HFCs in *2.F.4 Metered Dose Inhalers (MDIs)* and *Mobile Air Conditioning (2.F.1)* are also important components of the trend. On the other hand, following a review in 2013 on F-gases, emissions from *2.F.2 Foams* were proven to be not occurring in manufacturing process and consequently were removed from the whole time series. Similar was the finding in *2.F.3 Fire extinguishers* between 1990-1996 (incl.) and significant emission reductions for the following years in the trend have been applied, also emissions were proven to be not occurring in *2.F.1 Refrigeration and Air Conditioning* (between 1991-1995 incl.) and in *2.F.4 Aerosols* (in 1990 and 1992). Emissions from HFCs increased from 0.47 Gg CO_2 equivalent in 1990 reaching their peak at 992.28 Gg CO_2 equivalent in 2011 and falling to 982.01 Gg CO_2 in 2012.

Emissions of PFCs show an increasing trend from 0.09 Gg CO_2 equivalent in 1990 up to 130.82 Gg CO_2 equivalent in 1997 through their use in the semiconductor manufacturing process in *2.F.7 Semiconductor Manufacture.* Emissions subsequently decreased, only to significantly increase to reach 305.41 Gg CO_2 equivalent in 2000. Semiconductor manufacturers continue to investigate various reduction initiatives through gas substitution and new process technologies which is reflected in the downward trend in PFC emissions between 2000 and 2012 (8.03 Gg CO_2 equivalent in 2012).

SF_6 is used in a diverse number or products and processes and is therefore included in a number of IPCC source sub-categories including *2.F.7 Semiconductor Manufacture, 2.F.8 Electrical Equipment* and *2.F.9 Other*. Emissions of SF_6 were 36.07 Gg CO_2 equivalent and 39.21 Gg CO_2 equivalent in 1990 and 2012, respectively. However, total emissions of SF_6 across the time series vary considerably, primarily because the two largest sources (*Semiconductor Manufacture* and *Electrical Equipment*) vary considerably from year to year. Emissions of SF_6 grew steadily from 1990, peaking at 132.20 Gg CO_2 equivalent in 1997. The increase over the period 1990-1997 was largely due to increased use of SF_6 in *Semiconductor Manufacture*. Emissions from both *Semiconductor Manufacture* and *Electrical Equipment* then show a steady decline across the time series (although there are peaks in 2003 and 2005 due to elevated emissions from *Semiconductor Manufacture*). Emissions in 2012 (39.21 Gg CO_2 equivalent) were lower than those in 1991.

Similar to PFCs, semiconductor manufacturers have undertaken to reduce the use of SF_6 through gas substitution and new process technologies. In *2.F.8 Electrical Equipment,* where SF_6 is used for electrical insulation, arc quenching and current interruption, a leak reduction programme has been in place since 1997, when peak emissions are observed. SF_6 use and methodology, similar like HFC gases has undergone a revision resulting in some changes mainly in sector *2.F.9 Other - window soundproofing* with reduction of emissions in the first decade followed by increased emissions between 2000-2012.

2.3 Trends by IPCC Sector

Greenhouse gas emissions broken down by IPCC sector are presented in Table 2.1 (b). It can be seen that the largest contribution is from the *Energy* sector, which in 2012 contributes 63.3 per cent of total greenhouse gas emissions (excluding *LULUCF*). The second largest sector is *Agriculture*, which accounted for 30.7 per cent of total greenhouse gas emissions in 2012. Emissions from *Industrial Processes, Waste* and *Solvent and Other Product Use* accounted for 4.1 per cent, 1.7 per cent and 0.1 per cent, respectively of total emissions in 2012. The following sub-sections discuss the main contributors to trends within each IPCC source sector including LULUCF. Emissions of indirect gases are discussed in section 2.4.

2.3.1 Trends in Energy (IPCC Sector 1)

Emissions from the *Energy* sector increased by 19.7 per cent from 30,970.48 Gg CO_2 equivalent in 1990 to 37,062.65 Gg CO_2 equivalent in 2012. The most significant increases occurred between 1994 and 2001, driven by major increases in emissions from *1.A.1 Energy Industries* and *1.A.3 Transport.* Emissions were comparatively stable between 2001 and 2008, reaching a peak in 2005 with 45,586.61 Gg CO_2 equivalent. A major decrease occurred between 2008 and 2009 when the sectoral emissions fell by 8.4 per cent. Further reductions of 9.1 per cent have occurred to give 37,062.65 Gg CO_2 equivalent in 2012.

1.A.1 Energy Industries accounted for 20.3 per cent and 21.9 per cent of total national greenhouse gas emissions in 1990 and 2012, respectively. Total greenhouse gas emissions from this sub-sector increased by 54.5 per cent from 11,238.54 CO_2 equivalent in 1990 to 17,364.19 CO_2 equivalent in 2001. Some reductions were achieved in 2002, 2003 and 2004 from improvements in energy efficiency and fuel switching as some new electricity producers entered the market with the result that emissions decreased to 15,368.72 Gg CO_2 equivalent in 2004. Emissions subsequently increased in 2005 to 15,770.14 Gg CO_2 equivalent as levels of peat use returned to former levels with the entry into service of two new peat fired power plants. Emissions in 2006 decreased to 15,028.21 Gg CO_2 equivalent due to a reduction in the use of Moneypoint coal-fired station during the installation of pollutant control measures, while further reductions in 2007 (14,535.21 Gg CO_2 equivalent) are largely a result of the displacement of oil by natural gas. In 2008, emissions increased by 0.8 per cent to reach 14,652.76 Gg CO_2 equivalent, then decreased in 2009 by 10.8 per cent to 13,077.48 Gg CO_2 equivalent reflecting the impact of the economic recession in Ireland. There was a slight increase in emissions (2.0 per cent) in 2010 to reach 13,333.17 Gg CO_2 equivalent which reflects a reduction in the share of renewables in gross electricity consumption from 14.3 per cent in 2009 to 11.8 per cent in 2010. Wind and hydro resources were less in 2010 which resulted in more electricity generation from coal and gas-fired power stations. By 2012, wind and hydro energy generation had grown substantially, resulting in a renewables contribution to gross electricity consumption of 17.3 per cent. However, these changes combined with increased consumption of coal and reduction of natural gas resulted in an overall increase in emissions from the *Energy* sector of 0.1 per cent between 2011 and 2012. Overall drivers and trends in emissions from the *Energy* sector are presented in Figure 2.2 and Figure 2.3.

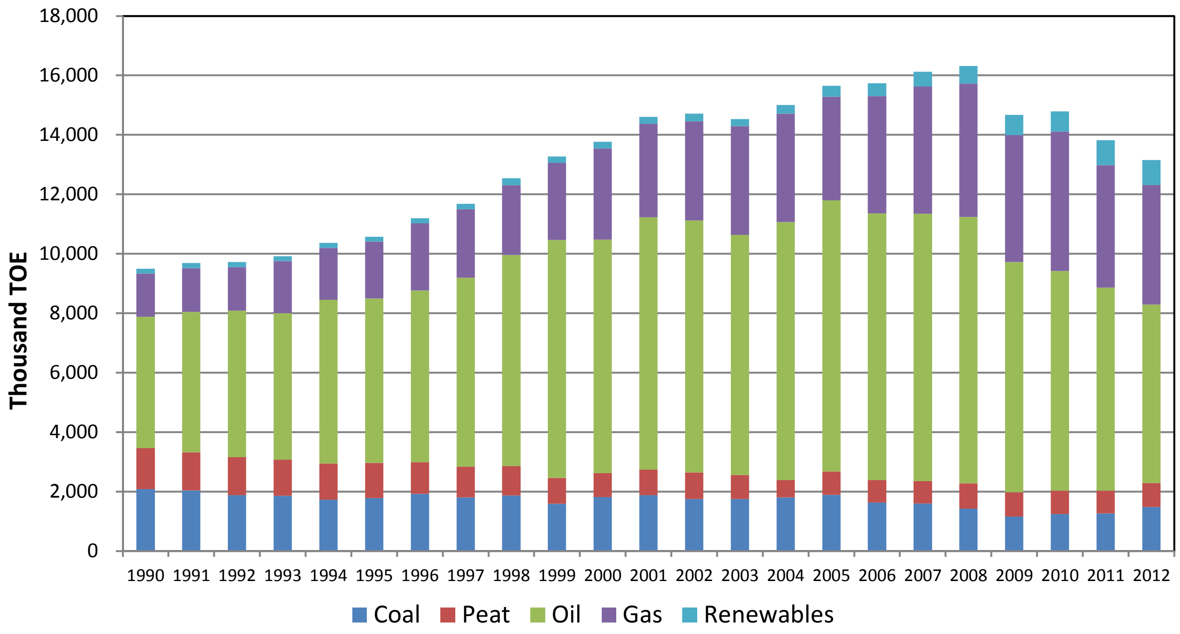


Figure 2.2 Total Primary Energy Requirement (TPER) 1990-2012

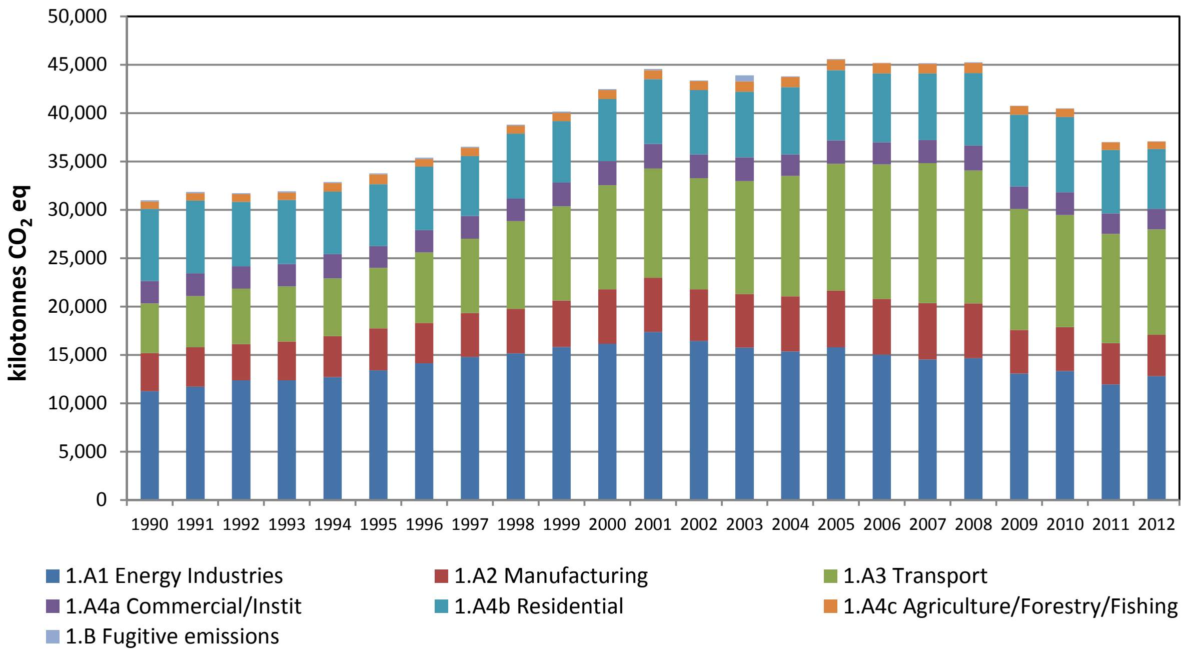


Figure 2.3 Trend in Emissions from Energy 1990-2012

There are only a small number of energy intensive industries in Ireland under sub-category *1.A.2 Manufacturing Industries and Construction*. This sub-category accounted for 7.2 per cent (3,961.19 Gg CO_2 equivalent) and 7.3 per cent (4,275.91 Gg CO_2 equivalent) of total national greenhouse gas emissions in 1990 and 2012, respectively. However, the trend shows an increase of 7.9 per cent over the same period as a result of large increases in use of petroleum coke and natural gas in *1.A.2.f Other Industries*.

Fuel combustion emissions in *1.A.3 Transport* accounted for 9.2 per cent and 18.4 per cent of total national greenhouse gas emissions in 1990 and 2012, respectively. The overall sectors emissions increased by 112.8 per cent from 5,121.45 Gg CO_2 equivalent in 1990 to 10,900.42 Gg CO_2 equivalent in 2012. This is largely accounted for by a 118.6 per cent increase in road transport emissions over the same period, due to sustained growth in the use of passenger cars and goods vehicles. The trend is however, somewhat exaggerated by so-called fuel tourism whereby a proportion of the automotive fuel sold in the Republic of Ireland is used in vehicles in the UK and other countries. Fuel tourism is estimated to account for 8 per cent of automotive fuels in 2012. It is worth noting that in the years 1990-1995 inclusive there was cross border movement of automotive fuels into the Republic of Ireland. The principal drivers in road transport emission trends are shown in Figures 2.4 and 2.5. *Transport* emissions were 3.59 million tonnes CO_2 equivalent lower in 2012 than in 2007. This represents a decrease of 24.8 per cent, following sustained increases in this sector since 1990. The decrease primarily reflects the impact of the economic downturn plus the changes in vehicle registration tax and road tax introduced in mid-2008 and the Biofuels Obligation Scheme.

Emissions from civil aviation decreased by 77.8 per cent between 1990 (51.73 Gg CO_2 equivalent) and 2012 (11.50 Gg CO_2 equivalent), having peaked in 2006 at 77.31 Gg CO_2 equivalent. However, their overall effect on transport emission trends is negligible.

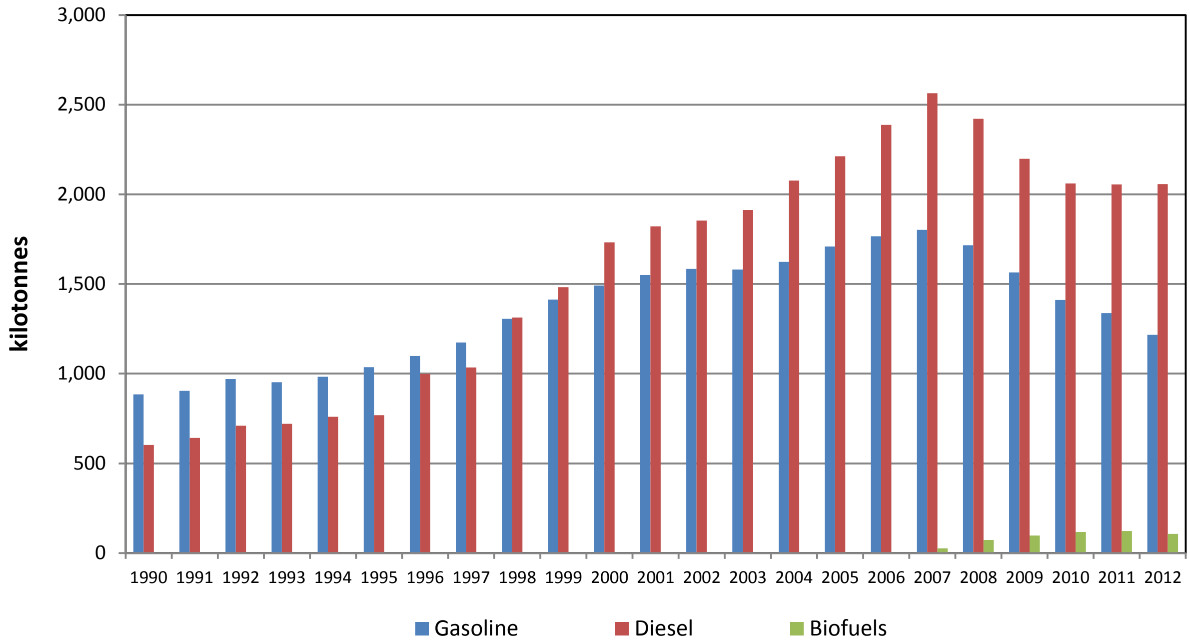


Figure 2.4 Fuel use in Road Transport 1990-2012

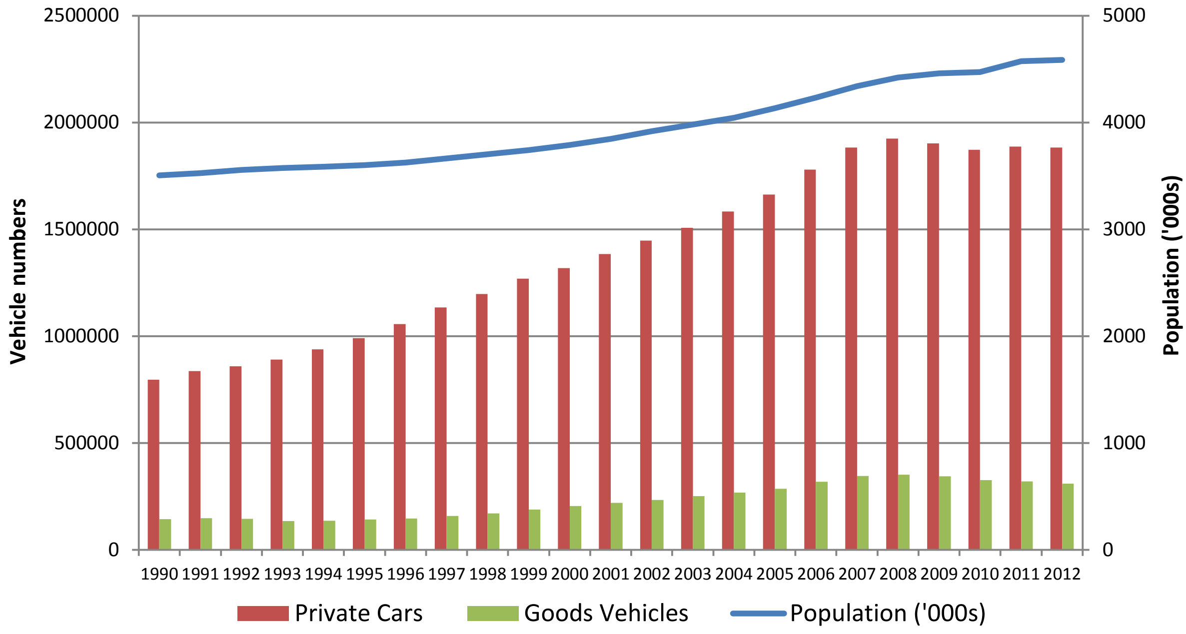


Figure 2.5 Vehicle numbers and Census of Population 1990-2012

Emissions from category *1.A.4 Other Sectors* decreased by 13.8 per cent from 10,518.03 Gg CO_2 equivalent in 1990 to 9,068.47 Gg CO_2 equivalent in 2012. Emissions from the *Commercial (1.A.4.a), Residential (1.A.4.b)* and *Agriculture/Forestry/Fisheries (1.A.4.c)* sub-categories decreased by 6.2, 16.9 and 6.0 per cent in the whole trend, respectively. Although residential fossil fuel consumption increased by 5.7 per cent from 1990 to 2012 there has been a decline in the use of carbon-intensive fuels, such as peat and coal, and greater use of oil and natural gas. The emissions of CO_2 from coal and peat use in the residential sector decreased by 66.4 per cent between 1990 and 2012 while those from oil and natural gas increased by 198.2 per cent over this period.

2.3.2 Trends in Industrial Processes (IPCC Sector 2)

The contribution from *Industrial Processes* is relatively small, accounting for 5.8 per cent of total greenhouse gases in 1990 and 4.1 per cent in 2012. Total emissions from the sector were 3,178.43 Gg CO_2 equivalent in 1990 and 2,421.22 Gg CO_2 equivalent in 2012. This is a decrease of 23.8 per cent in emissions over the time series. Overall trends in emissions from *Industrial Processes* are presented in Figure 2.6.

In the early 1990's (1990 to 1994) the contribution of *2.B Chemical Industry* to overall sectoral emissions was on average 63.2 per cent. By the late 1990's (1995 to 1999) this proportion had fallen to 53.0 per cent on average of total emissions from the sector. In 1990 emissions from *2.B. Chemical Industry* were 2,025.63 Gg CO_2 equivalent, however by 2000 they had reduced by 16.3 per cent to 1,694.75 Gg CO_2 equivalent. Emissions from *2.F Consumption of F Gas and SF_6* were increasing together with the Irish economy. Over the same period Ireland was experiencing increased levels of economic growth, the knock-on effect of which was an increase in construction and therefore an increased need for building products such as cement. In the period 1990-2000 emissions from *cement production (2.A.1)*, which are reported under *2.A Mineral Products,* increased by 92.4 per cent; from 884.00 Gg CO_2 in 1990 to 1,700.90 Gg CO_2 in 2000. Economic growth was sustained into the early years of the new millennium with associated increases in emissions from the sector, during which two new cement production plants were commissioned, with one opening in 2000 and the other in 2003. This resulted in even further growth in emissions from cement sector to reach peak of 2,374.06 Gg CO_2 in 2007 (an increase of 168.6 per cent from 1990). Due to the economic recession, emissions from sector *2.A.1* decreased by 59.3 per cent between 2007 and 2011 to reach 966.27 Gg CO_2. Emissions then rose to 1,177.02 Gg CO_2 in 2012 (and increase of 21.8 per cent between 2011 and 2012), reflecting economic recovery.

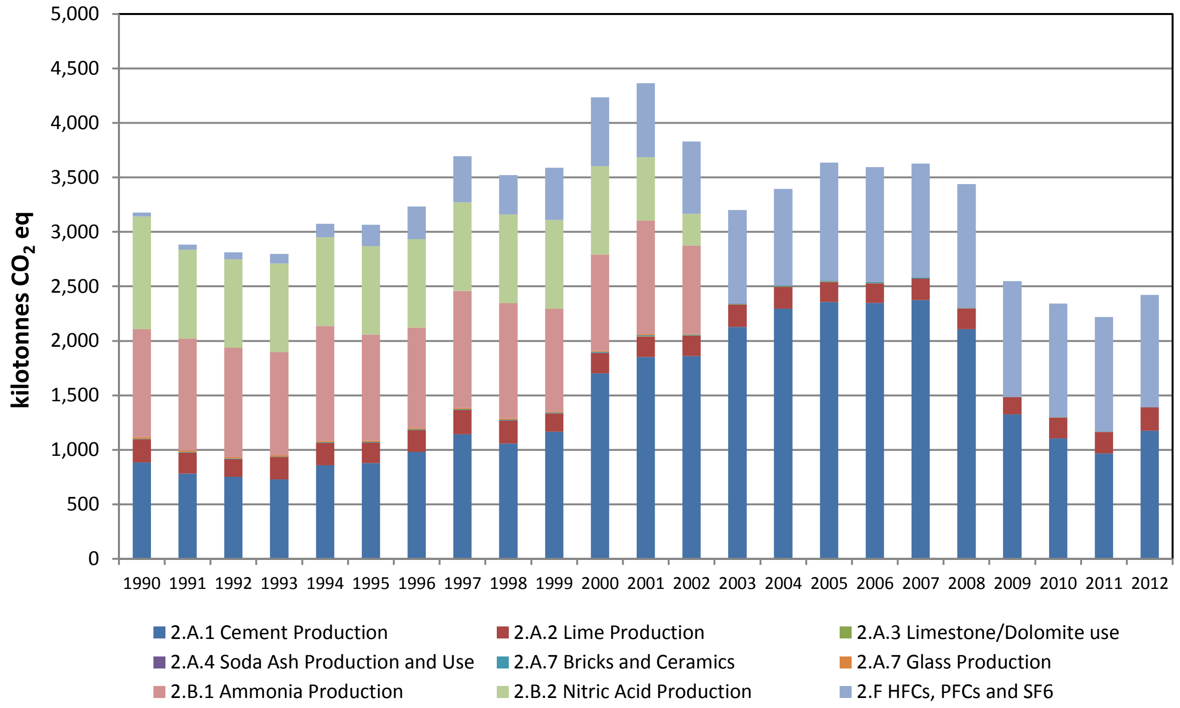


Figure 2.6 Trend in Emissions from Industrial Processes 1990-2012

The closure of Ireland's ammonia and nitric acid plants in 2003 and 2002 significantly changed the level of process emissions in Ireland. As a result CO_2 emissions from *cement production (2.A.1)* became the single major component of sector emissions from processes and these emissions increased steadily during the period of economic growth up to 2007, the year when they reached a peak of 2,374.06 Gg CO_2 equivalent. Emissions from cement manufacture then decreased in line with the economic downturn, accounting for 61.3 per cent of total emissions from *Industrial Processes* in 2008, falling to a 43.5 per cent contribution in 2011. However emissions in 2012 increased, reflecting economic recovery. This gave rise to a 48.6 per cent contribution from cement manufacture to emissions from Industrial Processes in 2012. Other sources of emissions within *2.A Mineral Products* in Ireland are *2.A.2 Lime Production, 2.A.3 Limestone and Dolomite Use, 2.A.4 Soda Ash Production and Use* and *2.A.7 Other Mineral Products (Bricks and Ceramics, Glass Production* ceased in 2009*),* which collectively accounted for 8.9 per cent of total IPCC 2 sector emissions in 2012. The emissions from these sub-categories are small and their effect on overall trends is negligible.

Emissions from *2.F Consumption of Halocarbons and SF_6* were estimated to be 1,029.25Gg CO_2 equivalent in 2012, compared to 36.07 Gg CO_2 equivalent in 1990. This represents a 27.5-fold increase over the time series with the result that the contribution of this category to the sectoral total for *Industrial Processes* increased from 1.1 per cent in 1990 to 42.5 per cent in 2012.

2.3.3 Trends in Solvent and Other Product Use (IPCC Sector 3)

Greenhouse gas emissions from *Solvents and Other Product Use* with 0.1 per cent share of total national greenhouse gas emissions in 2012 do not affect the overall trend in greenhouse gases in Ireland. The CO_2 emissions from this source were estimated to be 80.03 Gg CO_2 equivalent in 1990 and 72.72 Gg CO_2 equivalent in 2012, a decrease of 9.1 per cent. The largest contributor to overall emissions in this sector is *3.D Other,* largely represented by domestic use of solvents, which accounted for 49.1 and 57.9 per cent of total solvent sector emissions in 1990 and 2012, respectively. The contribution of sub-category, *3.A Paint Application,* to overall emissions from the sector decreased slightly from 26.6 per cent in 1990 to 26.2 per cent share in 2012. Although paint sales increased in this period, the market share of water-based paints, which have a lower VOC content, increased in response to market forces and EU Directive 2004/42/EC. Subsequently emissions from paint application, after steadily increasing by on average 3.5 per cent per annum between 1990 and 1998, have been decreasing since 1999. Sub-categories *3.B Degreasing and Dry Cleaning* and *3.C Chemical Products, Manufacture and Processing* accounted for 5.0 per cent and 10.9 per cent, respectively of total overall emissions in the sector in 2012. The emissions from both sub-categories show a downward trend over the time-series 1990-2012: *3.B* by 56.5 per cent and *3.D* by 28.4 per cent. A graphical representation of the trends in emissions from *Solvent and Other Product Use* is presented in Figure 2.7.

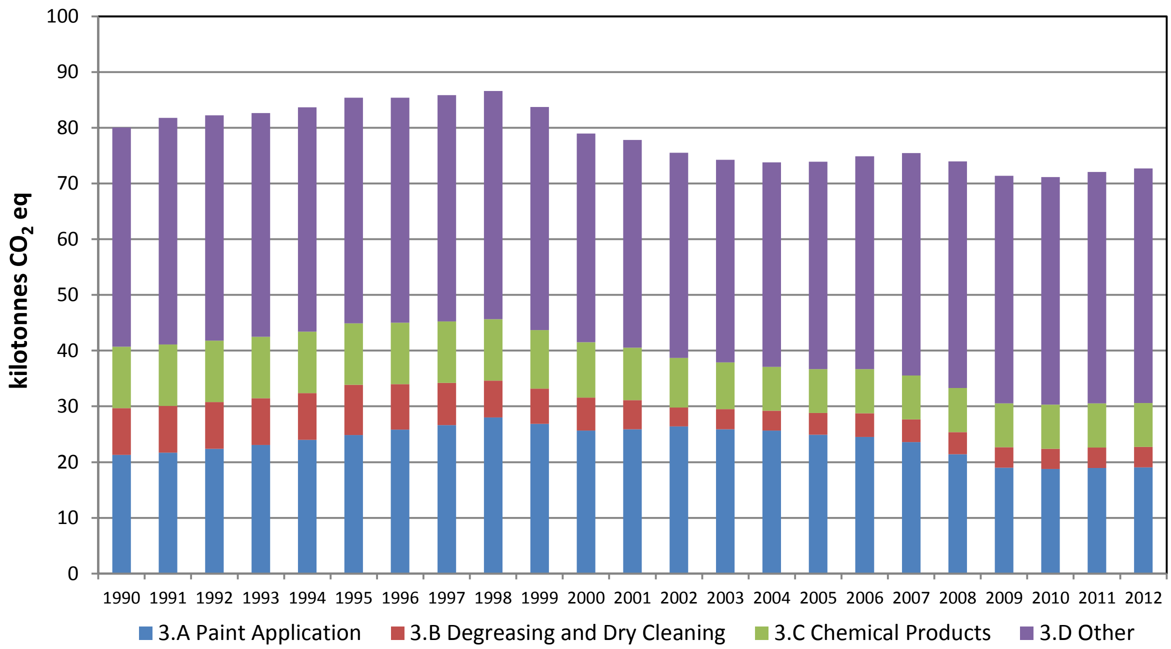


Figure 2.7 Trend in Emissions from Solvents and Other Product Use 1990-2012

2.3.4 Trends in Agriculture (IPCC Sector 4)

The trend in emissions from the *Agriculture* sector is presented in Figure 2.8 with the main drivers of the emissions presented in Figure 2.9. Emissions of greenhouse gases from the *Agriculture* sector amounted to 19,634.06 Gg CO_2 equivalent in 1990 and 17,967.39 Gg CO_2 equivalent in 2012, a reduction of 8.5 per cent. The total emissions from *Agriculture* increased by 0.59 million tonnes (3.4 per cent) from 2011 to 2012. Total emissions from the *Agriculture* sector increased by 9.6 per cent from 1990 to 1998, reflecting an increase in animal numbers and synthetic nitrogen use on farms. Following this peak in emission levels of 21,513.18 Gg CO_2 equivalent in 1998, emissions from the sector decreased by 19.2 per cent to 17,381.83 Gg CO_2 equivalent in 2011, to reach a level of emissions lower than those in 1990. The decrease post-1998 was a result of reductions in animal numbers and synthetic nitrogen fertiliser use due to reforms of the Common Agricultural Policy. Emissions in 2012 were 17,969.04 Gg CO_2 equivalent, representing a 3.4 per cent increase on the total emissions in 2011. This was primarily driven by an increase in cattle number of 4.4% between 2011 and 2012.

Methane emissions from *4.A Enteric Fermentation* and *4.B Manure Management* are dependent on the type and number of livestock present on farms and in Ireland's case, the amounts are largely determined by a large cattle population. The combined total of emissions of CH_4 from enteric fermentation and manure management expressed in CO_2 equivalents was 11,927.75 Gg in 1990. This increased by 7.4 per cent to reach 12,806.51 Gg CO_2 equivalent in 1998 and subsequently decreased by 13.7 per cent to 11,049.67 Gg CO_2 equivalent in 2012. Cattle account for 88.6 per cent of CH_4 emissions in Irish agriculture in 2012.

The emissions of N_2O from the Agriculture sector follow similar trends to those of CH_4 because cattle also largely determine the amount of nitrogen inputs to agricultural soils from synthetic fertiliser and animal manures, which produce the bulk of N_2O emissions (93.3 per cent of the sector N_2O emissions in 2012). Nitrous oxide emissions in the sector increased from 7,706.33 Gg CO_2 equivalent in 1990 by 13.0 per cent in the period 1990-1998 with emissions in 1998 totalling 8,706.67 Gg CO_2 equivalent. Nitrous oxide emissions totalling 6,917.72 CO_2 equivalent in 2012 represent a reduction of 20.5 per cent on the 1998 level and 10.2 per cent on the 1990 level. Crops contribute very little to N_2O emissions in Ireland and the amount fluctuates annually in response to varying production of the relevant crops.

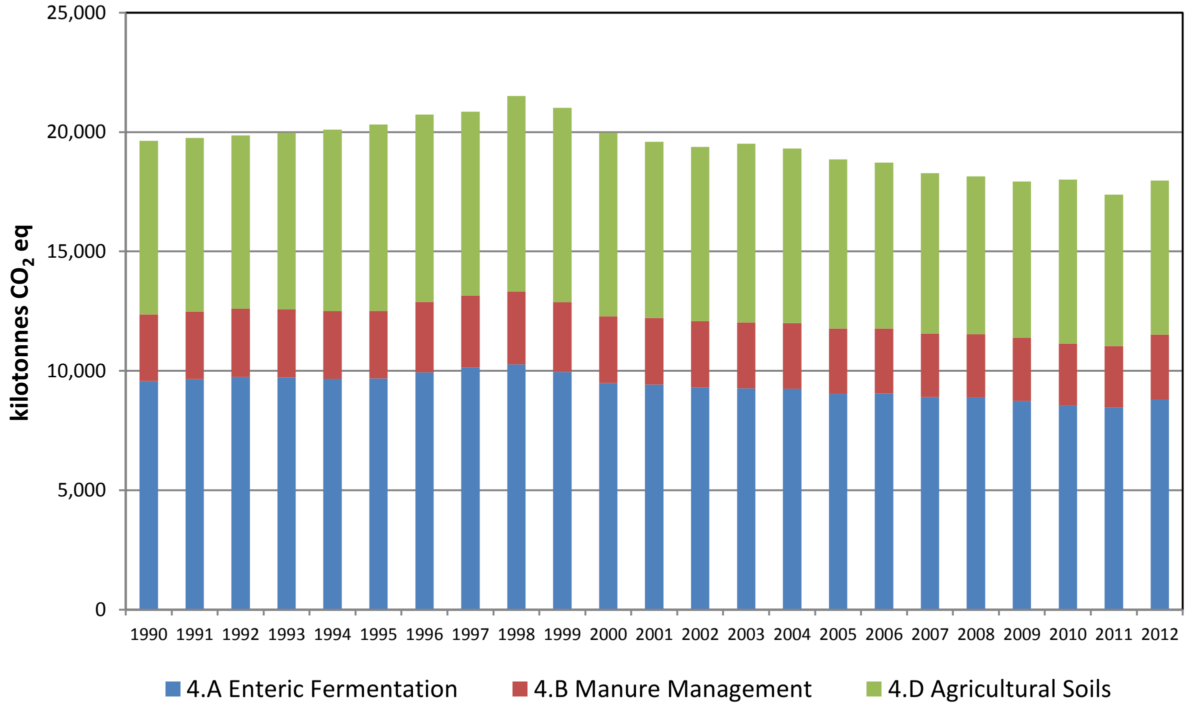


Figure 2.8 Trend in Emissions from Agriculture 1990-2012

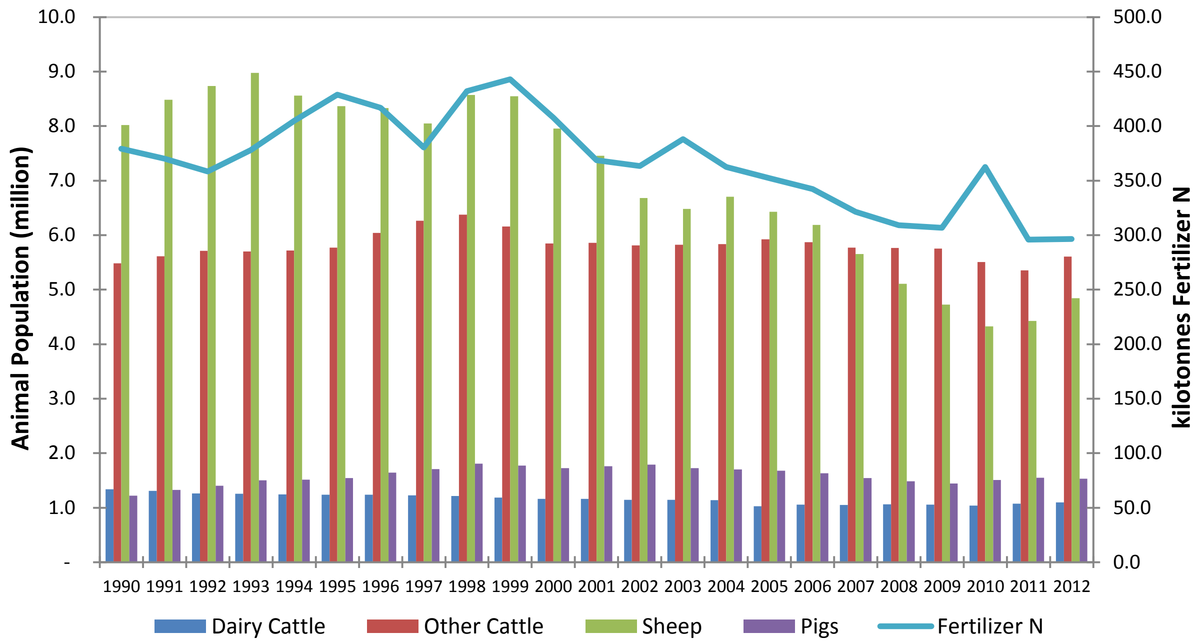


Figure 2.9 Principal Drivers of Emissions from Agriculture 1990-2012

2.3.5 Trends in Land Use, Land Use Change and Forestry (IPCC Sector 5)

The full assessment of emissions and removals in the LULUCF sector according to the reporting requirements of Decision 13/CP.9 has given a new understanding of the relative contributions of sub-categories in this sector. In addition, this assessment has identified a number of land-use categories that are important in terms of either emissions or removals of CO_2. This sector is a net sink of carbon in all years (Table 2.1 and Figure 2.10). This result is determined largely by the CO_2 emissions from *5.A Forest Land*, which is a major carbon sink, and *5.C Grassland*, where soil disturbance and liming of agricultural lands generate significant emissions of CO_2, as can be seen in in Figure 2.11. The complex dynamics of land-use changes between categories and the relative contributions from biomass and soils lead to highly fluctuating estimates of sectoral emissions and removals over the period 1990-2012.

The increase in carbon stocks in living biomass in the category *5.A.1 Forest Land remaining Forest Land* is the dominant removal that offsets CO_2 emissions. The *Wetland, Settlements* and *Other Land* categories are comparatively less important in terms of emissions or removals but *Cropland* constituted a significant net source of carbon to the atmosphere towards the end of the time series with a sharp rise in 2008, remaining relatively high in 2009-2012 compared to the earlier time series.

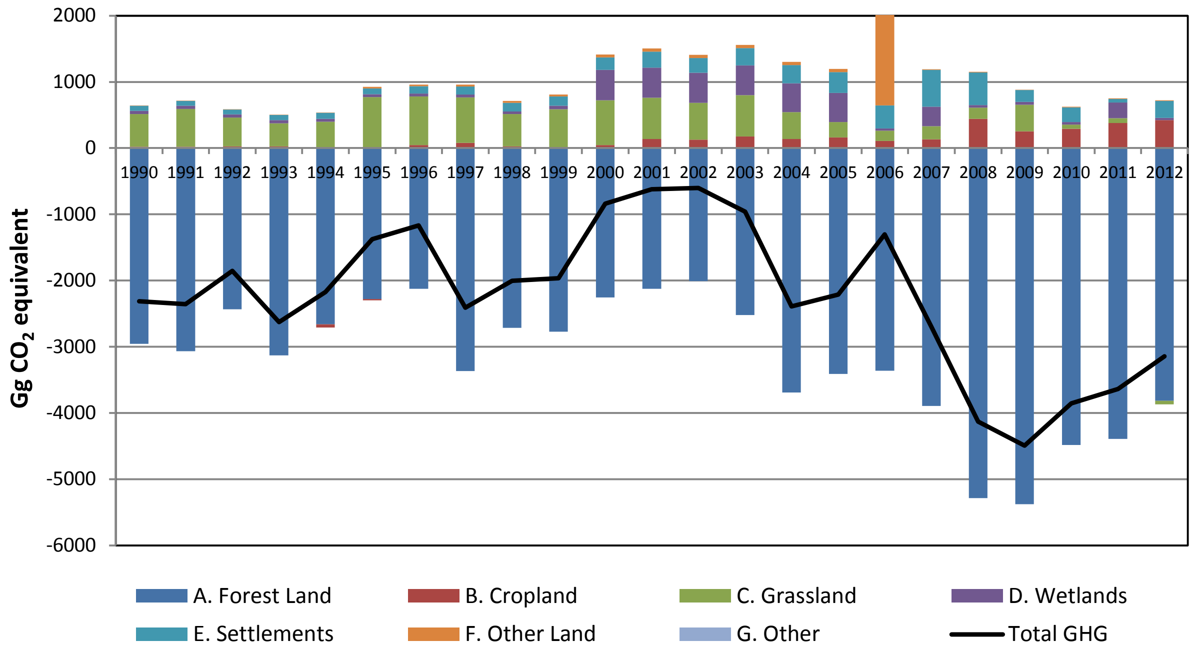


Figure 2.10 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2012

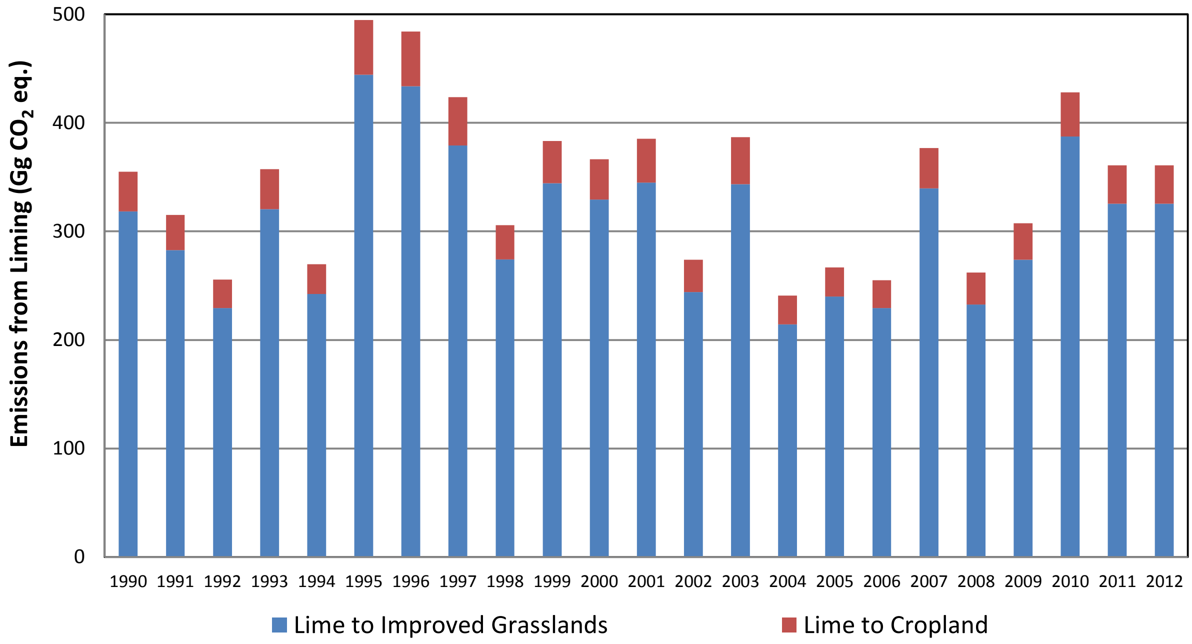


Figure 2.11 Trend in Emissions from Liming on Grasslands and Cropland 1990-2012

2.3.6 Trends in Waste (IPCC Sector 6)

The *Waste* sector remains an important source of CH_4 emissions (Figure 2.12) due to the continued dominance of landfills as a means of solid waste disposal in Ireland. Emissions from the waste sector increased by 29.2 per cent from 1,383.27 Gg CO_2 equivalent in 1990 to 1,786.81 Gg CO_2 equivalent in 2003 (peak) and then decreased by 43.6 per cent to 1,007.26 Gg CO_2 equivalent in 2012. Overall, emissions in the *Waste* sector have decreased by 27.2 per cent from 1990 to 2012. The main contributor to trends in the *Waste* sector is the CH_4 emissions from municipal solid wastes (MSW) disposed of in solid waste landfills (*6.A Solid Waste Disposal on Land*). The decrease in emission levels reflects increasing recovery of landfill gas for energy production and particularly through flaring at landfill sites, without which emissions in this sector would be considerably larger.

Since 1990 the population of Ireland increased by 30.8 per cent by 2012, giving an associated increase in the quantity of MSW produced and sustaining the amount of MSW disposed to landfills at close to 2 million tonnes per annum. However the quantities of MSW disposed of at landfills have decreased since 2007 due to lower personal consumption and increased recycling rates. Indeed total MSW disposed to landfill decreased by 48.7 per cent between 2007 and 2012 to 1.08 million tonnes. The proportion of organic materials in MSW has decreased from 40 per cent in 1990 to 31.9 per cent in 2012. The proportions of paper and textiles changed from 30 per cent and 10 per cent, respectively in 1990 to 21.9 per cent and 6.3 per cent, respectively in 2012, reflecting a significant diversion of paper products from landfills. This reduces CH_4 potential, as paper products are the main source of degradable organic carbon in landfills. A major increase in the use of flares as a means of odour control in landfills in recent years offsets a large proportion of the CH_4 generated. This offset from flares and utilisation was 67.9 per cent in 2012, hence there was 11.5 fold increase in flaring and utilisation since 1996 (9.1 per cent first year of methane recovery).

Emissions of CH_4 and N_2O from *6.B Wastewater Handling* accounted for 126.38 Gg CO_2 equivalent in 1990 and 163.96 Gg CO_2 equivalent in 2012 (29.7 per cent increase on 1990), which equates to 9.1 and 16.2 per cent of total emissions from the waste sector, respectively. The contribution of this sub-category to overall sectoral trends is negligible.

This submission includes emissions from *6.C Waste Incineration,* in line with current reporting of air pollutants under the Convention on Long Range Transboundary Air Pollution. Emissions are reported for clinical waste incineration for all years from 1990-1997, when all hospital waste incinerators were closed. Emissions are also reported for industrial waste incineration, solvent destruction by thermal oxidisers, for all years from 1990-2012. Emissions from *6.C Waste Incineration* accounted for 83.84 Gg CO_2 equivalent in 1990 and 39.68 Gg CO_2 equivalent in 2012 (52.7 per cent decrease on 1990) which equates to 6.1 and 3.9 per cent of total emissions from the waste sector, respectively. The contribution of this sub-category to overall sectoral trends is negligible.

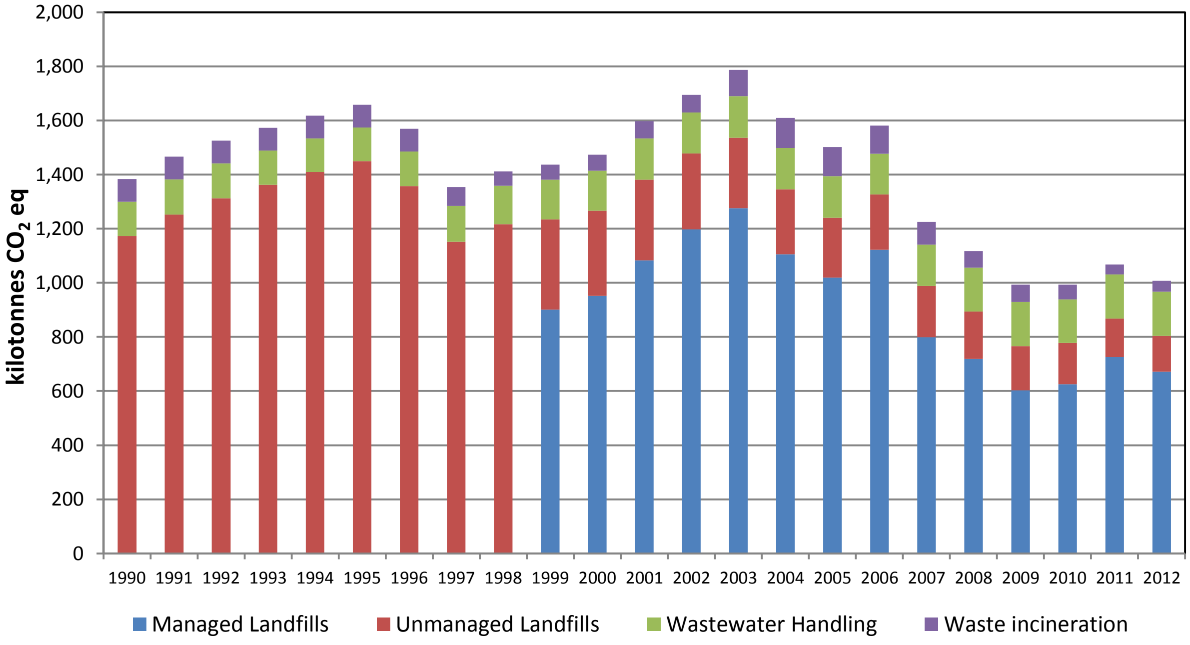


Figure 2.12 Trend in Emissions from Waste 1990-2012

2.4 Emissions of Indirect Greenhouse Gases

The total emissions of SO_2, NO_X, NMVOC and CO for the years 1990 to 2012 are summarised in Table 2.2 and Figure 2.13. As in the case of CO_2, the emissions of SO_2, NO_X and CO in Ireland are dominated by those emanating from fuel combustion activities, while the bulk of NMVOC emissions are generated by road traffic and solvent use. Since 1990, substantial decreases have occurred in the emissions of SO_2 (87.3 per cent) and CO (70.8 per cent). Significant reductions have also taken place in NMVOC emissions (46.6 per cent) and emissions of NO_X in 2012 were 40.2 per cent lower than those in 1990.

Table 2.2. Emissions of NO_X, SO_2, NMVOC and CO 1990-2012 (Tonnes)

	NO_x	SO_2	NMVOC	CO
1990	121,809.37	182,250.46	81,182.40	400,507.80
1991	124,178.74	180,612.77	82,236.33	402,290.01
1992	133,569.64	169,116.47	82,316.49	390,472.06
1993	123,815.99	160,120.92	79,342.44	358,397.71
1994	122,308.59	174,951.81	77,736.23	335,520.09
1995	121,741.68	160,866.54	75,996.37	312,886.43
1996	124,791.45	148,645.65	78,751.82	301,844.35
1997	124,477.16	166,078.84	78,447.89	290,432.66
1998	129,789.97	177,312.71	80,179.52	302,057.56
1999	130,055.99	158,614.14	73,354.95	270,520.06
2000	134,740.66	139,453.66	68,644.01	246,413.49
2001	137,617.11	134,113.37	66,799.24	235,794.54
2002	128,358.57	101,216.97	62,814.21	218,213.70
2003	128,089.87	79,028.24	60,486.54	206,585.71
2004	128,836.15	71,890.50	58,297.95	197,834.43
2005	128,296.03	71,519.84	56,628.35	186,165.32
2006	122,008.29	60,778.17	55,412.36	177,478.79
2007	119,814.65	54,452.58	53,942.05	167,524.43
2008	107,703.73	45,133.24	51,489.99	154,954.87
2009	86,061.57	32,299.72	48,607.45	148,178.20
2010	79,264.95	26,193.77	46,243.41	136,145.62
2011	70,902.76	24,583.38	44,712.58	124,580.09
2012	72,874.59	23,120.34	43,355.62	116,859.37

Total SO_2 emissions decreased from 182,250 tonnes in 1990 to 23,120 tonnes in 2012. This decrease in emissions reflects the economic downturn in recent years, reductions in the sulphur content of fuels, fuel switching and use of abatement technologies. Power stations remain the largest source of SO_2 emissions for the whole time series. However, from 2010 onwards, the *commercial/residential (1.A.4.a, 1.A.4.b)* sectors contributed a comparable amount to the total emissions (35.5 per cent compared to 41.3 per cent from power stations in 2012). Combustion sources in the *industrial (1.A.2)* sector largely account for the remainder of emissions, with a contribution of 18.6 per cent in 2012. In 1990, coal combustion accounted for 51.6 per cent of SO_2 emissions and fuel oil contributed 30.8 per cent. By 2012, the share of SO_2 emissions from coal had increased to 55.5 per cent and that from fuel oil had decreased to 9.7 per cent.

Road transport is the principal source of NO_X emissions, contributing 45.9 per cent of the total in 2012. The power generation sector is the other main source of NO_X emissions, accounting for 15.0 per cent of emissions in 2012. The reductions in NO_X emissions delivered by catalytic converters in cars and heavy-duty vehicles have been offset by large increases in vehicle numbers and fuel use in the past 10 years. This effect is exaggerated in latter years by so-called fuel-tourism, whereby a significant proportion of the automotive fuel sold in Ireland is used by vehicles in the UK and possibly to some extent in other countries.

The emissions of NMVOC are determined mainly by road traffic and solvent use. These two sources combined produced 72.0 per cent of the 2012 total NMVOC emissions in Ireland. Coal burning in the residential sector is another important source. Technological controls for NMVOCs in motor vehicles have been more successful than in the case of NO_X, and have given a significant reduction in emissions from road transport over recent years.

Emissions of CO continue to decline, driven by major reductions due to catalysts in gasoline cars, which is the principal source of CO, and a large decrease in the use of solid fuels for space heating in the residential sector. Further reductions in the emissions of SO_2, NO_X and NMVOC will occur in the coming years as Ireland continues to implement programmes to comply with various EU legislation aimed at air quality and emissions control.

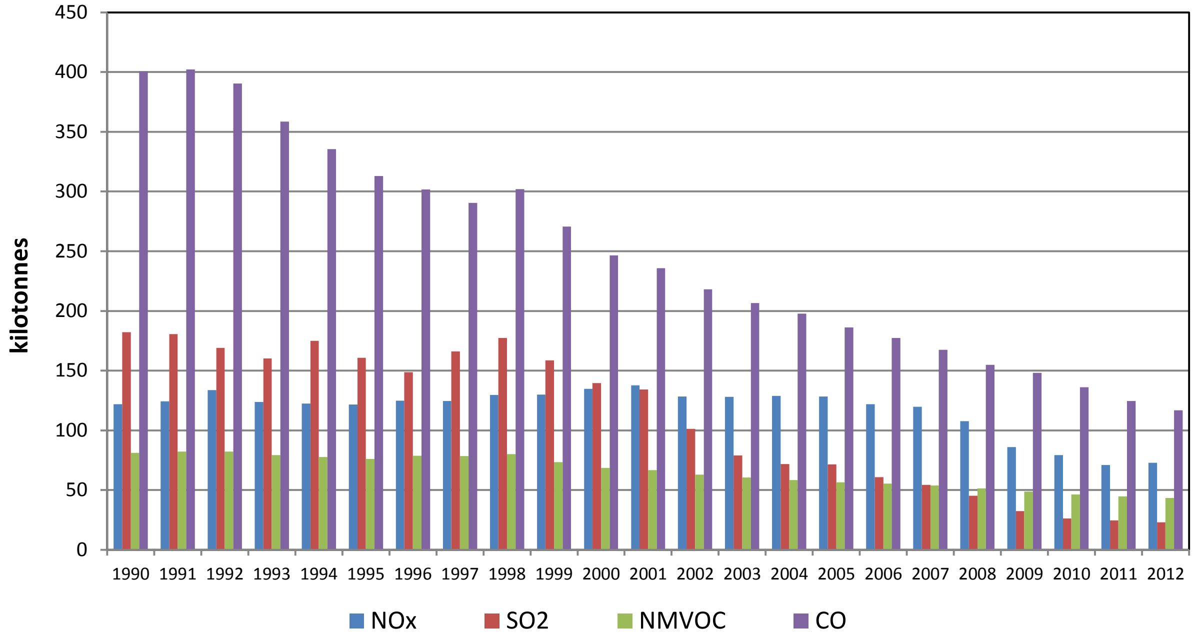


Figure 2.13 Trend in Indirect Greenhouse Gases 1990-2012

Chapter Three

Energy

3.1 Overview of Energy Sector

The *Energy* source category covers all combustion sources of CO_2, CH_4 and N_2O emissions and the fugitive emissions of these gases associated with the production, transport and distribution of fossil fuels. Table 3.1 presents the CRF Level 3 classification of sources concerned and indicates their degree of coverage in Ireland. Estimates are included for all emission sources that occur in the country and the required level of disaggregation is achieved for detailed completion of the CRF tables. The overall approach and methodologies used to estimate emissions in the *Energy* sector for 2012 remain largely as described in the 2013 NIR. As for all years since 2005, CO_2 estimates reported under the EU Emissions Trading Scheme (ETS) for 2012 data are used to achieve complete bottom-up results in respect of some important sub-categories in this sector for the 2014 inventory submission. This is a significant advance in terms of accuracy as the ETS estimates are verified and they represent a large proportion of the total emissions from the *Energy* sector.

The *Energy* sector accounted for two-thirds (63.3 per cent) of greenhouse gas emissions in Ireland in 2012, with CO_2 emissions making up 98.5 per cent of the total for the sector. The four categories in Combustion Sources (*1.A*): *1.A.1 Energy Industries, 1.A.2 Manufacturing Industries and Construction, 1.A.3 Transport* and *1.A.4 Other Sectors* are the principal sources, each contributing 34.5 per cent, 11.5 per cent, 29.4 per cent and 24.5 per cent respectively to the sector total in 2012. *Fugitive* greenhouse gas emissions (*1.B*) are insignificant in this sector and account for the remainder of the *Energy* sector share, less than 0.1 per cent.

Table C.2 of Annex C shows the national energy balance sheets for 2012, published by Sustainable Energy Authority of Ireland (SEAI), which form the key activity data for the *Energy* sector. The energy statistics are compiled using a combination of top-down and bottom-up methods and the 2012 example indicates the same form of expanded balance sheet as previously used for all years from 1990 to 2011. A full description of the stakeholders and the process used to compile energy statistics in Ireland is described in Annex C.1. The balance sheets reflect revisions made by SEAI over recent years following a programme to harmonise national energy balances in compliance with the needs of the International Energy Agency (IEA) and EUROSTAT and to facilitate their wider use nationally. The energy balances incorporate additional sectoral disaggregation specific to the needs of the greenhouse gas inventory, following close collaboration between SEAI and the inventory agency. The annual submission of up-to-date energy balances from SEAI to the inventory agency is one of the primary data inputs covered by MOU in Ireland’s national system. A fully consistent set of energy balance sheets for the years 1990-2012 underlies the estimates of emissions for *Energy* in this submission.

Following the methods decision tree of the IPCC good practice guidance for combustion sources, the information in Table C.2 of Annex C allows for the full application of the two available IPCC methods for emission sources in *Energy*, i.e. the Sectoral Approach and the Reference Approach. The Sectoral Approach uses the detailed sectoral breakdown of fuel consumption by all end users as the basis of the calculations for CO_2, CH_4 and N_2O. The relevant activity data are represented by the disaggregated entries below TPER (Total Primary Energy Requirement) in Table C.2 of Annex C. A combination of top-down and bottom-up methods is used in the sectoral application of the national statistics on fuel consumption to derive the emission estimates in the various sub-categories. The Reference Approach provides an estimate of aggregate CO_2 emissions only, based on the apparent consumption of fuels in the country. This estimate is not used in the compilation of total national emissions but rather for comparison purposes only. The apparent fuel consumption is determined from the energy balance items relating to primary and secondary fuels represented by those above TPER in Table C.2 of Annex C. The application of the Sectoral Approach and the Reference Approach is now described with reference to 2012 data and their results are then compared for CO_2, as required by the UNFCCC reporting guidelines. The Sectoral Approach is described according to the individual sub-categories listed in Table 3.1.

Table 3.1. Level 3 Source Category Coverage for Energy

1 Energy	**CO_2**	**CH_4**	**N_2O**
A. Fuel Combustion			
1. Energy Industries			
a. Public Electricity and Heat Production	All	All	All
b. Petroleum Refining	All	All	All
c. Manufacture of Solid Fuels and Other Energy Industries	All	All	All
2. Manufacturing Industries and Construction			
a. Iron and Steel	All	All	All
b. Non-Ferrous Metals	All	All	All
c. Chemicals	All	All	All
d. Pulp, Paper and Print	All	All	All
e. Food Processing, Beverages and Tobacco	All	All	All
f. Other	All	All	All
3. Transport			
a. Civil Aviation	All	All	All
b. Road Transportation	All	All	All
c. Railways	All	All	All
d. Navigation	All	All	All
e. Other Transportation	All	All	All
4. Other Sectors			
a. Commercial/Institutional	All	All	All
b. Residential	All	All	All
c. Agriculture/Forestry/Fisheries	All	All	All
5. Other	NO	NO	NO
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
a. Coal Mining	NO	NO	NO
b. Solid Fuel Transformation	NO	NO	NO
c. Other	NO	NO	NO
2. Oil and Natural Gas			
a. Oil	NO	All	NA
b. Natural gas	NO	All	NA
c. Venting and Flaring	All	NO	NA
d. Other	NO	NO	NO

All : all emission sources covered *NE : emissions not estimated* *NO : activity not occurring*
NA : not applicable (emissions of the gas do not occur in the source category) *IE : emissions included elsewhere*

3.2 Sectoral Approach for Emissions from Energy Use

3.2.1 Combustion Sources (1.A)

The combustion of fossil fuels accounts for the bulk of CO_2 emissions in most countries. In Ireland, emissions of CO_2 from fuel combustion contributed to 62.9 per cent of total emissions in 2012. The CO_2 emissions are quantified with reasonable accuracy as the fuel amounts are detailed in the energy balance sheets and information on their carbon contents is well established. The total amount of CO_2 released on combustion can therefore be readily ascertained. Only small amounts of CH_4 and N_2O are associated with fuel combustion activities. The emissions of these gases are generally not quantified with the same reliability as the emissions of CO_2 because the rates of CH_4 and N_2O production depend on several factors, in addition to fuel type, and consequently there is considerable uncertainty in the available emission factors for these gases.

Ireland's energy data in the expanded energy balance sheets (Table C.2 of Annex C) are well disaggregated according to fuel and sector for the purposes of calculating emissions in the IPCC Level 3 source categories in a top-down approach. Supplementary sources of information facilitate the use of bottom-up methods in some important sub-categories and they provide greater detail in the overall fuel-sector matrix, making it more compatible with the inventory reporting format required for the Sectoral Approach. The simple calculation spread sheet given in Table D.1 of Annex D shows how the emissions from combustion sources are computed for the year 2012 using the activity data and emission factors described below. The complete allocation to IPCC Level 1 source categories is readily achieved from this compilation, as shown in Table D.2 of Annex D. The correspondence between the national disaggregation of sources and IPCC combustion source categories is given in Table D.3 of Annex D.

All CO_2 emission factors for fuel combustion in the present submission, except in the case of biomass, are country-specific values, regardless of methodological tier used, which are determined directly from information on the carbon contents and net calorific values of the fuels used in stationary and mobile sources. Information on CO_2 emission factors, net calorific value is available for liquid, solid and gaseous fossil fuels in Annex C.3. The CO_2 emission factor for natural gas takes into account the increasing contribution of imported gas in the national total given by the energy balance. The importation of natural gas from the UK began around 1993 and imported gas accounted for 95.5 per cent of the total in 2012. The CO_2 emission factor appropriate to the split between domestic and imported natural gas, which is more carbon intensive, is now used for all years from 1993 to 2012.

The annual returns to the EPA's Climate Resource and Research Programme (CRRP) by participants in the EU Emissions Trading Scheme under Directive 2003/87/EC (EP and CEU, 2003) comprise an important source of information on CO_2 emissions and emission factors that is now fully utilised for the national inventory compilation. The fuel combustion CO_2 emission factors for solid fuels used by participants under ETS take account of the fact that a very small fraction (typically less than 1 per cent) of fuel carbon may remain un-oxidised and IPCC oxidation factors appropriate to these fuels are applied when computing the emissions under the scheme. Complete oxidation of carbon is assumed in the case of liquid and gaseous fuels. For other stationary combustion sources, where activity data are in general top-down fuel use quantities taken from the energy balance, the inventory agency adopts the approach that no specific allowance is needed for un-oxidised carbon in the calculation of CO_2 emissions. Default CO_2 emission factors from IPCC are used only for biomass, which almost invariably refers to wood and wood wastes. For stationary sources and all mobile sources except road traffic, Ireland relied largely on the default emission factors for CH_4 and N_2O available from the CORINAIR/EMEP Emission Factor Guidebook (McInnes, 1996 and Richardson, 1999) in preparing the submissions up to 2009.

A comprehensive internal review of CH_4 and N_2O emission factors was undertaken in 2009 (Annex C NIR 2011), which led to substantial revisions of these emission factors across stationary combustion sources in general so that they now conform to the latest available IPCC values.

3.2.1.1 Energy Industries (1.A.1)

The Annual Installation Emissions Reports (AIER) submitted by ETS participants in respect of their CO_2 emissions and fuel combustion in 2012 under Directive 2003/87/EC were used to report the inventory for category *1.A.1*. The emissions data from a total of 22 individual installations – 19 electricity generating stations in *1.A.1.a*, one oil refinery in *1.A.1.b* and two peat briquetting plants under *1.A.1.c* – are the basis for compiling the results in this important category. In each of the three sub-categories, the verified CO_2 estimates reported by the ETS participants were used directly and the corresponding fuel use, as given in the national energy balance, was used to estimate CH_4 and N_2O emissions using the appropriate IPCC emission factors mentioned in the previous section.

The CO_2 emissions for sub-category *1.A.1.a* obtained from AIERs are estimated by ETS operators using tier 3 methodologies in accordance with the monitoring and verification guidelines for combustion activities set down in Decision 2004/156/EC (EP and CEU, 2004), which were developed for the implementation of Directive 2003/87/EC. These methods involve a rigorous accounting of fuel consumption and detailed information on fuel properties based on fuel sampling protocols agreed in the greenhouse gas emission permits for each installation and the application of specific emission factors for each fuel determined by accredited laboratories. The summarised CO_2 emissions compiled in the ETS database according to fuel type for all installations that constituted sub-category *1.A.1.a* in 2012 are aggregated to report the CO_2 emissions for this category.

Three types of biomass fuel are also used in this sub-category which are not reported under ETS; landfill gas (LFG) used in engines at managed waste disposal sites, wood biomass co-fired at peat power plants and municipal solid waste (MSW) used in a waste to energy plant which was commissioned in 2011. Detailed information on these biomass fuels and the non-biogenic MSW fraction are shown in Annex D Table D.1-3.

The implementation of the ETS incorporates two layers of verification. The operator's report for the installation is verified independently in accordance with requirements specified in Directive 2003/87/EC before being submitted to the competent authority. This verification assesses whether the report contains omissions, misrepresentations or errors that lead to material misstatement of the reported information. Verification undertaken by the competent authority involves resolution of issues identified in the verified reports through consultation and installation site visits. The CO_2 emissions estimates compiled through ETS for sub-category *1.A.1.a* are cross-checked with a separate long-standing data flow to the inventory agency covering plant-specific emissions for electricity generating stations that are used to report on the Large Combustion Plant Directive and the Convention on Long-Range Transboundary Air Pollution. The aggregated CO_2 emissions reported in the latter data-flow correspond to the compilation available under the ETS for all years since the ETS data became available.

The rigour of the monitoring and verification process for CO_2 emissions under the ETS results in estimates for sub-category *1.A.1.a* that are more accurate and more reliable than previously reported plant-specific estimates for the same source activities. The ETS estimates are available only since 2005 and the detailed information that underlies these data cannot reasonably be acquired by the inventory agency for historical years of the relevant UNFCCC time-series. As such, the application of the improved methodology introduces a degree of inconsistency in the time-series that is unavoidable in this instance.

However, given that the ETS results fully cover sub-category *1.A.1.a* and that these estimates match those reported separately under parallel arrangements that have been in place for many years for the same plants, it is assumed that time-series consistency is not seriously affected and that there is no impact on the emission trend from using the ETS data.

The bottom-up CO_2 emission estimates received from the ETS participants, along with the emissions of CH_4 and N_2O estimated by the inventory agency, are aggregated on the basis of six main fuel types (peat, coal, oil, natural gas, biomass and other fuels (MSW)) in the calculation sheets shown in Annex D and also by solid, liquid, gaseous, biomass and other fuels for reporting in the CRF. However, the corresponding energy use as reported in the CRF is taken from the national energy balance, rather than from the ETS returns, following Ireland's established practice to always reflect the published official national energy data in emission inventories. The resulting implied emission factors (IEFs) appearing in the CRF may have large inter-annual fluctuations, which are often identified in the UNFCCC review process. These IEF fluctuations are a consequence of the difference between energy data reported to the inventory agency through the ETS and that reported by SEAI in the national energy balance. The inventory agency is working closely with SEAI to minimise these differences so that the IEF will better represent the reported emissions and activity data in future years. The inventory agency meets with SEAI regularly to resolve any issues regarding the national energy balance pending the outcome of the latest UNFCCC review. The national energy balance data now corresponds more closely to the data supplied directly to the inventory agency from ETS returns in sub-category *1.A.1.a* which can be seen by the IEF comparison for liquid and solid fuels for this sub-category in Tables D.6 and D.7 of Annex D.

Figure 3.1 shows the trend in emissions from *1.A.1.a Public Electricity and Heat Production* over the period 1990-2012, which account for 96.7 per cent of the total for category *1.A.1*. The emissions from this sub-category in 2012 at 12,375.46 Gg CO_2 eq. show an increase of 7.0 per cent on the 2011 emissions (11,562.74 Gg CO_2 eq.) due to a considerable increase in electricity generated from solid fuels (emissions increased by 20.3 per cent) at the expense of gaseous fuels (decreased by 13.0 per cent) and liquid fuels (decreased by 3.4 per cent).

One small oil refinery accounts for the emissions reported under *1.A.1.b Petroleum Refining*. The emissions from this category in 2012 at 313.55 Gg CO_2 eq. also show an increase of 9.9 per cent on the 2011 emissions (285.41 Gg CO_2 eq.). The reported CO_2 emissions are those available from the ETS database. These emissions are estimated using tier 2 methodologies in accordance with the monitoring and verification guidelines for combustion activities set down in Decision 2004/156/EC. The emissions are estimated from the use of high-pressure gas, low-pressure gas, LPG and small amounts of other gases as well as gasoil and residual fuel oil using country-specific emission factors. The use of residual fuel oil had been phased out at this plant in the last two years and replaced with natural gas. The CH_4 and N_2O emissions are estimated by the inventory agency using the IPCC default emission factors. Because refinery gas (high-pressure gas and low-pressure gas) and LPG account for the bulk of the emissions in *1.A.1.b* in all years and the emission factors for these fuels do not fluctuate significantly, the emissions reported using ETS data are consistent with the annual estimates for historical years.

Emissions for *1.A.1.c Manufacture of Solid Fuels and Other Energy Industries* were reported for the first time in the 2006 submission and refer to the production of peat briquettes from milled peat in two plants. The emissions from this category in 2012 at 104.83 Gg CO_2 eq. show an increase of 12.4 per cent on the 2011 emissions (93.25 Gg CO_2 eq.). The 2012 values for CO_2 are also taken from ETS returns which are based on tier 2 methodologies in accordance with the monitoring and verification guidelines for combustion activities set down in Decision 2004/156/EC. The CH_4 and N_2O estimates are estimated by the inventory agency using IPCC default emission factors. Milled peat is the principal fuel in sub-category *1.A.1.c* and while the annual emission factor may fluctuate in response to peat quality and moisture content, both the emission factor and activity data are sufficiently well established to ensure that the emissions time-series for this sub-category is consistent in the 2012 submission.

The inventory experts continue to collaborate with colleagues managing annual ETS returns from all participants to fully consolidate and formalise data gathering in respect of categories *1.A.1.a, 1.A.1.b* and *1.A.1.c* using the prescribed monitoring and verification mechanisms to ensure full consistency with reporting of CO_2 estimates under ETS and under the Convention and Decision 280/2004/EC.

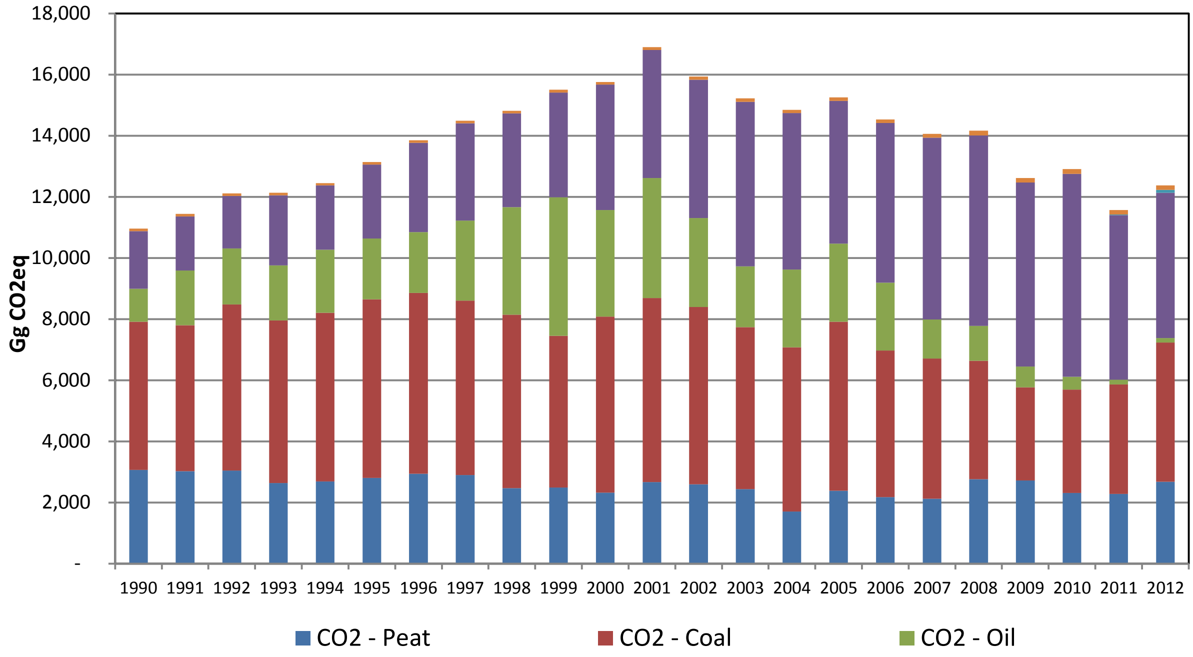


Figure 3.1 Emissions from 1.A.1.a Public Electricity and Heat Production 1990-2012

3.2.1.2 Manufacturing Industries and Construction (1.A.2)

The revised and expanded annual energy balance sheets published by SEAI incorporate a mapping of industrial fuel use in combustion into the CRF sub-categories *a-f* under *1.A.2 Manufacturing Industries and Construction*. This facilitates the complete disaggregation of emissions in this source category for completion of the CRF Table 1.A (a).s2.

The combustion CO_2 emissions in a variety of installations across the CRF sub-categories *1.A.2.a* through *1.A.2.f* are covered by the ETS Directive 2003/87/EC but the total CO_2 emissions in any sub-category cannot be reported for Ireland using ETS data alone, as in the case of the sub-categories under *1.A.1*. The ETS data are instead used to compare fuel quantities reported under ETS with corresponding amounts given in the preliminary national energy balance and to determine improved country-specific emission factors that can be applied for particular fuels and sub-categories. The emissions of CO_2 are estimated by the inventory agency on a top-down basis using the agreed final energy balance activity data and country-specific emission factors as shown in Table D.8 of Annex D. The emissions of CH_4 and N_2O are estimated using the IPCC default emission factors adopted following the review of emission factors referred to in section 3.2.1.

Information provided from the ETS on fuel data have been used to develop an annual country-specific CO_2 emission factor for petroleum coke since 2005. Petroleum coke is used in sub-categories *1.A.2.b*, *1.A.2.e* and *1.A.2.f*. The IPCC default emission factor of 97.5 t CO_2/TJ compares well with the year specific emission factors which vary from 92.87 to 95.13 CO_2/TJ. The average of the five years between 2005 and 2009 of yearly specific emission factors is applied to all years from 1990 to 2004, as ETS data is only available from 2005 onwards. When the country-specific emission factor for petroleum coke is taken into account, the implied emission factors for liquid fuels in category *1.A.2.f* fluctuate significantly depending on the proportion of petroleum coke in liquid fuels. For sub-category *1.A.2.e*, the largest quantities of petroleum coke are used in 2000 to 2002, giving rise to a peak in the implied emission factor of 79.83 t CO_2/TJ in 2001. However, the implied emission factor in 2012 is 70.65 t CO_2/TJ as no petroleum coke is consumed. In *1.A.2.f*, the implied emission factor for liquid fuels increases from 76.19 t CO_2/TJ in 1990 to 81.43 t CO_2/TJ in 2005, but then decreases substantially to 77.54 t CO_2/TJ in 2012 reflecting the decline in petroleum coke use in cement production.

Figure 3.2 shows the trend in emissions from *1.A.2 Manufacturing Industries and Construction* over the period 1990-2012. The emissions from this category in 2012 were almost identical and show only a slight 0.1 per cent increase on the 2011 emissions, following a large decrease between 2008 and 2009 of 20.5 per cent reflecting the impact of the recent economic downturn in Ireland particularly in the cement production sector. Increases in 2012 are only from sub-categories *1.A.2.b Non-ferrous metals* and *1.A.2.f Other industries (cement production)* with an annual increase of 0.2 per cent and 1.6 per cent, respectively between 2011 and 2012. Other sectors together decreased in the same time by 4.1 per cent on average.

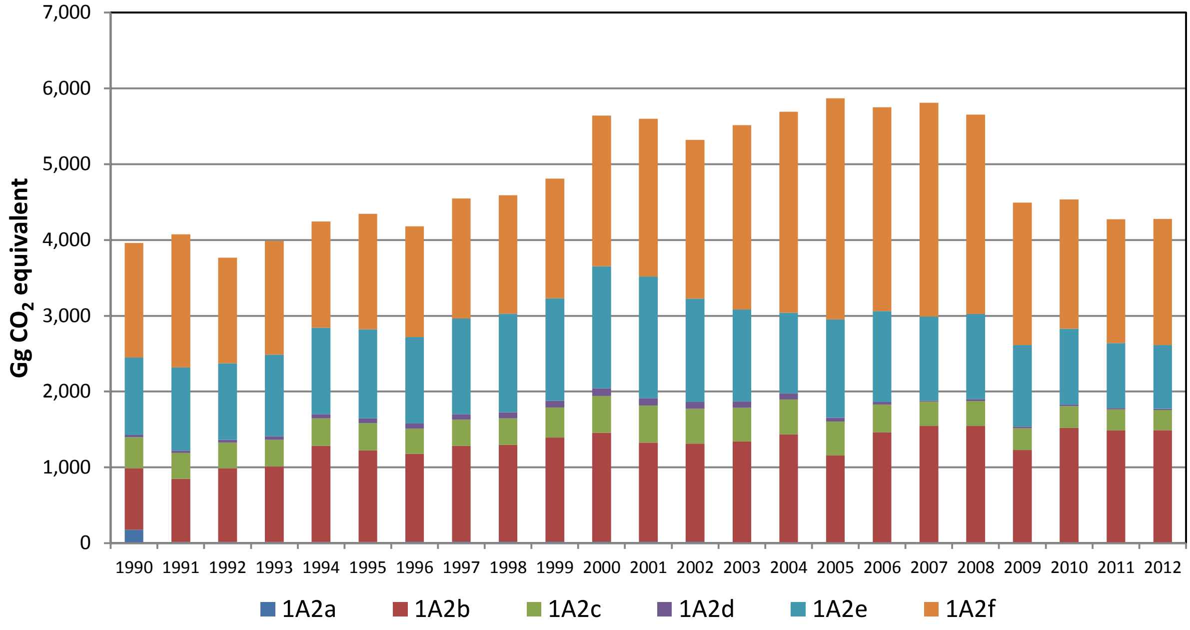


Figure 3.2 Emissions from 1.A.2 Manufacturing Industries and Construction 1990-2012

3.2.1.3 Transport (1.A.3)

Figure 3.4 shows the trend in emissions from *1.A.3 Transport* over the period 1990-2012. Road transport is the main driver in the trend with 95.7 per cent share of the total sectoral emissions in 2012. Overall Transport emissions increased by 182.9 per cent between 1990 (5,121.45 Gg CO_2 equivalent) and 2007 (14,490.86 Gg CO_2 equivalent) and since declined by 24.8 per cent by 2012 (10,900.42 Gg CO_2 equivalent), reflecting the impact of the recent economic downturn in Ireland.

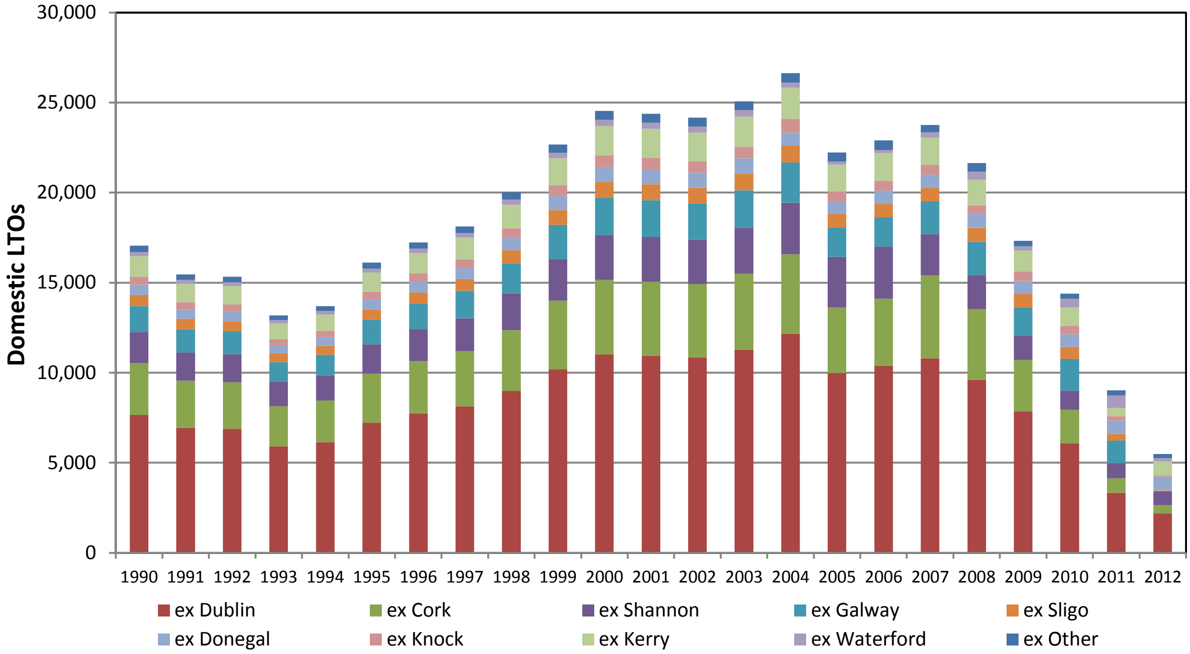


Figure 3.3 Number of LTOs from Irish airports 1990-2012

3.2.1.3.1 Civil Aviation (1.A.3.a)

The fuel consumption within Ireland associated with sub-category *1.A.3.a Civil Aviation* is estimated using a Tier 3a approach (Table 3.6.2, 2006 IPCC guidelines) based on origin and destination data for domestic air travel provided by the Irish Aviation Authority (IAA), the fuel consumption rates given by the EMEP/EEA emission inventory guidebook appropriate to the type of aircraft concerned and the length of the flights within Ireland. This approach is used for all years from 2004 to 2012 where airport pair data are available. This is the third year this improved method is used to estimate fuel consumption from civil aviation, the previous method (NIR 2011) was based on Tier 2a approach which aggregated aircraft types and was limited to aircraft movement data from only the three main airports.

The inventory agency received flight data for all Irish airports from the IAA in 2013 for the year 2012. This data is fully consistent with data received from the IAA in 2012 for all years from 2004 to 2011. This data included all flights, domestic and international, on an origin and destination basis and by aircraft type for over 25 different Irish origin airports. For the years 1990 to 2003, the number of flights for each airport was estimated based on domestic passenger and aircraft movement statistics as well as the relationship between all Irish airports and Dublin airport which is the principal destination of all civil flights. For data handling purposes, the inventory agency aggregated approximately 15 small regional airport/aerodrome pairs to "*Other*" which account for approximately 2 per cent of all domestic flights along with nine Irish airports which account for the remaining 98 per cent of all domestic flights. Figure 3.3 and Table E.1 of Annex E shows the number of LTOs for each or these nine airports and all remaining airports together under "*other*". Table E.2 of Annex E outlines the distance between the airport pairs in nautical miles (nm) used in estimating fuel used in the cruise phase.

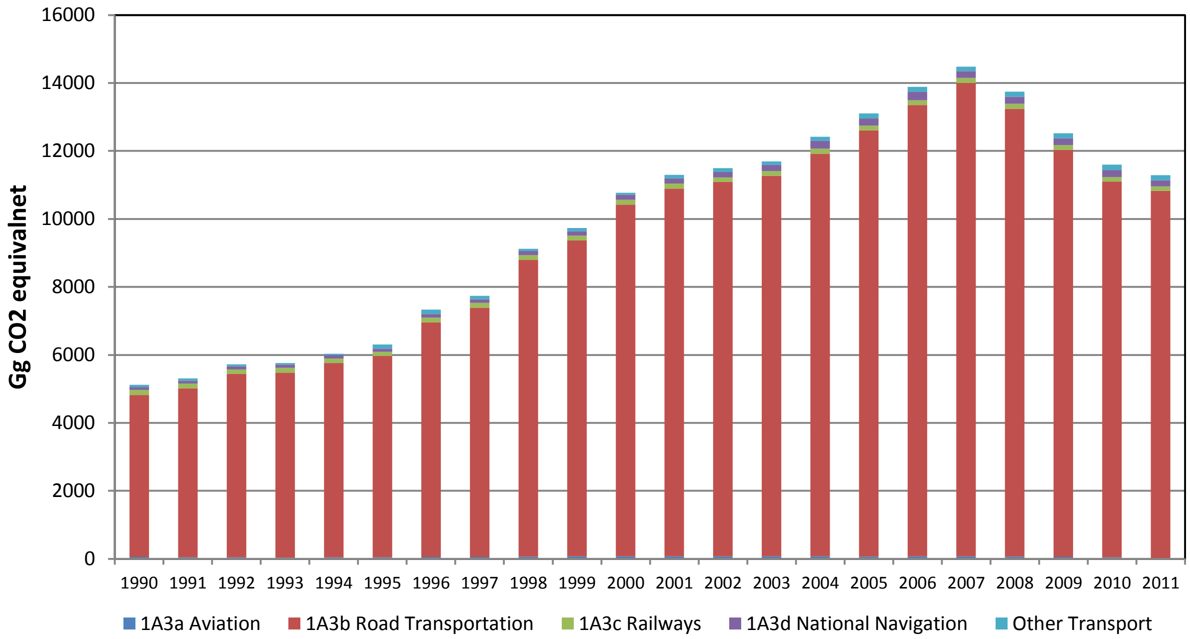


Figure 3.4 Emissions from 1.A.3 Transport 1990-2012

The tier 3a methodology estimates both LTO and cruise emissions based on origin and destination, flight distances and by aircraft type. The inventory agency estimated fuel consumption for the LTO and cruise phases of each flight based on 37 aircraft types using fuel consumption emission factors from the EMEP/EEA emission inventory guidebook. Table E.3 of Annex E outlines the emission factors used for LTO/cruise for fuel, CH_4 and N_2O by aircraft type. CH_4 and N_2O emission factors by aircraft type are from Table 3.6.9 of the 2006 IPCC guidelines. Table E.4 of Annex E presents implied emission factors (IEF) for fuel consumption used in the cruise phase of flights weighted by number of flights per airport.

3.2.1.3.2 Road Transportation (1.A.3.b)

Emissions of CO_2 reported under *1.A.3.b Road Transportation* are computed from the amounts of petrol, diesel and biofuels given under road transport in the national energy balance and country-specific emission factors for these fuels as shown in Table D.1 of Annex D. Following the IPCC good practice guidance, the activity data are based on fuel sales within Ireland, even though a significant proportion of automotive fuels purchased in Ireland are used in the UK. The CH_4 and N_2O emissions from road traffic are estimated in the COPERT 4v.10.0 model (Katsis et al., 2012), developed within the CORINAIR programme for estimating a range of emissions from this important source. This version of the COPERT model is used here for the first time, and gives rise to significant recalculations due to improved methodology and emission factors of CH_4 in: gasoline (for all years 1990-2011 but 1994), in diesel (for years 1990-2010), in LPG (for years: 1990, 1993, 2002 and 2009), N_2O emission factors: in gasoline (for all years 1990-2011), in diesel (for years 1990-2009) and in LPG for 2002, 2009 and 2011. This recalculation is due to a revision in the COPERT model software between version 9.1 and 10.0 that affects all three types of fuels and both pollutant emissions in the whole time series. Tables 3.5 and 3.8 show the impact of recalculations for N_2O. However, because emissions of CH_4 and N_2O are considerably smaller than CO_2, the impact on the total for *1.A.3.b Road Transportation* sector is small.

Figure 3.4 shows the trend in emissions from *1.A.3.b Road Transport* over the period 1990-2012. Road transport emissions in 2012 reached 10,429.07 Gg CO_2 eq. a decrease of 25.2 per cent since their peak in 2007 (at 13,941.81 Gg CO_2 eq.) but still showing a substantial increase (118.6 per cent) on their 1990 emissions (at 4,771.63 Gg CO_2 eq.). In 2012 CO_2,

CH_4 and N_2O were responsible for 99.0 per cent, 0.1 per cent and 0.9 per cent share of total road emissions, respectively.

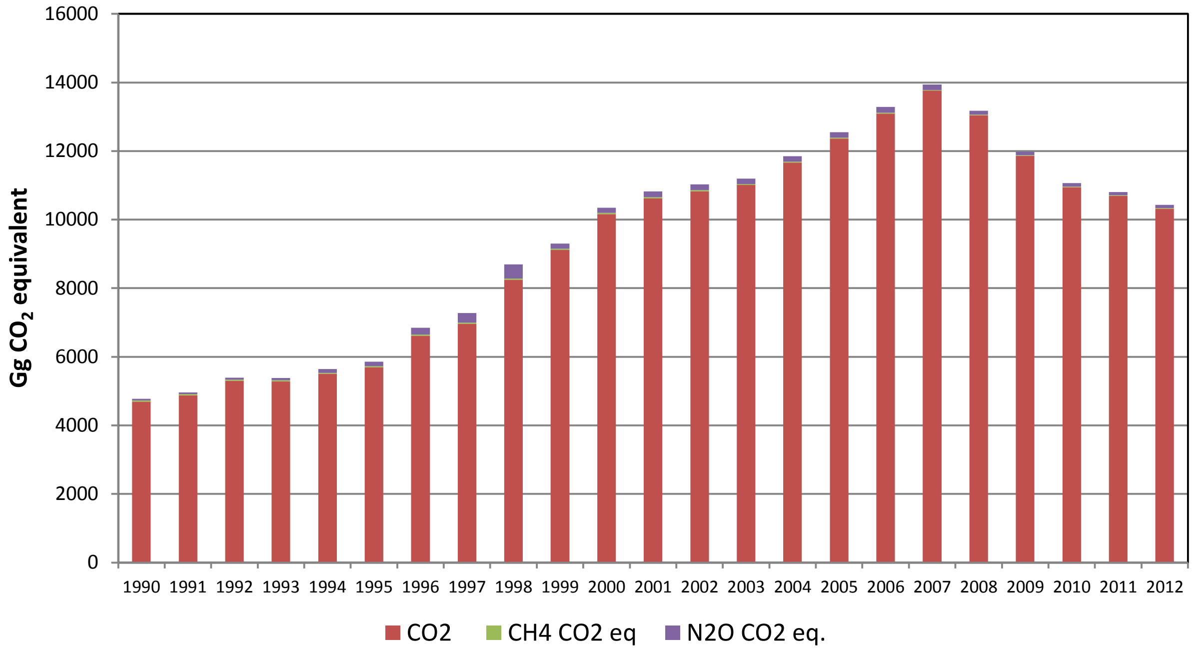


Figure 3.5 Emissions from 1.A.3.b Road Transport 1990-2012

The COPERT 4v.10.0 model estimates emissions of CH_4 and N_2O on the basis of distance travelled using a detailed bottom-up approach (Tier 3) that accounts for such factors as fuel type, fuel consumption, engine capacity, driving speed and a range of applicable technological emission controls that may be applied on the basis of the age of the vehicle. The model is applied annually in Ireland to derive CH_4 and N_2O emissions estimates. The resultant 2012 emission factors have been converted to national average values per fuel type for the purpose of Table D.1 in Annex D. Detailed information on vehicle population by type and vehicle kilometre data is presented in Tables E.5 and E.6 of Annex E.

COPERT 4 – background

COPERT 4 (COmputer Programme to calculate Emissions from Road Transport) is a Microsoft Windows application to calculate emissions from the road transport sector. It draws its origins in a methodology developed by a working group which was set up explicitly for this purpose in 1989 (COPERT 85). This was then followed by COPERT 90 (1993), COPERT II (1997) and COPERT III (1999). The current version is a synthesis of results of several large-scale activities and dedicated projects, such as:

- Dedicated projects funded by the Joint Research Centre / Transport and Air Quality Unit;
- The annual work-programme of the European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM);
- The European Research Group on Mobile Emission Sources (ERMES) work programme;
- The MEET project (Methodologies to Estimate Emissions from Transport), a European Commission (DG VII) sponsored project within 4th Framework Program (1996-1998);
- The PARTICULATES project (Characterisation of Exhaust Particulate Emissions from Road Vehicles), a European Commission (DG Transport) PROJECT within the 5th Framework Program (2000-2003);

- The ARTEMIS project (Assessment and Reliability of Transport Emission Models and Inventory Systems), a European Commission (DG Transport) PROJECT within the 5th Framework Program (2000-2007);
- A joint JRC/CONCAWE/ACEA project on fuel evaporation from gasoline vehicles (2005-2007).

COPERT 4 – methodology

A detailed methodology supports the software application. Relevant to GHGs methodology is called "Methodology for the calculation of exhaust emissions" (published by European Environment Agency, Guidebook 2009) and covers two GHG pollutants (CH_4 and N_2O) in four NFR categories:

1.A.3.b.i Passenger cars;
1.A.3.b.ii Light-duty trucks (*< 3.5 t);*
1.A.3.b.iii Heavy-duty vehicles (> 3.5 t and buses);
1.A.3.b.iv Motorcycles (and mopeds).

Exhaust emissions from road transport arise from the combustion of fuels such as gasoline, diesel, liquefied petroleum gas (LPG) and natural gas in internal combustion engines. The air/fuel charge may be ignited by a spark (spark-ignition' or positive-ignition' engines), or it may ignite spontaneously when compressed (compression-ignition' engines). For more detailed emission estimation methods the above four NFR categories (1.A.3.b.i-iv) are often subdivided according to the fuel used (in Irish model there are three fuel types: gasoline, diesel and LPG), and by the engine size, weight or technology level of the vehicle, giving a total of 23 vehicle categories. For certain pollutants, the emission factors for these vehicle categories can be further sub-divided according to three types of driving: "highway", "rural" and "urban".

CH_4 and N_2O are in the group (Group 1) of pollutants for which a detailed methodology exists, is based on specific emission factors and is covering different traffic situations (i.e. urban, rural, highway) and engine conditions. Ireland uses detailed Tier 3 method, where country specific information is available for: vehicle km and mean travelling speed per mode and vehicle technology.

In the following Tier 3 approach, total exhaust emissions from road transport are calculated as the sum of 'hot' emissions (when the engine is at its normal operating temperature) and emissions during transient thermal engine operation (named 'cold-start' emissions). It should be noted that, in this context, the word "engine" is used as shorthand for "engine and any exhaust after treatment devices". The distinction between emissions during the 'hot' stabilised phase and the transient 'warming-up' phase is necessary because of the substantial difference in vehicle emission performance during these two conditions. Concentrations of some pollutants during the warming-up period are many times higher than during hot operation, and a different methodological approach is required to estimate the additional emissions during this period.

To summarise, total emissions can be calculated by means of the following equation:
$E_{TOTAL} = E_{HOT} + E_{COLD}$

where,

E_{TOTAL} = total emissions (g) of any pollutant for the spatial and temporal resolution of the application,
E_{HOT} = emissions (g) during stabilised (hot) engine operation,
E_{COLD} = emissions (g) during transient thermal engine operation (cold start).

Hot exhaust emissions depend upon a variety of factors, including the distance that each vehicle travels, its speed (or road type), its age, its engine size and its weight. The basic formula for estimating hot emissions for a given time period, and using experimentally obtained emission factors, is:

emission [g] = EF [g/km] × number of vehicles [veh] × mileage per vehicle [km/veh]

Different emission factors, numbers of vehicles and mileages per vehicle need to be used for each vehicle category and class. The time period (month, year, etc.) depends upon the application. Therefore, the formula to be applied for the calculation of hot emissions of pollutants in Group 1 (like CH_4 and N_2O), and in the case of an annual emission estimation, yields:

$$E_{HOT;\, i,\, k,\, r} = N_k \times M_{k,r} \times e_{HOT;\, i,\, k,\, r}$$

where,

$E_{HOT;\, i,\, k,\, r}$ = hot exhaust emissions of the pollutant i [g], produced in the period concerned by vehicles of technology k driven on roads of type r,
N_k = number of vehicles [veh] of technology k in operation in the period concerned,
$M_{k,r}$ = mileage per vehicle [km/veh] driven on roads of type r by vehicles of technology k,
$e_{HOT;\, i,\, k,\, r}$ = emission factor in [g/km] for pollutant i, relevant for the vehicle technology k, operated on roads of type r.

Cold starts result in additional exhaust emissions. They take place under all three driving conditions. However, they seem to be most likely for urban and rural driving, as the number of starts in highway conditions is relatively limited (in principle starts from parking lots next to highways). In principle, they occur for all vehicle categories, but emission factors are only available, or can be reasonably estimated, for gasoline, diesel and LPG cars and - assuming that these vehicles behave like passenger cars - light-duty vehicles, so that only these categories are covered by the methodology. Moreover, they are not considered to be a function of vehicle age. Cold-start emissions are calculated as an extra emission over the emissions that would be expected if all vehicles were only operated with hot engines and warmed-up catalysts. A relevant factor, corresponding to the ratio of cold over hot emissions, is applied to the fraction of kilometres driven with a cold engine. This factor varies from country to country. Driving behaviour (varying trip lengths) and climatic conditions affect the time required to warm up the engine and/or the catalyst, and hence the fraction of a trip driven with a cold engine.

Cold-start emissions are introduced into the calculation as additional emissions per km using the following formula:

$$E_{COLD;\, i,\, j} = \beta_{i,\, k} \times N_k \times M_k \times e_{HOT;\, i,\, k} \times (e^{COLD} / e^{HOT}|_{i,k} - 1)$$

where,

$E_{COLD;\, i,\, k}$ = cold-start emissions of pollutant i (for the reference year), produced by vehicle technology k, i, k
$\beta_{i,\, k}$ = fraction of mileage driven with a cold engine or the catalyst operated below the light-off temperature for pollutant i and vehicle technology k,
N_k = number of vehicles [veh] of technology k in circulation,
M_k = total mileage per vehicle [km/veh] in vehicle technology k,
$e^{COLD} / e^{HOT}|_{i,k}$ = cold/hot emission quotient for pollutant i and vehicles of k technology.

Vehicle emissions are heavily dependent on the engine operation conditions. Different driving situations impose different engine operation conditions, and therefore a distinct emission performance. In this respect, a distinction is made between urban, rural and highway driving. Different activity data and emission factors are attributed to each driving situation. Cold-start emissions are attributed mainly to urban driving (and secondarily to rural driving), as it is expected that a limited number of trips start at highway conditions. Therefore, as far as driving conditions are concerned, total emissions can be calculated by means of the equation:

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY}$$

where,

E_{URBAN}, E_{RURAL} and $E_{HIGHWAY}$ are the total emissions (g) of any pollutant for the respective driving situations.

Total emissions are calculated by combining activity data for each vehicle category with appropriate emission factors. The emission factors vary according to the input data (driving situations, climatic conditions). Also, information on fuel consumption and fuel specification is required to maintain a fuel balance between the figures provided by the user and the calculations.

This methodology does not cover non-exhaust emissions such as fuel evaporation from vehicles (NFR code 1.A.3.b.v), tyre wear and brake wear (NFR code 1.A.3.b.vi), or road wear (NFR code 1.A.3.b.vii) as those are only relevant to air pollutant inventory.

More details on the methods, vehicle specifications, calculation algorithms and other parameters used for calculating relevant road traffic exhaust emissions can be found in EMEP/EEA emission inventory guidebook 2009, updated May 2012 (http://eea.europa.eu/emep-eea-guidebook).

3.2.1.3.3 Railways (1.A.3.c), Navigation (1.A.3.d) and Other Transportation (1.A.3.e)

The CO_2 emissions under *1.A.3.c Railways* and *1.A.3.d Navigation* are calculated from the amount of oil used by these activities as recorded in the energy balance and the country specific emission factors for oil. The emissions of CH_4 and N_2O are estimated using the IPCC default emission factors adopted following the review of emission factors in 2009, referred to in 2011 NIR. Emissions factors used in these two sub-categories are presented in Table 3.2.

Table 3.2. Emission factors for Rail and Navigation

IPCC category	Fuel	CO_2 t/TJ	Reference	CH_4 kg/TJ	N_2O kg/TJ	Reference
Railways	Gasoil	73.30	CS	4.15	28.60	2006 IPCC Guidelines Table 3.4.1 Default
Navigation	Fuel Oil	76.00	CS	7.00	2.00	2006 IPCC Guidelines Table 3.5.3
Navigation	Gasoil	73.30	CS	7.00	2.00	

The emissions reported in sub-category *1.A.3.e Other Transportation* are those due to the use of natural gas at off-shore production platforms and in pipeline compressor stations. The fuel use is estimated as the difference between the value given for natural gas under own use/losses in the national energy balance (Table C.1 of Annex C) and the amount of gas estimated to be lost from the distribution network, as reported under fugitive emissions in sub-category *1.B.2.b Natural Gas*. The country-specific emission factor for CO_2 and the default values for CH_4 and N_2O referred to in section 3.2.1 are used.

3.2.1.4 Other Sectors (1.A.4)

The CRF sub-category *1.A.4 Other Sectors* covers combustion sources in the residential, commercial/institutional and agriculture/forestry/fisheries sectors. The residential sub-category *1.A.4.b* with 68.3 per cent share of the sector emissions remains the most important source of emissions in this category in Ireland. This is evident from Figure 3.5, which shows the trend in the principal components of emissions in *1.A.4 Other Sectors* over the period 1990-2012. While the shift from carbon-intensive fuels, such as coal and peat, to oil and natural gas in *1.A.4.b* has been sufficient to maintain sectoral emissions relatively constant up to 2007, the benefits from fuel switching have been fully realised and the emissions from oil and gas are increasing in line with higher overall fuel consumption resulting from greater housing stock and population. Emissions in *1.A.4* Other Sectors decreased by 4.3 per cent from 2011 to 2012 which is attributed to milder than normal winter months with the largest sub-category, residential, decreasing by 5.9 per cent. In the full trend emissions decreased by 13.8 per cent, from 10,518.03 Gg CO_2 eq. in 1990 to 9,068.47 Gg CO_2 eq. in 2012.

Table D.2 of Annex D shows the calculation of emissions for sub-category *1.A.4 Other Sectors*, using the fuel quantities as given by the energy balance (Table C.1 of Annex C). The inventory agency uses country-specific emission factors for CO_2, including that for petroleum coke referred to in section 3.2.1.2, and IPCC default values for CH_4 and N_2O. The energy balance provides no indication on the specific end-use of gasoil in the agricultural sector *1.A.4.c*. Consequently, a split based on information from agricultural experts (10 per cent stationary sources and 90 per cent mobile sources) is used by the inventory agency to distinguish between the use of this fuel in stationary and mobile combustion sources. This split has no bearing on emissions of CO_2, but it is important in relation to CH_4 or N_2O and the indirect greenhouse gases. Emissions factors used for stationary and mobile sources in sub-category *1.A.4.c agriculture/forestry/fisheries*, are presented in Table 3.3. No biomass is used as fuel in sub-category *1.A.4.c agriculture/forestry/fisheries*.

Emissions from charcoal used for cooking are reported in sub-category *1.A.4.b* for all years. The quantity of charcoal used in Ireland was provided by the CSO and emission factors used for estimating emissions from this biomass fuel are presented in Table 3.4.

Table 3.3. Emission factors for Agriculture/Forestry/Fishing

IPCC category	Fuel	CO_2 t/TJ	Reference	CH_4 kg/TJ	N_2O kg/TJ	Reference
Agriculture Stationary	Gasoil	73.30	CS	10.00	0.60	2006 IPCC Guidelines Table 3.4.1 Default
Agriculture Mobile	Gasoil	73.30	CS	4.15	28.60	2006 IPCC Guidelines Table 3.3.1 Default
Fishing	Gasoil	73.30	CS	7.00	2.00	1996 IPCC Guidelines Table 1-48 2006 IPCC Guidelines Table 3.5.3

Table 3.4. Emission factors for Charcoal use in Residential

IPCC category	Fuel	Gas	kg/TJ	Reference
Residential	Charcoal	CO_2	111,833	2006 IPCC Guidelines Table 1.3 Chapter 1
Residential	Charcoal	CH_4	200	2006 IPCC Guidelines Table 2.5 Chapter 2 1996 IPCC Guidelines Table 1-7 Vol III
Residential	Charcoal	N_2O	1	2006 IPCC Guidelines Table 2.5 Chapter 2 1996 IPCC Guidelines Table 1-8 Vol III

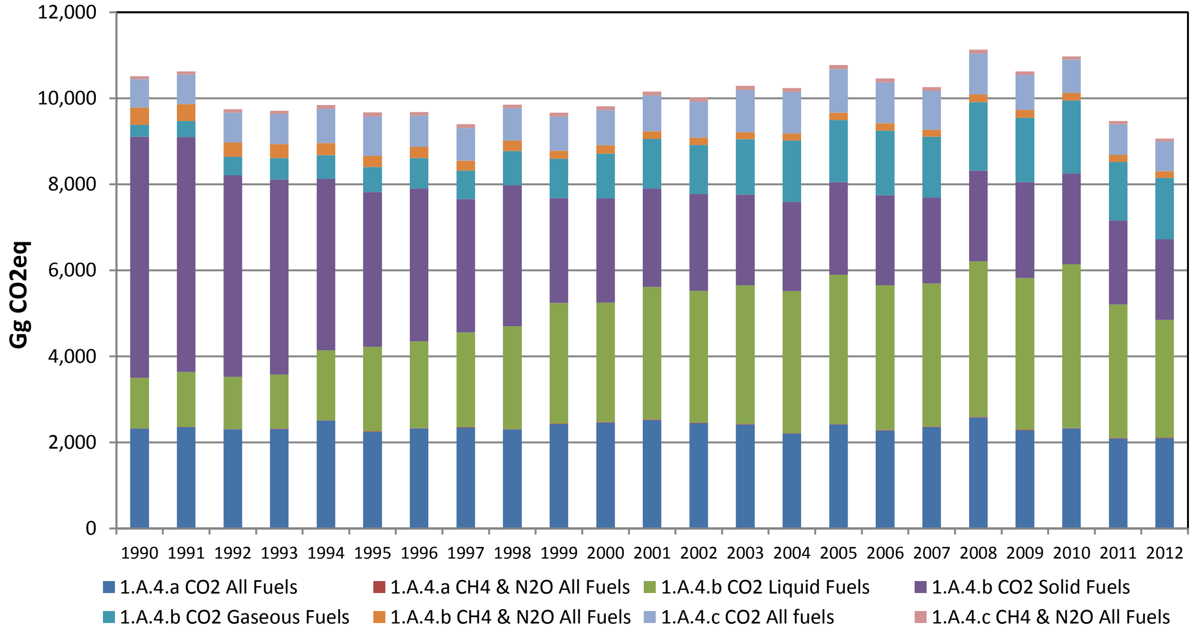


Figure 3.6 Emissions from 1.A.4 Other Sectors 1990-2012

3.2.2 Fugitive Emissions (1.B)

Ireland has no coal or oil industries and therefore fugitive emissions of greenhouse gases are limited to those associated with natural gas production and distribution. Natural gas has been produced from gas fields off the south coast of Ireland since the 1970s but this source is being rapidly depleted. Substantial reserves of natural gas have been discovered off the west coast and which will soon come into production in late 2014 or early 2015.

Bord Gais Eireann (BGE), Ireland's gas company has assessed gas losses in the pipeline network in the context of the needs of annual inventory reporting and a long-term programme to replace cast-iron mains with polyethylene pipe in all urban areas served by natural gas. The change to polyethylene pipe is considered to result in negligible losses. The gas company indicated that gas loss in 1995, determined as the difference between system input and metered sales, was 1.92 million therms, which equates to 4,085 tonnes of methane, when the amounts of indigenous and imported gas and their respective properties are taken into account. This value implied a loss of the order of 0.2 per cent of total sales. Projections made by BGE for five-year intervals from 2000 show losses decreasing to zero by 2020 on completion of the pipe replacement programme.

The BGE data continue to be used as the best available for this particular fugitive emission source. The rate of loss implied by the 1995 value and the projections is applied to give an emission for all years of the inventory time-series referred to in this report. The gas consumption recorded in the energy balance for the industrial, commercial and residential sectors is used as activity data rather than total sales and the appropriate split between indigenous and imported gas is applied for all years. The inventory agency was informed by BGE in 2004 that natural gas losses from the distribution network were so small that they could not be measured.

Only one company is involved in natural gas production in Ireland. Emissions to the atmosphere from this company's offshore gas production platforms are reported to the Department of Communications Energy and Natural Resources (DCENR) under the OSPAR Convention. Such reports have been obtained for several years in the 1990-2012 time series and are currently covered by MOU with the inventory agency. The available data, which relate largely to gas extraction but which also account for a small amount of flaring in some years, indicate a close relationship between emissions and the amount of gas produced. This relationship has been applied in terms of the indicative emission rates of CO_2 and CH_4 per unit of gas extracted to estimate the emissions for those years for which no reports were received. A report on emissions was supplied to the inventory agency for 2012.

3.3 IPCC Reference Approach for CO_2 Emissions from Energy Use

The IPCC Reference Approach is a top-down methodology for CO_2 that estimates emissions by accounting for the overall production of primary fuels, the external trade in primary and secondary fuels, stock changes and for the carbon that may enter long-term storage in non-energy products and feedstocks. It can be used to report national emissions in cases where the detailed activity data required for the Sectoral Approach are not available but it is more usually applied for verification of the results of the latter for those countries that have the information to apply both methods. The Reference Approach is used in Ireland as a verification procedure for CO_2 emissions from fuel combustion activities. The calculation sheet for the Reference Approach (Table 1.A (b) of the 2012 CRF) is reproduced as Table D.4 of Annex D of this report. The apparent consumption of fuels, the basic activity data in this case, is determined as:

Apparent Consumption = Production + Imports - Exports - International Bunkers - Stock Changes

where production applies only to primary fuels. Naphtha was previously the only petroleum product to be considered in relation to non-energy fuel-use, where the carbon is not fully released as in combustion. The IPCC default value of 0.50, 1.00 and 1.00 are used for the proportion of carbon stored in lubricants, bitumen and white spirit respectively. Ireland's only oil refinery is a small hydroskimming refinery where there is no production of other petroleum products normally used for non-energy purposes, such as bitumen, lubricants, plastics and asphalt. The expanded SEAI energy balance sheets now record the import of some of these products, thereby allowing improved completeness in the Reference Approach estimation of CO_2 emissions and carbon storage. A significant amount of natural gas feedstock was traditionally used in ammonia production in Ireland but the company closed in 2003 and there is consequently no feedstock use of natural gas since then.

3.4 Comparison between Sectoral Approach and Reference Approach

The national energy consumption and CO_2 emissions estimates obtained using the Sectoral Approach usually differ to some extent from the corresponding values resulting from the Reference Approach. According to the UNFCCC guidelines, differences greater than 2 per cent should be explained and investigated to see whether they indicate systematic underestimation or overestimation of energy consumption by one or other of the methods. The differences in 2012 indicate that in the Reference Approach, energy use and CO_2 emissions were -2.48 per cent and -2.35 per cent lower than in the Sectoral Approach. The differences between the two approaches for liquid, solid and gaseous fuels are presented in Table D.5 of Annex D and CRF Table 1.A (d) for 2012.

3.5 Memo Items

The memo items of the IPCC reporting format refer to activities for which the emissions are excluded from national totals. The use of fuels in international aviation and marine bunkers is the most important of these activities. Some of the associated emissions, particularly CO_2 emissions from international aviation, are increasing very rapidly and it is therefore important that they are closely monitored for comparison with other sources and for the benefit of the international organisations that will have to develop control strategies for them in the future. The emissions of CO_2 from biomass combustion are not included in national totals of greenhouse gases because it is assumed that an equivalent amount of CO_2 is removed from the atmosphere by the growth of the next biomass crop. The estimation of emissions for memo items is described here because they are calculated as part of the general estimation procedures for the *Energy* sector.

The activity data for biomass appear as a specific item in the Irish energy balance sheets (Table C.1 of Annex C). For the industrial and residential sectors, this is known to refer to wood and wood wastes. Default emission factors for CO_2, CH_4 and N_2O for wood burning are used to estimate the emissions from biomass in these sectors using the simple Tier 1 approach. The estimates for all gases appear in the CRF tables covering these sectors, but in the case of CO_2, they do not contribute to the total for *Energy* or to the national total in the CRF summary tables.

The national energy balance sheets include marine bunkers and international aviation as specific items and the emissions may be calculated directly. The allocation of fuels to marine bunkers in the national energy balance is achieved on the basis of particular tax and excise rates applicable to the sale of such fuels. The allocation of jet kerosene use to international aviation (bunker fuel) is done by subtracting jet kerosene used in civil aviation estimated by the inventory agency, described in section 3.2.1.3.1 above, from total jet kerosene fuel sales compiled by SEAI. In 2012, the amount of jet kerosene fuel allocated to domestic aviation was 0.8 per cent of the total recorded under air transport in the energy balance.

Emissions of CH_4 and N_2O have been estimated for all years for fuel used in marine bunkers for the first time in this submission following a recommendation from a previous annual review. Emissions factors from the Revised 1996 IPCC guidelines of 7 kg/TJ and 2 kg/TJ, for CH_4 and N_2O respectively, have been used to estimate emissions.

3.6 Quality Assurance and Quality Control

Extensive QA/QC procedures have again been followed for the Energy sector during the present reporting cycle by fully implementing the plan that underpins Ireland's formal national system. The inventory agency continues to apply a system of quality control checks and documentation spread sheets to the front of all calculation workbooks. These workbooks correspond directly to the disaggregation given by the CRF sectoral background data tables and are designed so that calculations may be made on a time-series basis, rather than by individual year. This increases efficiency in the use of the time-series energy data provided by SEAI and allows for rapid recalculation and checking across the time-series and facilitates the transfer of the output emission estimates and energy quantities to the CRF Reporter Tool. Additional summary sheets are used for aggregation to various levels to provide full cross-checking with completed CRF tables for any year.

The quality checks at inventory level build on the extensive upgrading and quality control of energy balances completed by SEAI in recent years. This work, together with further collaboration with inventory experts and thorough evaluation of the SEAI role in relation to the national system and QA/QC procedures, has resulted in substantial improvements that are now taken into account in the emissions for *Energy* for the years 1990 through 2012 included in the present submission. In recognition of its role as a key data provider, SEAI is continuing to develop its own procedures to ensure that energy balances fully harmonised with Eurostat and IEA requirements are made available in a timely manner to facilitate the annual reporting of greenhouse gas emissions estimates. Arrangements have been established whereby the bottom-up energy data reported to the EPA for individual enterprises in all relevant energy-use sectors covered by the EU emissions trading scheme may be reconciled at an early stage with the corresponding top-down information collected by SEAI (section 3.2.1.2). This procedure aims to progressively minimise differences between the energy amounts reported by SEAI and that supplied for particular sub-categories and fuels.

The incorporation of the ETS data in the *Energy* sector for the last several submissions is again considered an important step towards improved reliability and accuracy of the estimates for categories *1.A.1* and *1.A.2.* Thorough checking of this input is achieved in collaboration with colleagues in the Climate, Resource and Research Programme (CRRP) of the EPA, which acts as the competent authority for the ETS in Ireland. Following receipt of the raw ETS data from CRRP, the inventory experts allocate the CO_2 estimates and corresponding energy amounts to the appropriate sub-categories for CRF reporting and then return the compilation to the CRRP contact person for final checking and accounting of any amendments following the ETS verification process. This ensures that where ETS emissions estimates cover a category completely, such as in *1.A.1*, the verified CO_2 values are transferred directly to the national inventory and consistency of results is guaranteed. In the case where the CO_2 estimates from ETS do not completely cover the category, as for *1.A.2*, the benefit is realised as better information on fuels and more representative emission factors, which improves the top-down estimates of emissions obtained using the energy balance.

The inventory agency completed a verification exercise comparing civil aviation flight and LTO fuel estimates for 2004 to 2010 using data sourced from Eurocontrol through the EU's Working Group 1 of the Climate Change Committee and national data. The verification exercise showed close agreement between the two datasets for the number of civil LTOs and fuel used for both LTO and cruise phases. The only significant difference in the two datasets was for 2004 which showed Eurocontrol data 20 per cent lower than Ireland's national data. The main findings of this verification procedure are outlined in Figures 3.6 to 3.8.

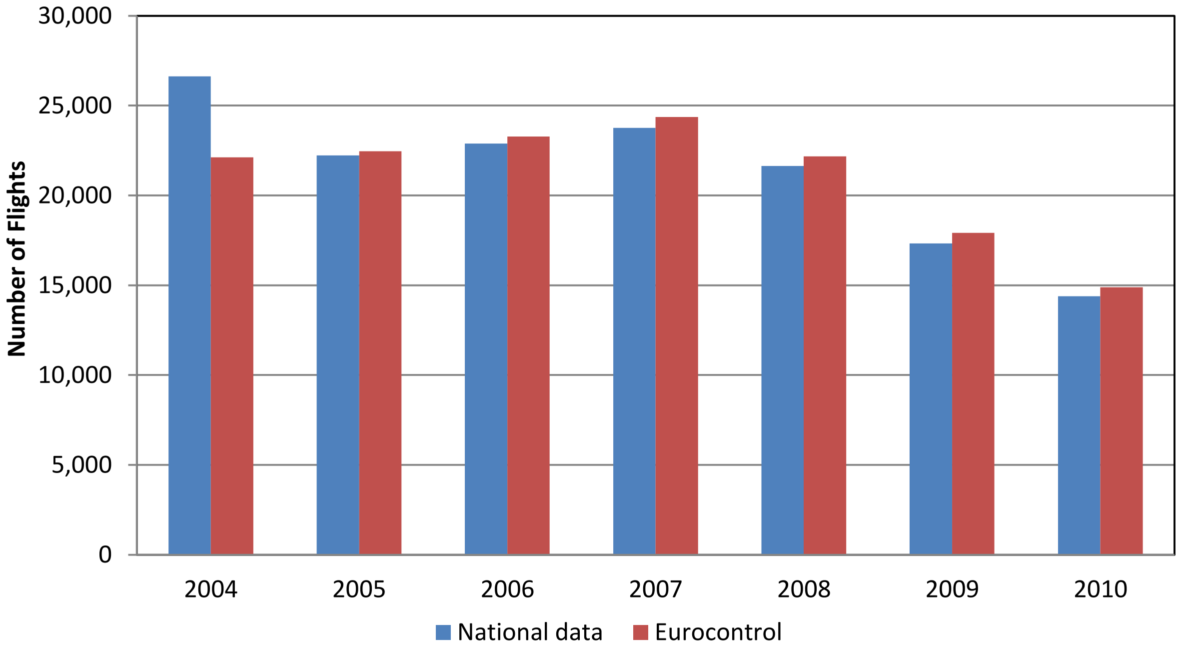


Figure 3.7 National LTO data and Eurocontrol LTO data for 2004-2010

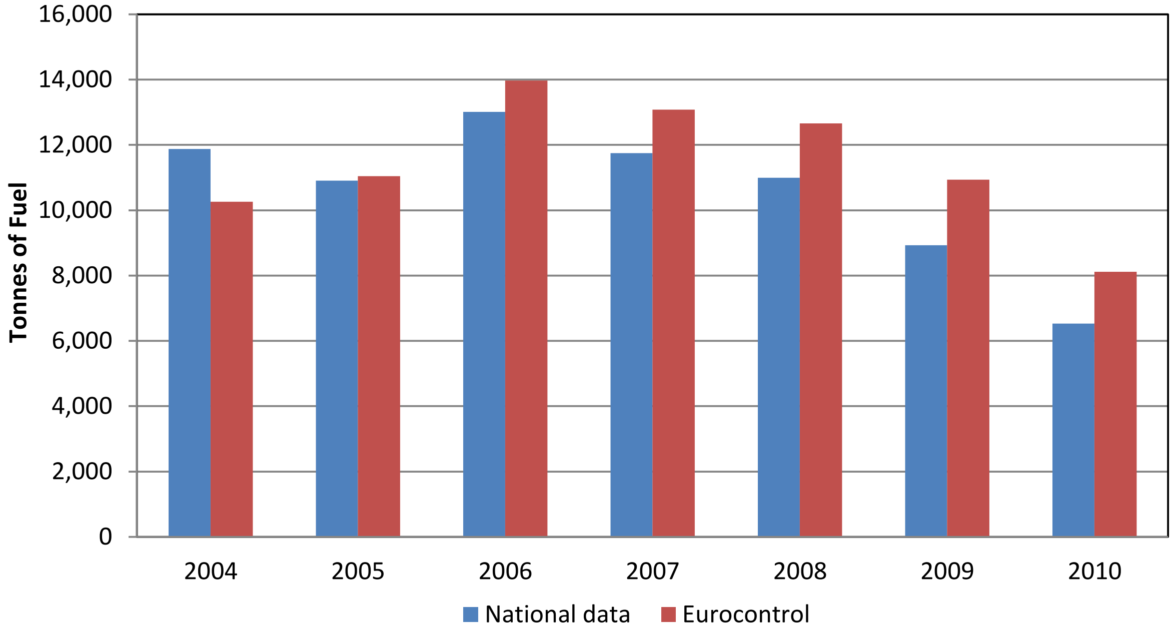


Figure 3.8 National LTO fuel data and Eurocontrol LTO fuel data for 2004-2010

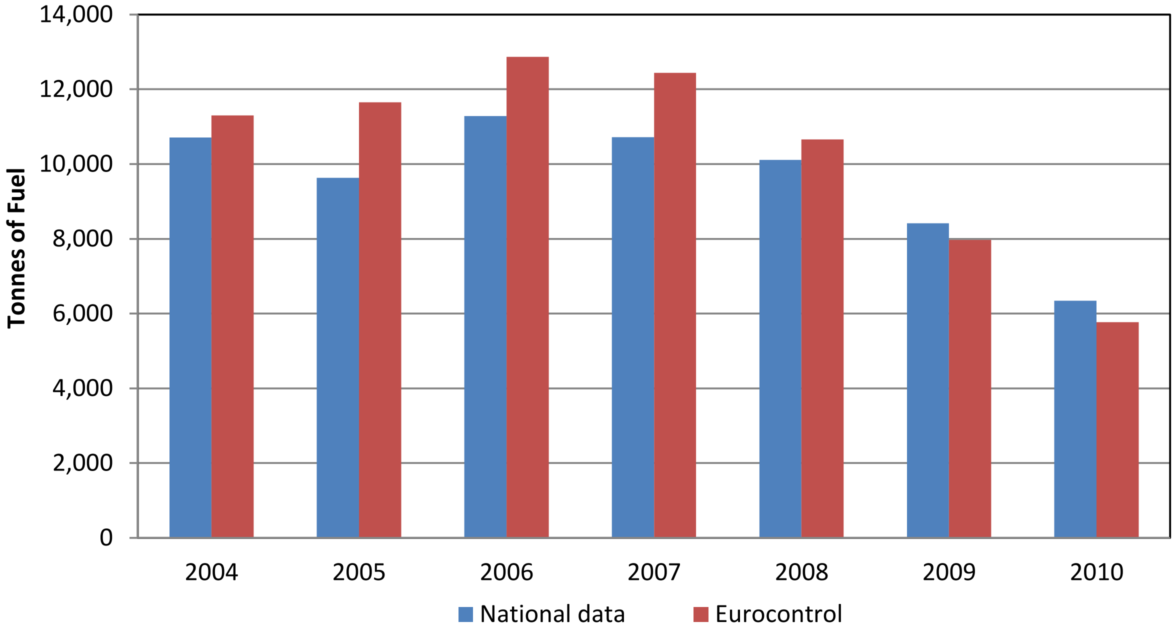


Figure 3.9 National Cruise fuel data and Eurocontrol Cruise fuel data for 2004-2010

3.7 Recalculations in Energy

Recalculations have been undertaken in the *Energy* sector for the years 1990-2011 to account for the following revisions and improvements:

1.A.1 Energy Industries

- A revision to energy data in sub-category *1.A.1.c* for years 2005-2011: revised (increased) CO_2 emission factors (from ETS data) and revised peat consumption activity data from Energy Balance (decreased). The impact has been a negligible decrease in sector *1.A.1* emissions.

1.A.2 Manufacturing Industries and Construction

- Revisions to sub-categories in *1.A.2 (a to f)* were a result of revised fuel quantities in Energy Balance: natural gas (in 2004-2007 and 2011), petroleum coke (in 2003), fuel oil (in 2011) and coal (in 2009). Also new inclusion of peat in Energy Balance (2005 onwards, *1.A.2.e*) and revised natural gas CO_2 emission factors for 2004-2011 resulted in decrease of the *1.A.2* sector emissions by 1.5 per cent (CO_2 eq.) on average in the period 2004-2011.

1.A.3 Transport

- Revisions to road transport, *1.A.3.b* sub-category are mainly due to methodological and emission factor change of implementing the most recent COPERT model (version 10.0), replacing version 9.1. Specifically, this has decreased emissions of N_2O and CH_4 from road transport by combined 0.7 per cent (CO_2 eq.) on average between 1991 and 1998.

1.A.4 Other Sectors

- Revised fuel data, in particular, petroleum coke between 2003 and 2009 (in *1.A.4.a* and *1.A.4.b*), natural gas for years 2004-2007, 2009 and 2011 in *1.A.4.a*, bituminous coal between 2009-2011 in *1.A.4.b* plus revised natural gas CO_2 emission factors for 2006-2011 in both *1.A.4.a* and *1.A.4.b* have led to decrease in sector *1.A.4* emissions by 0.2 per cent (CO_2 eq.) on average between 2003-2011.

3.8 Improvements in Energy

The following improvements have been made to *Energy* sector in this annual submission:

- Revising the road transport model used to estimate CH_4 and N_2O emissions from COPERT 4 version 9.1 to COPERT 4 version 10.0;
- Included detailed description of methodology and rationale behind COPERT4 software for calculation of road transport emissions following a recommendation from in-country review in 2013.
- Following a recommendation of improved transparency and completeness additional information was included in Annex C: section C.1: Ireland’s Energy Balance - Stakeholders, Surveys and Sources and section C.3: Country specific carbon emission factors – fossil fuels.

3.9 Planned Improvements in Energy

The changes referred to above for 2012 conclude a series of improvements affecting activity data, emission factors and methodologies that have been applied to inventories for the *Energy* sector over recent years. The inventory agency believes that CO_2 from this sector, which accounts for 98.5 per cent of emissions, are accurately quantified and there is therefore little scope for further improvement in the inventories as delivered in the 2012 submission.

Table 3.5. Percentage Change in total GHG Emissions from Energy due to Recalculations

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		Estimates in 2013 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	11,238.54	11,699.00	12,363.63	12,378.59	12,716.77	13,401.40	14,120.58	14,782.31	15,167.24	15,822.28	16,140.48	17,364.19	16,453.80	15,761.63	15,368.72	15,770.30	15,028.57	14,535.37	14,652.91	13,077.67	13,333.36	11,941.48
1.A.2.	Manuf Ind and Constn	3,961.19	4,073.89	3,768.28	3,986.23	4,242.17	4,347.15	4,182.21	4,550.03	4,589.04	4,809.90	5,641.70	5,598.68	5,322.37	5,514.42	5,911.40	6,019.11	5,910.28	6,148.45	5,648.32	4,429.71	4,569.00	4,196.25
1.A.3.	Transport	5,121.44	5,305.22	5,727.58	5,756.63	6,037.20	6,304.42	7,335.66	7,738.86	9,118.82	9,731.27	10,770.43	11,296.55	11,491.57	11,696.90	12,418.82	13,110.37	13,892.09	14,481.79	13,744.52	12,524.63	11,602.80	11,290.44
1.A.4.	Other Sectors	10,518.03	10,627.22	9,747.82	9,713.66	9,845.35	9,678.01	9,684.41	9,397.85	9,854.57	9,665.49	9,820.14	10,162.06	10,018.14	10,291.21	10,268.86	10,775.75	10,477.49	10,290.73	11,152.56	10,667.82	10,993.68	9,482.91
1.B.	Fugitive Emissions	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	127.63	85.05	147.74	68.95	626.26	65.95	56.58	46.86	59.58	51.25	35.26	31.35	27.50
1	Total	30,970.29	31,832.72	31,730.12	31,956.86	32,959.43	33,845.16	35,432.95	36,574.54	38,821.77	40,156.57	42,457.80	44,569.22	43,354.83	43,890.41	44,033.75	45,732.09	45,355.29	45,515.92	45,249.56	40,735.08	40,530.19	36,938.58
		Recalculated Estimates in 2014 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	11,238.54	11,699.00	12,363.63	12,378.59	12,716.77	13,401.40	14,120.58	14,782.31	15,167.24	15,822.28	16,140.48	17,364.19	16,453.80	15,761.63	15,368.72	15,770.14	15,028.21	14,535.21	14,652.76	13,077.48	13,333.17	11,941.40
1.A.2.	Manuf Ind and Constn	3,961.19	4,073.89	3,768.28	3,986.23	4,242.17	4,347.15	4,182.21	4,550.03	4,589.04	4,809.90	5,641.70	5,598.68	5,322.37	5,513.10	5,693.29	5,869.86	5,751.00	5,810.30	5,652.84	4,492.79	4,536.51	4,275.45
1.A.3.	Transport	5,121.45	5,300.54	5,721.83	5,703.62	5,957.20	6,238.97	7,275.10	7,680.44	9,081.88	9,729.35	10,771.72	11,299.91	11,496.53	11,703.05	12,425.38	13,116.93	13,901.11	14,490.86	13,747.51	12,527.45	11,605.30	11,292.87
1.A.4.	Other Sectors	10,518.03	10,627.22	9,747.82	9,713.62	9,845.34	9,677.97	9,684.65	9,397.85	9,854.51	9,665.49	9,820.13	10,161.74	10,018.11	10,288.81	10,238.59	10,772.78	10,465.65	10,263.23	11,135.42	10,628.32	10,975.72	9,471.44
1.B.	Fugitive Emissions	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	127.63	85.05	147.74	68.95	626.26	65.95	56.58	46.86	59.57	51.25	35.24	31.33	27.49
1	Total	30,970.30	31,828.04	31,724.37	31,903.82	32,879.43	33,779.66	35,372.62	36,516.13	38,784.77	40,154.65	42,459.09	44,572.27	43,359.75	43,892.85	43,791.94	45,586.29	45,192.84	45,159.17	45,239.77	40,761.29	40,482.03	37,008.65
		Percentage Change in Total Emissions due to Recalculations																					
1.A.1.	Energy Industries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.	Manuf Ind and Constn	0.00	0.00	-	0.00	-	-	-	-	-	-	-	-	-	-0.02	-3.69	-2.48	-2.69	-5.50	0.08	1.42	-0.71	1.89
1.A.3.	Transport	0.00	-0.09	-0.10	-0.92	-1.33	-1.04	-0.83	-0.75	-0.41	-0.02	0.01	0.03	0.04	0.05	0.05	0.05	0.06	0.06	0.02	0.02	0.02	0.02
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00	-	0.00	0.00	0.00	-0.02	-0.29	-0.03	-0.11	-0.27	-0.15	-0.37	-0.16	-0.12
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-0.03	0.00	-0.04	-0.06	-0.06
1	Total	0.00	-0.01	-0.02	-0.17	-0.24	-0.19	-0.17	-0.16	-0.10	0.00	0.00	0.01	0.01	0.01	-0.55	-0.32	-0.36	-0.78	-0.02	0.06	-0.12	0.19

Table 3.6. Percentage Change in CO_2 Emissions from Energy due to Recalculations

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		Estimates in 2013 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	11,158.61	11,617.34	12,279.74	12,297.59	12,634.28	13,317.47	14,031.86	14,692.87	15,080.52	15,732.98	16,050.38	17,266.56	16,345.85	15,643.76	15,265.22	15,657.29	14,906.98	14,406.63	14,495.44	12,926.12	13,176.05	11,798.29
1.A.2.	Manuf Ind and Constn	3,942.64	4,055.14	3,752.29	3,969.39	4,225.46	4,329.85	4,163.99	4,531.31	4,569.07	4,789.52	5,617.89	5,573.79	5,298.41	5,489.40	5,884.02	5,988.24	5,881.04	6,119.64	5,621.80	4,407.28	4,545.56	4,175.23
1.A.3.	Transport	5,021.69	5,199.86	5,614.73	5,577.05	5,799.89	6,054.20	7,023.59	7,344.83	8,618.23	9,532.18	10,561.82	11,079.75	11,280.50	11,491.16	12,211.72	12,906.10	13,688.40	14,287.77	13,595.01	12,383.33	11,471.09	11,162.29
1.A.4.	Other Sectors	10,031.09	10,146.53	9,325.65	9,299.88	9,457.73	9,305.04	9,330.93	9,073.28	9,516.89	9,378.29	9,530.36	9,878.67	9,737.53	10,017.43	10,002.06	10,494.45	10,205.40	10,026.72	10,869.21	10,389.89	10,724.72	9,235.41
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	38.27	-	56.05	-	-	-	-	-	-	-	-	-	-
1	Total	30,154.04	31,018.87	30,972.41	31,143.91	32,117.35	33,006.56	34,550.36	35,642.29	37,784.72	39,471.24	41,760.44	43,854.83	42,662.29	42,641.75	43,363.02	45,046.09	44,681.83	44,840.76	44,581.46	40,106.61	39,917.42	36,371.22
		Recalculated Estimates in 2014 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	11,158.61	11,617.34	12,279.74	12,297.59	12,634.28	13,317.47	14,031.86	14,692.87	15,080.52	15,732.98	16,050.38	17,266.56	16,345.85	15,643.76	15,265.22	15,657.29	14,906.98	14,406.63	14,495.44	12,926.12	13,176.05	11,798.29
1.A.2.	Manuf Ind and Constn	3,942.64	4,055.14	3,752.29	3,969.39	4,225.46	4,329.85	4,163.99	4,531.31	4,569.07	4,789.52	5,617.89	5,573.79	5,298.41	5,488.09	5,666.12	5,839.05	5,721.76	5,781.95	5,626.30	4,470.10	4,513.15	4,254.21
1.A.3.	Transport	5,021.69	5,199.86	5,614.73	5,577.05	5,799.89	6,054.20	7,023.59	7,344.83	8,618.23	9,532.18	10,561.82	11,079.75	11,280.50	11,491.16	12,211.72	12,906.10	13,688.40	14,287.80	13,595.01	12,383.37	11,471.15	11,162.36
1.A.4.	Other Sectors	10,031.09	10,146.53	9,325.65	9,299.88	9,457.73	9,305.04	9,330.93	9,073.28	9,516.89	9,378.29	9,530.36	9,878.67	9,737.53	10,015.05	9,971.83	10,491.42	10,193.62	9,999.31	10,852.14	10,350.66	10,708.09	9,225.15
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	38.27	-	56.05	-	-	-	-	-	-	-	-	-	-
1	Total	30,154.04	31,018.87	30,972.41	31,143.92	32,117.35	33,006.56	34,550.36	35,642.29	37,784.72	39,471.24	41,760.44	43,854.83	42,662.29	42,638.06	43,114.89	44,893.87	44,510.77	44,475.69	44,568.90	40,130.25	39,868.43	36,440.00
		Percentage Change in CO2 Emissions due to Recalculations																					
1.A.1.	Energy Industries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.A.2.	Manuf Ind and Constn	0.00	0.00	-	0.00	-	-	-	-	-	-	-	-	-	-0.02	-3.70	-2.49	-2.71	-5.52	0.08	1.43	-0.71	1.89
1.A.3.	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00
1.A.4.	Other Sectors	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-0.02	-0.30	-0.03	-0.12	-0.27	-0.16	-0.38	-0.16	-0.11
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.57	-0.34	-0.38	-0.81	-0.03	0.06	-0.12	0.19

Table 3.7. Percentage Change in CH_4 Emissions from Energy due to Recalculations

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Estimates in 2013 Submission (Gg CO2eq)																						
1.A.1.	Energy Industries	5.56	5.57	5.61	6.11	6.17	6.58	7.51	7.80	7.74	8.37	9.19	9.64	9.13	8.56	7.58	7.73	7.34	7.55	6.08	5.89	5.82	4.85
1.A.2.	Manuf Ind and Constn	5.60	5.66	4.75	5.02	4.86	5.05	5.41	5.50	5.94	6.02	7.06	7.43	7.19	7.50	8.31	9.45	9.06	8.90	8.16	6.99	7.35	6.74
1.A.3.	Transport	37.28	38.09	41.21	37.50	36.02	38.70	40.10	38.71	39.70	39.25	36.73	35.46	32.28	30.61	29.20	27.70	26.71	25.55	23.73	21.63	19.36	17.90
1.A.4.	Other Sectors	378.89	370.32	315.46	307.21	272.08	246.39	245.87	216.09	228.67	176.38	176.05	168.42	165.57	157.28	154.26	161.28	156.88	153.44	163.90	172.84	166.88	152.93
1.B.	Fugitive Emissions	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	89.36	85.05	91.70	68.95	626.26	65.95	56.58	46.86	59.58	51.25	35.26	31.35	27.50
1	Total	558.42	547.02	489.84	477.60	437.06	410.89	408.98	373.60	374.14	319.38	314.08	312.65	283.10	830.22	265.30	262.74	246.85	255.02	253.13	242.60	230.76	209.92
	Recalculated Estimates in 2014 Submission (Gg CO2eq)																						
1.A.1.	Energy Industries	5.56	5.57	5.61	6.11	6.17	6.58	7.51	7.80	7.74	8.37	9.19	9.64	9.13	8.56	7.58	7.71	7.31	7.54	6.07	5.88	5.80	4.85
1.A.2.	Manuf Ind and Constn	5.60	5.66	4.75	5.02	4.86	5.05	5.41	5.50	5.94	6.02	7.06	7.43	7.19	7.50	8.23	9.41	9.03	8.75	8.16	7.06	7.32	6.79
1.A.3.	Transport	37.29	38.10	41.20	37.50	36.02	38.71	38.78	37.70	38.48	38.23	36.16	34.88	31.86	30.23	29.13	27.89	26.59	25.52	23.70	21.54	19.31	17.96
1.A.4.	Other Sectors	378.89	370.32	315.46	307.17	272.08	246.35	246.09	216.09	228.61	176.38	176.04	168.12	165.54	157.28	154.22	161.29	156.85	153.39	163.87	172.60	165.66	151.82
1.B.	Fugitive Emissions	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	89.36	85.05	91.70	68.95	626.26	65.95	56.58	46.86	59.57	51.25	35.24	31.33	27.49
1	Total	558.42	547.02	489.83	477.56	437.06	410.85	407.88	372.59	372.86	318.37	313.50	311.77	282.65	829.83	265.11	262.88	246.65	254.76	253.06	242.32	229.42	208.91
	Percentage Change in CH4 Emissions due to Recalculations																						
1.A.1.	Energy Industries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.16	-0.38	-0.18	-0.21	-0.26	-0.27	0.20
1.A.2.	Manuf Ind and Constn	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-0.01	-0.99	-0.45	-0.37	-1.70	0.00	1.03	-0.31	0.79
1.A.3.	Transport	0.01	0.01	-0.02	0.01	0.00	0.01	-3.29	-2.61	-3.07	-2.59	-1.56	-1.65	-1.30	-1.24	-0.22	0.69	-0.42	-0.13	-0.13	-0.41	-0.29	0.33
1.A.4.	Other Sectors	0.00	0.00	0.00	-0.01	0.00	-0.02	0.09	-	-0.03	-	0.00	-0.18	-0.02	0.00	-0.03	0.01	-0.02	-0.03	-0.02	-0.14	-0.74	-0.73
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-0.03	0.00	-0.04	-0.06	-0.06
1	Total	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.27	-0.27	-0.34	-0.32	-0.18	-0.28	-0.16	-0.05	-0.07	0.05	-0.08	-0.10	-0.03	-0.12	-0.58	-0.48

Table 3.8. Percentage Change in N_2O Emissions from Energy due to Recalculations

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		Estimates in 2013 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	74.37	76.09	78.28	74.89	76.33	77.35	81.22	81.64	78.98	80.93	80.92	87.99	98.82	109.31	95.92	105.28	114.25	121.19	151.39	145.66	151.50	138.35
1.A.2.	Manuf Ind and Constn	12.95	13.09	11.24	11.82	11.85	12.26	12.80	13.23	14.03	14.36	16.76	17.46	16.77	17.51	19.07	21.41	20.18	19.91	18.35	15.44	16.09	14.28
1.A.3.	Transport	62.47	67.27	71.65	142.08	201.30	211.52	271.97	355.31	460.89	159.84	171.87	181.34	178.80	175.13	177.90	176.56	176.98	168.47	125.79	119.68	112.35	110.25
1.A.4.	Other Sectors	108.05	110.38	106.71	106.57	115.53	126.58	107.62	108.48	109.01	110.82	113.74	114.97	115.04	116.49	112.54	120.02	115.21	110.57	119.45	105.10	102.08	94.56
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Total	257.84	266.83	267.87	335.35	405.01	427.71	473.61	558.66	662.91	365.95	383.28	401.75	409.43	418.44	405.43	423.27	426.61	420.14	414.97	385.87	382.02	357.44
		Recalculated Estimates in 2014 Submission (Gg CO2eq)																					
1.A.1.	Energy Industries	74.37	76.09	78.28	74.89	76.33	77.35	81.22	81.64	78.98	80.93	80.92	87.99	98.82	109.31	95.92	105.14	113.92	121.04	151.24	145.49	151.32	138.26
1.A.2.	Manuf Ind and Constn	12.95	13.09	11.24	11.82	11.85	12.26	12.80	13.23	14.03	14.36	16.76	17.46	16.77	17.51	18.95	21.40	20.21	19.61	18.37	15.63	16.03	14.44
1.A.3.	Transport	62.47	62.59	65.90	89.06	121.30	146.06	212.73	297.91	425.17	158.94	173.74	185.29	184.18	181.66	184.53	182.93	186.12	177.54	128.79	122.54	114.85	112.55
1.A.4.	Other Sectors	108.05	110.38	106.71	106.57	115.53	126.58	107.63	108.48	109.01	110.82	113.73	114.94	115.04	116.48	112.54	120.07	115.18	110.53	119.41	105.06	101.98	94.48
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Total	257.84	262.15	262.13	282.34	325.01	362.25	414.38	501.25	627.19	365.05	385.15	405.68	414.81	424.96	411.94	429.54	435.43	428.72	417.81	388.73	384.19	359.74
		Percentage Change in N2O Emissions due to Recalculations																					
1.A.1.	Energy Industries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-0.13	-0.29	-0.12	-0.10	-0.12	-0.12	-0.06
1.A.2.	Manuf Ind and Constn	-	-	-	-	-	-	-	0.00	0.00	-	-	0.00	-	-0.01	-0.67	-0.07	0.19	-1.52	0.06	1.23	-0.38	1.14
1.A.3.	Transport	0.01	-6.95	-8.02	-37.31	-39.74	-30.95	-21.78	-16.16	-7.75	-0.56	1.09	2.18	3.01	3.73	3.73	3.61	5.16	5.38	2.39	2.40	2.22	2.09
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.02	-	0.00	-	0.00	-0.02	0.00	0.00	0.00	0.04	-0.03	-0.04	-0.03	-0.03	-0.09	-0.09
1.B.	Fugitive Emissions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Total	0.00	-1.75	-2.14	-15.81	-19.75	-15.31	-12.51	-10.28	-5.39	-0.25	0.49	0.98	1.31	1.56	1.60	1.48	2.07	2.04	0.68	0.74	0.57	0.64

Chapter Four

Industrial Processes

4.1 Overview of the Industrial Processes Sector

The list of activities under *Industrial Processes* in the IPCC reporting format is given in Table 4.1. Some of these activities are well known sources of one particular greenhouse gas, such as cement production for CO_2 or adipic acid production in the case of N_2O, while others may be more important in terms of their indirect greenhouse gas emissions. Major industrial processes within the chemical sector and metal production that are common to many other developed countries have never been an important part of the Irish economy. Consequently, many of the production processes listed in Table 4.1 are not relevant to the inventories of greenhouse gases in Ireland. Historically, the four key industrial sources are cement and lime production under *2.A Mineral Products* and ammonia and nitric acid production under *2.B Chemical Industry.* The nitric acid and ammonia plants, both operated by Irish Fertilizer Industries, ceased production in 2002 and 2003, respectively. 2*.A.3 Limestone and Dolomite Use* is a relevant activity in Ireland due to the use of a small amount of limestone to abate SO_2 emissions in peat-fired electricity generating stations and the use of limestone by a number of companies as a raw material. *2.A.4 Soda Ash Production and Use* is also a minor source of emissions and is reported in this submission for the full time-series 1990-2012.

The process CO_2 emissions for the relevant source categories under *2.A Mineral Products* are largely covered by Directive 2003/87/EC (EP and CEU, 2003) on emissions trading in the EU and full use is made of this data source for the compilation of the national inventory. In general, the annual verified CO_2 emissions in respect of the installations concerned are used directly for the years covered by the EU ETS. The category-level emission factors indicated by EU ETS data are used together with the best available production data to obtain the emissions estimates for years previous to 2005.

The *Industrial Processes* source category is the only IPCC Level 1 category for which emissions of HFC, PFC and SF_6 are reported in annual inventories. The IPCC methods estimate potential emissions by equating emissions to total consumption while actual emissions are the estimated losses to air of the substances concerned. Both potential and actual emissions of the 21 individual F-gases (Table A.1, Annex A) should be reported for source category *2.F Consumption of Halocarbons and SF_6.* Actual emissions are only required in source categories *2.C Metal Production* and *2.E Production of Halocarbons and SF_6*. There is no production of halocarbons or SF_6 in Ireland and therefore source category *2.F Consumption of Halocarbons and SF_6* is the only relevant source category of HFC, PFC and SF_6 emissions in the country. All relevant sub-categories are fully covered in Ireland's inventories (Table 4.1), as described below.

Table 4.2 and Figure 4.1 present the estimates of greenhouse gas emissions for *Industrial Processes* over the period 1990-2012 for the relevant sources in Ireland. They indicate contributions of 5.8 per cent and 4.1 per cent to total national emissions in 1990 and 2012, respectively. As such, the sector is not a particularly important one in the Irish greenhouse gas inventories. Ammonia and nitric acid production were the principal sources of emissions in the sector in 1990, accounting for approximately two-thirds of the total, but the plants ceased operation in 2003 and 2002 respectively, leaving cement production as the dominant emission source thereafter.

The combined contribution of HFC, PFC and SF_6 to the total emissions for *Industrial Processes* remains small and highly variable from year to year. A review of the F-gas emission estimates was undertaken in 2013, and more detailed activity data obtained. The use of this more comprehensive data has resulted in improved completeness in the 2014 emissions estimates of F-gases. The 2013 revision resulted in improved estimates of HFC and SF_6 emissions in the following sectors:

HFC emissions in:

2.F.1 Refrigeration and Air-Conditioning (stationary)
2.F.1 Mobile Air Conditioning (MAC)
2.F.2 Foams
2.F.3 Fire-extinguishers
2.F.4 Metered Dose Inhalers
2.F.4 Aerosols
2.F.7 Semiconductor manufacture

SF_6 emissions in:

2.F.9 Other - window soundproofing
2.F.9 Other - sporting goods
2.F.9 Other - gas-air tracers

The main causative factor of the increase in F-gas emissions has been the growth in HFC emissions from *2.F.1 Refrigeration and Air Conditioning* through their use as replacement refrigerants across virtually all refrigeration sub-categories since 1995 (first year of emissions from this source) as well as due to inclusion in this submission of activity data and additional refrigerants from new and existing supplier sources. The revised total 2.F.1 estimates for the years 1995-2011 increased from the previously estimated values by 124.6 per cent on average in that period. The revised methodological approach resulted in a 3.6 per cent increase in emissions from *2.F.1 Mobile Air Conditioning (MAC)* on average from 1993-2011. Increased use of HFCs in *2.F.4 Metered Dose Inhalers (MDIs)* is also an important component of the trend and the values have been revised following new industry information and updated in this submission. Also revised emissions from *2.F.4 Metered Dose Inhalers* resulted in 0.9 per cent increase from 1992-2011 with the years 1990 and 1991 deemed to be not occurring. The 2013 F-gases revision also provided new information to show that emissions from *2.F.2 Foams* were not occurring in the manufacturing process and consequently were removed from the whole time series. Similarly, for emissions of HFC-227ea from 2*.F.3 Fire extinguishers* from 1990-1995 were shown to be not occurring and that HFC-23 is not used as a fire extinguishing gas in this category. Emissions of HFC-134a gas (in bulk) were reallocated from *Semiconductor manufacture (2.F.7)* sector to *2.F.1 Refrigeration and Air-Conditioning (stationary)* for the years *from* 1997-2000.

Emissions of PFC arise solely from semiconductor manufacture. Emissions continue to follow the downward trend post 2000, which has been evident in previous submissions. This is due process optimization, use of alternative chemicals, employment of alternative manufacturing processes and improved abatement systems in the sector. From 2001 onwards, installation specific emissions data are used in the methodology. This is expected to give considerably more accurate emission estimates, and therefore a more certain trend with time. There were no revisions in PFC estimates in this submission.

Emissions of SF_6 in the recent years are dominated by *semiconductor manufacture (2.F.7)* and *electrical equipment (2.F.8)*, and remain variable from year to year. In 1990s the main sources of SF_6 were: *electrical equipment (2.F.8)* and *air-gas tracers (2.F.9 Other)*.

A summary of the emissions from the Industrial Processes sector is given in Table 4.2 for the period 1990-2012.

Table 4.1. Level 3 Source Category Coverage for Industrial Processes

2. Industrial Processes	CO_2	CH_4	N_2O	HFC	PFC	SF_6
A. Mineral Products						
1. Cement Production	All	NA	NA	NA	NA	NA
2. Lime Production	All	NA	NA	NA	NA	NA
3. Limestone and Dolomite Use	All	NA	NA	NA	NA	NA
4. Soda Ash Production and Use	All	NA	NA	NA	NA	NA
5. Asphalt Roofing	NE	NA	NA	NA	NA	NA
6. Road Paving with Asphalt	NE	NA	NA	NA	NA	NA
7. Other	All	NO	NO	NO	NO	NO
B. Chemical Industry						
1. Ammonia Production*	All	NO	NA	NA	NA	NA
2. Nitric Acid Production*	NA	NA	All	NA	NA	NA
3. Adipic Acid Production	NO	NO	NA	NA	NA	NA
4. Carbide Production	NO	NO	NA	NA	NA	NA
5. Other	NO	NO	NO	NO	NO	NO
C. Metal Production						
1. Iron and Steel Production	NO	NO	NA	NA	NA	NA
2. Ferroalloys Production	NO	NO	NA	NA	NA	NA
3. Aluminium Production	NO	NO	NA	NA	NA	NA
4. SF_6 Use in Aluminium and Magnesium Foundries	NA	NA	NA	NA	NA	NO
5. Other	NO	NO	NO	NO	NO	NO
D. Other Production						
1. Pulp and Paper	NA	NA	NA	NA	NA	NA
2. Food and Drink	NE	NA	NA	NA	NA	NA
E. Production of Halocarbons and SF_6						
1. By-product Emissions	NA	NA	NA	NO	NO	NO
2. Fugitive Emissions	NA	NA	NA	NO	NO	NO
3. Other	NA	NA	NA	NO	NO	NO
F. Consumption of Halocarbons and SF_6						
1. Refrigeration and Air Conditioning Equipment	NA	NA	NA	All	NA	NA
2. Foam Blowing	NA	NA	NA	NO	NO	NO
3. Fire Extinguishers	NA	NA	NA	All	NA	NA
4. Aerosols/ Metered Dose Inhalers	NA	NA	NA	All	NA	NA
5. Solvents	NA	NA	NA	NO	NO	NO
6. Other applications using ODS substitutes	NA	NA	NA	NO	NO	NO
7. Semiconductor Manufacture	NA	NA	NA	All	All	All
8. Electrical Equipment	NA	NA	NA	NO	NO	All
9. Other	NA	NA	NA	NO	NO	All
G. Other	NO	NO	NO	NO	NO	NO

* Ammonia and Nitric Acid plants closed down in 2003 and 2002 respectively.

All : all emission sources covered; NE : emissions not estimated; NO : activity not occurring; NA : not applicable (emissions of the gas do not occur in the source category); IE : emissions included elsewhere

Table 4.2. Emissions from Industrial Processes 1990-2012

	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2.A.1 Cement Production	CO_2	kt	884.0	782.0	753.0	729.0	859.0	879.0	983.0	1145.0	1059.0	1166.0	1700.9	1851.2	1859.8	2127.0	2295.1	2357.1	2347.9	2374.1	2106.7	1326.8	1105.1	966.3	1177.0
2.A.2 Lime Production	CO_2	kt	214.1	192.2	162.4	204.9	205.4	187.5	198.2	221.9	211.7	170.1	190.4	189.4	190.3	206.3	201.5	183.5	180.3	196.7	187.8	156.4	192.4	199.1	214.4
2.A.3 Limestone & Dolomite Use	CO_2	kt	0.15	0.14	0.13	0.11	0.13	0.18	0.17	0.24	0.23	0.25	0.18	4.50	2.17	2.38	3.55	4.29	2.64	2.32	2.71	1.54	1.03	1.04	0.44
2.A.4 Soda Ash Production & Use	CO_2	kt	0.10	0.09	0.07	0.11	0.05	0.07	0.09	0.10	0.11	0.05	0.07	0.09	0.05	0.06	0.08	0.08	0.06	0.06	0.04	0.05	0.07	0.07	0.09
2.A.7 Glass Production	CO_2	kt	13.33	13.06	12.59	12.52	12.31	11.97	11.63	11.46	11.05	10.96	10.71	10.14	5.13	0.55	0.58	0.48	0.49	0.45	0.31	0.02	NO	NO	NO
2.A.7 Other Mineral Products	CO_2	kt	5.07	4.88	4.79	4.50	4.79	5.46	5.27	6.23	6.08	6.37	6.49	6.12	5.91	6.12	6.23	7.41	7.40	6.83	4.00	0.53	0.42	0.83	0.03
2.B.1 Ammonia Production*	CO_2	Gg	990.2	1030.3	1003.6	946.2	1056.6	973.4	922.9	1073.1	1058.8	942.8	882.3	1041.2	810.9	0.3	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B.2 Nitric Acid Production*	N_2O	kt CO_2 eq	1035.4	812.4	812.4	812.4	812.4	812.4	812.4	812.4	812.2	812.2	812.4	584.4	292.2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions of HFC	HFC	Gg CO_2 eq	0.47	0.60	1.5	4.0	13.3	37.1	94.6	161.8	207.0	215.6	270.8	313.7	382.0	515.0	635.4	813.5	844.6	850.9	973.1	957.1	973.4	992.3	982.0
Emissions of PFC	PFC	Gg CO_2 eq	0.09	7.62	15.2	30.2	45.3	75.4	103.1	130.8	61.9	195.9	305.4	296.0	212.4	228.8	182.4	168.3	148.3	130.6	106.2	65.6	37.0	13.2	8.0
Emissions of SF6	SF_6	Gg CO_2 eq	35.51	40.74	46.0	55.5	64.9	82.9	102.2	132.2	93.1	67.4	54.3	67.8	67.7	115.4	68.8	102.0	63.4	66.2	57.5	41.2	34.7	47.7	39.2
Total Industrial Processes			**3178.4**	**2884.1**	**2811.6**	**2799.4**	**3074.2**	**3065.5**	**3233.5**	**3695.4**	**3521.1**	**3587.6**	**4234.1**	**4364.4**	**3828.6**	**3201.8**	**3393.8**	**3636.6**	**3595.1**	**3628.1**	**3438.3**	**2549.2**	**2344.2**	**2220.4**	**2421.2**

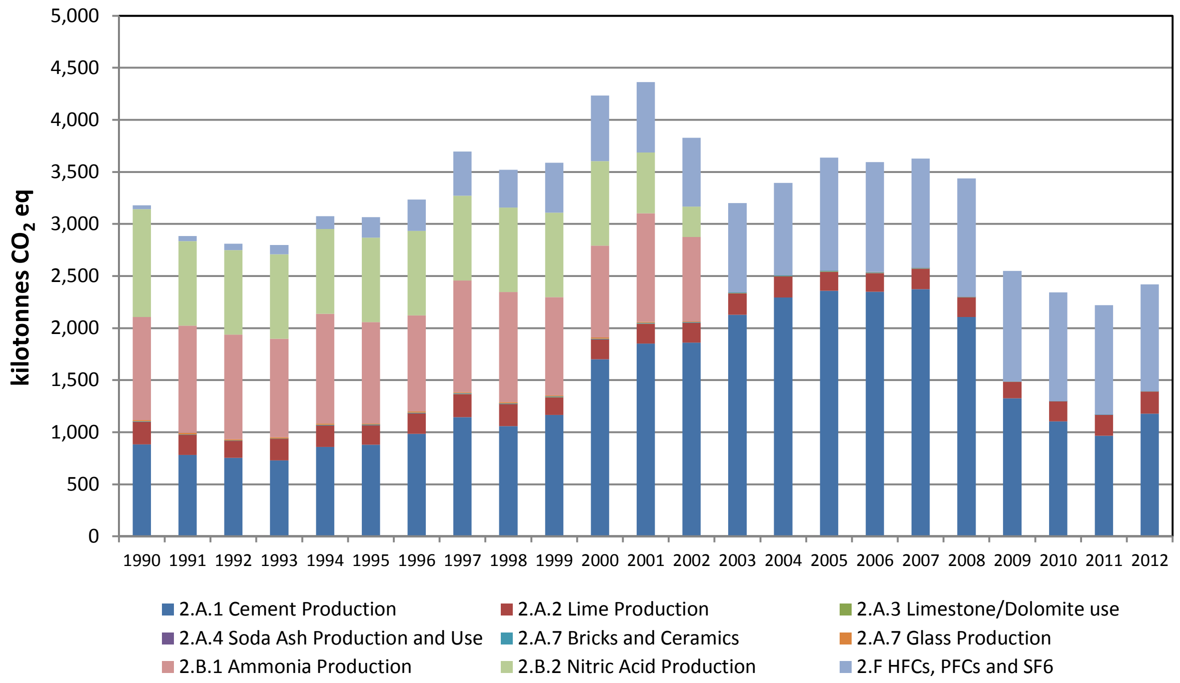


Figure 4.1 Trend in Emissions from Industrial Processes 1990-2012

4.2 Emissions from Mineral Products (2.A)

The IPCC Level 3 emission source categories relevant under *2.A Mineral Products* in 2012 are *2.A.1 Cement Production, 2.A.2 Lime Production, 2.A.3 Limestone and Dolomite Use, 2.A.4 Soda Ash Production and Use* as well as the production of bricks and ceramics under *2.A.7 Other Mineral Products*. Total CO_2 emissions from these activities amounted to 1,391.97 Gg, in 2012 of which cement production accounted for 84.6 per cent.

4.2.1 Cement Production (2.A.1)

During the cement manufacturing process, calcium carbonate in the cement kiln feed (typically $CaCO_3$ in limestone) undergoes calcination at high temperature to produce lime (CaO) and CO_2. The activated lime that results from this process combines with silica in the kiln feed to form cement clinker. The emissions of CO_2 are usually calculated from the amount of clinker produced and the stoichiometric ratio of CO_2 to CaO. A small amount of raw material may be converted into cement kiln dust (CKD) due to incomplete calcination. If the CKD is not recycled as part of subsequent kiln input, the CO_2 emissions based on clinker production must be corrected to account for the carbonate fraction lost in CKD.

Up until the year 2000, one company operated two cement plants in Ireland. A second company opened a new cement plant in 2000 and a third cement producer entered the market in 2003, bringing the total number of plants to four. In 2004, plant-specific information relating to CO_2 emissions in 2002 and 2003 was obtained by the EPA for all cement plants for the development of Ireland’s First National Allocation Plan (NAP1) under Directive 2003/87/EC (EP and CEU, 2003) on emissions trading in the EU. The reported process CO_2 emissions for each plant in 2002 and 2003 were calculated using the Tier 2 method according to the guidelines for the monitoring and reporting of greenhouse gas emissions in Decision 2004/156/EC that supports Directive 2003/87/EC. This method is fully consistent with the Tier 2 method in the IPCC good practice guidance and its application employs reliable data on clinker production, corrected as appropriate for CKD, and CaO content of the clinker. As the EU ETS subsequently became operational, plant specific CO_2 emissions and corresponding clinker production data are also available for all cement plants for the years 2004 through 2012 and these data are used directly to report emissions for category *2.A.1* in Ireland. The annual results incorporate verification of fuel use, limestone and carbonate use, combustion and process CO_2 estimates in accordance with Decision 2004/156/EC. Total process emissions for cement production in 2012 were 1,177.02 Gg CO_2. The plant-specific emission factors for process CO_2 emissions in 2012 ranged from 0.530 to 0.546 t CO_2/ t clinker with a weighted average of 0.538 t CO_2/ t clinker, which is very similar to the 2011 values. Additional information on clinker production, emissions and IEFs is provided in Table F.1 of Annex F.

For the two original cement plants that were operated by the single cement producer, the company concerned supplied estimates of process emissions for the years 1990-2001 that it had calculated internally in line with the specific information provided for the years 2002 and 2003 and used for NAP1. The associated values of annual clinker production were not provided. For the purposes of complete and consistent reporting, the inventory agency estimated annual clinker production for the years 1990-2001 based on the plant specific process emission factors available for the two plants for the years from 2002 onwards. This is appropriate, as the company has always used the same local on-site supply of limestone, and the time-series of process CO_2 emissions for cement production overall may therefore be considered consistent for the period 1990-2012. The revised estimates for category 2.A.1 were included in the 2006 submission and no further recalculations have been made since the EU ETS data were adopted as the best available for inventory purposes.

Information on calcium oxide (CaO) and magnesium oxide (MgO) content of clinker, for each of the four cement plants, has been provided to the inventory agency by the plant operators for all years from 2008 to 2012 as recommended in the previous annual inventory review reports. This information is not published in this inventory report as the cement producers deem it to be confidential. The data are available to the expert review teams for annual GHG inventory reviews upon request.

Process emissions of CO_2 from cement production have declined by 56.8 per cent since 2007, falling from a peak of 2,374.06 Gg CO_2 in 2007, to 966.27 Gg CO_2 in 2011. This is a reflection of the recent economic downturn. However, emissions increased in 2012 and at 1,177.02 Gg CO_2 they were 21.8 per cent higher than in 2011.

4.2.2 Lime Production (2.A.2)

Statistical data on lime production in Ireland are obtained annually from the lime manufacturers (three companies up to 1999 and two companies thereafter). As in the case of cement production, lime producers provided their own estimates of CO_2 emissions from lime manufacture for the development of NAP1 under Directive 2003/87/EC on ETS. These were calculated in accordance with the methods described in the supporting Decision 2004/156/EC, thus providing detailed information on emission estimates and activity data for another important source of CO_2 emissions in *Industrial Processes*. The CO_2 estimates for lime production in 2012 have been obtained from the ETS returns to the EPA. The implied emission factor for aggregated lime production was 0.763 t CO_2/t lime in 2012, which is very similar to that for the other years for which ETS data are available. Data provided by the lime producers form the basis for emissions over the period 1990-2004. The implied emission factors for the 1990-2004 time-series indicated by the information supplied by the lime producers are in the range 0.753 to 0.877 t CO_2/t lime produced with an average of 0.82 t CO_2/t lime. EU ETS data for the years 2005 to 2012 are used to confirm the estimates for the years 1990-2004, as given in Table 4.2.

Additional detailed information on lime production, emissions and IEFs is available in Table F.2 in Annex F.

4.2.3 Limestone and Dolomite Use (2.A.3)

The CO_2 emissions reported under this category refer to those emissions associated with the use of limestone ($CaCO_3$) for flue gas desulphurisation and limestone used in the manufacture of bricks and tiles. Limestone has been used to capture the sulphur emitted from peat burning in one electricity generating station since 2001 and in a second such plant since 2007. The CO_2 emissions estimates are taken from ETS returns. They are estimated on the basis of limestone quantity used by the companies and an emission factor of 0.44 t CO_2/t limestone, which is the stoichiometric ratio of CO_2 to $CaCO_3$. A further minor use of limestone relevant to *2.A.3 Limestone and Dolomite Use* in Ireland is its application in the purification of sugar produced from sugar beet. However, sugar production ceased in 2006 and the only information on emissions is that obtained under ETS in respect of 2005 and 2006.

Since 2008, when the last brick and tile manufacturing plants closed, the only source of emissions in this sub-category is the use of limestone for flue gas desulphurisation at peat fired power plants. The emission trend in recent years is entirely due to the amount of desulphurisation required at these power plants. Additional detailed information on activity data, emissions and IEFs is available in Table F.3 in Annex F.

4.2.4 Soda Ash Production and Use (2.A.4)

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is used as a raw material in a large number of industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. The emissions associated with soda ash use by one company in Ireland are reported by the company under ETS for the years 2005-2012 and have been used directly in the inventory. Activity data for years prior to the ETS data were sourced by the inventory agency from the company. These data were combined with an emission factor of 0.41 t CO_2/t soda ash, indicated by the ETS data. This approach has allowed a full 1990-2012 time series of emissions to be included in the inventory. Additional detailed information on activity data, emissions and EFs is available in Table F.4 in Annex F.

4.2.5 Other Mineral Products (2.A.7)

The emissions of CO_2 from glass production (which ceased in 2009) as well as the emissions arising from the use of clays and shale as a raw material in the manufacture of bricks and ceramics are reported under this CRF category. Similar to other categories under 2.A, information from individual plants that are participants in the Emissions Trading Scheme is used to report the emissions estimates in the national inventory.

Glass production is treated as a separate sub-category under 2.A.7, and a full time-series of CO_2 emissions has been developed; glass production ceased in Ireland in 2009. The production of bottle glass was the major source of emissions. The CO_2 emissions are estimated from the annual production quantities obtained from the company for the development of annual inventories for heavy metals. Equation 2.11 of the 2006 IPCC guidelines and the emission factor of 0.21 kg CO_2/kg glass are used. Allowance is made for recycled glass, which is assumed to be 5 per cent in 1990, increasing to 30 per cent in 2002 when the plant closed. In the case of crystal glass, the CO_2 emissions are based on the use of potassium carbonate and sodium carbonate use (soda ash) as reported under ETS, using the emission factors of 0.415 t CO_2/t Na_2CO_3 and 0.267 t CO_2/t K_2CO_3, provided by the ETS monitoring and reporting guidelines. The company concerned has supplied estimates for all years up to and including 2009, when the plant closed. Emissions from the production of glass-based insulation materials are also based largely on soda ash use although small amounts of dolomite and limestone were also used up to 2005. The emissions of CO_2 from glass production amounted to 13.3 kt in 1990 and have reduced to 0.02 kt in 2009, due to plant closures. The last glass manufacturing plant closed in 2009. Additional detailed information on glass production, emissions and IEFs is available in Table F.5 in Annex F.

In the case of bricks and ceramics, the ETS data for two companies provide estimates of emissions for the years 2005-2012 and a further two companies for the years 2005-2008 which have now ceased trading, along with the corresponding quantities of carbonate input materials and the relevant emission factors. The emission factors for clay bricks and flue liners are in the range 0.026 to 0.049 tonne CO_2/tonne carbonate input while the emission factor for ceramic tiles averages 0.062 tonne CO_2/tonne carbonate input. The emissions for the years prior to ETS are calculated from the companies' estimates of material use and their respective average ETS emission factors. Additional detailed information on raw material use, emissions and IEFs is available in Table F.6 in Annex F.

4.3 Emissions from Chemical Industry (2.B)

Emissions of CO_2 and N_2O from *ammonia production (2.B.1)* and *nitric acid production (2.B.2)* are reported under *2.B Chemical Industry.* Ammonia and nitric acid production in Ireland was undertaken by two plants, both of which were operated by Irish Fertilizer Industries for the production of nitrogenous fertilisers. However, during 1999 and 2000 the major fertiliser manufacturers introduced severe rationalisation and restructuring measures, which resulted in the closure of the nitric acid and ammonia plants in 2002 and 2003, respectively. Fertiliser manufacture in Ireland no longer takes place and all fertilisers are either imported as a finished product or undergo further blending only in Ireland.

4.3.1 Ammonia Production (2.B.1)

Ammonia is the basis of all nitrogen fertilisers and is normally manufactured by synthesis of nitrogen and hydrogen, with natural gas as the basic raw material. Utilising the Haber Bosch process, natural gas, air and water were reacted to produce ammonia in liquid form and CO_2 as a by-product. Urea was one of the main end products of the plant, which was formed when the ammonia produced and the CO_2 by-product reacted together to form prills (small particles) of urea. The other main product, liquid ammonia, was stored and transported to Irish Fertilizer Industries other plant where it underwent further processing (discussed in section 4.3.2 Nitric Acid Production below). Carbon dioxide emissions from ammonia production are estimated from the natural gas feedstocks to the plant as indicated in the national energy balance provided by SEAI. In accordance with the 1996 IPCC guidelines, it is assumed that no feedstock carbon is sequestered in urea and the emission factor is 54.94 kg CO_2/TJ, the value for indigenous natural gas, which equates to 2.3 tonne CO_2/tonne natural gas. The CO_2 emissions from ammonia production were 990.23 Gg in 1990 and 0.30 Gg in 2003, the last year of operation.

4.3.2 Nitric Acid Production (2.B.2)

Nitric acid is used as raw material mainly in the manufacture of nitrogenous-based fertiliser. It may also be used in the production of adipic acid and explosives, for metal etching and in the processing of ferrous metals. Nitric acid production in Ireland ceased in 2002 due to the liquidation of Irish Fertilizer Industries. Ammonia transported from Irish Fertilizer Industries urea production plant (section 4.3.1) to the ammonium nitrate production plant was oxidised over a catalyst to form nitric acid. The nitric acid was then combined with more ammonia to produce ammonium nitrate which, when solidified into granules or made into bead-like prills, is applied to land using a fertiliser spreader. Other fertiliser blends were also manufactured at the plant. For the years 1990-1995, the inventory agency received direct correspondence from the plant operator specifying the quantities of nitric acid produced and the company's estimates of N_2O emitted during the production process. Four units at this plant produced 338,000 tonnes of nitric acid in 1990 with associated N_2O emissions of 3,340 tonnes. The emissions were estimated from nitrogen loading and the type of catalyst used in the process.

4.4 Emissions of HFC, PFC and SF_6 from Industrial Processes (2.F)

4.4.1 Special Studies

The compilation of emission estimates for fluorinated gases presents major challenges for inventory agencies because they emanate from diverse sources that are entirely different to those traditionally covered by atmospheric emissions inventories. In addition, the use of many of the substances concerned is continuing to change very rapidly in the marketplace. Issues of confidentiality are common among many of the source activities concerned and this also hinders the inventory process and the transparency of reporting in relation to fluorinated gases (F-gases). The first attempts to quantify emissions of HFC, PFC and SF_6 in Ireland were made for the year 1995 for inclusion in Ireland's Second National Communication published in 1997 (DOE, 1997). Little was known at that time about the sources of these fluorinated gases and the methodologies to estimate their emission were not well established. The results for 1995 were therefore regarded as tentative and incomplete. However, the indications were that, in common with emissions from industrial processes in general in Ireland, those of HFCs, PFCs and SF_6 were likely to be small. In 2000, the EPA commissioned special studies on HFC, PFC and SF_6 emissions, led by the Clean Technology Centre (CTC) at Cork Institute of Technology that were designed to identify the important sources in Ireland and to quantify the emissions in 1998 on the basis of separate bottom-up and top-down methodologies. The reports on these studies (O'Doherty and McCulloch, 2002 and O'Leary *et al*, 2002) describe a very comprehensive investigation into the emissions of fluorinated gases in Ireland and the bottom-up method provided a readily applicable approach that could be used for developing inventories of these gases for other years.

The methodological approach adopted in the special studies for 1998 was subsequently used in early 2002, again under contract with CTC (O'Leary, 2002), to compile emissions estimates for HFCs, PFCs and SF_6 for the time-series 1995 through 2000, which were incorporated in the recalculated inventories submitted in 2002. Estimates were also compiled to the extent possible at that time for 1990, but data were difficult to obtain and it was clear that the use of many of the substances had not become established in the country by then. The focus in this particular follow-up study was on the years from 1995 to 2000, in the knowledge that 1995 could be selected as the base year for emissions of fluorinated gases under the Kyoto Protocol. The inventory agency subsequently continued reporting for the years up to 2003, based broadly on the CTC approach used for the 1995-2000 time-series.

As part of the general round of improvements conducted for the 2006 submission, the inventory agency decided that it would be useful to again examine, on a contract basis, the known sources of HFCs, PFCs and SF_6 emissions over an extended time period. The contract was undertaken jointly by CTC and UK consultants NETCEN, the latter having considerable experience in developing emission inventories for the UK. The work and results are fully described in a supplementary document (Adams *et al*, 2005). The intention was to re-assess the use and application of the various substances in the Irish market as a whole, initially to compile the best possible estimates of emissions in 2004, and to make revisions as appropriate for earlier years based on better information, particularly for 1995 (the base year adopted by Ireland with respect to HFC, PFC and SF_6) and for those years (2001-2003) for which the estimates had been produced by the inventory agency. A second objective of the study was to extend the F-gas emissions time-series back to 1990 so that Ireland could make available information that had been lacking for the years 1990-2004, requested under Decision 280/2004/EC, to enable the European Union to complete the inventories at the European level for all years. In performing this update of the previous emission inventories for fluorinated gases, a number of users and distributors were contacted and any data obtained were used for estimating emissions of the various gases for the period 2001-2004. Where data allowed, emission estimates were calculated following the guidance for individual sub-categories provided by IPCC good practice guidance. The approach developed by Adams *et* al. (2005) was used for the submissions until 2013 (for 1990-2011 data).

A review of existing approach on F-gases was carried out in 2013. The time series 1990-2011 was reviewed and emission estimates for 2012 were compiled along with the revised estimates. Information obtained from stakeholders was used to update the current inventory using best practice and methodologies as outlined in the Revised 1996 Guidelines and IPCC GPG. The uncertainties associated with these emission estimates were assessed; resulting recalculations of the emissions were evaluated; a comparison of emissions with other European countries was carried out. Quality assurance and quality control (QA/QC) procedures were carried out on the inventory including a full quality check by an international expert that was not directly involved in the compilation update. Further information on the recalculations of each sector in the F-Gases inventory can be found in each relevant sub-section. Recalculations for HFCs, PFCs and SF_6 are discussed in section 4.6.

Emission estimates for 1990-2012 are shown in Table 4.3. In 2012, *air conditioning* (stationary and mobile combined) *and refrigeration (2.F.1)* account for some 81.3 per cent of the total F-gas emissions. The emission estimates clearly indicate that the combined emissions of HFCs, PFCs and SF_6 have generally increased year on year. This overall trend largely reflects the increasing use of HFCs across a range of applications (e.g. often as replacements in applications where the use of CFC and HCFCs is no longer permitted under the Montreal Protocol) and hence the presence of larger fluid banks from which operational leakage potentially occurs. In contrast, PFC emissions have decreased while emissions of SF_6 fluctuate significantly. This combined PFC and SF_6 trend is determined principally by their use in the *manufacture of semiconductors (2.F.7)* and *electrical equipment (2.F.8)*, for which the reported emissions received directly from manufacturing companies in Ireland show annual fluctuations reflecting changing manufacturing activity in response to the global trends in this market. From 2006 onwards, emissions of PFC show significant decline due to process optimization and use of alternative chemicals in the semiconductor industry. SF_6 emissions also generally decline but with large fluctuations.

4.4.2 HFC, PFC and SF_6 Time-Series 1990-2012

In the following sections a brief description is provided for the activities for which emissions of HFCs, PFCs and SF_6 are estimated for the time-series 1990-2012. Total emissions of the main three F-gases reached 1,029.25 Gg CO_2 eq. in 2012 and were 2.3 per cent lower than the previous year and by 9.5 per cent lower than at their peak in 2008 (at 1,136.75 Gg CO_2 eq.). Emissions from HFCs from 2.F.1-2.F.8 and emissions from all F-Gases are presented in Figures 4.2 and 4.3. Emissions increased steadily between 1995 and 2008 mainly due to increasing emissions of HFCs from *refrigeration and mobile air-conditioning (2.F.1)* and PFC and SF_6 emissions from the *semi-conductor industry (2.F.7)*.

HFC emissions are reported from six sources:

2.F.1 Refrigeration and Air-Conditioning
2.F.1 Mobile Air Conditioning
2.F.3 Fire-extinguishers
2.F.4 Aerosols
2.F.4 Metered Dose Inhalers

2.F.7 Semiconductor manufacture

PFC emissions are reported from one source:

2.F.7 Semiconductor manufacture

SF_6 emissions are reported from six sources:

2.F.7 Semiconductor manufacture
2.F.8 Electrical equipment
2.F.9 Other - window soundproofing
2.F.9 Other - medical applications
2.F.9 Other - sporting goods
2.F.9 Other - gas-air tracers

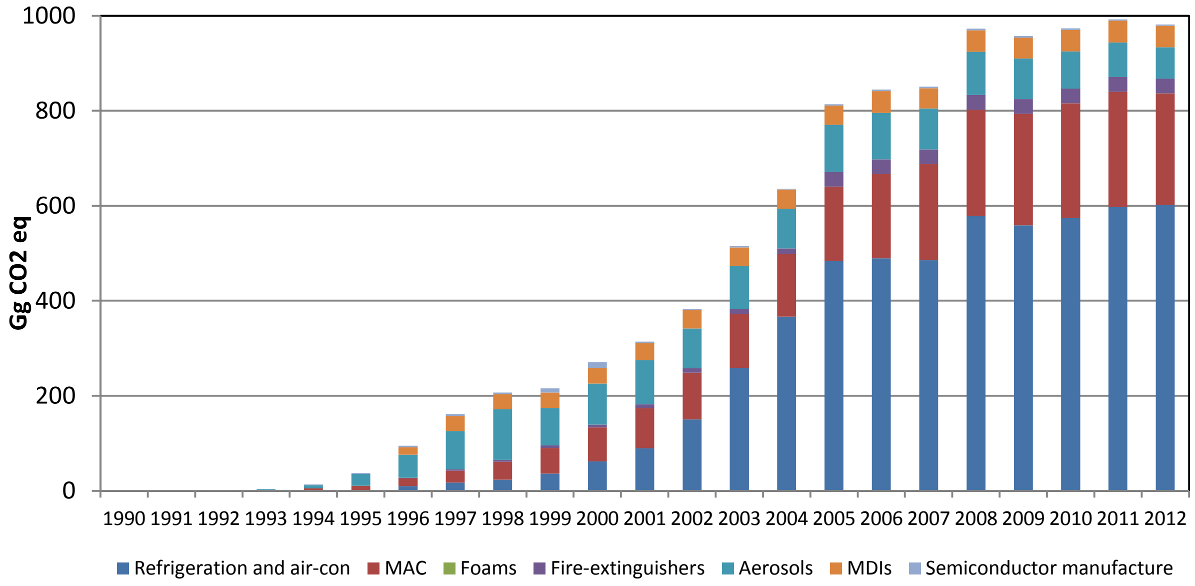


Figure 4.2 Trend in Emissions of HFCs from Consumption of Halocarbons and SF_6 (2.F) 1990-2012

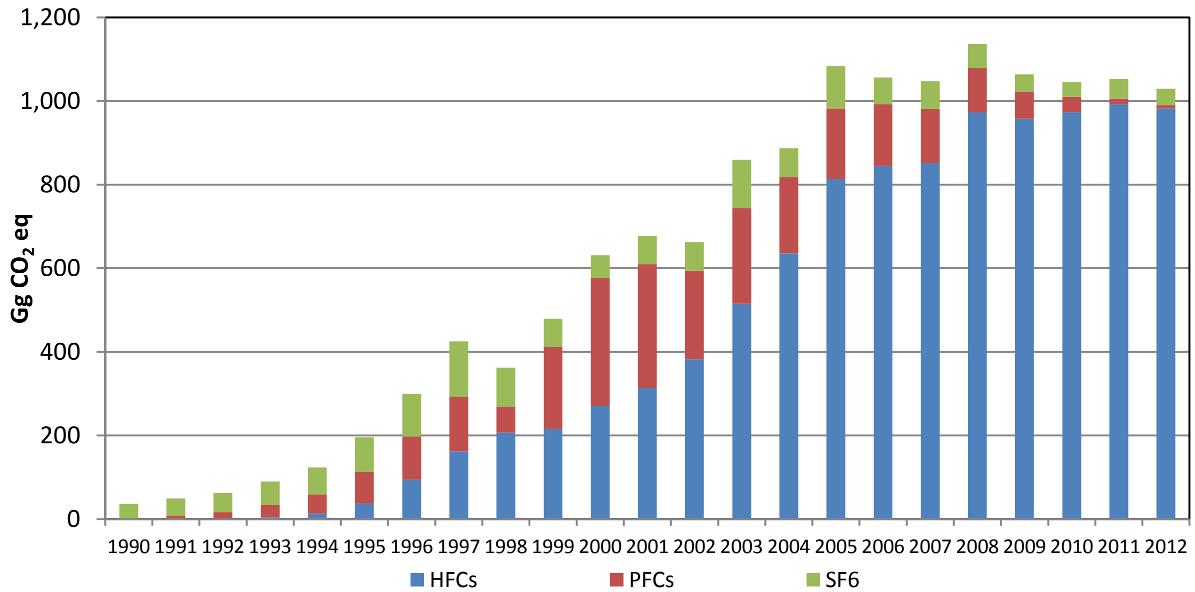


Figure 4.3 Trend in Emissions of F-Gases from Consumption of Halocarbons and SF_6 (2.F) 1990-2012

Additional information is provided in O'Doherty and McCulloch (2002), O'Leary *et al.* (2002) and Adams *et al*. (2005), Goodwin *et al.* (unpublished 2013). The CRF sectors *2.C Metal Production, 2.E Production of Halocarbons and* SF_6, *2.F.2 Foams, 2.F.5 Solvents* and *2.F.6 Other applications using ODS substitutes* are not applicable to or not occurring in Ireland therefore the relevant notation keys are used in respect of F-gases in these categories in the CRF.

4.4.2.1 Refrigeration and Air Conditioning (2.F.1)

Emissions of HFCs from *Refrigeration and Air Conditioning* (stationary and mobile combined) with their 81.3 per cent share were the largest source of total F-gases emissions in 2012, as opposed to 1.3 per cent share in the first year of *Mobile air conditioning (MAC)* emissions and together with *stationary refrigeration* in operation since 1995 their share of sectoral emissions has been growing annually. They reached the level of 836.58 Gg CO_2 eq. in 2012 which was 0.4 per cent lower than in the previous year and 2011 at 839.90 Gg CO_2 eq. was also their peak emissions year. In *2.F.1 stationary refrigeration* sector emissions the revised estimates for the years 1995-2011 increased from the previously estimated values by 124.6 per cent on average in that period and emissions before 1995 were found to be not occurring and removed from the time series. Estimates from *2.F.1 MAC* were revised for years 1993-2011 and resulted in 3.6 per cent increase on average in that period. Recalculations in *2.F.1* subsectors (stationary and MAC) were due to revised methodological approach and due to inclusion in 2014 submission of new activity data and new refrigerants from new and existing supplier sources.

HFCs and HFC blends have been widely used as replacement refrigerants for CFC and HCFC refrigerants across virtually all refrigeration sub-sectors (i.e. domestic refrigeration, small commercial distribution systems, industrial systems, building air conditioning systems and refrigerated transport). The first HFC refrigerant on the market was R134a in the 1990s. The composition of the HFC refrigerants present on the Irish market has undergone some significant changes across the time series. These changes are due to the rapid phase-in of different HFC refrigerants in various applications, and the introduction of new refrigerant blends i.e. R404A, 407A, 407C, R410A. R404A, R134a and R407C have been the main refrigerants since 2000. In the early part of the time series (1995 through to 2000) large quantities of HCFCs were used as refrigerants (mainly R22, which are not subject to greenhouse gas emission reporting as controlled under the Montreal Protocol). In terms of stationary refrigeration, data on the quantities of industrial gases supplied to the refrigeration sector is obtained from chemical suppliers and manufacturers of refrigeration units. Sales data is provided for a range of HFCs and blends corresponding to the individual HFC species:

HFC-23
HFC-32
HFC-125
HFC-134a
HFC-143a
HFC-152a

Potential emissions from the sector are calculated using a Tier 1 approach as follows:

Potential emissions = production + import – export – destruction

As there is no manufacture of fluorinated gases in Ireland, the production term above is zero. Imported HFCs are calculated using the data supplied as described above. Exports are calculated on the basis of refrigeration unit manufacturers' share of exports. Destruction of air conditioning units in Ireland started in 2009 as per revised calculations regarding the size and life span of all imported units. Recovered gas is used either in other equipment (retrofit) or exported for recycling.

A bottom-up approach is not feasible for estimating actual emissions from stationary refrigeration and air conditioning in Ireland due to the lack of data available on equipment types and HFC sales data in equipment sub-categories. Therefore emissions are estimated using a top-down approach based on reported import data and information on market shares, which are applied to calculate estimates of total HFCs sales in the Irish stationary refrigeration and air-conditioning sectors. As a result, emissions arising from sub-sectors *2.IIA.F.1.1 Domestic Refrigeration, 2.IIA.F.1.3 Transport Refrigeration, 2.IIA.F.1.4 Industrial Refrigeration* and *2.IIA.F.1.5 Stationary Air-Conditioning* are reported under *2.IIA.F.1.2 Commercial Refrigeration*.

Emissions of HFCs from sub-category *2.IIA.F.1.6 Mobile Air-Conditioning* are estimated using a Tier 3b bottom-up analysis which uses national vehicle fleet statistics (Table E.5, Annex E) and assumed rates of air-conditioning unit penetration in the national vehicle fleet (AEA, 2011). The methodology used takes account of vehicle lifetime (12 years), the percentage of vehicles having HFCs in their air-conditioning systems, average charge per unit, product manufacturing emissions (AEA, 2011), effective lifetime leakage rates (incorporating emissions from normal operating losses and accidental releases arising from collision damage) and decommissioning losses (EP and CEU, 2006).

4.4.2.2 Foam Blowing (2.F.2)

Following a revision on F-gases in 2013, emissions from *2.F.2 Foams* were shown to be not occurring in Ireland and consequently were removed from the whole time series (emissions were reported in the previous submission for the time series 1990-2011). During this revision, it was identified that no manufacturing of open-cell foams have occurred in Ireland. The production of closed-cell foams takes place in Ireland by one company that used HCFC-141b and now uses pentane. Therefore, no manufacturing emissions of HFCs occur in Ireland.

4.4.2.3 Fire Extinguishers (2.F.3)

HFC emissions from this sub-category were 31.10 Gg CO_2 eq. in 2012 and accounted for 3.0 per cent of the total emissions from F-gases, the third largest source of F-gases (after categories *2.F.1* and *2.F.4*). Emissions from fire extinguishers in 2012 remained similar to emission levels in previous years 2005-2011 following continuous rise from 1996 to 2005. The current inventory was thoroughly reviewed during 2013. All calculations and assumptions were checked to assess the current approach. As a result of this and further stakeholder consultation, the estimates from category *2.F.3* were recalculated resulting in 60.2 per cent decrease on average between 1996 and 2011.

HFCs are used as a partial substitute for halon in fixed fire protection systems. They are most commonly used in fixed flooding systems in the protection of electronic and telecommunications equipment, in data centres, military applications, records offices, bank vaults and oil production facilities. There are a number of companies operating these systems in Ireland. Although HFC-23 can be used in some systems, the 2013 study identified none within Ireland so the only HFC used is HFC-227ea. The majority of emissions occur when fire protection systems are triggered either accidentally or due to the occurrence of a fire. Smaller emissions occur during maintenance and filling.

Activity data on the use of HFCs in this sector has been provided by industry. From this information the number of systems and the quantity of HFCs present in the market has been estimated for the time series. These systems were first introduced into the Irish market in 1996 so emissions are not occurring (NO) prior to 1996. This is a recalculation since the previous submission, which assumed emissions since 1990. The emission calculation methodology used for this category is a Tier 2a emission model. The model estimates emissions from three situations where emissions may occur:

- The first situation is from discharge (intentional and accidental). Although a major company within this sector has not recorded any discharges, they do apply the assumption that each system will discharge once over a ten year period. This conservative assumption has been applied within the model.
- The second source covers leakage emissions and is estimated as 1 per cent of the total charge for all systems present.
- The third source is from the decommissioning of systems, but this activity has not yet taken place in Ireland.

Sectoral background data for HFC-227ea is provided for all relevant years from 1996-2012 in the CRF Tables.

4.4.2.4 Aerosols and Metered Dose Inhalers (2.F.4)

HFC emissions from these combined sub-categories in 2012 accounted for 10.8 per cent the total and second largest source of emissions from F-gases. Trends for the two sources fluctuated reaching their peak in 2006 at 143.75 Gg CO_2 eq. and declined by 22.4 per cent to 111.50 Gg CO_2 eq. in 2012. Following the 2013 study estimates from Metered Dose Inhalers (MDI) were recalculated in the existing time series: 1996 to 2011 due to new methodology based on the new industry information. Aerosols were also revised and resulted in minor recalculations between 1993 and 2011 due to revision of officially published population data in UK and years 1990 and 1991 were removed from the time series as not occurring.

For the purposes of estimating emissions, Aerosols and Metered Dose Inhalers are treated separately in the inventory calculations. The category Aerosols, is one which can cover a large number of products, however HFCs are generally only used as propellants where the use of HFCs is considered critical. The two HFCs of interest are HFC-134a and HFC-152a. In submissions up to and including 2011 the assumed species ratio was 90 per cent: 10 per cent, respectively for HFC-134a and HFC-152a. That assumption was revised in 2012 submission (1990-2010 data) on the basis of updated information (AEA 2011) which suggests a species ratio of 97 per cent: 3 per cent in 1990 to 2004, 99 per cent: 1 per cent for 2005 and 96 per cent: 4 per cent for 2006 onwards, respectively for HFC-134a and HFC-152. There is no trade association for aerosol manufacturers or importers in Ireland. Furthermore Adams *et al* (2005) found that importation of HFC containing aerosols is carried out independently by retailers. As a result little information exists in relation to the Irish market for these products. Following consultations with the British Trade Association (BAMA), O'Leary *et al*. (2002) and Adams *et al*. (2005) recommended the use of a population based proxy to estimate Irish emissions from those for the UK, which are based on trade data for the UK, on the assumption that the market for aerosols would be similar in Ireland. Emissions of HFC-134a and HFC-152a from aerosols are therefore derived using the UK estimates for lifetime and decommissioning emissions (as used in the UK national GHG inventory) and the ratio of the Irish population (CSO) to the UK population (Office of National Statistics, UK) in each year. The estimate for potential emissions is calculated using the UK trade data and the population ratio.

Emission estimates for Metered Dose Inhalers (MDI) are made on the basis of data received from industry for manufacturing emissions, and population data coupled with emission factors for emissions from use. The HFCs used in MDI's in Ireland are HFC-134a and HFC-227ea. Process losses are based on an analysis of gross stock minus closing stock and usage data of the gases. The MDI market in Ireland is supplied by both Irish manufactured products and imported products. Irish manufactured products only contain HFC-134a based on annual industry returns and Adams *et al*. (2005). Imported products on the other hand can contain HFC-134a and HFC-227ea. As a result there is no emissions from manufacture in for HFC-227ea in CRF Table2(II).Fs2. Total emissions are calculated based on reported manufacturing losses (for HFC-134a) in conjunction with in-life emissions.

Ireland has a high prevalence of asthma and in order to reflect this country-specific circumstance, a bottom-up approach to estimating in-life emissions is applied which is an improvement from a top-down approach applied before this submission. Approximately 10 per cent of the Irish population are suffering from asthma (Asthma Survey by the Irish Asthma Society) and about 80 per cent of the asthma medication sold relates to MDIs (Asthma Support Team of a large pharmacy chain) with the remaining 20 per cent relating to DPIs. A calculation based on population and these data was undertaken in order to establish an estimate for the total annual demand. This demand is catered for by imported products from a number of manufacturers as well as those manufacturing in Ireland.

Information on the amount of HFCs contained in MDIs per patient was determined empirically at approximately 0.074kg per user per annum (Schwarz *et al.*, 2010). Furthermore, it was estimated that of the HFCs used in MDIs in Ireland, HFC-134a accounted for 90 per cent and HFC-227ea for 10 per cent. HFC-227ea is mainly used by a non-Irish, European MDI producer. These data were used for the estimation of lifetime emissions.

4.4.2.5 Semiconductor Manufacture (2.F.7)

Combined HFCs, PFCs and SF_6 emissions in category *2.F.7 Semiconductor manufacture* were responsible for 0.3 per cent, 0.8 per cent and 1.9 per cent share of the sector, respectively. The trend in total at 30.16 Gg CO_2 eq. accounted for 2.9 per cent of total F-gas emissions in 2012 indicating a decrease of 91.3 per cent since its peak at 348.44 Gg CO_2 eq. in 2000.

HFC emissions from this sub-category accounted for 2.84 Gg CO_2 eq. or 0.3 per cent of the total emissions from F-gases and were 15.4 per cent higher than the previous year emissions and 76.3 per cent lower than their peak at 11.96 Gg CO_2 eq. in 2000. There were minor revisions in emissions in the four consecutive years: 1997-2000 (incl.) since the previous submission and resulted in 5.3 per cent decrease of emissions on average in the four years. These were due to the 2013 study finding and concluding that HFC-134a reported from semiconductor manufacturers was used as a refrigerant and, therefore, those emissions were reallocated to sub-category, *2.F.1 – Refrigeration and Air-Conditioning*.

This sub-category is the only source of reported PFC emissions and accounted for 8.03 Gg CO_2 eq. or 0.8 per cent of the total emissions from F-gases in 2012. PFC emissions from this sub-category decreased from the previous year by 39.2 per cent and by 97.4 per cent from their peak at 305.41 Gg CO_2 eq. in 2000. In addition to the current global recession, which has affected the market for semiconductors, the European Semiconductor Industry Association (ESIA, 2011) also has in place a voluntary agreement on the reduction of PFC emissions. There were no recalculations in this category for PFC emissions in the current submission.

SF_6 emissions from this sub-category accounted for 19.30 Gg CO_2 eq. or 1.9 per cent share of the total emissions from F-gases in 2012. Emissions from this sub-category decreased by 16.9 per cent from the previous year and remained lower by 76.3 per cent from their peak in 1997 (81.26 Gg CO_2 eq.). There were no recalculations in this category for SF_6 emissions in the current submission.

The semiconductor industry uses HFCs, PFCs and SF_6 in manufacturing processes. Both HFCs and PFCs are used in the cleaning of chambers used for chemical vapour deposition processes, dry plasma etching, vapour phase soldering and vapour phase blanketing, leak testing of hermetically sealed components and as coolants. Cleaning and etching during semiconductor manufacture account for the majority of emissions from the category. In addition SF_6 is used in the etching processes. There are a small number of large semiconductor manufacturers in Ireland. These installations provide data on the annual use and estimated emissions of HFCs, PFCs and SF_6 in their plants over the full time series 1990-2012.

4.4.2.6 Electrical Equipment (2.F.8)

SF_6 emissions reported from this sub-category accounted for 1.7 per cent of the total emissions from F-gases in 2012. The trend fluctuated significantly to peak in 2003 at 38.45 Gg CO_2 eq., then decreased in 2008 to 10.90 Gg CO_2 eq. and remained at similar levels for the next two years before increasing by 68.1 per cent between 2010 (at 12.91 Gg CO_2 eq.) and 2011 (at 21.70 Gg CO_2 eq.) and decreased by 21.6 per cent to reach 17.00 Gg CO_2 eq. in 2012. The significant reduction in emissions in the years 2008 to 2010 are attributed to the network operators investment in staff training, leak detection equipment and closed cycle SF_6 handling equipment. This resulted in 3 year rolling average losses declining from approximately 1.5 per cent in 2007 to 0.5 per cent in 2010. The latest increase in 2011 is due the highest installed inventory stock levels occurring in the period 2009 to 2011, but losses remain low around 0.5 per cent. There were no quantitative recalculations in this category for SF_6 emissions in the current submission.

SF_6 is used for electrical insulation, arc quenching, and for current interruption in equipment used in the transmission and distribution of electricity. The Electricity Supply Board (ESB) is the owner of both the high and low voltage distribution systems and the owner and operator of the medium and lower voltage distribution systems in Ireland. The company supplies an estimate of SF_6 emissions from their equipment maintenance operations to the inventory agency on a yearly basis. Those annual SF_6 usage returns include:

- The number of cylinders that are booked out for each year;
- Cylinder size: 40kg, 63kg and 5kg;
- Assumption that for the 40kg and 63kg cylinders, 60 per cent of the contained SF_6 is used for maintenance and the remaining 40 per cent is either unused or used for new works and thus not related to leakage emissions;
- Assumptions that one third of the SF_6 in the smaller cylinders (5kg) is used for maintenance whilst the remaining quantity is used for new works;

Electrical equipment containing SF_6 is imported into Ireland. Quantities of SF_6 are needed for servicing and repair of existing equipment. There are, therefore, no manufacturing emissions. The inventory estimates assume that the usage of SF_6 in equipment maintenance for one year is equal to the leakage emissions from electrical equipment in the same year. This means that the emission estimates are potential emission estimates rather than actual emission estimates. This method was reviewed by the project team and deemed to be acceptable and in line with IPCC GPG. Emissions are estimated using a Tier 1 approach based on an analysis of opening and closing stocks of SF_6.

4.4.2.7 Other Emission Sources (2.F.9)

SF_6 emissions under this sub-category are reported from four sources:

2.F.9 Other - window soundproofing
2.F.9 Other - medical applications
2.F.9 Other - sporting goods
2.F.9 Other - gas-air tracers

The above sources combined together accounted for 2.91 Gg CO_2 eq. or 0.3 per cent share of the total emissions from F-gases in 2012. Recalculations following the 2013 study occurred in three of the above four categories, except *medical applications*.

This category includes emissions of SF_6 from minor uses within Ireland including emissions from double glazed windows, medical applications, sporting goods and as a gas-air tracer in leak detection.

SF_6 was previously used as an insulation gas in double-glazing; however its use has been phased out in response to F-gas regulations and is assumed not to have occurred since 2000. Typically windows are manufactured using air or inert gases such as argon between double-glazing layers. Emission estimations account for opening and closing stock of the gas, assembly losses for Irish manufactured products, stocks in imported windows and leakage once installed. Even though the use of SF_6 was discontinued in window insulation after 2000, the bank of gas in installed units is an emission source and is therefore accounted for in emission estimates. Recalculated estimates for this source were undertaken in this submission to account of disposal emissions that weren't previously included in the estimates. A life-time of 25 years was applied; therefore, emissions at disposal are calculated as 100 per cent of the remaining charge after 25 years of leakage at a rate of 1 per cent per annum. The entire quantity of SF_6 remaining inside the window at the end of life is emitted, because to-date no recovery process exists.

SF_6 is used in certain medical application such as eye surgery where it is used to seal retinal holes internally and to hold reattached retina in place. Use of the gas is small with one hospital reporting the use of one 10-litre cylinder every three years. Based on this data, it is assumed that a similar quantity is used in a total of 10 hospitals, which undertake similar procedures. It is assumed that actual and potential emissions are equal on the basis that in each of the 10 hospitals once a cylinder is used (over a three year period) it is replaced.

SF_6 is used as a cushioning agent in sports shoes. The use of SF_6 in this type of application is due to its chemically and biologically inert properties and its high molecular weight which means that it does not diffuse across membranes. Thus the gas is not released until the sports shoe is destroyed at the end of its useful life. As there is no specific information available in relation to the use of SF_6 in sports goods in Ireland, a population-proxy is used to estimate emissions based on UK inventory data for the release of SF_6 upon disposal of sporting goods, as the market share of such products is assumed to be similar to that in the UK. Emissions are therefore derived using the annual UK per capita sales for sporting goods and the Irish population in each year. The use of SF_6 in sporting goods was discontinued in 2007, however, emissions from their disposal will continue based on an average lifetime of eight years. Emissions from this sector were slightly revised to take into account the latest updated UK SF_6 emissions UK that form the base for Irish estimates (when scaled by Ireland's population).

The remaining minor uses of SF_6 in Ireland are as a tracer gas for leak detection in the testing of seals on cans containing tennis balls and as a tracer gas for agricultural research to determine the rates of CH_4 emissions from enteric fermentation in cattle. The latter source is considered negligible in an Irish context. The use of SF_6 in leak detection was previously a relatively large source in the period 1990-2004. However the company who used SF_6 for the purpose of leak detection has since ceased trading. A number of research projects, conducted in 2009, were identified and included in the inventory. The total use of SF_6 amounted to 80kg. No projects since have been identified so this sub-category is no longer a source of emissions of SF_6 in the Irish inventory. Additional information on experiments carried out in 2009 were obtained from the relevant researchers and included in the inventory:

- Maize experiment: emission rate of 1.8 mg SF_6/day from 60 capsules (1/animal) for 105 days;
- Whole-crop wheat experiment: emission rate of 3.14 mg SF_6/day from 90 capsules (1/animal) for 154 days;
- Another experiment at a research facility where SF_6 was used, which was very similar to the above.
- Actual emissions for two of the experiments were calculated using information from published articles regarding the methodology and results of these experiments. The information for these two experiments was used to estimate emissions from the third research project. The recalculations are due to emissions from research projects that were carried out in approximately 2009.

4.5 Uncertainties and Time-Series Consistency

As part of the work undertaken by Adams *et al*. (2005) uncertainty analysis was performed for the aggregated emissions derived from a specific consideration of the individual sector uncertainty estimates. An iterative Monte Carlo simulation procedure was used to estimate uncertainties in total and aggregated HFC, PFC and SF_6 emissions. The use of Monte Carlo Simulation complies with IPCC Good Practice Tier 2 approaches to uncertainty estimation.

Emission estimates are made using the same methodology and data sources for each year of the time series 1995-2012 and are therefore consistent over this period. Estimates of F-gas emissions pre 1995 are in some cases made using alternative techniques such as interpolation between years for which data is available. This approach is used in particular for the sectors *2.F.7 Semiconductor manufacture* and *2.F.8 Electrical Equipment* for which no activity data is available for the years 1991-1994 inclusive.

As the emission estimates for sectors *2.A.1, 2.A.2, 2.A.3, 2.A.4* and *2.A.7* are estimated from individual plant data, which are subject to verification under Directive 2003/87/EC, their validity is fully established in the context of the companies' documented methods and data and the associated guidance on emissions estimation methods provided by Decision 2004/156/EC (CEC, 2004). Such verification allows for accurate accounting of combustion emissions and process emissions separately. Whilst there have been improvements to the methods and underlying activity data in this submission, the 2013 project did not consider it appropriate to reduce the uncertainty estimates from the original inventory.

4.6 Quality Assurance and Quality Control

Sources in the industrial processes sector vary considerably in nature, and a wide range of different methodologies are used to make emission estimates. As a result, sector specific quality assurance and quality control is needed.

Many of the emissions estimates use a bottom-up compilation process because individual plant data are available through the EU ETS for years since 2005. Data from each plant for the most recent year in the inventory are checked for consistency with historic data from that plant. Implied emission factors are also calculated and checked for variability or step changes across the time series.

Comparisons are also made across the different plant in the same source sector, to check for consistency. Typically implied emission factors are compared. These checking procedures help to identify any erroneous point source data, and are readily undertaken due to the limited number of plant in Ireland. Data reported under ETS for plants in the *2.A Mineral Products* category are also cross checked with data supplied by the same operators for other reporting requirements, such as, Integrated Pollution Prevention and Control directive (IPPC) and under the European Pollutant Release and Transfer Register (E-PRTR) for consistency.

Quality control checks are in place to ensure that the sectoral emissions total in calculation sheets is the same as that in the final inventory dataset that is reported to the UNFCCC. The current inventory approach was also reviewed at the start of the F-gas 2013 project. All calculations and cell references were checked to assess the current approach. The approach did not require any improvements except the addition of research projects that have taken place in recent years. The estimates for these were added in a way that was consistent with the current format of the inventory.

4.7 Recalculations for *Industrial Processes*

Recalculations in the *Industrial Processes* sector in this submission are confined to sub-categories *2.F*; HFC and SF_6 gases and are mainly due to a new F-gas study conducted in 2013 including revised activity data from new and existing supplier sources in sector *2.F.1 Refrigeration and stationary air conditioning*. Revisions in other subsectors are mainly due to revised methodology approach and/or new industry data information.

Recalculations affected HFC mix of gases in sectors:

- *2.F.1 Refrigeration and air-con; stationary:* emissions for the years 1991-1994 are now reported as “Not Occurring” and revised emissions resulting in 124.6 per cent increase on average in the 1995-2011 time series;
- *2.F.1 MAC:* 3.6 per cent increase on average in the period 1993-2011;
- *2.F.2 Foams:* emissions are now reported as “not occurring” (NO) for the whole time series;
- *2.F.3 Fire extinguishers:* emissions are now reported as “not occurring” (NO) between 1990-1996 and resulted in 60.2 per cent decrease on average in the following years: 1997-2011;
- *2.F.4 MDI*: revised method based on new industry information resulted in 26.50 Gg CO_2 eq. annual emission increase on average for all the years 1996-2011 (incl.);
- *2.F.7 Semiconductor manufacture:* 4.2 per cent decrease on average between 1997-2000;

Recalculations affected SF_6 gas in sectors:

- *2.F.9 Other – window soundproofing:* 2.7-fold increase on average between 2004-2011;
- *2.F.9 Other – sporting goods:* 8.6 per cent decrease on average between 1998-2011;
- *2.F.9 Other – gas-air tracer* (an emission value replaced NO as previously reported for 2009).

The combined impact of the above recalculations increased the subcategory combined sector 2.F emissions by 18.5 per cent on average between 1990 and 2011 but their relative impact on total GHG emissions remained minor as emissions from this sector account for a very small part of the total emissions i.e. 1.8 per cent share of the total GHGs in 2012 and even less in the previous years (0.1 per cent share in 1990). The results of the recalculations are given by category and gas in Tables 4.4 and 4.5 and in CRF Tables 8(b) for the relevant years.

4.8 Improvements in *Industrial Processes*

The inventory agency operates a continuous improvement approach to the inventory. To deliver this, the agency will continue to use verified CO_2 emissions estimates that are reported under the EU emissions trading scheme as the most reliable data for emission sources within category *2.A*. The following improvements have been made to *Industrial Processes* sector in this annual submission.

Revised notation keys, methodologies and activity data from new and existing supplier sources of HFC gases in following sectors and years;

- *2.F.1 Refrigeration and stationary air conditioning* for years: 1991-2012;
- *2.F.1 Mobile Air Conditioning* for years: 1993-2012;
- *2.F.2 Foams* for years 1991-2012;
- *2.F.3 Fire extinguishers* for years 1990-2012;
- *2.F.4 Aerosols* for years 1990-2012;
- *2.F.4 MDI* for years 1996-2012;
- *2.F.7 Semiconductor manufacture* for years 1997-2000.

Revised methodologies and activity data of SF_6 gas in sectors;

- *2.F.9 Other – window soundproofing* for years 2004-2012;
- *2.F.9 Other - sporting goods* for years 1998-2012;
- *2.F.9 Other - gas-air tracer* for 2009.

Table 4.3. Emissions of HFC, PFC and SF_6 from Industrial Processes 1990-2012 (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2.F.1 Refrigeration and Air-Conditioning	NO	NO	NO	NO	NO	0.65	10.08	17.29	23.60	36.24	62.04	89.18	150.13	259.01	366.86	484.19	489.54	485.08	578.12	559.11	574.49	597.03	601.67
2.F.1 Mobile Air Conditioning	NO	NO	NO	1.18	4.94	9.97	16.14	24.75	37.78	53.94	71.00	84.84	98.62	113.26	131.79	156.33	177.13	202.48	224.30	234.67	241.29	242.87	234.91
2.F.2 Foams	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F.3 Fire-extinguishers	NO	NO	NO	NO	NO	NO	1.35	2.68	4.00	5.31	6.60	7.88	9.15	10.40	11.65	31.06	31.06	31.07	31.07	31.08	31.08	31.09	31.10
2.F.4 Aerosols	NO	NO	0.72	1.81	7.04	24.68	48.47	81.34	106.36	79.04	86.29	93.16	83.92	90.43	83.48	98.74	98.04	86.37	91.19	85.03	78.31	73.13	65.87
2.F.4 Metered Dose Inhalers	NO	NO	NO	NO	NO	NO	15.60	31.37	31.70	32.04	32.93	35.50	38.27	39.24	40.30	40.94	45.71	42.50	44.75	44.31	44.82	45.70	45.62
2.F.7 Semiconductor manufacture	0.47	0.60	0.74	1.01	1.28	1.83	2.94	4.40	3.54	9.04	11.96	3.10	1.88	2.64	1.36	2.23	3.16	3.39	3.63	2.93	3.37	2.46	2.84
TOTAL HFC	**0.47**	**0.60**	**1.46**	**4.00**	**13.26**	**37.13**	**94.57**	**161.83**	**206.99**	**215.60**	**270.82**	**313.65**	**381.97**	**514.99**	**635.44**	**813.46**	**844.63**	**850.89**	**973.06**	**957.12**	**973.37**	**992.28**	**982.01**
2.F.7 Semiconductor manufacture	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20	8.03
TOTAL PFC	**0.09**	**7.62**	**15.15**	**30.21**	**45.27**	**75.38**	**103.09**	**130.82**	**61.87**	**195.93**	**305.41**	**295.98**	**212.40**	**228.79**	**182.43**	**168.34**	**148.32**	**130.58**	**106.20**	**65.57**	**37.02**	**13.20**	**8.03**
2.F.7 Semiconductor manufacture	0.48	4.73	8.99	17.49	26.00	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55	27.52	30.20	41.03	20.93	18.25	23.22	19.30
2.F.8 Electrical equipment	21.51	22.47	23.42	24.38	25.33	26.29	26.39	37.28	25.24	34.99	7.79	32.05	22.79	38.45	21.55	23.52	28.11	29.83	10.90	13.98	12.91	21.70	17.00
2.F.9 Other - window soundproofing	0.54	0.56	0.58	0.60	0.62	0.64	0.65	0.67	0.69	0.56	0.43	0.29	0.29	0.29	0.44	0.60	0.76	0.92	1.08	1.24	1.39	1.55	1.71
2.F.9 Other - medical applications	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
2.F.9 Other - sporting goods	NO	NO	NO	NO	NO	NO	NO	NO	1.60	2.11	2.08	2.08	3.09	3.80	7.29	11.51	6.22	4.44	3.70	2.26	1.39	0.40	0.41
2.F.9 Other - gas-air tracers	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	6.09	NO	NO	NO	NO	1.97	NO	NO	NO
TOTAL SF_6	**35.51**	**40.74**	**45.97**	**55.46**	**64.94**	**82.93**	**102.17**	**132.20**	**93.09**	**67.38**	**54.35**	**67.84**	**67.74**	**115.43**	**68.83**	**101.98**	**63.40**	**66.18**	**57.50**	**41.17**	**34.74**	**47.66**	**39.21**
TOTAL HFC, PFC and SF_6	**36.07**	**48.97**	**62.58**	**89.66**	**123.47**	**195.44**	**299.82**	**424.85**	**361.95**	**478.91**	**630.58**	**677.47**	**662.11**	**859.22**	**886.70**	**1083.78**	**1056.35**	**1047.65**	**1136.75**	**1063.86**	**1045.12**	**1053.14**	**1029.25**

Table 4.4. Percentage Change in Total Emissions from Consumption of Halocarbons and SF_6 due to Recalculations

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Estimates in 2013 Submission (Gg CO2eq)																								
Refrigeration and air-con	2F1	HFC	NO	3.32	3.51	3.69	3.98	4.48	7.14	21.58	42.38	49.26	52.64	49.09	64.50	112.52	135.16	153.05	196.88	175.36	172.36	128.01	158.54	134.85
MAC	2F1	HFC	-	-	-	1.22	5.07	10.14	16.36	25.08	38.23	54.12	70.46	83.36	96.38	110.15	126.12	147.21	169.04	192.00	210.20	210.43	210.10	205.64
Foams	2F2	HFC	NO	0.00	0.02	0.06	0.30	0.64	1.11	1.78	3.62	5.22	6.25	9.13	11.37	13.49	16.83	19.35	21.51	23.55	25.14	26.44	27.52	28.41
Fire-extinguishers	2F3	HFC	0.22	2.56	4.94	7.40	10.10	13.03	16.21	19.67	23.44	27.54	32.00	33.52	34.72	35.32	35.18	34.14	39.01	44.49	50.65	57.59	65.39	74.16
Aerosols	2F4	HFC	0.62	0.62	0.70	1.75	6.99	24.49	48.07	80.64	105.41	78.28	85.40	92.58	83.39	89.87	82.97	98.10	97.41	85.82	90.62	84.49	77.81	73.44
MDIs	2F4	HFC	NO	NO	NO	NO	NO	NO	0.02	0.06	0.08	0.11	0.67	9.06	16.99	18.21	18.41	21.74	21.64	11.06	14.06	13.44	16.57	19.66
Semiconductor manufacture	2F7	HFC	0.47	0.60	0.74	1.01	1.28	1.83	2.94	4.63	3.88	9.42	12.38	3.10	1.88	2.64	1.36	2.23	3.16	3.39	3.63	2.93	3.37	2.46
TOTAL HFCs			1.31	7.11	9.90	15.13	27.73	54.60	91.85	153.44	217.03	223.94	259.81	279.85	309.24	382.20	416.04	475.81	548.66	535.67	566.66	523.33	559.30	538.61
Semiconductor manufacture	2F7	PFC	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
TOTAL PFCs			0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
Semiconductor manufacture	2F7	SF6	0.48	4.73	8.99	17.49	26.00	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55	27.52	30.20	41.03	20.93	18.25	23.22
Electrical equipment	2F8	SF6	21.51	22.47	23.42	24.38	25.33	26.29	26.39	37.28	25.24	34.99	7.79	32.05	22.79	38.45	21.55	23.52	28.11	29.83	10.90	13.98	12.91	21.70
2F9 Other – window soundproofing	2F9	SF6	0.54	0.56	0.58	0.60	0.62	0.64	0.65	0.67	0.69	0.56	0.43	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.27	0.27	0.27	0.26
2F9 Other - medical application	2F9	SF6	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
2F9 Other - sporting goods	2F9	SF6	-	-	-	-	-	-	-	-	1.60	2.11	2.07	2.08	3.09	3.79	7.28	11.48	6.20	4.42	3.68	2.26	2.29	2.32
2F9 Other - gas-air tracer	2F9	SF6	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	6.09	-	-	-	-	-	-	-
TOTAL SF6			35.51	40.74	45.97	55.46	64.94	82.93	102.17	132.20	93.09	67.38	54.35	67.84	67.73	115.43	68.65	101.63	62.90	65.52	56.68	38.24	34.51	48.29
Grand Total			36.91	55.48	71.03	100.80	137.93	212.92	297.10	416.47	371.99	487.25	619.56	643.67	589.37	726.42	667.12	745.78	759.87	731.76	729.53	627.13	630.83	600.10
Recalculated estimates in 2014 Submission (Gg CO2eq)																								
Refrigeration and air-con	2F1	HFC	-	-	-	-	-	0.65	10.08	17.29	23.60	36.24	62.04	89.18	150.13	259.01	366.86	484.19	489.54	485.08	578.12	559.11	574.49	597.03
MAC	2F1	HFC	NO	NO	NO	1.18	4.94	9.97	16.14	24.75	37.78	53.94	71.00	84.84	98.62	113.26	131.79	156.33	177.13	202.48	224.30	234.67	241.29	242.87
Foams	2F2	HFC	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fire-extinguishers	2F3	HFC	NO	NO	NO	NO	NO	NO	1.35	2.68	4.00	5.31	6.60	7.88	9.15	10.40	11.65	31.06	31.06	31.07	31.07	31.08	31.08	31.09
Aerosols	2F4	HFC	-	-	0.72	1.81	7.04	24.68	48.47	81.34	106.36	79.04	86.29	93.16	83.92	90.43	83.48	98.74	98.04	86.37	91.19	85.03	78.31	73.13
MDIs	2F4	HFC	NO	NO	NO	NO	NO	NO	15.60	31.37	31.70	32.04	32.93	35.50	38.27	39.24	40.30	40.94	45.71	42.50	44.75	44.31	44.82	45.70
Semiconductor manufacture	2F7	HFC	0.47	0.60	0.74	1.01	1.28	1.83	2.94	4.40	3.54	9.04	11.96	3.10	1.88	2.64	1.36	2.23	3.16	3.39	3.63	2.93	3.37	2.46
TOTAL HFCs			0.47	0.60	1.46	4.00	13.26	37.13	94.57	161.83	206.99	215.60	270.82	313.65	381.97	514.99	635.44	813.46	844.63	850.89	973.06	957.12	973.37	992.28
Semiconductor manufacture	2F7	PFC	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
TOTAL PFCs			0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
Semiconductor manufacture	2F7	SF6	0.48	4.73	8.99	17.49	26.00	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55	27.52	30.20	41.03	20.93	18.25	23.22
Electrical equipment	2F8	SF6	21.51	22.47	23.42	24.38	25.33	26.29	26.39	37.28	25.24	34.99	7.79	32.05	22.79	38.45	21.55	23.52	28.11	29.83	10.90	13.98	12.91	21.70
2F9 Other – window soundproofing	2F9	SF6	0.54	0.56	0.58	0.60	0.62	0.64	0.65	0.67	0.69	0.56	0.43	0.29	0.29	0.29	0.44	0.60	0.76	0.92	1.08	1.24	1.39	1.55
2F9 Other - medical application	2F9	SF6	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
2F9 Other - sporting goods	2F9	SF6	-	-	-	-	-	-	-	-	1.60	2.11	2.08	2.08	3.09	3.80	7.29	11.51	6.22	4.44	3.70	2.26	1.39	0.40
2F9 Other - gas-air tracer	2F9	SF6	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	6.09	-	-	-	-	1.97	-	-
TOTAL SF6			35.51	40.74	45.97	55.46	64.94	82.93	102.17	132.20	93.09	67.38	54.35	67.84	67.74	115.43	68.83	101.98	63.40	66.18	57.50	41.17	34.74	47.66
Grand Total			36.07	48.97	62.58	89.66	123.47	195.44	299.82	424.85	361.95	478.91	630.58	677.47	662.11	859.22	886.70	1083.78	1056.35	1047.65	1136.75	1063.86	1045.12	1053.14

Table 4.4. Percentage Change in Total Emissions from Consumption of Halocarbons and SF_6 due to Recalculations (continued)

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
										Percentage change in total emissions due to recalculations														
Refrigeration and air-con	2F1	%	NA	-100.0%	-100.0%	-100.0%	-100.0%	-85.5%	41.1%	-19.9%	-44.3%	-26.4%	17.8%	81.6%	132.7%	130.2%	171.4%	216.4%	148.6%	176.6%	235.4%	336.8%	262.4%	342.7%
MAC	2F1	%	NA	NA	NA	-3.2%	-2.5%	-1.7%	-1.3%	-1.3%	-1.2%	-0.3%	0.8%	1.8%	2.3%	2.8%	4.5%	6.2%	4.8%	5.5%	6.7%	11.5%	14.8%	18.1%
Foams	2F2	%	NA	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%
Fire-extinguishers	2F3	%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	-91.7%	-86.4%	-82.9%	-80.7%	-79.4%	-76.5%	-73.6%	-70.5%	-66.9%	-9.0%	-20.4%	-30.2%	-38.7%	-46.0%	-52.5%	-58.1%
Aerosols	2F4	%	-100.0%	-100.0%	3.4%	3.5%	0.7%	0.8%	0.8%	0.9%	0.9%	1.0%	1.0%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	-0.4%
MDIs	2F4	%	NA	NA	NA	NA	NA	NA	79918.9%	53526.9%	39233.9%	30323.3%	4781.3%	291.7%	125.2%	115.5%	118.9%	88.3%	111.3%	284.4%	218.4%	229.7%	170.4%	132.5%
Semiconductor manufacture	2F7	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-5.1%	-8.7%	-4.0%	-3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL HFCs			-64.2%	-91.5%	-85.3%	-73.6%	-52.2%	-32.0%	3.0%	5.5%	-4.6%	-3.7%	4.2%	12.1%	23.5%	34.7%	52.7%	71.0%	53.9%	58.8%	71.7%	82.9%	74.0%	84.2%
Semiconductor manufacture	2F7	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOTAL PFCs			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Semiconductor manufacture	2F7	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electrical equipment	2F8	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2F9 Other – window soundproofing	2F9	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	56.8%	114.7%	173.8%	234.1%	295.5%	358.2%	422.1%	487.3%
2F9 Other - medical application	2F9	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2F9 Other - sporting goods	2F9	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%	0.4%	0.0%	-39.5%	-82.7%
2F9 Other - gas-air tracer	2F9	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%
TOTAL SF6			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.8%	1.0%	1.4%	7.7%	0.7%	-1.3%
Grand Total			-2.3%	-11.7%	-11.9%	-11.0%	-10.5%	-8.2%	0.9%	2.0%	-2.7%	-1.7%	1.8%	5.3%	12.3%	18.3%	32.9%	45.3%	39.0%	43.2%	55.8%	69.6%	65.7%	75.5%

Table 4.5. Percentage Change in Total Emissions from Industrial Processes due to Recalculations 1990-2011

			1990	1991	1992	1993	2010	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
													Estimates in 2013 Submission (Gg CO_2eq)											
2.A.1	Cement Production	CO_2	884.0	782.0	753.0	729.0	859.0	879.0	983.0	1145.0	1059.0	1166.0	1700.9	1851.2	1859.8	2127.0	2295.1	2357.1	2347.9	2374.1	2106.7	1326.8	1105.1	966.3
2.A.2	Lime Production	CO_2	214.1	192.2	162.4	204.9	205.4	187.5	198.2	221.9	211.7	170.1	190.4	189.4	190.3	206.3	201.5	183.5	180.3	196.7	187.8	156.4	192.4	199.1
2.A.3	Limestone and Dolomite Use	CO_2	0.15	0.14	0.13	0.11	0.13	0.18	0.17	0.24	0.23	0.25	0.18	4.50	2.17	2.38	3.55	4.29	2.64	2.32	2.71	1.54	1.03	1.04
2.A.4	Soda Ash Production and Use	CO_2	0.10	0.09	0.07	0.11	0.05	0.07	0.09	0.10	0.11	0.05	0.07	0.09	0.05	0.06	0.08	0.08	0.06	0.06	0.04	0.05	0.07	0.07
2.A.7	Bricks and Tiles	CO_2	5.07	4.88	4.79	4.50	4.79	5.46	5.27	6.23	6.08	6.37	6.49	6.12	5.91	6.12	6.23	7.41	7.40	6.83	4.00	0.53	0.42	0.83
2.A.7	Glass Production	CO_2	13.33	13.06	12.59	12.52	12.31	11.97	11.63	11.46	11.05	10.96	10.71	10.14	5.13	0.55	0.58	0.48	0.49	0.45	0.31	0.02	NO	NO
2.B.1	Ammonia Production	CO_2	990.2	1030.3	1003.6	946.2	1056.6	973.4	922.9	1073.1	1058.8	942.8	882.3	1041.2	810.9	0.3	NO	NO	NO	NO	NO	NO	NO	NO
2.B.2	Nitric Acid Production	N_2O	1035.4	812.4	812.4	812.4	812.4	812.4	812.4	812.4	812.2	812.2	812.4	584.4	292.2	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F.7	Consumption of Halocarbons and SF_6	HFCs	1.3	7.1	9.9	15.1	27.7	54.6	91.8	153.4	217.0	223.9	259.8	279.9	309.2	382.2	416.0	475.8	548.7	535.7	566.7	523.3	559.3	538.6
2.F.7	Consumption of Halocarbons and SF_6	PFCs	0.1	7.6	15.2	30.2	45.3	75.4	103.1	130.8	61.9	195.9	305.4	296.0	212.4	228.8	182.4	168.3	148.3	130.6	106.2	65.6	37.0	13.2
2.F.7	Consumption of Halocarbons and SF_6	SF_6	35.5	40.7	46.0	55.5	64.9	82.9	102.2	132.2	93.1	67.4	54.3	67.8	67.7	115.4	68.7	101.6	62.9	65.5	56.7	38.2	34.5	48.3
2	Total		3179.3	2890.6	2820.0	2810.6	3088.7	3083.0	3230.8	3687.0	3531.1	3596.0	4223.1	4330.6	3755.8	3069.0	3174.2	3298.6	3298.6	3312.2	3031.1	2112.5	1929.9	1767.4
													Recalculated Estimates in 2014 Submission (Gg CO_2eq)											
2.A.1	Cement Production	CO_2	884.0	782.0	753.0	729.0	859.0	879.0	983.0	1145.0	1059.0	1166.0	1700.9	1851.2	1859.8	2127.0	2295.1	2357.1	2347.9	2374.1	2106.7	1326.8	1105.1	966.3
2.A.2	Lime Production	CO_2	214.1	192.2	162.4	204.9	205.4	187.5	198.2	221.9	211.7	170.1	190.4	189.4	190.3	206.3	201.5	183.5	180.3	196.7	187.8	156.4	192.4	199.1
2.A.3	Limestone and Dolomite Use	CO_2	0.15	0.14	0.13	0.11	0.13	0.18	0.17	0.24	0.23	0.25	0.18	4.50	2.17	2.38	3.55	4.29	2.64	2.32	2.71	1.54	1.03	1.04
2.A.4	Soda Ash Production and Use	CO_2	0.10	0.09	0.07	0.11	0.05	0.07	0.09	0.10	0.11	0.05	0.07	0.09	0.05	0.06	0.08	0.08	0.06	0.06	0.04	0.05	0.07	0.07
2.A.7	Bricks and Tiles	CO_2	5.07	4.88	4.79	4.50	4.79	5.46	5.27	6.23	6.08	6.37	6.49	6.12	5.91	6.12	6.23	7.41	7.40	6.83	4.00	0.53	0.42	0.83
2.A.7	Glass Production	CO_2	13.33	13.06	12.59	12.52	12.31	11.97	11.63	11.46	11.05	10.96	10.71	10.14	5.13	0.55	0.58	0.48	0.49	0.45	0.31	0.02	NO	NO
2.B.1	Ammonia Production	CO_2	990.2	1030.3	1003.6	946.2	1056.6	973.4	922.9	1073.1	1058.8	942.8	882.3	1041.2	810.9	0.3	NO	NO	NO	NO	NO	NO	NO	NO
2.B.2	Nitric Acid Production	N_2O	1035.4	812.4	812.4	812.4	812.4	812.4	812.4	812.4	812.2	812.2	812.4	584.4	292.2	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.F.	Consumption of Halocarbons and SF_6	HFCs	0.5	0.6	1.5	4.0	13.3	37.1	94.6	161.8	207.0	215.6	270.8	313.7	382.0	515.0	635.4	813.5	844.6	850.9	973.1	957.1	973.4	992.3
2.F.	Consumption of Halocarbons and SF_6	PFCs	0.1	7.6	15.2	30.2	45.3	75.4	103.1	130.8	61.9	195.9	305.4	296.0	212.4	228.8	182.4	168.3	148.3	130.6	106.2	65.6	37.0	13.2
2.F.	Consumption of Halocarbons and SF_6	SF_6	35.5	40.7	46.0	55.5	64.9	82.9	102.2	132.2	93.1	67.4	54.3	67.8	67.7	115.4	68.8	102.0	63.4	66.2	57.5	41.2	34.7	47.7
2	Total		3178.4	2884.1	2811.6	2799.4	3074.2	3065.5	3233.5	3695.4	3521.1	3587.6	4234.1	4364.4	3828.6	3201.8	3393.8	3636.6	3595.1	3628.1	3438.3	2549.2	2344.2	2220.4
													Percentage Change in Total Emissions due to Recalculations											
2.A.1	Cement Production	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.2	Lime Production	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.3	Limestone and Dolomite Use	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.4	Soda Ash Production and Use	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Bricks and Tiles	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Glass Production	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.2	Nitric Acid Production	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.	Consumption of Halocarbons and SF_6	HFCs	-64.22	-91.51	-85.27	-73.57	-52.17	-32.01	2.97	5.47	-4.63	-3.72	4.24	12.08	23.52	34.75	52.74	70.96	53.95	58.85	71.72	82.89	74.03	84.23
2.F.	Consumption of Halocarbons and SF_6	PFCs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.	Consumption of Halocarbons and SF_6	SF_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.26	0.35	0.80	1.01	1.45	7.67	0.65	-1.30
2	Total		-0.03	-0.23	-0.30	-0.40	-0.47	-0.57	0.08	0.23	-0.28	-0.23	0.26	0.78	1.94	4.33	6.92	10.25	8.99	9.54	13.43	20.67	21.47	25.63

Chapter Five

Solvent and Other Product Use

5.1 Overview of Solvent and Other Product Use Sector

The IPCC source sector, *Solvent and Other Produce Use*, is considered separately because of its importance in relation to the emissions of NMVOC (non-methane volatile organic compounds). Non-methane volatile organic compounds are indirect greenhouse gases which result from the use of solvents and various other volatile compounds. The use of N_2O as an anaesthetic is also included in the *Solvent and Other Product Use* sector, however no specific methodology exists in the IPPC Guidelines and the Good Practice Guidance.

The UNFCCC reporting format explicitly provides for the inclusion of CO_2 emissions that result from the oxidation of the carbon in NMVOC emissions. This approach is consistent with the overall sectoral approach adopted for estimating CO_2 from the combustion of fuels (Section 3.2), where the CO_2 emissions are based on the full carbon content of the fuel even though some of the carbon is usually emitted as NMVOC or CO. CO_2 emission estimates are derived from NMVOCs by assuming that 85 per cent of the mass of NMVOCs is converted to CO_2.

The activity data used for computing estimates of CO_2 emissions in *Solvent and Other Product Use* are the mass emissions of NMVOC determined for the relevant source categories (3*.A Paint Application, 3.B Degreasing and Dry Cleaning, 3.C Chemical Products, Manufacturing and Processing and 3.D Other Solvent Uses*). The Irish data used for this purpose are the NMVOC emissions which are compiled according to the CORINAIR methodology for reporting to the UNECE under the Convention on Long Range Transboundary Air Pollution (CLRTAP) (UNECE, 1999) and the National Emissions Ceilings Directive (EP and CEU, 2001).

5.2 NMVOC and CO_2 Inventory Time Series

The levels of solvent use and the emissions from solvents have changed substantially in response to product replacement and reformulation and emission controls being implemented under Integrated Pollution Prevention Control (IPPC) and the Solvents Directive (CEC, 1999). Given these developments, the inventories of NMVOC emissions from solvent use were assessed in 2005 when a project was commissioned to carry out an in-depth analysis of the specified NMVOC source categories (CTC, 2005). This work enabled the best possible estimates of emissions for the period 1990- 2004 to be derived, and built upon earlier commissioned work in 1998 (Finn et al, 2001). The revised estimates for the time series 1990-2003 indicated lower NMVOC emissions than had been previously reported and used as the basis for estimating CO_2 in the sector *Solvent and Other Product Use.* In 2011, further improvements were undertaken which focussed on the appropriateness of activity data and emission factors and the consistency of emission estimates for the time series 1990-2008.

CTC (2005) developed a bottom-up approach for estimating NMVOCs from activities that are subject to IPPC licensing in the four source categories (3*.A Paint Application, 3.B Degreasing and Dry Cleaning, 3.C Chemical Products, Manufacturing and Processing and*

3.D Other Solvent Uses). Relevant data on emissions and solvent use were extracted from their electronic or paper Annual Environmental Reports (AERs) or Pollution Emissions Registers (PERs). Where such information was not available, European PERs were assessed.

Top-down methods were used for activities (i.e. the use of paints and the use of domestic solvents) that are not covered by the IPPC licensing system. For these activities, Irish statistics such as vehicle stock, population and housing stock were used.

Input, usage and emissions data for each individual activity is collated into IPPC and non-IPPC spread sheets. Emissions are estimated by applying EMEP/CORINAIR methods, using default, UK and literature emission factors and general guidance as appropriate. Interpolation and extrapolation are used to elaborate a time series where no annual specific data is available. These are combined with Irish statistics for the number of vehicles, population, housing stock and a range of other activity data. In some instances activity data is currently not available in Ireland and where this occurs emission estimates are undertaken using Irish and UK population statistics and UK emission data. In other instances, emissions are estimated using GDP as a surrogate activity data.

The estimates of CO_2 emissions from Solvent and Other Product Use for the period 1990-2012 are presented in Table 5.1 and Figure 5.1. However, the overall impact of the sector on total GHG emissions has been minimal and responsible for similar level of 0.1 per cent of the share in the total trend. Emissions from the sector increased by 8.2 per cent between 1990 (at 80.03 Gg CO_2) and 1998 when they reached their peak (at 86.63 Gg CO_2) to decrease by 16.1 per cent in 2012 (at 72.72 Gg CO_2). Overall emissions decreased by 9.1 per cent between 1990 and 2012.

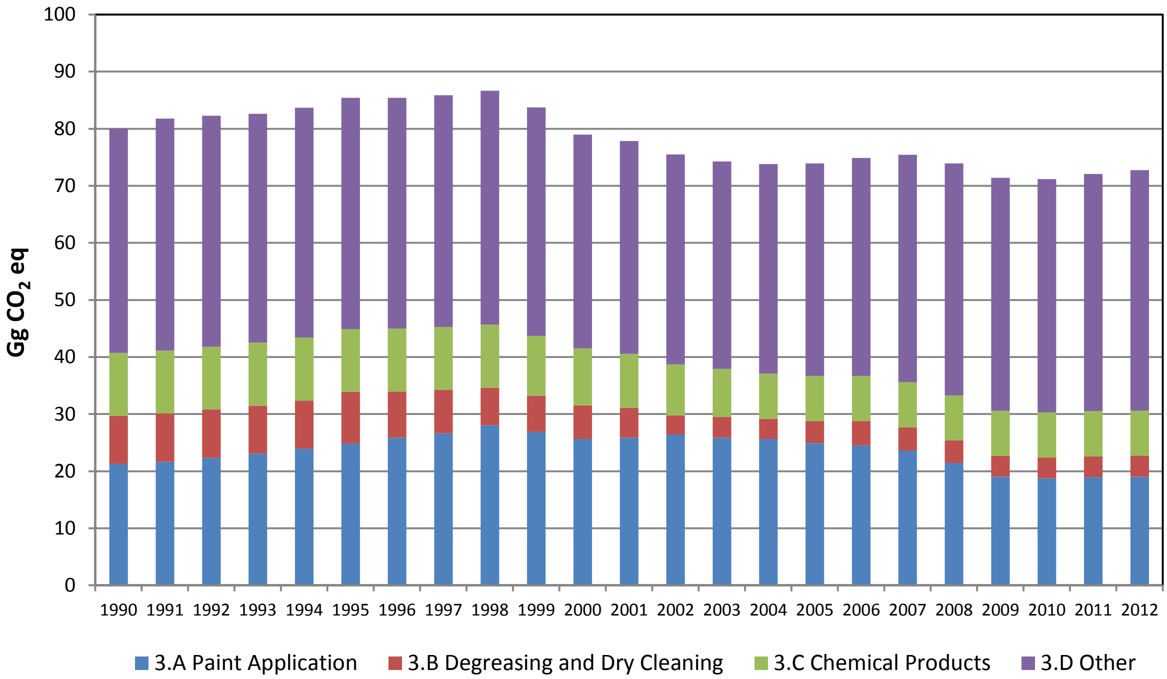


Figure 5.1 Trend in Emissions of Solvents and Other Product Use 1990-2012

The largest contributor to overall emissions is the source category 3.D Other Use of Solvents which accounts for 57.9 per cent of NMVOC emissions in 2012, having increased by 7.2 per cent from 1990. It is estimated that on average over the whole trend 60 per cent of emissions from this sub-category are attributable to domestic solvent use. Emissions from domestic solvent use have increased by 41 per cent in the 1990-2012 trend (and from 51 per cent share in 1990 to 67 per cent share in 2012 of category 3.D emissions), while those from the majority of other sub-categories have decreased due in general to reduced solvent contents in paints and coatings and the economic downturn in recent years. The main drivers for the increasing emissions from domestic solvent use are considered to be the increased per-capita consumption of cosmetics, toiletries and household products.

Source category 3.A Paint Application is a significant source of NMVOC, accounting for 26.2 per cent of total NMVOC emissions in 2012. Emissions from this sub-category in 2012 have substantially fallen (by 32.1 per cent) since their peak in 1998 and by 10.5 per cent since 1990 as the solvent content of paint (both water and solvent based paints) has decreased. This trend has primarily been driven by legislation such as the Deco Paints Directive (EP and CEU, 2004b; DEHLG, 2007) and the Solvents Directive (CEC 1999). Both Directives have had a substantial impact on the solvent content of paints, coatings and other products. Integrated Pollution Prevention and Control has also impacted on the industrial users of solvents, requiring solvent management plans and improvements to working practices and the implementation of abatement techniques.

Category 3.C Chemical Products Manufacturing or Processing was responsible for 10.9 per cent share of the overall sector 3 emissions in 2012. However, the sub-category emissions decreased steadily by 28.4 per cent between 1990 and 2012.

The smallest contributor to the IPCC sector 3 with its 5.0 per cent share was sub-category 3.B Degreasing, Dry Cleaning and Electronics. Similar to other categories (apart from 3.D) the trend has been decreasing between 1990 and 2012 and with 56.5 per cent change it has decreased the most from all categories in Solvent and Other Produce Use sector.

5.3 Quality Assurance and Quality Control

There are a large number of NMVOC sources within this sector, and hence a wide range of methodologies and input datasets. For many of the methodologies, it is not possible to obtain a full time series of the input data. As a result, extrapolation, interpolation and surrogate data is used to complete the time series of emissions.

All calculations requiring extrapolation, interpolation and the use of surrogate data are clearly presented in the data processing sheets and are accompanied by comments and explanatory text from the inventory compilers to ensure transparency. In particular the use of colour coding to indicate where extrapolation and interpolation is used allows a high degree of transparency.

Some methodologies draw on point source data. This is always checked for consistency with historic data and for consistency across the different point sources within the same source sector.

Quality control checks have been installed to ensure that the emission estimates calculated in the data processing sheets are the same as those in the inventory dataset that is used for reporting purposes.

5.4 Recalculations for Solvents and Other Product Use

Recalculation for *Solvent and Other Product Use* are minor and confined to the sector 3.A Paint Application and the period 1999-2011 and are due to the revised UK activity data used as a proxy for Irish emission estimates. The total impact of recalculations in this sector is presented in Table 5.2 below.

5.5 Improvements in Solvents and Other Product Use

In December 2012, the EPA funded a two year research proposal aimed at updating the air emission inventory estimates for the Solvent and Other Product Use sector, including updating emission estimates in accordance with the latest Inventory Guidebook for reporting to the UNECE under the Convention on Long Range Transboundary Air Pollution (CLRTAP). This project will conclude in November 2014 and will provide revised estimates for this sector for all years of the time series for the submission in 2015.

Table 5.1. Estimates of NMVOC and CO_2 Emissions from Solvent and Other Product Use 1990-2012

Year	3A Paint Application	3B Degreasing, Dry Cleaning & Electronics	3C Chemical Products and Manufacturing & Processing	3D Other Use of Solvents & Related Activities	Total NMVOC emissions	Estimated CO_2 from NMVOC
	Mg NMVOC					Gg CO_2
1990	6,829	2,704	3,538	12,606	25,677	80.03
1991	6,956	2,704	3,538	13,041	26,239	81.78
1992	7,175	2,704	3,538	12,973	26,391	82.25
1993	7,400	2,704	3,538	12,866	26,508	82.62
1994	7,694	2,692	3,538	12,924	26,847	83.67
1995	7,972	2,896	3,538	12,993	27,399	85.39
1996	8,294	2,605	3,538	12,960	27,397	85.39
1997	8,556	2,425	3,538	13,035	27,554	85.88
1998	8,998	2,110	3,538	13,148	27,795	86.63
1999	8,629	2,022	3,370	12,838	26,858	83.71
2000	8,234	1,890	3,203	12,017	25,344	78.99
2001	8,310	1,669	3,035	11,961	24,975	77.84
2002	8,475	1,081	2,868	11,806	24,229	75.51
2003	8,307	1,158	2,700	11,667	23,833	74.28
2004	8,226	1,142	2,532	11,773	23,674	73.78
2005	7,997	1,246	2,532	11,943	23,717	73.92
2006	7,868	1,364	2,532	12,264	24,028	74.89
2007	7,575	1,304	2,532	12,797	24,208	75.45
2008	6,879	1,270	2,532	13,041	23,723	73.94
2009	6,098	1,178	2,532	13,091	22,899	71.37
2010	6,014	1,178	2,532	13,109	22,833	71.16
2011	6,086	1,178	2,532	13,327	23,123	72.07
2012	6,111	1,178	2,532	13,512	23,332	72.72

Table 5.2 Recalculations for Solvent and Other Product Use 1990-2011

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
		Estimates in 2013 Submission (Gg)																					
3.A	Paint Application	6.83	6.96	7.18	7.40	7.69	7.97	8.29	8.56	9.00	8.64	8.25	8.33	8.50	8.34	8.27	8.04	7.94	7.65	7.00	6.27	6.18	6.23
3.B	Degreasing, dry cleaning, electronics	2.70	2.70	2.70	2.70	2.69	2.90	2.61	2.42	2.11	2.02	1.89	1.67	1.08	1.16	1.14	1.25	1.36	1.30	1.27	1.18	1.18	1.18
3.C	Chemical Products and Manufacturing & Processing	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.37	3.20	3.04	2.87	2.70	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
3.D	Other Use of Solvents	12.61	13.04	12.97	12.87	12.92	12.99	12.96	13.03	13.15	12.84	12.02	11.96	11.81	11.67	11.77	11.94	12.26	12.79	13.04	13.09	13.10	13.32
3	Total NMVOC emissions	25.68	26.24	26.39	26.51	26.85	27.40	27.40	27.55	27.79	26.87	25.36	25.00	24.26	23.87	23.72	23.76	24.10	24.28	23.84	23.06	22.99	23.26
3	Estimated CO_2 from NMVOC	80.03	81.78	82.25	82.62	83.67	85.39	85.39	85.88	86.63	83.73	79.04	77.91	75.60	74.39	73.92	74.07	75.10	75.67	74.30	71.88	71.66	72.49
		Recalculated Estimates in 2014 Submission (Gg)																					
3.A	Paint Application	6.83	6.96	7.18	7.40	7.69	7.97	8.29	8.56	9.00	8.63	8.23	8.31	8.47	8.31	8.23	8.00	7.87	7.57	6.88	6.10	6.01	6.09
3.B	Degreasing, dry cleaning, electronics	2.70	2.70	2.70	2.70	2.69	2.90	2.61	2.42	2.11	2.02	1.89	1.67	1.08	1.16	1.14	1.25	1.36	1.30	1.27	1.18	1.18	1.18
3.C	Chemical Products and Manufacturing & Processing	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.37	3.20	3.04	2.87	2.70	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53
3.D	Other Use of Solvents	12.61	13.04	12.97	12.87	12.92	12.99	12.96	13.03	13.15	12.84	12.02	11.96	11.81	11.67	11.77	11.94	12.26	12.80	13.04	13.09	13.11	13.33
3	Total NMVOC emissions	25.68	26.24	26.39	26.51	26.85	27.40	27.40	27.55	27.79	26.86	25.34	24.98	24.23	23.83	23.67	23.72	24.03	24.21	23.72	22.90	22.83	23.12
3	Estimated CO_2 from NMVOC	80.03	81.78	82.25	82.62	83.67	85.39	85.39	85.88	86.63	83.71	78.99	77.84	75.51	74.28	73.78	73.92	74.89	75.45	73.94	71.37	71.16	72.07
		Percentage Change in Total Emissions due to Recalculations																					
3.A	Paint Application	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.2%	-0.3%	-0.3%	-0.4%	-0.5%	-0.6%	-0.9%	-0.9%	-1.7%	-2.7%	-2.7%	-2.3%
3.B	Degreasing, dry cleaning, electronics	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.C	Chemical Products and Manufacturing & Processing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D	Other Use of Solvents	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	Total NMVOC emissions	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%	-0.3%	-0.3%	-0.5%	-0.7%	-0.7%	-0.6%
3	Estimated CO_2 from NMVOC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%	-0.3%	-0.3%	-0.5%	-0.7%	-0.7%	-0.6%

Chapter Six

Agriculture

6.1 Overview of Agriculture Sector

The IPCC Level 3 source categories in *Agriculture,* where CH_4 and N_2O are the key greenhouse gases, are listed in Table 6.1. The agricultural activities of particular importance in Ireland are those under *4.A Enteric Fermentation, 4.B Manure Management* and *4.D Agricultural Soils*, some of which are identified as being among the largest greenhouse gas emission sources in the country. The inventory time-series for the years 1990-2012 contains emission estimates for all relevant sources and gases in these three important source categories. The availability of improved national statistics and the completion of major national research in agriculture in the last decade have facilitated major improvements in methodologies and in the manner of data application for many of the sources concerned. Source categories *4.C Rice Cultivation, 4.E Prescribed Burning of Savannas* and *4.F Field Burning of Agricultural Residues* are not relevant to Ireland and the notation key NO is used in relation to all associated emissions in the CRF. The practice of field burning of agricultural residues does not occur in Ireland. This is as a result of requirements imposed on farmers who are in receipt of payments under the Common Agricultural Policy and national environmental schemes[1].

The methods provided by the IPCC good practice guidance are applied as completely as possible for agricultural emission sources pertaining to Irish circumstances. The IPCC methods require considerable detailed information on activity data, emission factors and other input parameters for the emission calculations. There were major changes in the inventories for *Agriculture* in the 2006 submission with the adoption of Tier 2 methods for CH_4 emissions from enteric fermentation in cattle and also improvements in estimates of emissions from manure management. Both of these developments were based on the results of major research and an extensive Farm Facilities Survey (Hyde et al., 2008). This research, together with other relevant work related to the development of a nitrogen-flow approach to NH_3 emissions and regulations on the implementation of SI 788 of 2005 (DEHLG, 2005), SI 378 of 2006 (DEHLG, 2006), SI 101 of 2009 (DEHLG, 2009), SI 610 of 2010 (DEHLG, 2010) and SI 31 of 2014 (DECLG), has facilitated the application of a large amount of country-specific information underlying the various estimates of emissions. The same approach and methods are used for the purposes of this submission while further development and minor updating of the underlying activity data remains part of the on-going work and assessment in relation to agricultural emissions.

There is extensive and up-to-date statistical data on all aspects of the agriculture sector in Ireland. The majority of this data is compiled and published by the CSO and is the official source of the basic data for inventory purposes. The exception is for statistics on synthetic fertiliser use and the poultry population which are obtained from the Department of Agriculture Food and the Marine (DAFM). The CSO and DAFM are key data providers whose annual statistical inputs to the inventory agency are covered by Memorandum of Understanding (MOU) in Ireland's national system (Figure 1.1 and Table 1.1). The time-series of key agricultural statistics, as used for the various activity data (e.g. livestock populations and fertiliser use) are given in Table G.1 of Annex G.

[1] http://www.agriculture.gov.ie/farmerschemespayments/crosscompliance/

Ireland continues to use one annual average population characterisation, used for the first time in submission 2012, as opposed to two annual population characterisations (one in June and one in December) as used in previous submissions. The publication of separate census data for June and December annually and the application of these statistics in order to achieve the most representative annual average population related to cattle and some other livestock explains differences that are often seen between national and FAO statistics for agriculture. Ireland has high quality agricultural statistics and differences with FAO are to be expected, but they are of no consequence to the emissions estimates.

Table 6.1. Level 3 Source Category Coverage for Agriculture

Agriculture	**CO_2**	**CH_4**	**N_2O**
A. Enteric Fermentation			
1. Cattle	NA	All	NA
Dairy Cattle	NA	All	NA
Non-Dairy Cattle	NA	All	NA
2. Buffalo	NA	NO	NA
3. Sheep	NA	All	NA
4. Goats	NA	All	NA
5. Camels and Llamas	NA	NO	NA
6. Horses	NA	All	NA
7. Mules and Asses	NA	All	NA
8. Swine	NA	All	NA
9. Poultry	NA	NE	NA
10. Other	NA	NO	NA
B. Manure Management			
1. Cattle	NA	All	All
Dairy Cattle	NA	All	All
Non-Dairy Cattle	NA	All	All
2. Buffalo	NA	NO	NO
3. Sheep	NA	All	All
4. Goats	NA	All	All
5. Camels and Llamas	NA	NO	NO
6. Horses	NA	All	All
7. Mules and Asses	NA	All	All
8. Swine	NA	All	All
9. Poultry	NA	All	All
10. Anaerobic Lagoons	NA	NA	NA
11. Liquid Systems	NA	All	All
12. Solid Storage and Dry Lot	NA	All	All
13. Other	NA	NO	NO
C. Rice Cultivation	NO	NO	NO
D. Agricultural Soils			
1. Direct Soil Emissions	IE*	NE	All
2. Pasture Range and Paddock Manure	NA	NO	All
3. Indirect Emissions	NA	NO	All
4. Other	NO	NO	NO
E. Prescribed Burning of Savannas	NO	NO	NO
F. Field Burning of Agricultural Residues	NO	NO	NO
G. Other	NO	NO	NO

All: all emission sources covered; NE: emissions not estimated; NO: activity not occurring; NA: not applicable (activity exists but no emissions of the gas occur); IE: emissions included elsewhere* CO_2 emissions from Liming of Agricultural Lands included in category 5.B and 5.C of LULUCF (Chapter Seven)

In 2012, the emissions from Agriculture were 17,969.04 Gg CO_2 equivalent or 30.7 per cent of national emissions. This proportion has decreased in relative terms from 35.5 per cent in 1990 as the emissions from Energy use increased significantly while emissions from Agriculture decreased by 8.5 per cent. Methane accounted for 61.5 per cent and N_2O accounted for 38.5 per cent of the emissions in the sector in 2012. The CH_4 emissions from enteric fermentation in cattle and the N_2O emissions associated with large inputs of chemical and organic nitrogen to agricultural soils are the major emission categories.

6.2 CH_4 Emissions from Enteric Fermentation (4.A)

6.2.1 Overall Approach

Implementation of the IPCC good practice guidance for GHG inventories requires that Parties use Tier 2 (i.e. detailed country-specific) methods for key sources of emissions. Prior to the inventory submission in 2006, Ireland used Tier 1 methods to estimate CH_4 emissions from enteric fermentation. At the time this basic approach showed that enteric fermentation in dairy and non-dairy cattle produced 8.5 per cent and 3.6 per cent respectively of total GHG emissions in 2003. The Tier 1 approach also showed that, in 1990, enteric fermentation in non-dairy cattle was the single largest individual source of greenhouse gas emissions in Ireland, accounting for 9.6 per cent of the national total. The recommendation to use Tier 2 methods had been made in several annual review reports of Ireland's inventory submissions to the UNFCCC. As a result, a major research project funded by the EPA was undertaken to provide appropriate Tier 2 emission factors for CH_4 from enteric fermentation for the Irish cattle herd. In addition, a Farm Facilities Survey (Hyde et al., 2008) provided detailed data on manure management practices to support the adoption of a higher tier method. The Farm Facilities Survey was conducted on a representative sample of farms, the results of which are available at both national level and for each of the three designated Nitrates Directive regions (SI 788 of 2005 (DEHLG, 2005), SI 378 of 2006 (DEHLG, 2006), SI 101 of 2009 (DEHLG, 2009), SI 610 of 2010 (DEHLG, 2010), SI 31 of 2014 (DECLG, 2014)). The results of this research (O'Mara, 2007) and the Farm Facilities Survey (Hyde et al., 2008) were applied for the first time in the 2006 submission for the generation of country specific emission factors and a Tier 2 methodological approach.

In the Tier 2 approach, the Irish cattle herd is characterised by 11 principal animal classifications as shown in Table 6.2, for which annual census data are published by the CSO. In-depth analysis of production systems and the associated animal feed and energy requirements was conducted for all categories within the Irish cattle population to determine CH_4 production. Substantial further subdivision was incorporated for dairy and beef cattle to adequately describe the wide range of cattle rearing and finishing systems applicable in Ireland. In total, dairy cows were covered by 12 systems and 18 system types were analysed for suckler cows, while up to 30 systems were examined for both male and female beef cattle (O'Mara, 2007).

The proportioning of Animal Waste Management Systems (AWMS) within the model is undertaken on an individual subsystem basis. The partitioning of the year into pasture and housing periods is based on expert opinion in conjunction with the results of the Farm Facilities Survey (Hyde et al., 2008) for each particular subsystem. Having derived the time spent at pasture and the time spent in housing for cattle, the Farm Facilities Survey is used to determine the partitioning of liquid and solid manures to AWMS within the housing period, and the estimation of the number of animals that are out-wintered (i.e. at pasture all year round).

The Tier 2 approach has been used for 1990 and for the years 2003 to 2012. Interpolation has been used to complete the time series.

Table 6.2. Animal Classifications for Cattle Population

Cattle Type	**Classification**		
Breeding cattle	Dairy cows	Suckler (Beef) cows	
Beef cattle	Male < 1 year Female < 1 year	Male 1 – 2 years Female 1 – 2 years	Male > 2 years Female > 2 years
Other cattle	Breeding bulls	Dairy in-calf heifers	Beef in-calf heifers

6.2.2 Enteric Fermentation in Breeding Cattle

For both dairy cows and suckler cows, the country is divided into three regions: (1) south and east, (2) west and midlands, and (3) north-west, coinciding with the regions used for the implementation of regulations on Good Agricultural Practices for the protection of Waters SI 788 of 2005 (DEHLG, 2005), SI 378 of 2006 (DEHLG, 2006), SI 101 of 2009 (DEHLG, 2009), SI 610 of 2010 (DEHLG, 2010), and SI 31 of 2014 (DECLG, 2014)). This division facilitates in-depth analysis of separate regions with different lengths of winter housing and takes account of different animal feeding practices. The cattle production systems in each region are defined in terms of calving date, the dates of winter housing and spring turn-out to grass, milk yield and composition, forage and concentrate feeding level, cow live-weight and live-weight change and lactation period. The number of cows in each category, given by CSO statistics, is allocated to the three regions identified above using the Cattle Movement Monitoring System (CMMS) and Animal Identification and Movement (AIM) system reports published by the Department of Agriculture, Fisheries and Food (DAFF, 2004; 2005; 2006; 2007; 2008, 2009, 2010) and the Department of Agriculture Food and the Marine (DAFM, 2011, 2012, 2013). The CSO produces two censuses of animal numbers per year, one reflecting the number of animals nationally in June and the other referring to populations in December. For the purposes of calculating emissions from breeding cattle, an average of the number in each category of breeding animals present in the national herd in June and December is used.

In the approach outlined by O'Mara (2007), the daily energy requirement of cows in each region is calculated by month or part thereof based on maintenance requirements, milk yield and composition, requirements for foetal growth and gain or loss of bodyweight using the French energy system (INRA, 1989). In this system, net energy requirement is defined in terms of *unites fourragere lait* (UFL), where 1 UFL is the net energy value of 1 kg of barley at 86 per cent dry matter and is equal to 7.11 MJ net energy for lactation (NE_l). This international energy system, which is well established and used locally in Ireland, was considered more appropriate to the local conditions than the system and equations used by the IPCC guidelines and IPCC good practice guidance. The energy gains and losses refer to intra-annual changes for the animal and do not mean that average body weight for animals in the dairy herd is increasing from year to year. The live-weight of 535 kg for dairy cows is an indicative weight supplied by the Department of Agriculture, Food and the Marine, as dairy cow live-weights are not in general monitored on farms. The live-weight is adopted as the reference point for the annual emission factor derivation for the herd and is chosen to be consistent with other parameters relevant to the estimation of emissions from cattle, e.g. manure production.

The important equations are:

Maintenance NE_l requirements (MJ) = 9.96 + (0.6 x LW/100), where LW is live-weight. A 10 per cent activity allowance was added for the housed period and a 20 per cent allowance was added for the grazing period as outlined by INRA (1989);
NE_l (MJ) required per kg milk = 0.376 * fat content + 0.209 * protein content + 0.948;

Pregnancy: mean of 12.1 MJ NE_l /day for the last 3 months of pregnancy;

Live-weight change: each kg live-weight lost contributed 24.9 MJ NE_l to energy requirements, while each kg of live-weight gained required 32 MJ NE_l.

The composition of the diet of cows in each region was described by month or part thereof and daily intake was calculated by reference to the daily energy requirement. The concentrate allowance was fixed while forage intake varied according to energy requirements. Daily methane emissions (MJ/day) were calculated from digestible energy intake using the equation of Yan et al. (2000).

$$CH_4 = DEI * [\ 0.096 + (0.035 \times S_{DMI}/T_{DMI})\ ] - 2.298 * (FL - 1)$$

where DEI is digestible energy intake (MJ/day), S_{DMI} and T_{DMI} are silage and total dry matter intakes (kg/day), respectively, and FL is feeding level (multiples of the maintenance energy requirement).

A constant methane conversion rate of 0.065 of gross energy intake is applied when the diet consists of grazed grass and 3 kg or less of concentrate supplement per day. This is based on a large New Zealand database of measurements for grazing animals on similar production systems to those in Ireland. A methane output of 21.6 g/kg DM is used for pasture diets with a grass GE content of 18.45 MJ/kg, which is equivalent to 6.5 per cent of GE (Harry Clark, AgResearch New Zealand Personal Communication). Daily CH_4 emissions are summed to give annual emissions for cows in each region, and a weighted national average emission factor is then calculated.

6.2.3 Enteric Fermentation in Beef Cattle

Emission factors for the beef cattle categories, given in Table 6.3, are determined by calculating lifetime emissions for the animal and by partitioning between the first, second and third years of the animal's life. This approach allows the published CSO animal populations for June to be used directly as the activity data most representative of the inventory year for enteric fermentation while taking into account the movement of cattle from one category to another (i.e. from 0-1 year old to 1-2 year old to over 2 years old), as enumerated by the June census, up to two times in their three-year lifetime (O'Mara 2007).

Analysis is undertaken for a total of 11 separate production systems covering the three groups of male and female beef cattle given in Table 6.3 after the proportion of the herd in each category is calculated using the CMMS/AIM reports published by the Department of Agriculture, Fisheries and Food (DAFF, 2004; 2005; 2006; 2007; 2008, 2009, 2010) and the Department of Agriculture, Food and the Marine (DAFM, 2011, 2012, 2013). Important parameters such as housing dates (expert opinion and Hyde et al., 2008), turnout dates (expert opinion and Hyde et al., 2008) and live-weight gains (expert opinion reconciled with actual national carcass weights) during winter housing periods and grazing seasons are defined for each system (O'Mara, 2007). The most important parameter is live-weight gain, as it directly affects the energy requirement and thus the feed intake. There is little statistical information on the live-weight gain of the different types of cattle in the cattle herd, but the weight of carcasses of all slaughtered cattle is recorded by the Department of Agriculture, Food and the Marine. Using data for the average carcass weight of male and female cattle, appropriate live-weight gains are applied to the various life stages of each animal category, such that when all categories are combined, that data is consistent with the national statistics for carcass weight (plus or minus 10 kg difference).

Given these data for live-weight and live-weight gain, O'Mara, (2007) estimated the energy requirements of animals during the winter housing periods and grazing seasons of the animals lifetime using the INRAtion computer programme, version 3.0. This programme was devised by the French research organisation Institute National de la Recherche Agronomique (INRA) and is based on the net energy system for cattle. In version 3 of INRAtion, some adaptation for Irish conditions was made to the equations for estimating the energy requirements of growing and finishing animals (O'Mara, 1997, Crowley, 2001 and Crowley *et al*, 2002). Net energy requirements of growing beef cattle are defined in terms of UFL, as in the case of dairy cattle, while for finishing cattle, net energy requirements are defined in terms of UFV (from the French *unite fourragere viande*) where 1 UFV is the net energy value of 1 kg of barley for meat production and is equal to 7.61 MJ NE_{mg}.

The composition of the diet in each system is described by grazing season and winter housing period and daily intake is calculated by reference to the daily energy requirement.

The concentrate allowance is fixed while forage intake is varied according to energy requirements. The Irish modifications to the INRAtion programme were predominantly for animals at weanling and finishing stages (i.e. at times that concentrates were likely to be fed). No modifications were made for 'heavy' growing animals, (typically animals in their second grazing season or later that were not being finished). For animals in these stages, intakes were adjusted as appropriate by expert opinion. Daily methane emissions were calculated using the equation of Yan et al. (2000), however a constant of 0.065 of gross energy intake was applied when the diet was grazed grass plus 3 kg or less of concentrate supplement/day. Daily emissions are aggregated to give annual emissions per system and a weighted national average emission factor is then calculated.

6.2.4 Enteric Fermentation in Other Cattle

Bulls for breeding and in-calf heifers account for on average 6 per cent of the national cattle herd. Separate production systems were not defined for these categories because of the lack of published data on their feed intake and the small number of animals involved (O'Mara, 2007). Bulls for breeding are mostly of continental breeds, and their emission factors are based on those for late maturing male beef cattle of suckler origin in their second year. The emission factor for animals in this category is determined by an applicable period of 310 days in their second year, which is adjusted upwards to the full period of 365 days in the case of breeding bulls.

In-calf heifers are assigned the same emission factors as female beef cattle in their second year (i.e. corresponding to the category 1–2 years old). In-calf heifers only require emissions associated with the period March – December of their second year to be accounted for, as they are subsequently enumerated as dairy or suckler cows in the CSO animal census thereafter. Female beef cattle in the category 1-2 years old are assumed to be slaughtered on 3rd February of their third year (O'Mara, 2007). Adjustment for the slightly longer period is not made in respect of in-calf heifers, as they are carrying a calf in addition to normal growth which is reflected in the calculation methodology.

6.2.5 Summary of Tier 2 Emission Factors for Cattle

The Tier 2 emission factors developed by the detailed analysis outlined above are summarised in Table 6.3 for the 11 principal classifications chosen to characterise the Irish cattle herd. Emission factors for the full time series 1990–2012 in respect of the 11 principal classifications are presented in Table G.2 of Annex G. The emission factor for dairy cows in 1990 is very close to the IPCC default emission factor of 100 kg CH_4/head/year for highly productive dairy cattle in Western Europe. The corresponding value for 2011 indicates an increase of 10.6 per cent from 1990 in line with increased milk yield.
The emission factors for beef cattle (Table 6.3) show a reduction between 1990 and 2012, as a result of higher proportions of later maturing breeds, lower quality forage and lower usage of concentrates during the 1990's. The reduction in emission factors for male cattle in the category greater than two years old can also be explained by the earlier finishing time for male beef cattle since the BSE crisis that affected agriculture during the 1990s.

Table 6.3. Tier 2 CH_4 Emission Factors for 1990, 2008- 2012

	Enteric Fermentation (kg/head/year)						Manure Management (kg/head/year)					
	1990	2008	2009	2010	2011	2012	1990	2008	2009	2010	2011	2012
Dairy cows	101.38	109.99	108.54	113.06	113.22	112.77	21.60	20.61	20.42	20.85	20.86	20.82
Suckler cows	74.03	74.92	72.78	72.95	74.07	75.53	14.25	41.30	13.83	13.89	14.14	14.40
Male cattle < 1 year	30.46	29.71	29.77	29.11	29.82	30.15	9.30	8.25	8.30	8.49	8.38	8.49
Male cattle 1 - 2 years	62.22	59.07	58.57	59.96	58.01	56.63	16.89	13.95	13.88	14.25	13.53	12.91
Male cattle > 2 years	55.08	36.98	38.84	39.79	38.29	37.25	5.16	2.02	2.28	2.38	2.20	2.05
Female cattle < 1 year	27.05	27.59	27.58	26.99	27.61	27.67	8.41	7.92	7.90	7.88	7.92	7.92
Female cattle 1 - 2 years	53.54	47.00	47.71	48.62	47.93	47.99	14.93	10.08	10.44	10.76	10.38	10.44
Female cattle > 2 years	21.65	22.55	22.63	22.63	22.72	22.73	0.33	0.34	0.35	0.35	0.35	0.35
Bulls for breeding	86.38	81.55	81.55	81.55	81.55	81.55	23.79	18.95	18.95	18.95	18.95	18.95
Dairy in-calf heifers	51.82	50.16	50.16	50.16	50.16	50.16	13.40	10.93	10.93	10.93	10.93	10.93
Beef in-calf heifers	55.42	53.68	53.68	53.68	53.68	53.68	15.61	12.87	12.87	12.87	12.87	12.87

6.2.6 Enteric Fermentation in Other Livestock

The type of information used to derive the Tier 2 emission factors for cattle is not available for other important livestock categories in Ireland, such as sheep and swine. Therefore, the inventory agency continues to use the Tier 1 approach for enteric fermentation for all livestock categories other than cattle. The emission factors used are generally those for Western Europe given in Table 4.3 of the IPCC Guidelines. However, in order to fully utilise Irish national statistics and the detailed CSO breakdown in respect of sheep and swine populations, the base emission factors from IPCC are adjusted as shown in Table G.2 of Annex G. For sheep, the emission factor for lambs is calculated on the basis that lambs have an assumed lifetime of 180 days before slaughter and a CH_4 conversion rate (Y_m) of 0.06 as per Table 4.9 of the IPCC good practice guidance. For swine the default emission factor of 1.5 kg CH_4 per head per year is adjusted for each subcategory of swine on the basis of a default swine weight of 82 kg (Table B6 IPCC Reference Manual) and the known average weight of each subcategory of swine in Ireland. As a result, the implied emission factors produced by the CRF related to total populations of sheep and swine in Ireland are lower than the IPCC base default values for these animal categories.

6.3 CH_4 Emissions from Manure Management (4.B)

6.3.1 CH_4 Emissions from Manure Management in Cattle

The decomposition of the organic material in animal manures may be a significant source of CH_4 emissions if anaerobic conditions prevail in the animal waste management systems being used. The estimation of such emissions requires information on the quantity of manure production for the animal groups concerned, the type of waste management systems employed and the CH_4 production potential of the wastes. Information obtained from a national farm facilities survey (Hyde et al., 2008) and the work on emission factors for enteric fermentation in cattle described in section 6.2 is the basis of the CH_4 emission factors for manure management. The results of the farm facilities survey (Hyde et al., 2008) provide a much improved representation of animal waste allocation among the relevant waste management systems in the country while the excretion of organic matter by cattle is fully characterised as part of the analysis of their feed and energy requirements relating to enteric fermentation (O'Mara, 2007). The main results of the farm facilities survey pertinent to inventory calculations are outlined in Tables G.4.1 and G.4.2 of Annex G.

The analysis of the feeding regime for cattle (O'Mara, 2007) included a full evaluation of the organic matter content of the feeds applicable to the 11 classifications that characterise the national herd (Table 6.2), which facilitates the estimation of their respective levels of organic matter excretion. The emission factors for manure management are derived using the quantified organic matter excretion as volatile solids (VS), the methane production potential (B_O) of animal waste, the allocation to animal waste management system based on the farm facilities survey (Hyde et al., 2008) and the corresponding values of MCF (methane conversion factor) given for the cool climate zone in Table 4.10 of the IPCC good practice guidance. Ireland uses the value of 0.24 m^3 CH_4/kg VS (the value for dairy cattle in the IPCC good practice guidance) for B_o for all cattle based on input from agricultural experts who advise that the methane potential of dairy cattle manures and non-dairy cattle manures in Ireland is the same, given the similarity of their grass-based feeding systems. Volatile solids values for dairy cows and non-dairy cattle are estimated using the information provided in O'Mara (2007). These values differ from the default values provided in the IPCC Good Practice Guidance due to the higher digestibility of feeds in Ireland. The default digestibility of 60 per cent is very low in comparison to the digestibility of silage (70 per cent), grazed grass (80 per cent) and concentrates (80 per cent). Grazed grass and silage make up the majority of feed intake of cattle in Ireland due grass based production systems. The emission factors for cattle are given in Table 6.3.

6.3.2 CH_4 Emissions from Manure Management in Other Livestock

The estimation of CH_4 emissions from domestic livestock includes the derivation of the emission factors for manure management for sheep, goats, swine, horses, mules and poultry. The allocations to animal waste management system are again based on the national farm facilities survey (Hyde et al., 2008) and appropriate values of B_O and VS are taken from the IPCC Guidelines while MCF is again as given in Table 4.10 of the IPCC good practice guidance. The application of the manure management emission factors for sheep, goats, swine, horses, mules, and poultry means that all CH_4 emissions from livestock are included in the national inventory.

6.4 N_2O Emissions from Manure Management (4.B)

Nitrogen excretion rates have been adopted in Ireland for all animal categories for which annual census data are published by the CSO. In 2011, the inventory agency reviewed the applicability of the nitrogen excretion rates used in the inventory in collaboration with the Department of Agriculture, Food and the Marine, agricultural researchers and animal nutritionists. Nitrogen excretion rates are provided in Tables G.5 of Annex G. In the case of cattle, the excretion rates are consistent with the nitrogen content of cattle feed intake as analysed in conjunction with the determination of Tier 2 CH_4 emission factors for cattle. The nitrogen excretion rates are used by the inventory agency, along with the information on the allocation of animal manures to each applicable animal waste management system from the Farm Facilities Survey (Hyde et al., 2008) as the basis of CRF Table 4.B (b).

Approximately two-thirds of animal manure nitrogen is excreted at pasture annually, reflecting the relatively short period that cattle and sheep are housed in Ireland. Animal manures excreted at pasture are unmanaged and the associated emissions are accounted for under agricultural soils (Section 6.5.1). In 2012 the bulk of animal manures in housing were managed in liquid storage systems (93.8 per cent and 73.5 per cent for dairy cattle and other cattle respectively, and 100 per cent for swine) for eventual spreading on agricultural lands. The remainder of animal manures produced in-house are in solid manure systems. The emission factors given by the IPCC good practice guidance indicate that 1 kg of nitrogen per tonne of nitrogen handled in liquid manure storage systems is lost as N_2O while the corresponding loss is 20 kg per tonne for nitrogen in solid manure storage systems. These default emission factors, for which uncertainty ranges up to 100 per cent, are assigned in the IPCC good practice guidance, are used to estimate N_2O emissions from manure management in Ireland. The N_2O emissions from manures managed in liquid and solid storage systems in 2012 amounted to 1.50 Gg N_2O.

6.5 N_2O Emissions from Agricultural Soils (4.D)

Agricultural soils are the principal source of N_2O emissions in Ireland. The IPCC methodologies for the source categories concerned involve a simple accounting of all inputs of nitrogen to agricultural soils and the subsequent application of default rates of nitrogen loss to the atmosphere as N_2O. The primary nitrogen inputs are subject to complex processes and partitioning between various nitrogen compounds within soils and the emissions are highly dependent on soil properties and meteorology. The methodologies are therefore simplified and they are based on a consideration of separate direct and indirect contributions to national emissions. Ireland uses the IPCC good practice guidance methodology completely to estimate N_2O emissions from agricultural soils and the procedure may be followed from the description below. Values for each of the terms used in the calculation of direct and indirect soil emissions for the full time series 1990-2012 are presented in Table G.6 of Annex G.

6.5.1 Direct Soil Emissions (4.D.1)

According to the IPCC good practice guidance the direct emissions of N_2O to be reported in CRF sub-category 4.D.1 Direct Soil Emissions may be calculated in a Tier 1 approach from

$$N_2O_{direct} = [(F_{SN} + F_{AM} + F_S + F_{BN} + F_{CR}) * EF_1] + [F_{OS} * EF_2]$$

where

N_2O_{direct} = the direct emissions of N_2O
F_{SN} = amount of synthetic fertiliser nitrogen applied to soils, adjusted for the amount that volatilises as NH_3 and NO_X
F_{AM} = amount of animal manure nitrogen applied directly to soils, adjusted for the amount that volatilises as NH_3 and NO_X
F_S = amount of organic nitrogen in sludge applied to agricultural soils
F_{BN} = amount of nitrogen fixed by nitrogen-fixing crops
F_{CR} = amount of nitrogen in crop residues returned to soils
F_{OS} = the area of cultivation of organic soils
EF_1 = N_2O emission factor for emissions from direct nitrogen inputs (kg N_2O-N/kg N)
EF_2 = N_2O emission factor for emissions from cultivation of organic soils (kg N_2O-N/kg N)

The estimates of direct N_2O emissions from agricultural soils for the years 1990-2012 take into account the nitrogen inputs from all of these sources, except that due to the cultivation of organic soils. Tillage farming in Ireland is concentrated in the south and southeast of the country while the bulk of organic soils occur in the midlands and west. Nitrogen inputs due to the cultivation of organic soils are thus considered negligible. The equation for estimating N_2O emissions in Ireland reported in sub-category *4.D.1 Direct Soil Emissions* therefore becomes

$$N_2O_{direct} = (F_{SN} + F_{AM} + F_S + F_{BN} + F_{CR})*EF_1$$

Where

$F_{SN} = N_{fert} * (1-Frac_{GASF})$

$F_{AM} = [N_{ex} * (1- Frac_{GRAZ}) * (1- Frac_{GASM1})] – N_2O\text{-}N_{hs}$

$F_S = SS_I * NSSF$

$F_{BN} = \sum_i [Crop_i * (1 + Res_i/Crop_i) * DMF_i * NCRF_i]$

$F_{CR} = \sum_i [Crop_j * Res_j/Crop_j * DMF_j * NCRF_j]$

and

N_{fert} = total amount of synthetic fertiliser nitrogen applied to soils (kg N)
$Frac_{GASF}$ = fraction of synthetic fertiliser nitrogen that volatilises as NH_3 (0.021 in 2012)
N_{ex} = total amount of animal manure nitrogen excreted by livestock (kg N)

$Frac_{GRAZ}$ = fraction of N_{ex} that is excreted by livestock during grazing (0.611 in 2012)
$Frac_{GASM1}$ = fraction of animal manure nitrogen that volatilises as NH_3 during housing, manure storage and landspreading (0.362 in 2012)
$N_2O\text{-}N_{hs}$ = amount of animal manure nitrogen emitted as N_2O in housing and storage (kg N_2O-N)
SS_l = quantity of sewage sludge spread on agricultural lands (kt)
NSSF = nitrogen fraction of sewage sludge (3 per cent of dry solids)
$Crop_i$ = production of nitrogen-fixing crop i (kt)
$Res_i/Crop_i$ = residue to crop product mass ratio of nitrogen-fixing crop i
DMF_i = dry matter fraction of nitrogen-fixing crop i
$NCRF_i$ = nitrogen fraction of nitrogen-fixing crop i
$Crop_j$ = production of crop j (including nitrogen-fixing crops) (kt)
$Res_j/Crop_j$ = residue to crop product mass ratio of crop j (including nitrogen-fixing crops)
DMF_j = dry matter fraction of crop j (including nitrogen-fixing crops)
$NCRF_j$ = nitrogen fraction of crop j (including nitrogen-fixing crops)

The annual statistics on nitrogen fertiliser use (N_{fert}) are obtained from the Department of Agriculture, Food and the Marine while the organic nitrogen inputs (N_{ex}) are outlined in section 6.4. A significant proportion of the nitrogen applied to soils in synthetic fertilisers and animal manures is volatilised as NH_3 and NO_X. These proportions, $Frac_{GASF}$ and $Frac_{GASM}$ respectively in the IPCC guidelines, must be taken into account in order to determine the amount of nitrogen available for direct N_2O production. The IPCC good practice guidance gives the default proportions of chemical fertiliser and animal manure nitrogen lost in this way as 10 per cent and 20 per cent, respectively. The volatilisation rates for Ireland are, however, determined in an elaborate NH_3 inventory for agriculture (Duffy et al, 2013). It is assumed that nitrogen lost as NO_X is negligible in comparison to NH_3. In addition, $Frac_{GASM}$ is split into $Frac_{GASM1}$ and $Frac_{GASM2}$ with $Frac_{GASM1}$ referring to NH_3-N losses from animal manures in housing, storage and landspreading and $Frac_{GASM2}$ being the proportion of nitrogen excreted at pasture that is volatilised as NH_3. The 2012 values of $Frac_{GASM1}$ and $Frac_{GASM2}$ are 0.362 and 0.056, respectively indicating an overall volatilisation rate of 0.175 for animal manure nitrogen. Additional information on parameters is available in Table G.6 of Annex G.

The expression for the amount of synthetic fertiliser nitrogen applied to soils, adjusted for the amount that volatilises as NH_3 and NO_x, (F_{AM}) given above, is used to estimate the amount of animal manure nitrogen ultimately available for direct application to agricultural soils. It is more precise than that given in the IPCC good practice guidance, as the nitrogen in animal manures emitted as N_2O and as NH_3 during animal housing and storage of manures is deducted from total nitrogen excreted in housing. Accordingly, the fraction $Frac_{GASM1}$ used here refers to the loss of nitrogen by volatilisation as NH_3 during housing and storage together with that from landspreading. These modifications have been made to achieve more accurate accounting of nitrogen and to maintain consistency with Ireland's inventory of NH_3. The fractions, $Frac_{GASF}$ and $Frac_{GASM1}$ are estimated at 0.021 and 0.362, respectively in 2012 from the NH_3 inventory. Published estimates of sludge production (O'Leary et al, 1997; O'Leary and Carty, 1998; O'Leary et al, 2000; Smith et al, 2003; Smith et, 2004; Smith et al, 2007; Monaghan et al, 2009) and the proportion applied on agricultural lands are used to estimate F_S on the basis of 3 per cent nitrogen content in sewage sludge with typical dry solids content of 25 per cent (Fehily Timoney, 1985). The estimate of F_S is included in N_2O_{direct} without deduction for volatilisation and the value is added to F_{AM} for reporting purposes in CRF Table 4.D. Although the amount of sludge spreading on land is increasing, it contributed less than 1 per cent of the organic nitrogen input to agricultural soils in 2012. Table G.7 of Annex G shows the total quantity of nitrogen applied each year to agricultural soils through sewage sludge for the time series 1990-2012.

The Tier 1b method given by the IPCC good practice guidance is used to estimate the nitrogen contributions from nitrogen-fixing crops (F_{BN}) and from crop residues (F_{CR}) returned to the soil. Annual crop production statistics provided by the CSO and the default values of nitrogen content and other input parameters given by the IPCC good practice guidance are the basis for these estimates. The IPCC default value of 0.0125 kg N_2O-N/kg N is currently used for EF_1 to estimate direct emissions of N_2O from the inputs calculated from the above equations. The direct emissions of N_2O in 2012 for category *4.D.1 Direct Soil Emissions* amounted to 8.12 Gg, of which synthetic fertilisers accounted for 5.70 Gg, 2.23 Gg was due to land spreading of animal manures and sewage sludge and crops (N-fixing and crop residue) produced 0.18 Gg. The contribution from crops in Ireland is small relative to other nitrogen sources and it fluctuates significantly in response to the production level of the relevant crops. Additional information on data used to estimate N_2O emissions from N-fixing crops and nitrogen in crop residues returned to soils is provided in Tables G.8 and G.9 of Annex G, as recommended in a previous annual inventory review.

6.5.2 Pasture Range and Paddock Manure (4.D.2)

The direct N_2O emissions associated with nitrogen excretion by animals during grazing is not allocated to sub-category *4.D.1 Direct Soil Emissions* but is reported instead in the CRF under *4.D.2 Pasture Range and Paddock Manure*. The amount of organic nitrogen input concerned is large in Ireland, as shown by the value of 0.61 for $Frac_{GRAZ}$ in 2012, due to the relatively short period that cattle and sheep remain in housing. The value of nitrogen input for this activity is available from CRF Table 4.B(b). The direct N_2O emission factor (EF_3) for this nitrogen input is 0.02 kg N_2O-N/kg N and the estimate of emissions in 2012 was 8.67 Gg.

6.5.3 Indirect Emissions (4.D.3)

The IPCC methodology for indirect emissions reported in CRF sub-category *4.D.3 Indirect Emissions* is based on a simple approach that allocates emissions of N_2O due to nitrogen deposition resulting from NH_3 and NO_X emissions in agriculture and from nitrogen leaching to the country that generated the source nitrogen. The contributions from NH_3 and NO_X emission sources in other sectors, such as transport and stationary combustion, are excluded and the import of nitrogen from other countries through atmospheric transport and runoff is not considered. Accordingly, the total nitrogen volatilized as NH_3, deducted from total nitrogen inputs in synthetic fertilisers, animal manures and sewage sludge for estimating the amount contributing to direct N_2O emissions as described in the previous section, becomes the input value of nitrogen used to calculate indirect emissions due to deposition, as follows

$$N_2O_{indirect\text{-}dep} = [(N_{fert} * Frac_{GASF}) + ((N_{ex} * (1 - Frac_{GRAZ}) * Frac_{GASM1})) + (N_{ex} * Frac_{GRAZ} * Frac_{GASM2}) + (N_{SEWSLUDGE} * Frac_{GASM})] * EF_4$$

$$N_2O_{indirect\text{-}leach} = [\, N_{fert} + F_{AM} + N_{ex} * Frac_{GRAZ}) \,] * Frac_{LEACH} * EF_5$$

where

$N_2O_{indirect\text{-}dep}$ = the indirect emissions of N_2O due to atmospheric nitrogen deposition
$N_2O_{indirect\text{-}leach}$ = the indirect emissions of N_2O due to nitrogen leaching
$Frac_{GASM2}$ = fraction of animal manure nitrogen that volatilises as NH_3 during grazing (0.056 in 2012)
$N_{SEWSLUDGE}$ = Sewage sludge nitrogen
$Frac_{GASM}$ = fraction of sewage sludge nitrogen that volatilizes as NH_3 (0.2)
$Frac_{LEACH}$ = fraction of synthetic fertiliser nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2012)
EF_4 = N_2O emission factor for nitrogen inputs from atmospheric deposition
EF_5 = N_2O emission factor for nitrogen leaching

The expressions for the indirect emissions of N_2O due to atmospheric nitrogen deposition ($N_2O_{indirect-dep}$) and the indirect emissions of N_2O due to nitrogen leaching ($N_2O_{indirect-leach}$) are slightly modified to be consistent with those for estimating direct emissions in section 6.5.1 and to account for the two separate volatilisation fractions $Frac_{GASM1}$ and $Frac_{GASM2}$. The contribution to $N_2O_{indirect-dep}$ from F_S, the nitrogen input from sludge spreading is included. For $N_2O_{indirect-leach}$, F_S is accounted through its inclusion in F_{AM}. The default value for $Frac_{LEACH}$, the fraction of nitrogen lost through leaching, in the IPCC Guidelines is 30 per cent. Estimates of the nitrogen loads in Irish rivers reported under the OSPAR Convention (NEUT, 1999) suggest that approximately 10 per cent of all applied nitrogen in Irish agriculture is lost through leaching. More recent research (Ryan et al., 2006; Del Prado et al., 2006 and Richards et al., 2009) also suggest an average value of 10%. The value of 0.1 is thus considered to be a more realistic estimate of $Frac_{LEACH}$ for Irish conditions than the default value of 0.3 and it is used in this submission, as it was for previous submissions.

The IPCC default values of the emission factors EF_4 and EF_5 (0.01 kg N_2O-N/kg NH_3-N emitted for synthetic fertilizer and animal waste nitrogen and 0.025 kg N_2O-N/kg N leached) are used to estimate indirect N_2O emissions. Total indirect emissions in 2012 amounted to 4.04 Gg N_2O, or approximately 49.7 per cent of direct emissions from soils (sub-category 4.D.1).

The in-country review of Ireland's 2013 submission identified a potential underestimation in indirect N_2O emissions from atmospheric deposition. It was identified that Ireland had not included the contribution of sewage sludge nitrogen to the pool of nitrogen which is required in the estimation of N_2O emissions from atmospheric deposition as outlined in Equation 4.32 of the IPCC good practice guidance. Indirect N_2O emissions from sewage sludge application to soils are included for the first time in this submission as described above.

6.6 Uncertainties and Time-Series Consistency

Uncertainties in estimates of emissions from the agriculture sector were reduced through the use of Tier 2 methods for the calculation of CH_4 emissions from enteric fermentation and manure management for 1990 and 2003 onwards.

The use of country-specific information in relation to manure management has reduced the uncertainties associated with the estimation of N_2O from manure management and agricultural soils. A comparison of the uncertainties associated with emission estimates prior to the use of Tier 2 methodologies for CH_4 and the use of country-specific information in relation to manure management are shown in Table 6.4. Large uncertainties still remain in relation to the N_2O emissions from the agricultural sector due primarily to uncertainties in the emission factors. These uncertainties are the main determinant behind uncertainty in total national emissions outlined in Table 1.8. The uncertainties provided in Table 6.4 for pre 2006 are based on the default Tier 1 uncertainties as provided for in sections 4.2.1.6, 4.3.1.6, 4.4.1.4 and 4.7.1.6 of the IPCC good practice guidance. Uncertainty estimates post 2006 refine these estimates using expert judgement and the GPG where guidance is provided for estimating the uncertainty associated with using country specific activity data.

The emission time series for agriculture 1990–2012 is consistent. Key activity data such as disaggregated animal number and fertiliser use statistics are available for all years and are used in a consistent manner. Tier 2 methodologies for categories 4.A and 4.B are used in conjunction with the key activity data to provide emission estimates for all years in the time series 1990-2012.

Table 6.4. Uncertainties in Activity Data and Emission Factors

		Pre 2006		Post 2006	
		Activity Data Uncertainty	Emission Factor Uncertainty	Activity Data Uncertainty	Emission Factor Uncertainty
4.A Dairy Cattle	CH_4	1	20	1	15
4.A Other Cattle	CH_4	1	30	1	15
4.A Other Livestock	CH_4	1	50	1	30
4.B Dairy Cattle	CH_4			1	15
4.B Other Cattle	CH_4	32	50	1	15
4.B Other Livestock	CH_4			1	30
4.B Liquid System	N_2O				
4.B Solid Storage and Dry lot	N_2O	32	100	11.2	100
4.D Direct Soil emissions	N_2O				
4.D Pasture Rand and Paddock	N_2O	32	100	11.2	100
4.D Indirect Emissions	N_2O				

6.7 Quality Assurance and Quality Control

A spreadsheet system developed for the 2006 submission is used to estimate emissions from *Agriculture* in an efficient and transparent manner, which takes into account the strong links to Ireland's Tier 2 inventory of NH_3 in *Agriculture* and other factors relevant to a more complete country-specific application of the IPCC good practice guidance. The general QA/QC procedures set down in Ireland's QA/QC plan (section 1.6) have been followed in this compilation and inventory management system, from which the time-series outputs may be readily imported to the CRF Reporter. The spreadsheets incorporate transparent linking between input data statistics and calculations as well as internal checks on the calculations. The outputs are directly compatible with the CRF Reporter.

There is significant collaboration between inventory experts, agriculture researchers and the Department of Agriculture, Food and Marine, which grew out of the improved inventory methodologies for both CH_4 and $NH_{3.}$ These collaborations are maintained by the inventory agency and are an important part of the overall QA/QC procedures being undertaken on an annual basis.

6.8 Recalculations for Agriculture

A number of minor changes were implemented in this submission due to revision in animal populations for 2010 and 2011 for dairy cattle, other cattle, sheep, goats, horses, mules and asses, resulting in an overall decrease of GHG emissions of 1.76 per cent in 2011.

6.9 Improvements in Agriculture

The key to developing better estimates of CH_4 and N_2O emissions from agriculture and reducing uncertainty is to take full account of national circumstances of climate, soil types, livestock and crop production practices, management systems and other influencing factors in a robust and justifiable manner. This has been largely achieved in the case of both CH_4 and N_2O emissions associated directly with animal production, such as those from enteric fermentation and manure management. However, this is not possible for estimating N_2O emissions from soils using the current IPCC approach and the recommended simple default emission factors. A much more in-depth model approach is needed to take account of all the factors that determine such emissions and to capture the inter-annual variation in the national emission rate. The inventory agency continues to engage with researchers working on N_2O emissions from soils, with a view to adopting a methodology that systematically accounts for the influences of soil type, fertilizer type and application rates, temperature and rainfall, which are not captured by the current IPCC methodology. However, the lack of reliable data in relation to the key soil properties including bulk density and organic carbon content has delayed the application of such a methodology at national level and therefore is unlikely to be implemented during the first commitment period. Other countries are in similar positions, in that they are using relatively sophisticated methods for estimating emissions from enteric fermentation and manure management, but do not have the data to allow a Tier 2 approach for estimating emissions of N_2O from soils.

The Department of Agriculture, Food and the Marine has funded the establishment of The Agricultural Greenhouse Gas Research initiative for Ireland (AGRI-I). This is an organisational and collaborative framework designed to: build a critical mass of scientific expertise in GHG research, co-ordinate uniform measurement protocols, and address a specific set of research issues. The AGRI-I network has a specific set of research aims, primarily focussed on the inclusion of validated GHG emissions mitigation strategies into the national inventory. This research will also include a review of feed intake parameters and assumed nitrogen content of feeds and updates as necessary. A separate but related research project is investigating the development of country specific B_O and MCF values using a range of cattle manures and environmental conditions.

The inventory agency is also currently in the process of investigating the applicability of developing Tier 2 estimates of CH_4 from enteric fermentation and manure management from sheep as recommended in the previous annual inventory review reports. Discussions are on-going with agricultural research institutions in relation to sourcing appropriate country specific data with respect to feed intake and management regimes for sheep in Ireland.

The inventory agency has undertaken a review of crop residue burning (CRF 4.F) using the MODIS fire detection archive for Ireland which utilizes NASA earth data (https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data). The review examined 602 active fire points for the years 2001 to 2011 (years for which information is available). There is limited evidence to suggest that burning of crop residues is common practice in Ireland with only eight active fires (of the 602 identified) being within a 500m radius of cropland over the timeseries as shown through GIS analysis. The study is part of a larger body of work aimed at tracking land use change for inclusion in LULUCF estimates. Thus a published report is not available for this submission but can be provided to expert review teams if required.

Table 6.5. Percentage change in emissions from Agriculture due to Recalculations (1990-2011)

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
			Estimates in 2013 Submission (Gg)																					
4.A	Enteric Fermentation	CH_4	455.91	459.97	464.11	463.20	460.35	460.89	473.31	482.83	488.90	473.70	452.14	448.69	442.98	441.31	440.77	430.07	430.92	424.04	422.59	416.07	406.80	401.85
4.B	Manure Management	CH_4	112.08	113.04	114.26	113.94	112.98	112.64	116.97	119.57	120.94	115.83	110.18	110.46	109.93	108.66	107.87	107.85	107.29	104.68	104.48	103.75	102.51	101.55
4.B	Manure Management	N_2O	1.40	1.46	1.47	1.47	1.49	1.51	1.57	1.62	1.66	1.60	1.53	1.54	1.53	1.52	1.54	1.56	1.52	1.49	1.51	1.50	1.44	1.41
4.D.1	Direct Soil emissions	N_2O	9.75	9.59	9.35	9.72	10.29	10.82	10.71	10.07	11.10	11.22	10.45	9.69	9.56	10.08	9.68	9.40	9.03	8.61	8.37	8.27	9.30	8.91
4.D.2	Pasture Range and Paddock	N_2O	9.25	9.41	9.59	9.57	9.56	9.59	9.83	10.05	10.30	10.06	9.64	9.56	9.46	9.48	9.45	9.06	9.07	8.89	8.81	8.73	8.52	8.42
4.D.3	Indirect emissions	N_2O	4.45	4.47	4.48	4.55	4.66	4.76	4.81	4.74	5.03	4.99	4.70	4.54	4.51	4.60	4.48	4.37	4.32	4.18	4.14	4.13	4.30	4.23
4	Total Methane	CH_4	567.99	573.01	578.38	577.14	573.33	573.54	590.28	602.40	609.83	589.52	562.32	559.15	552.92	549.97	548.64	537.92	538.21	528.71	527.07	519.82	509.30	503.40
4	Total Nitrous oxide	N_2O	24.86	24.92	24.89	25.30	25.99	26.68	26.92	26.48	28.09	27.87	26.33	25.33	25.06	25.68	25.14	24.39	23.94	23.17	22.83	22.63	23.55	22.97
4	Total (CO_2 eq)	CO_2 eq	19,634.08	19,757.40	19,862.29	19,964.15	20,097.37	20,314.40	20,740.09	20,858.61	21,513.18	21,018.65	19,970.19	19,594.75	19,378.62	19,510.45	19,315.01	18,857.48	18,723.70	18,284.27	18,146.98	17,932.52	17,996.85	17,693.21
			Recalculated Estimates in 2014 Submission (Gg)																					
4.A	Enteric Fermentation	CH_4	455.91	459.97	464.11	463.20	460.35	460.89	473.31	482.83	488.90	473.70	452.14	448.69	442.98	441.31	440.77	430.07	430.92	424.04	422.59	416.07	406.74	402.86
4.B	Manure Management	CH_4	112.08	113.04	114.26	113.94	112.98	112.64	116.97	119.57	120.94	115.83	110.18	110.46	109.93	108.66	107.87	107.85	107.29	104.68	104.48	103.75	102.46	101.74
4.B	Manure Management	N_2O	1.40	1.46	1.47	1.47	1.49	1.51	1.57	1.62	1.66	1.60	1.53	1.54	1.53	1.52	1.54	1.56	1.52	1.49	1.51	1.50	1.45	1.42
4.D.1	Direct Soil emissions	N_2O	9.75	9.59	9.35	9.72	10.29	10.82	10.71	10.07	11.10	11.22	10.45	9.69	9.56	10.08	9.68	9.40	9.03	8.61	8.37	8.27	9.30	8.03
4.D.2	Pasture Range and Paddock	N_2O	9.25	9.41	9.59	9.57	9.56	9.59	9.83	10.05	10.30	10.06	9.64	9.56	9.46	9.48	9.45	9.06	9.07	8.89	8.81	8.73	8.54	8.46
4.D.3	Indirect emissions	N_2O	4.45	4.47	4.48	4.55	4.66	4.76	4.81	4.74	5.03	4.99	4.70	4.54	4.51	4.60	4.48	4.37	4.32	4.18	4.14	4.13	4.30	3.97
4	Total Methane	CH_4	567.99	573.01	578.38	577.14	573.33	573.54	590.28	602.40	609.83	589.52	562.32	559.15	552.92	549.97	548.64	537.92	538.21	528.71	527.07	519.82	509.20	504.59
4	Total Nitrous oxide	N_2O	24.86	24.92	24.89	25.30	25.99	26.68	26.92	26.48	28.09	27.87	26.33	25.33	25.06	25.68	25.14	24.39	23.94	23.17	22.83	22.63	23.59	21.89
4	Total (CO_2 eq)	CO_2 eq	19,634.08	19,757.40	19,862.29	19,964.15	20,097.37	20,314.40	20,740.09	20,858.61	21,513.18	21,018.65	19,970.19	19,594.75	19,378.62	19,510.45	19,315.01	18,857.48	18,723.70	18,284.27	18,146.98	17,932.52	18,005.58	17,381.83
			Percentage Change in Total Emissions due to Recalculations																					
4.A	Enteric Fermentation	CH_4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.25%
4.B	Manure Management	CH_4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.05%	0.18%
4.B	Manure Management	N_2O	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.42%	0.49%
4.D.1	Direct Soil emissions	N_2O	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	-9.86%
4.D.2	Pasture Range and Paddock	N_2O	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.23%	0.47%
4.D.3	Indirect emissions	N_2O	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.14%	-5.98%
4	Total Methane	CH_4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.02%	0.24%
4	Total Nitrous oxide	N_2O	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.15%	-4.72%
4	Total (CO_2 eq)	CO_2 eq	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	-1.76%

Chapter Seven

Land-Use, Land-Use Change and Forestry

7.1 Introduction

Following the publication of the IPCC Special Report on Land Use, Land-Use Change and Forestry (LULUCF) and adoption of the IPCC good practice guidance on Land Use, Land-Use Change and Forestry (IPCC, 2003), the source category classification for reporting on the LULUCF sector was revised by Decision 13/CP.9 to that given in Table 7.2.1. The six top-level categories are used to represent managed land areas and they are broadly defined to accommodate all land areas in most countries, taking into account possible differences in national classification systems. Each category is split into two sub-categories, which are, in some cases, further sub-divided to reflect national circumstances and the level of detail considered most appropriate for the estimation of relevant emissions and removals. The conversion sub-categories allow for the tracking of land to the principal fixed categories using 1990 as a base year. Hence, the two sub-categories cover lands remaining the initial land use before 1990 and lands converted to other land uses since 1990. Previous inventories for Ireland used the 20 year transition before lands converted to other land uses are reclassified into the lands remaining the land use category, unless otherwise stated. The revised approach attempts to address issues of consistency and comparability of activities reported under the convention and those reported under the Kyoto Protocol. The area-based approach is intended to make the best use of the various types of data likely to be available for the given categories of land and reduce possible overlaps and omissions in reporting for national total land areas.

The net CO_2 emissions to, or removals from, the atmosphere are to be reported with respect to overall carbon gain or loss for up to five relevant carbon pools for the defined land categories. These pools are above-ground biomass, below-ground biomass, dead organic matter (litter and dead wood) and soils. For Convention reporting above-ground biomass and below-ground biomass are reported together as living biomass and litter and deadwood are reported together as dead organic matter (DOM). The IPCC good practice guidance on LULUCF provides basic methodologies for calculating changes in carbon pools where land areas form the basic activity data and carbon stock change is determined from a number of other parameters. Various levels of land sub-division may be used to capture differences due to climate, management system, vegetation type or other factors influencing carbon exchange. As for other sectors of the inventory, the IPCC good practice guidance for LULUCF also provides higher tier methods for estimating emissions and removals, which may be used if the necessary data are available. The liming of agricultural lands, which produces CO_2 emissions, is another important source included in the LULUCF sector. Emissions of N_2O in the LULUCF sector are reported for such activities as soil disturbance associated with land-use conversion to cropland and optionally for drainage of forest land and wetlands, while taking into account potential overlap with the *Agriculture* sector in some cases. Emissions of N_2O and CH_4 are also to be reported for biomass burning.

7.2 Overview of LULUCF Sector

7.2.1 Sector Coverage

The 2006 inventory submission included the results of Ireland's first attempts to comply with the reporting requirements of Decision 13/CP.9 for the LULUCF sector. Following the same basic approach, complete coverage of the relevant gases has been achieved for the years 1990-2012 in all IPCC land categories, as indicated by Table 7.2.1. This chapter presents a broad description of data treatment and the methodologies used to estimate emissions and removals for the relevant land categories in the time-series 1990-2012. The estimates for 5.A Forest Land are prepared under the responsibility of COFORD/Department of Agriculture Food and the Marine (DAFM) and submitted to the inventory agency in accordance with the memorandum of understanding (MOU) between DAFM and the Office of Climate Licensing and Resource Use (OCLR) of the EPA (see section 1.3 of this report). All other emissions and removals estimates are prepared by a research fellow working directly to the inventory agency in OCLR. A detailed report on the work undertaken to report for the 2006 inventory submission on the LULUCF sector is available (O'Brien, 2008), with subsequent revisions to methodology reported in this report where necessary.

Table 7.2.1. Level 3 Source Category Coverage for Land Use, Land-Use Change and Forestry

5 Land Use Land-Use Change and Forestry	Carbon Stock Change Emissions of CO_2			CH_4	N_2O
	Biomass	DOM	Soils		
A. Forest Land					
1. Forest Land remaining Forest Land	All	All	All, NA	All	Part, IE
2. Land converted to Forest Land	All	All	All, NA	NA	IE
B. Cropland					
1. Cropland remaining Cropland	NO	NO	NO*	NA	IE
2. Land converted to Cropland	All	NO	All	NA	All
C. Grassland					
1. Grassland remaining Grassland	NO	NO	All, NO*	NO	IE
2. Land converted to Grassland	All	NO	All	NO	IE
D. Wetlands					
1. Wetlands remaining Wetlands	All	NO	All	NO	IE
2. Land converted to Wetlands	All	NO	All	NO	All
E. Settlements					
1. Settlements remaining Settlements	NO	NO	NA	NO	NA
2. Land converted to Settlements	All	NO	All	NO	NA
F. Other Land					
1. Other Land remaining Other Land	NO	NO	NO*	NO	NO
2. Land converted to Other Land	NO	NO	All	NO	NO
G. Other					
Agricultural Lime Application	NA	NA	All	NA	NA

Biomass - includes above and below ground biomass
DOM - dead organic matter (deadwood and litter)
All - all emission sources covered; NE - emissions not estimated; NO - activity not occurring; NA - not applicable (no emissions of the gas occur in the pool/source category); IE - emissions included elsewhere.
** Under the Tier 1 method, there is no carbon stock change in soil for these land categories , if there is no change in management*

The 1990-2012 inventory for LULUCF (submission 2014) follows the same general approach and methodologies as those used for the submissions from 2008 to 2013. However, in response to previous annual review reports (ARR) reports (2010, 2011 and 2012) there have been significant changes to all LULUCF categories to ensure transparent and consistent reporting of activities and land use transition under the Convention and under the Kyoto Protocol. In particular, in the 2013 submission, there was a major reappraisal of the transition of areas remaining in a land use category and those lands converted to other land uses. Previous CRF tables 5.A to 5.F reported land use transition based on a 20-year transition. This new approach reports all land areas converted to another land use after the1st of

January 1990, and lands not subject to land use change before the the1st of January 1990. For example, forest land remaining forests (5.A) includes all forest area remaining forest before 1990 and lands converted to forests after 1990. This now ensures consistent and transparent comparison of areas reported under Convention reporting and those elected under KP LULUCF.

In the 2014 submission, a significant reclassification of natural grasslands has been implemented. Whereas in previous submissions, natural grasslands, i.e. unmanaged native grassland, were included in the Other Land category, in this year's submission, natural grasslands are included in the Grassland land use category. Also in the 2014 submission, an estimate has been made, for the first time, for the carbon change in soils due to conversion to Settlement from other land uses.

The estimates of emissions and removals from LULUCF over the period 1990-2012 are presented in Table 7.2.2 for all land-use categories. The LULUCF sector a net sink of carbon in all years, with removals increasing substantially towards the end of the reported time-series. This result is determined mainly by the balance between the removals in category *5.A Forest Land* and the emissions from *5.C Grassland* and from lime applications. The most important individual emission categories over the time-series are the carbon releases from soils in *5.A.2 Land Converted to Forest Land* and the CO_2 emissions from agricultural lime application on Grassland and Cropland. The increase in carbon stocks in living biomass in the category *5.A.1 Forest Land remaining Forest Land* is the dominant removal that offsets CO_2 emissions.

The Wetland, Settlements and Other Land categories are comparatively less important in terms of emissions or removals but Cropland constitutes a significant net source of carbon to the atmosphere towards the end of the time series. The inclusion of CH_4 and N_2O through the coverage of additional emission sources has a very minor effect on total emissions from LULUCF.

7.2.2 Land Use Definitions and Land Use Change Matrices

Table 7.2.3 summarises the definitions and coverage of the IPCC land-use categories in the LULUCF sector as they relate to Ireland along with the data sources that are used for estimating the respective areas remaining in the categories before 1990, the areas converted to the categories since 1990 and their associated greenhouse gas emissions and removals. The IPCC *Wetlands* category has been sub divided into natural unexploited wetlands (unmanaged), and exploited peatlands, the latter being managed wetland areas that are drained for the purpose of commercial and domestic harvesting of peat for combustion or horticultural use.

Table 7.2.4 records the net change in land-use area among the various categories over the period 1990-2012 in the form of land-use change matrices for the individual years relative to the total national area of 7.11 million hectares, based on a combination of CORINE land-cover data, forest statistics and digital afforestation maps (see Figure 7.2.1 and Section 7.3.1). Annex H.2 give a more detailed breakdown of the annual exchange of land between land use types and the cumulative change over time. The matrices of land use are intended to show the dynamism of changes in Irish land use and to identify the conversions that are most significant in terms of their potential to contribute to either emissions or removals of greenhouse gases over the inventory time-series. As mentioned, the relationship between areas afforested since 1990 (KP Article 3.3 sub-category AR) are now fully consistent with convention area in lands converted to forest land since 1990.

7.2.2.1 Land use classification hierarchy

The flow diagram shown in Figure 7.2.1 illustrates how different data sources are used to derive land use categories in a hierarchal manner. Forest lands are initially derived using forest datasets and statistics. This is primarily based on Forest Information and Planning System which used 1995 as the baseline (FIPS 95), afforestation and deforestation data (see section 7.3.1 and Annex H). The areas under forest land include open areas within forest boundaries. The submission includes biomass CSC for these areas using information obtained from the 2006 national forest inventory and a reconstruction of historical age class distributions (see section 7.3.2) Emissions from soils are reported for all areas besides open areas within forest boundaries (e.g. forest roads, biodiversity areas not covered by trees) where no drainage occurs. Identification of land cover type converted to forest land (L-F) is based on an analysis of the EU Coordination of Information on the Environment (CORINE) land cover data set. Deforestation in identified forests areas is assessed using a combination of CORINE, National Forest Inventory data (NFI), maps and aerial photography datasets to obtain information on transitions to other land use categories (see section 7.3.1).

Other land use categories (i.e. non-forest land) are then allocated to other land uses using other generally non-spatial data sources such as annual publication of agricultural areas from the Central Statistics Office of Ireland, or specific information from industry experts, as in the case of areas of industrial drainage of peatland for exploitation. Additional spatial databases such as the Land Parcel Information System, CORINE, Irish General Soils Map, are used estimate the soil types associated with each land use. However, these data do not have sufficient resolution, spatially or temporally, to allow land use tracking. Table 7.2.3 details the data sources used to estimate land use areas and soil types typical of each land use type.

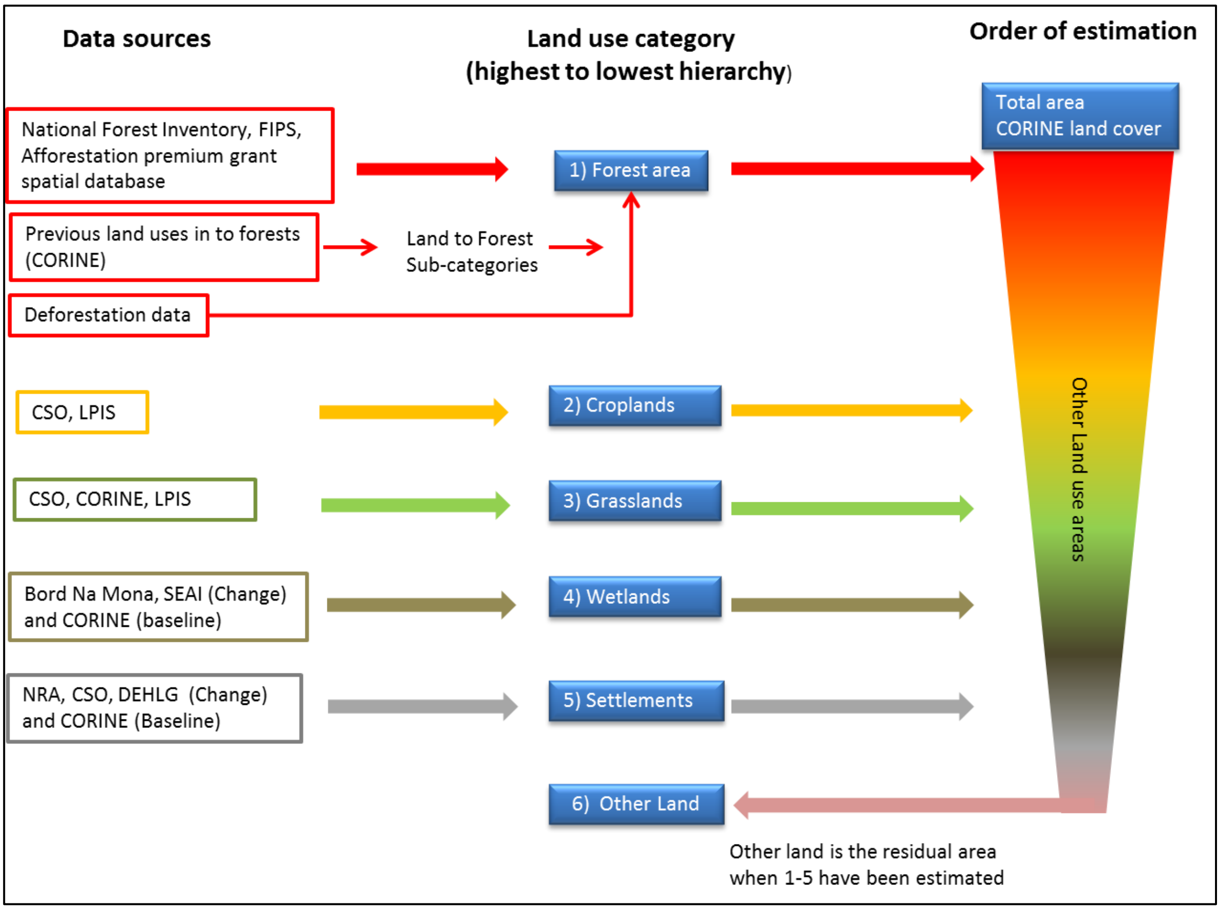


Figure 7.2.1 Methodologies and hierarchy of determining land use areas and transitions

See table 7.2.3 for a detailed description of data sources. Other Land is derived from the land not included in the forest, cropland, wetland and settlement areas and as such is the residual land area not included on the other land categories.

7.2.3 Land use change trends

The reclassification of the transition period for a 20 year period to pre and post 1990 for all LULUCF categories, except Other Land, has resulted in a significant change in land use change trends.

Grassland is the dominant land-use category in all years, accounting for 62.1 per cent of total area in 1990, followed by *Wetland* accounting for 18.4 per cent. The Forest Land covered 6.8 per cent, followed and C*ropland* at 5.7 per cent and Settlements at 1.4 per cent. Other Land is the residual land use at 5.6 per cent. The major land-use changes since 1990 have been the conversion of Grassland and Wetland to Forest Land. In 2012, Grassland accounted for 61.0 per cent of land area, Wetland 16.2 per cent, Forest Land 10.4 per cent, Other Land 5.4 per cent, with Cropland at 5.4 per cent and Settlement 1.6 per cent.

Table 7.2.2. Emissions[a] and Removals[a] from Land Use Land-Use Change and Forestry 1990-2012 (Gg CO_2 eq)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
		Estimates in 2013 Submission (Gg CO_2 eq.)																						
5.A	**Forest Land**	**-2,956.0**	**-3,068.9**	**-2,435.6**	**-3,128.4**	**-2,661.5**	**-2,279.5**	**-2,126.9**	**-3,367.3**	**-2,714.9**	**-2,772.0**	**-2,253.4**	**-2,126.3**	**-2,010.9**	**-2,520.2**	**-3,689.6**	**-3,410.1**	**-3,362.0**	**-3,892.8**	**-5,285.0**	**-5,379.9**	**-4,483.2**	**-4389.8**	**-3815.8**
5.A.1	Forest Land remaining Forest Land (CO_2)	-3,007.7	-3,066.3	-2,369.6	-3,010.3	-2,457.2	-1973.1	-1682.3	-2,763.1	-1949.6	-1825.2	-1,104.3	-769.5	-409.7	-671.9	-1,568.7	-972.7	-669.4	-1,122.9	-2,152.5	-1990.2	-878.3	-642.7	-9.0
5.A.2	Land converted to Forest Land (CO_2)	17.6	-34.6	-96.3	-153.4	-240.4	-351.0	-488.7	-641.9	-802.0	-980.8	-1,192.7	-1410.3	-1638.7	-1911.1	-2,173.3	-2,480.0	-2,734.8	-2,812.6	-3,175.7	-3,430.5	-3,664.9	-3793.5	-3847.3
5.A	Biomass burning (CH_4 and N_2O)	10.1	6.5	4.2	8.4	9.7	13.2	14.7	8.0	4.2	3.5	8.7	17.3	4.0	24.5	14.3	5.2	5.2	5.8	6.0	3.4	22.2	8.2	2.1
5.A	Drainage of soils	24.0	25.5	26.1	26.9	26.5	31.4	29.5	29.6	32.4	30.6	34.9	36.2	33.5	38.3	38.1	37.4	37.1	36.9	37.2	37.5	37.8	38.2	38.4
5.B	**Cropland**	**20.0**	**21.2**	**25.6**	**25.6**	**-49.9**	**-21.9**	**43.9**	**78.4**	**24.8**	**0.4**	**46.7**	**135.6**	**129.5**	**176.6**	**135.6**	**161.8**	**108.3**	**132.3**	**443.1**	**254.5**	**293.6**	**377.6**	**422.4**
5.B.1	Cropland remaining Cropland	20.0	21.2	9.7	-58.9	-87.5	-62.9	-25.1	-20.1	-39.1	-63.6	-22.2	-28.2	-34.7	-35.3	-26.3	-0.1	-53.6	-29.6	-20.6	-27.3	11.8	20.2	9.6
5.B.2	Land converted to Cropland	NO	NO	15.3	80.8	33.9	36.9	62.7	92.1	57.6	57.6	62.4	153.3	151.4	195.8	145.8	145.8	145.8	145.8	435.6	253.7	253.7	326.4	377.8
5.B	Agricultural Lime Application[b]	36.7	32.5	26.3	37.0	27.5	50.3	50.3	44.3	31.4	38.9	37.2	40.5	29.7	43.2	26.4	26.8	25.5	37.2	29.7	33.4	40.6	35.2	23.4
5.B.2	Emissions from soil disturbance	NA,NO	NA,NO	0.6	3.7	3.7	4.1	6.4	6.4	6.4	6.4	6.6	10.5	12.8	16.1	16.1	16.1	16.1	16.1	28.1	28.1	28.1	31.0	35.1
5.C	**Grassland**	**493.9**	**568.5**	**435.4**	**347.3**	**396.9**	**769.4**	**736.0**	**689.5**	**488.2**	**588.4**	**677.3**	**626.4**	**556.2**	**621.7**	**406.8**	**233.6**	**154.6**	**199.0**	**168.3**	**400.4**	**59.7**	**72.9**	**-52.2**
5.C.1	Grassland remaining Grassland	600.3	612.6	476.0	387.8	446.2	711.7	678.4	639.2	461.2	577.8	594.3	543.3	473.0	538.4	394.2	400.9	365.2	399.5	346.0	348.2	450.7	341.3	302.8
5.C.2	Land converted to Grassland	-106.4	-44.1	-40.6	-40.5	-49.3	57.6	57.6	50.3	27.1	10.6	82.9	83.0	83.1	83.2	12.5	-167.3	-210.5	-200.5	-177.7	52.2	-391.0	-268.4	-355.0
5.C	Agricultural Lime Application[b]	318.4	282.6	229.3	320.3	242.2	444.3	433.7	379.2	274.2	344.4	329.1	344.8	244.2	343.6	214.4	239.9	229.4	339.5	232.5	273.9	387.3	325.5	206.0
5.D	**Wetlands**	**50.7**	**49.0**	**49.1**	**47.4**	**45.4**	**43.8**	**41.5**	**39.9**	**38.5**	**49.3**	**457.8**	**455.8**	**453.1**	**450.4**	**436.8**	**440.1**	**32.0**	**292.2**	**36.9**	**42.8**	**39.4**	**235.7**	**34.9**
5.D.1	Wetlands remaining Wetlands	47.1	45.5	45.5	44.0	41.9	40.3	38.1	36.5	35.2	46.1	43.5	42.0	39.8	37.6	24.5	27.7	30.8	33.1	35.9	38.7	38.6	38.5	34.1
5.D.2	Land converted to Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	411.2	410.8	410.4	410.0	409.7	409.7	-1.5	256.4	-1.6	1.5	-1.8	194.6	-1.8
5.D	Drainage of soils	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.5
5.E	**Settlements**	**77.9**	**71.7**	**72.7**	**77.3**	**93.8**	**88.1**	**111.6**	**122.3**	**132.0**	**141.3**	**187.3**	**237.6**	**221.2**	**261.2**	**272.9**	**311.5**	**349.4**	**559.8**	**495.9**	**177.1**	**223.4**	**55.6**	**256.5**
5.E.1	Settlements remaining Settlements	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
5.E.2	Land converted to Settlements	77.9	71.7	72.7	77.3	93.8	88.1	111.6	122.3	132.0	141.3	187.3	237.6	221.2	261.2	272.9	311.5	349.4	559.8	495.9	177.1	223.4	55.6	256.5
5.F	**Other Land**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**26.3**	**27.1**	**27.4**	**27.7**	**27.9**	**46.5**	**47.9**	**48.2**	**48.6**	**48.9**	**49.3**	**1,413.4**	**7.7**	**9.1**	**9.3**	**9.3**	**9.3**	**9.3**
5.F.1	Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.F.2	Land converted to Other Land	0.9	0.9	0.9	0.9	0.9	26.3	27.1	27.4	27.7	27.9	46.5	47.9	48.2	48.6	48.9	49.3	1,413.4	7.7	9.1	9.3	9.3	9.3	9.3
5.G	**G. Other**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
5	**TOTAL LULUCF CO_2 (net emissions/removals)**	**-2,350.2**	**-2,393.1**	**-1,886.3**	**-2,672.4**	**-2,217.8**	**-1,426.0**	**-1,220.6**	**-2,457.1**	**-2,050.0**	**-2,008.3**	**-891.1**	**-690.1**	**-656.0**	**-1,043.6**	**-2,459.8**	**-2,275.3**	**-1,365.4**	**-2,763.2**	**-4,205.7**	**-4,567.3**	**-3,948.4**	**-3718.6**	**-3223.0**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**-2,312.6**	**-2,357.6**	**-1,852.0**	**-2,629.9**	**-2,174.4**	**-1,373.9**	**-1,166.7**	**-2,409.9**	**-2,003.7**	**-1,964.7**	**-837.9**	**-623.1**	**-602.7**	**-961.8**	**-2,388.5**	**-2,213.8**	**-1,304.3**	**-2,701.6**	**-4,131.7**	**-4,495.8**	**-3,857.8**	**-3638.6**	**-3144.9**

[a] positive values indicate emissions and negative values indicate removals

[b] the emissions from lime application to grassland and cropland are reported in CRF Table 5(IV) rather than under Grassland in CRF Tables 5.B and 5.C, respectively. These emissions are not included in the totals for 5.C Grassland and 5.B Cropland

Table 7.2.3. Land Use Categories

Land Use Category	Definition and Coverage	Area 1990 (ha)	Area 2012 (ha)	Percentage change 1990-2012	Sources of Information	Principal Conversions	
						To	**From**
Forest Land**	All public and private plantation forests. Forest land is an area of land where tree crown cover is greater than 20% of the total area occupied. It has a minimum width of 20m and a minimum area of 0.1ha and includes all trees with a potential to reach 5m in height in situ. Trees grown for fruit or horticulture are excluded, as are non-tree woody species such as furze and rhododendron. The forest area includes open areas within forest boundaries, assumed to be 15% based on NFI statistics.	481,074	742,481	+54.3%	National Forest Inventory (NFI) FIPS (Forest Inventory and Planning System) 1995 COILLTE database Forest Service Premiums database CORINE Land Cover General Soil Map Deforestation statistics	Grassland Wetland Settlement Other land	Grassland Wetland
Cropland	Permanent crops and tillage areas (including set-aside) recorded by the Central Statistics Office (CSO)	404,562	380,500	-5.9%	Central Statistics Office (CSO), CORINE Land cover, LPIS (Land Parcel Information System) and expert opinion on soil types	Grassland	Grassland
Grassland	Areas of improved grassland (pasture and areas used for the harvesting of hay and silage) and unimproved grassland in use (rough grazing) as recorded by CSO annual statistics. with extrapolation of long term trends to estimate values in 2010 to 2012. Natural grassland as estimated using CORINE Land Cover.	4,432,760	4,334,917	-2.2%	CSO, CORINE Land Cover LPIS (Land Parcels information System) General Soil Map for Ireland	Cropland	Other Land
Unmanaged Wetlands	Natural unexploited wetlands	1,225,898	1,096,955	-10.5%	CORINE Land Cover General Soil Map for Ireland	Peatlands	Forestry
Managed Wetland	Wetland areas commercially exploited for public and private extraction of peat and areas used for domestic harvesting of peat	73,452	52,422	-28.6%	Bord na Mona (BNM) area statistics; Expert opinion	Wetlands, Grassland	
Settlements	Urban areas, roads, airports and the footprint of industrial, commercial/institutional and residential buildings	98,145	117,269	+19.5%	CORINE Land Cover; National Roads Authority (NRA) road construction statistics; CSO housing stock, house completions and other construction floor area statistics; General Soil Map		Grassland, Forest Land
Other Land	Residual when all other land use area have been determined	395,894	387,241	-2.2%	CORINE, (includes, water bodies, bare rock etc.)	Forest land	
Total Land	National territorial area (including inland water bodies and salt marshes and intertidal zones)	7,111,785	7,111,785		CORINE Land Cover		

Table 7.2.4 Summary Land Use Matrices 1990-2012 (units ha)

	Forest	Grassland	Cropland	Managed Wetland	Unmanaged Wetlands	Settlements	Other land	Total	Total Wetlands
1989	**465,278**	**4,419,271**	**424,648**	**74,051**	**1,234,375**	**97,777**	**396,386**	**7,111,785**	**1,308,426**

Forest	**465,278**	**-4,737**	**-1,582**	**-320**	**-8,696**	**10**	**-472**		
Grassland	4,737	4,419,271	-18,475	-61	0	310	0		
Cropland	1,582	18,475	424,648	0	0	28	0		
Managed Wetland	320	61	0	74,051	219	0	0		
Unmanaged Wetland	8,696	0	0	-219	1,234,375	0	0		
Settlements	-10	-310	-28	0	0	97,777	-20		
Other land	472	0	0	0	0	20	396,386		
1990	**481,074**	**4,432,760**	**404,563**	**73,452**	**1,225,898**	**98,145**	**395,894**	**7,111,785**	**1,299,350**

Forest	**481,074**	**-5,736**	**-1,915**	**-320**	**-10,594**	**10**	**-572**		
Grassland	5,736	4,432,760	-929	-61	0	282	0		
Cropland	1,915	929	404,563	0	0	25	0		
Managed Wetland	320	61	0	73,452	563	0	0		
Unmanaged Wetland	10,594	0	0	-563	1,225,898	0	0		
Settlements	-10	-282	-25	0	0	98,145	-18		
Other land	572	0	0	0	0	18	395,894		
1991	**500,201**	**4,427,732**	**401,694**	**72,508**	**1,215,867**	**98,480**	**395,303**	**7,111,785**	**1,288,375**

Forest	**500,201**	**-5,002**	**-1,670**	**-320**	**-9,198**	**10**	**-499**		
Grassland	5,002	4,427,732	2,618	-61	0	286	0		
Cropland	1,670	-2,618	401,694	0	0	26	0		
Managed Wetland	320	61	0	72,508	163	0	0		
Unmanaged Wetland	9,198	0	0	-163	1,215,867	0	0		
Settlements	-10	-286	-26	0	0	98,480	-19		
Other land	499	0	0	0	0	19	395,303		
1992	**516,879**	**4,419,887**	**402,616**	**71,964**	**1,206,832**	**98,821**	**394,786**	**7,111,785**	**1,278,796**

Forest	**516,879**	**-4,791**	**-1,600**	**-320**	**-8,799**	**10**	**-478**		
Grassland	4,791	4,419,887	12,797	-61	0	306	0		
Cropland	1,600	-12,797	402,616	0	0	28	0		
Managed Wetland	320	61	0	71,964	343	0	0		
Unmanaged Wetland	8,799	0	0	-343	1,206,832	0	0		
Settlements	-10	-306	-28	0	0	98,821	-20		
Other land	478	0	0	0	0	20	394,786		
1993	**532,857**	**4,402,054**	**413,785**	**71,241**	**1,198,376**	**99,185**	**394,288**	**7,111,785**	**1,269,616**

Table 7.2.4 Summary Land Use Matrices 1990-2012 (units ha) (continued)

Forest	**532,857**	**-5,830**	**-1,946**	**-320**	**-10,772**	**10**	**-582**		
Grassland	5,830	4,402,054	-1,504	-61	0	380	0		
Cropland	1,946	1,504	413,785	0	0	34	0		
Managed Wetland	320	61	0	71,241	167	0	0		
Unmanaged Wetland	10,772	0	0	-167	1,198,376	0	0		
Settlements	-10	-380	-34	0	0	99,185	-25		
Other land	582	0	0	0	0	25	394,288		
1994	**552,295**	**4,397,409**	**410,301**	**70,693**	**1,187,771**	**99,634**	**393,682**	**7,111,785**	**1,258,464**

Forest	**552,295**	**-6,846**	**-2,371**	**-140**	**-13,375**	**0**	**-645**		
Grassland	6,846	4,397,409	1,381	-30	0	392	0		
Cropland	2,371	-1,381	410,301	0	0	35	0		
Managed Wetland	140	30	0	70,693	650	0	0		
Unmanaged Wetland	13,375	0	0	-650	1,187,771	0	0		
Settlements	0	-392	-35	0	0	99,634	-26		
Other land	645	0	0	0	0	26	393,682		
1995	**575,672**	**4,388,820**	**409,277**	**69,873**	**1,175,046**	**100,086**	**393,012**	**7,111,785**	**1,244,919**

Forest	**575,672**	**-6,028**	**-2,098**	**-140**	**-11,819**	**0**	**-563**		
Grassland	6,028	4,388,820	9,418	-30	0	497	0		
Cropland	2,098	-9,418	409,277	0	0	45	0		
Managed Wetland	140	30	0	69,873	1,047	0	0		
Unmanaged Wetland	11,819	0	0	-1,047	1,175,046	0	0		
Settlements	0	-497	-45	0	0	100,086	-32		
Other land	563	0	0	0	0	32	393,012		
1996	**596,319**	**4,372,908**	**416,552**	**68,656**	**1,164,274**	**100,660**	**392,416**	**7,111,785**	**1,232,930**

Forest	**596,319**	**-3,164**	**-1,143**	**-140**	**-6,377**	**0**	**-276**		
Grassland	3,164	4,372,908	-1,260	-30	0	544	0		
Cropland	1,143	1,260	416,552	0	0	49	0		
Managed Wetland	140	30	0	68,656	732	0	0		
Unmanaged Wetland	6,377	0	0	-732	1,164,274	0	0		
Settlements	0	-544	-49	0	0	100,660	-36		
Other land	276	0	0	0	0	36	392,416		
1997	**607,420**	**4,370,490**	**414,100**	**67,754**	**1,158,629**	**101,289**	**392,104**	**7,111,785**	**1,226,383**

Forest	**607,420**	**-3,612**	**-1,293**	**-140**	**-7,229**	**0**	**-321**		
Grassland	3,612	4,370,490	-4,754	-30	0	587	0		
Cropland	1,293	4,754	414,100	0	0	53	0		
Managed Wetland	140	30	0	67,754	731	0	0		
Unmanaged Wetland	7,229	0	0	-731	1,158,629	0	0		
Settlements	0	-587	-53	0	0	101,289	-38		
Other land	321	0	0	0	0	38	392,104		
1998	**620,015**	**4,371,075**	**408,000**	**66,853**	**1,152,131**	**101,967**	**391,745**	**7,111,785**	**1,218,984**

Table 7.2.4 Summary Land Use Matrices 1990-2012 (units ha) (continued)

Forest	**620,015**	**-3,534**	**-1,267**	**-140**	**-7,081**	**0**	**-313**		
Grassland	3,534	4,371,075	-5,777	-30	0	629	0		
Cropland	1,267	5,777	408,000	0	0	57	0		
Managed Wetland	140	30	0	66,853	1,144	0	0		
Unmanaged Wetland	7,081	0	0	-1,144	1,152,131	0	0		
Settlements	0	-629	-57	0	0	101,967	-41		
Other land	313	0	0	0	0	41	391,745		
1999	**632,350**	**4,372,719**	**400,900**	**65,539**	**1,146,194**	**102,694**	**391,390**	**7,111,785**	**1,211,733**

Forest	**632,350**	**-4,308**	**-1,570**	**-327**	**-8,449**	**171**	**-356**		
Grassland	4,308	4,372,719	816	-75	0	517	0		
Cropland	1,570	-816	400,900	0	0	46	0		
Managed Wetland	327	75	0	65,539	1,628	0	0		
Unmanaged Wetland	8,449	0	0	-1,628	1,146,194	0	0		
Settlements	-171	-517	-46	0	0	102,694	-34		
Other land	356	0	0	0	0	34	391,390		
2000	**647,187**	**4,367,153**	**400,100**	**63,509**	**1,139,374**	**103,462**	**391,001**	**7,111,785**	**1,202,883**

Forest	**647,187**	**-4,433**	**-1,456**	**-327**	**-8,163**	**171**	**-401**		
Grassland	4,433	4,367,153	16,023	-75	0	738	0		
Cropland	1,456	-16,023	400,100	0	0	66	0		
Managed Wetland	327	75	0	63,509	1,542	0	0		
Unmanaged Wetland	8,163	0	0	-1,542	1,139,374	0	0		
Settlements	-171	-738	-66	0	0	103,462	-48		
Other land	401	0	0	0	0	48	391,001		
2001	**661,795**	**4,346,034**	**414,600**	**61,565**	**1,132,753**	**104,486**	**390,552**	**7,111,785**	**1,194,318**

Forest	**661,795**	**-4,492**	**-1,330**	**-327**	**-7,782**	**171**	**-437**		
Grassland	4,492	4,346,034	9,689	-75	0	661	0		
Cropland	1,330	-9,689	414,600	0	0	59	0		
Managed Wetland	327	75	0	61,565	1,546	0	0		
Unmanaged Wetland	7,782	0	0	-1,546	1,132,753	0	0		
Settlements	-171	-661	-59	0	0	104,486	-43		
Other land	437	0	0	0	0	43	390,552		
2002	**675,992**	**4,331,266**	**422,900**	**59,617**	**1,126,517**	**105,421**	**390,072**	**7,111,785**	**1,186,134**

Forest	**675,992**	**-2,670**	**-751**	**-327**	**-4,415**	**171**	**-249**		
Grassland	2,670	4,331,266	13,626	-75	0	837	0		
Cropland	751	-13,626	422,900	0	0	75	0		
Managed Wetland	327	75	0	59,617	1,545	0	0		
Unmanaged Wetland	4,415	0	0	-1,545	1,126,517	0	0		
Settlements	-171	-837	-75	0	0	105,421	-55		
Other land	249	0	0	0	0	55	390,072		
2003	**684,232**	**4,314,209**	**435,700**	**57,670**	**1,123,647**	**106,559**	**389,768**	**7,111,785**	**1,181,318**

Table 7.2.4 Summary Land Use Matrices 1990-2012 (units ha) (continued)

Forest	684,232	-3,008	-747	-327	-4,664	171	-307		
Grassland	3,008	4,314,209	-12,074	-75	0	886	0		
Cropland	747	12,074	435,700	0	0	80	0		
Managed Wetland	327	75	0	57,670	1,542	0	0		
Unmanaged Wetland	4,664	0	0	-1,542	1,123,647	0	0		
Settlements	-171	-886	-80	0	0	106,559	-58		
Other land	307	0	0	0	0	58	389,768		
2004	693,114	4,322,463	422,800	55,726	1,120,526	107,754	389,403	7,111,785	1,176,252

Forest	693,114	-3,260	-715	-133	-4,946	171	-356		
Grassland	3,260	4,322,463	-38,190	-88	0	1,055	0		
Cropland	715	38,190	422,800	0	0	95	0		
Managed Wetland	133	88	0	55,726	216	0	0		
Unmanaged Wetland	4,946	0	0	-216	1,120,526	0	0		
Settlements	-171	-1,055	-95	0	0	107,754	-69		
Other land	356	0	0	0	0	69	389,403		
2005	702,353	4,356,427	383,800	55,288	1,115,796	109,144	388,978	7,111,785	1,171,084

Forest	702,353	-3,617	-241	-133	-3,483	400	1,037		
Grassland	3,617	4,356,427	-4,678	-88	0	900	0		
Cropland	241	4,678	383,800	0	0	81	0		
Managed Wetland	133	88	0	55,288	195	0	0		
Unmanaged Wetland	3,483	0	0	-195	1,115,796	0	0		
Settlements	-400	-900	-81	0	0	109,144	-59		
Other land	-1,037	0	0	0	0	59	388,978		
2006	708,390	4,356,676	378,800	54,872	1,112,507	110,583	389,957	7,111,785	1,167,379

Forest	708,390	-3,229	-215	-133	-2,695	1,200	-502		
Grassland	3,229	4,356,676	-1,233	-88	0	580	0		
Cropland	215	1,233	378,800	0	0	52	0		
Managed Wetland	133	88	0	54,872	265	0	0		
Unmanaged Wetland	2,695	0	0	-265	1,112,507	0	0		
Settlements	-1,200	-580	-52	0	0	110,583	-38		
Other land	502	0	0	0	0	38	389,957		
2007	713,965	4,354,188	377,300	54,386	1,110,076	112,454	389,417	7,111,785	1,164,462

Forest	713,965	-2,412	-187	-133	-2,679	1,200	-37		
Grassland	2,412	4,354,188	49,120	-88	0	357	0		
Cropland	187	-49,120	377,300	0	0	32	0		
Managed Wetland	133	88	0	54,386	275	0	0		
Unmanaged Wetland	2,679	0	0	-275	1,110,076	0	0		
Settlements	-1,200	-357	-32	0	0	112,454	-23		
Other land	37	0	0	0	0	23	389,417		
2008	718,214	4,302,388	426,200	53,889	1,107,673	114,066	389,356	7,111,785	1,161,562

Table 7.2.4 Summary Land Use Matrices 1990-2012 (units ha) (continued)

Forest	**718,214**	**-2,592**	**-199**	**-133**	**-2,458**	**0**	**-466**		
Grassland	2,592	4,302,388	-17,234	-88	0	743	0		
Cropland	199	17,234	426,200	0	0	67	0		
Managed Wetland	133	88	0	53,889	252	0	0		
Unmanaged Wetland	2,458	0	0	-252	1,107,673	0	0		
Settlements	0	-743	-67	0	0	114,066	-48		
Other land	466	0	0	0	0	48	389,356		
2009	**724,062**	**4,316,376**	**408,700**	**53,415**	**1,105,467**	**114,924**	**388,842**	**7,111,785**	**1,158,882**
Forest	**724,062**	**-2,941**	**-249**	**-133**	**-3,608**	**0**	**-582**		
Grassland	2,941	4,316,376	-56,165	-88	0	949	0		
Cropland	249	56,165	408,700	0	0	85	0		
Managed Wetland	133	88	0	53,415	245	0	0		
Unmanaged Wetland	3,608	0	0	-245	1,105,467	0	0		
Settlements	0	-949	-85	0	0	114,924	-62		
Other land	582	0	0	0	0	62	388,842		
2010	**731,576**	**4,368,739**	**352,200**	**52,948**	**1,102,104**	**116,021**	**388,198**	**7,111,785**	**1,155,052**
Forest	**731,576**	**-1,794**	**-200**	**-133**	**-2,461**	**0**	**-466**		
Grassland	1,794	4,368,739	12,118	-88	0	202	0		
Cropland	200	-12,118	352,200	0	0	18	0		
Managed Wetland	133	88	0	52,948	244	0	0		
Unmanaged Wetland	2,461	0	0	-244	1,102,104	0	0		
Settlements	0	-202	-18	0	0	116,021	-13		
Other land	466	0	0	0	0	13	388,198		
2011	**736,629**	**4,354,714**	**364,100**	**52,482**	**1,099,888**	**116,254**	**387,719**	**7,111,785**	**1,152,370**
Forest	**736,629**	**-2,993**	**-200**	**0**	**-2,993**	**800**	**-466**		
Grassland	2,993	4,354,714	16,616	0	0	187	0		
Cropland	200	-16,616	364,100	0	0	17	0		
Managed Wetland	0	0	0	52,482	60	0	0		
Unmanaged Wetland	2,993	0	0	-60	1,099,888	0	0		
Settlements	-800	-187	-17	0	0	116,254	-12		
Other land	466	0	0	0	0	12	387,719		
2012	**742,481**	**4,334,917**	**380,500**	**52,422**	**1,096,955**	**117,269**	**387,241**	**7,111,785**	**1,149,376**

7.3 Forest Land (Category 5.A)

7.3.1 Overall approach and activity data

Ireland adopts the gains and losses approach for reporting biomass carbon stock changes (CSC) using tier 3 models. The reporting of other C pools is done using a C flow modelling framework. The activity data for identification of changes in forest area is based on a combination of different approaches using the following data sources (also see section 7.2.2):

- The 1995 forest information parcel data (FIPS95);
- The grant and premiums application system (GPAS) and spatial database (iFORIS) for identification of afforested lands since 1990. Information on identification of land uses converted to forest is derived from the CORINE land cover change 1990 to 2006 data set;
- Deforestation data is derived from a combination of sources including CORINE 1990 and 2000, FIPS95, National Forest Inventory (NFI) data, felling licence information and aerial photography;
- The forest fires database;
- Stratification of forest areas into different soil strata is done using NFI information and the EPA indicative soil map (IFS map).

The activity data used to derive state variables for the modelling framework is primarily derived from the FIPS95 data, harvest statistics and the 2006 NFI. The first Irish NFI was completed in 2006 and the second NFI inventory was completed in 2012. The NFI data is the primary activity data used to provide initial state variables within different forest strata for calculation of carbon stock changes (CSC) from 2006 onwards using the CARBWARE model (section 7.3.3.1 and Annex K). Estimation of CSC in the forest lands before 2006 cannot be determined using the CARBWARE model due to limited historical activity data on stand variables. Therefore, a more generalised stand model (FORCARB), based on British Forestry commission yield tables, is used to provide CSC estimates prior to 2006 (Edwards and Christy, 1981; Black et al., 2012).

Figure 7.3.1 shows a schematic overview of the activity data used by the different models and the different time series the model outputs represent. The CARBWARE model has been subject to external validation and uncertainty analysis and is considered more accurately represent CSC in Irish forests, when compared to the British forestry commission (BFC) based FORCARB model. The FORCARB model is based on static management interventions (i.e. set clearfelling at maximum mean annual increment and thinnings at a 5 year marginal thinning intensity cycle), which do not reflect management interventions in Ireland (Broad and Lynch, 2006; Black et al., 2008, 2012). In addition, it is well documented that the productivity index or yield class of the major species in Ireland, Sitka spruce, is higher than those in the UK, exceeding the highest documented BFC yield class (YC 24) table (Farrelly et al., 2011). Therefore, the CARBWARE v 5 model, which has been used for KP LULUCF reporting since 2008, is now also used for convention reporting from 2007 onward. Use of two different models for the historic and post 2006 time series does offer the potential of introducing a time series bias or inconsistency. However, this is addressed by re-scaling the historic (FORCARB) time series by interpolation against the CARBWARE model outputs as indicated in Figure 7.3.1 (also see section 7.3.4.1).

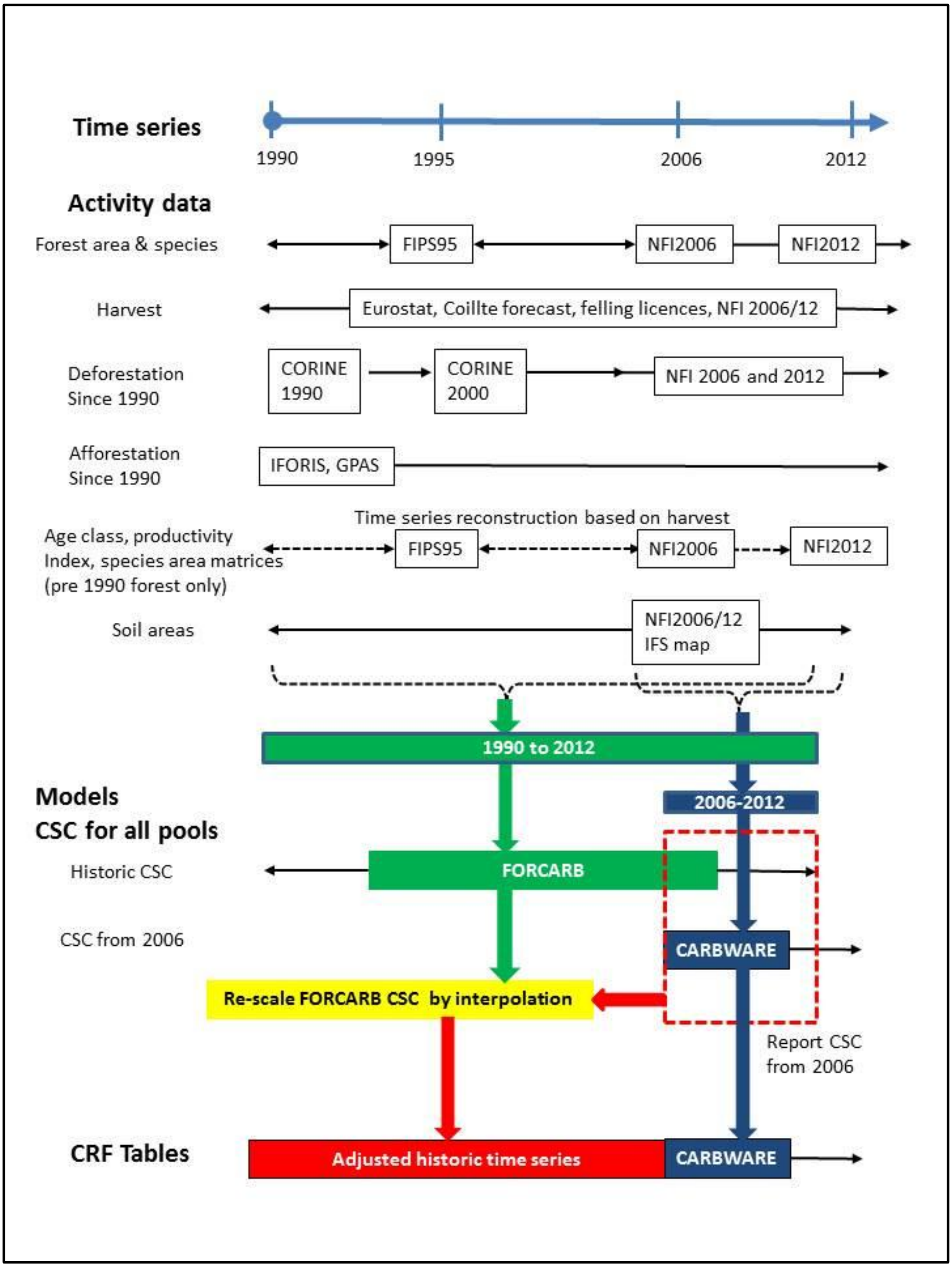


Figure 7.3.1 Activity data and models used to derive CSC for forest lands

Figure 7.3.1 shows the data sources used for different forest activities (clear boxes) are represented in relation to the time series. For example FIPS95 was collected in 1995 and is used to derive information of species and forest areas in forest land from 1990 to 2006 as indicated by the black arrows. The vertical brackets show which activity data is used by different modelling frameworks FORCARB and CARBWARE. The red open box and yellow box in figure 7.3.1 indicated interpolation and adjustment of the historic data against CARBWARE outputs to ensure a consistent representation of the entire time series.

7.3.2 Detailed description of activity data

7.3.2.1 FIPS95

A full survey of the private and state forests was completed in 1996 under the Forest Service's Forest Planning and Inventory System (FIPS 95). It provides information on areas by species as identified by remote sensing (Fogarty et al 1999). This activity data is used for the determination of forest areas, species and broad age class categories for 1995 used in the FORCARB model for forest land remaining forest category (Gallagher et al., 2004). The forest area going back to 1990 and projected forward to 2005 are derived from FIPS95 minus afforestation since 1990 (iFORIS data) and deforestation since 1990. The age class structure and yield class distribution for each year was reconstructed based on felling and replanting statistics and annual harvest data (see section 7.3). The FIPS 95 data provides no information on volume, stocking density or management of forest lands and cannot be used by the new CARBWARE model. However, it is used to provide historic CSC estimates for the period 1990 to 2006 using the FORCARB model, which are then subject to re-scaling using CARBWARE estimates (Figure 7.3.1 and section 7.3.4.1).

7.3.2.2 IFORIS

The IFORIS database is used to derive the total area of forests established before 1990 and afforestation areas of lands converted to forests since 1990. Ireland adopts combined approaches 2 and 3 as set out by the IPCC GPG (2003). Spatially explicit GIS polygons, representing all forest areas in 1995, were derived from the available FIPS 95 spatial layer. Digitised maps of afforested areas since 1990 using the Grants and Premiums Administration System (GPAS), archived in the iFORIS database (Figure 7.3.2). After attributing the species information with the unique ID from the Species Data table, the spatial and attribute data were joined in the Premiums layer, representing all afforested land since 1990. The data was quality controlled and the reasons for records not meeting the data validation criteria were recorded by the Forest Service. There were four separate stages in the data validation process, which occurred in successive iterations. The validated data were appended together and then reformatted and quality controlled. The FIPS95 afforested areas was then erased from the resulting Premiums table to produce the Forestry07 layer. These data sources are being updated for the new grant aided afforestation scheme areas. For example, the Forestry08 layer is derived from the GPAS08 data and the Forestry07 layer (Figure 7.3.2). Finally, the total forest areas and afforestation area is derived directly from the GPAS and IFORIS database after removal of areas identified as deforested (see deforestation data).

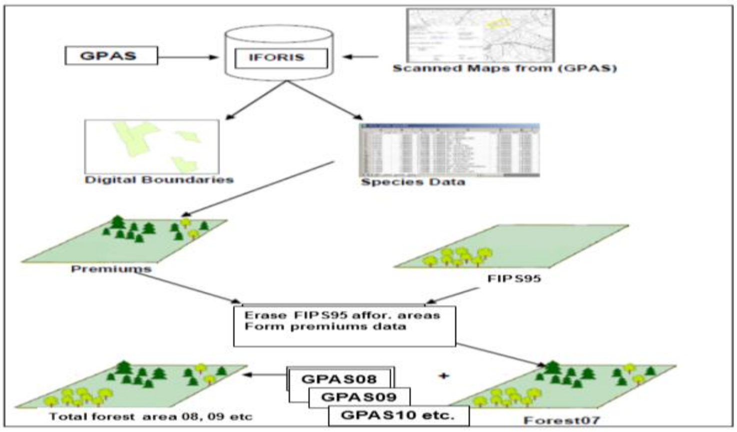


Figure 7.3.2 The process involved in deriving the total forest area and afforestation areas since 1990 using the IFORIS database

7.3.2.3 The National Forest Inventory

Ireland's first National Forest Inventory was completed in 2006 using a sampling approach, based on a randomised systematic grid sample design. The second inventory was completed in 2012. This system is also designed to track land use change trends. A pilot study in Co. Wexford showed that a grid resolution of 2 km x 2 km was required to provide the density of plots needed to achieve a national estimate of timber volume with a precision of 95 per cent at the 95 per cent confidence level. This grid resolution equates to 17,423 points nationally, each representing approximately 400 ha.

There are three stages of land-use classification undertaken in the NFI, primarily to identify forest areas according to the forest definition (see chapter 11). These stages are land-use type, land-use category and land-use class (Figure 7.3.3). They form the basis of the NFI, as the classification process dictates whether the sample points are included in the NFI or not, and also the range of attributes to be collected at the individual sample points.

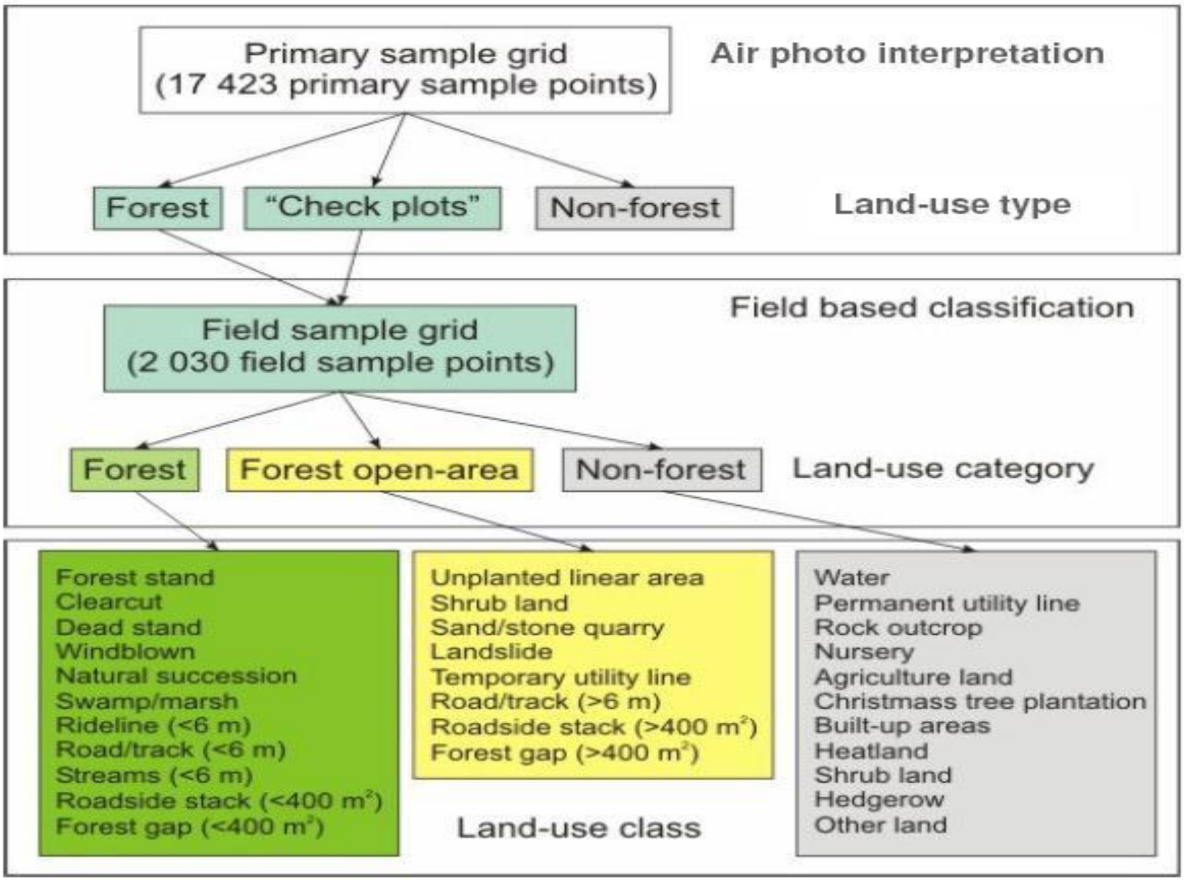
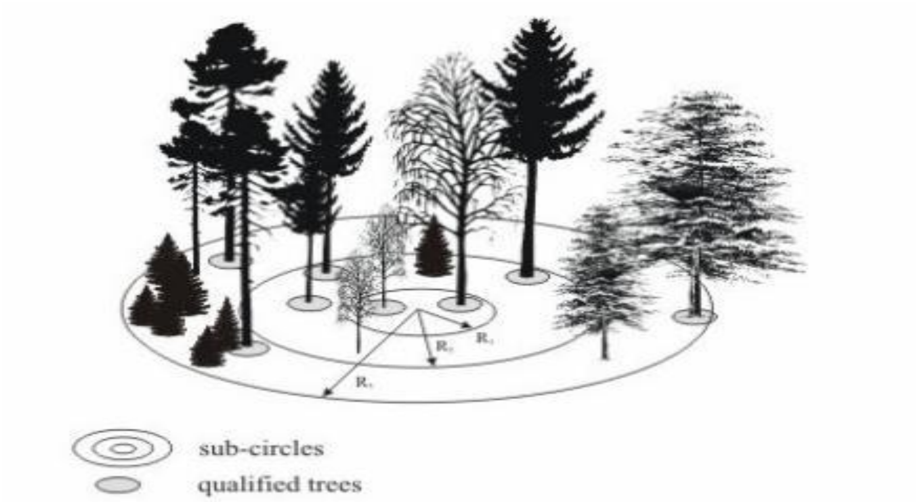


Figure 7.3.3 Overview of the NFI classification system (taken from NFI, 2007a)

The 2 km x 2 km grid is overlaid on the total land base map of the Republic of Ireland to facilitate land-use type (LUT) interpretation using colour air photographs (OSI, 2005, 2011/12). The primary focus of the interpretation is to identify forest land transitions. In tandem with this, other land-use types are identified for LULUCF reporting under the Convention. The grid is permanent and this allows for the re-assessment of primary sample points at future dates to monitor forest and other land-use change (i.e. afforestation and deforestation) when the OSI produces the next range of ortho-rectified aerial photos (NFI, 2007).

Once a forest plot has been identified, field measurements are undertaken in established permanent plots. The exact location of the centre of ground survey plots is identified in the field by navigating to a six digit Irish national grid co-ordinate using both GPS and electronic compass/laser technology. The total area of the circular sample plot is 500 m^2 (i.e. 25.24 m in diameter). Adjustments for slope are automatically made by the laser/range-finding equipment. The concentric circle approach, comprising three concentric circles with different radii is used for tree assessment. Trees of different dimensions are mapped and described on each particular plot (Figure 7.3.4). Individual trees in the plot are mapped and treemetric data are collected and archived in a GPS format. Forest mensuration measurements are made on selected individual trees within the plot based in the position within the plot and the threshold diameter (Figure 7.3.4)[2]. This information is used to estimate plot-level parameters and to scale up to 1 ha (section 7.3.3.1.3). The permanent plot data describing single tree dimensions, deadwood and plot level information, is used to initiate the CARBWARE model.

[2] Note: The concentric plot sampling approach used (see Fig 7.3.4) has implications for uncertainty (see validation and uncertainty sections)



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12,62
Sub-circle area (m^2)	28,3	153,9	500
Treshold diameter (mm)	70	120	200

Figure 7.3.4 The concentric plot design and mapping of individual trees NFI, 2007a

Soil surveys were also conducted in permanent sample plots. The soil group classification used in the NFI was a modification of the great soil groups employed in the National Soil Survey (Gardiner and Radford, 1980), with the addition of sand, making 11 great soil groups. These are brown earth, gley, regosol, grey brown podzolic, rendzina, sand, brown podzolic, basin peat, lithosol, podzol and blanket peat. For a soil to be classified as peat, the peat depth had to be greater than 30 cm. Soil categories were aggregated into three major groups on the basis of their soil carbon characteristics, which can be used to estimate carbon stock change in soils. All mineral soils were grouped together. All organic soils with a depth greater than 30 cm were classified as peats soils. Mineral soils with an organic layer less than 30 cm were classified as mineral/peat soils.

7.3.2.4 Harvests and Deforestation

Harvest

EUROSTAT information is compiled by a contractor on behalf of the DAFM. The EUROSTAT harvest is obtained from timber mills and information from the industry (e.g. Coillte and the private sector). Harvest data from 1990 to 2005 were compiled using data national data submitted to the FAO and EUROSTAT. For this time series the EUROSTAT harvested volume was used to simulate harvest in the FORECARB model. This was done by adjusting age class distributions using optimisation procedures based the prescribed rotation age, thinning intervals and total harvest volume for each species cohort (see section 7.3.3.2). The simulated harvest was validated against the official FAO/EUROSTAT data as shown in section 7.3.4 (Table 7.3.2)

The 2005 and 2012 NFIs were used to derive harvest data for the periods after 2005. The NFI records individual trees within PSP that are harvested and the indicative date of harvest based on:

I. The previous DBH and height of the tree in the 2006 inventory
II. The estimate year of harvest. This is based on assessment of condition of stumps and deadwood on site.
III. The volume at year of harvest is then estimates using the DBH and height in 2006 and the projected growth using the CARBWARE model (see section 7.3.3.1).
IV. The simulated harvest was validated against the official FAO/EUROSTAT data as shown in section 7.3.4 (Table 7.3.10)

Harvest from forest land remaining forest land (CRF 5.A.1) increased from ca. 1.5 Mm^3 in 1990 to ca. 3 Mm^3 by 2012 due to changes in the age class structure and clearfell of more crops at rotation age (Table 7.3.1). Harvest from lands converted to forest land (i.e. all forests established since 1990, CRF 5.A.2) only occurred from 2007 onwards due to the young age class structure of this category. All harvests occurring on afforested land since 1990 are carried out as first thinnings of more productive conifer crops. The total timber volumes harvested from the areas afforestated since 1990 was 82,903 m^3 in 2007, 21,617 m^3 in 2008, 224,437 m^3 in 2009, 153,841 m^3 in 2010 and 179,408 in 2011 and 110,811 in 2012. Harvesting from the Coillte lands represented 80 to 91 per cent of the total timber harvest from post-1990 forests (afforestation areas only). However, approximately 65 per cent of the afforestation area is privately owned, where thinnings are not commonly carried out because of the small fragmented nature of private forest, making it economically unviable to thin forest stands. NFI analysis suggests that 70 per cent of stands, which are suitable for thinning, are not thinned.

Deforestation

Clearfelled areas, which were not restocked within 5 years or if there was clear indication of land use change, were deemed to be deforested. The following approaches are used to determine deforestation areas. (see Annex H.1):

1) Sampling approach: NFI grid points and aerial photography

This is a modification of IPCC GPG approach 3, where the grids or centroids are sampled using a systematic sampling procedure adopted in the NFI. Assessment of ca.18000 NFI point intersects with aerial photographs form 2000 and 2006 provides the opportunity to report deforestation for this period. This method identified 15 NFI PSP grid samples, which were deemed to be deforested between 2000 and 2006. The current land uses of these previously deforested lands were determined from photo interpretation using the 2006 images.

Assessments of deforestation from 1995 to 2000 were based on a GIS intersection of the 18,000 NFI plots with the FIPS 95 forest parcel polygon layer. This exercise produced 105 forest parcels, which were classified as forest in the FIPS 1995 dataset, but then re-classified as non-forest land in the NFI aerial photography 2000 interpretation. These 105 polygons were cross-checked with 1995 black and white aerial photographs to verify that they were forests in 1995. However, most of the sampled forest polygons were deemed to not be deforested or were originally other land uses in 1995. This was due to original FIPS 95 interpretation inconsistencies of photographs and mapping errors in the FIPS95 layer. Only 5 NFI sample points were identified to be deforested between 1995 and 2000. Although it is recognised that a grid based sample introduces a high level of uncertainty due to the poor resolution of detecting highly fragmented deforestation, this is the only available data set for this time series. Importantly these uncertainties should not introduce bias, because deforestation could be both over and under estimated using this approach.

The final deforestation-land use change-soils matrices for 1995-2000 and 2000-2006 were obtained by intersecting identified deforested PSP points with the national soils map database (see Annex H 1.2).

2) Tracking deforestation using CORINE Land cover (CLC) data sets

Although the reporting of LUC matrices uses CORINE, classification and resolution problems have been highlighted comparative studies across Europe (Black et al., 2009; Hazeu and de Wit 2004, Cruickshank and Tomlinson 1996). Despite the abovementioned inappropriateness of CLC for reporting areas under LULUCF in a representative and accurate manner, this is the only data currently available to track historic deforestation prior to FIPS 95 (see method 1 above).

For this excise we extracted CLC codes 311 (conifers), 312 (broadleaves) and 313 (mixed woodlands) to represent forest land area that were present in 1990. The transitional land cover classes were re-classified into the LULUCF land use categories to identify land uses following deforestation. The resulting polygons were then intersected with a national soils map using ARCGIS to derive a land use change and soil type matrix to the periods 1990 to 1995.

3) Modification to deforestation records from 2006-2012 using the NFI

The new NFI 2012 and previous NFI 2006 are now used to derive deforestation data for the period 2006 to 2012. This method replaced the previously used activity data from felling licence applications. The national forest inventory programme will continue to monitor whether clear felled forest land is replanted. The NFI performs land use transition analysis based on a 2 x 2 km grid using aerial photography every 5 years. The first NFI was completed in 2006 with a follow up completed at the end of 2012. A unit of land is defined as deforested land if there is a clear indication of land use change, either from limited felling licences or aerial photography and a permanent sample point, which was recorded as unplanted previously clearfelled land in the previous inventory, is still unplanted at the time of the subsequent inventory.

A QA exercise conducted in 2013 highlighted that the previously used felling licence record approach underestimated the areas and C stock of deforested land. Therefore, the new NFI data is now used to derive both the area and C stock activity data, derived directly from NFI permanent sample plots before deforestation occurred using the CARBWARE model.

The land use transitions due to deforested lands since 2006 are shown in detail in Annex H (Table H.2). According to the deforestation definition, a total of 1600 ha of forests, which were clearfelled before the 2006 NFI and were not replanted by the repeat inventory in 2012, were classified and deforested other land.

7.3.2.5 Activity Data for Afforestation Areas

Afforestation areas were derived from IFORIS data see Figure 7.3.2. Activity data of land afforested since 2006 is derived from the NFI 2006 and 2012.

Previous land use 1990-2000

Initially, the lands converted to forestry were of relatively poor quality, with marginal potential for economic returns under agricultural practices. In more recent years, and especially with the increase in private afforestation, land of higher quality has been converted to forestry, reflecting improved grant-aid under the afforestation programme, the decline in economic returns for conventional farming practices and a preference for less labour-intensive land usage. For deriving the previous land use prior to afforestation between 1990 and 2000 the CORINE 1990-2000 Land Cover Map of Ireland (level 6) was overlayed on NFI sample plots. This overlay combination delineated the individual areas and underlying soil type of afforested lands. It also revealed the plantation date and gave an indication of the previous land use. The previous land use given by CORINE was used as a general guidance.

Based on this analysis of *5.A.2.Land Converted to Forest Land* a constant proportion for land use transitions were applied, where *5.A.2.3 Wetlands Converted to Forest Land* account for 57 per cent of the total area; *5.A.2.2 Grassland Converted to Forest Land* account for 30 per cent of the total area; *5.A.2.1 Cropland Converted to Forest Land* account for 10 per cent of the total area; and *5.A.2.5 Other land Converted to Forest Land* account for 3 per cent of the total area converted to forest in any given year between 1990 and 2000. Additional disaggregation into soil types under each land use transition is also applied to enable the calculation of emissions from organic soils.

Previous land use 2006-2012

The land use prior to afforestation for 2006-2012 was derived using the 2006 and 2012 NFI data (see section 7.3.2.3 and Figure 7. 3.3). Based on this analysis *5.A.2.3 Wetlands Converted to Forest Land* account for 45 per cent of the total area; *5.A.2.2 Grassland Converted to Forest Land* account for 45 per cent of the total area; *5.A.2.1 Cropland Converted to Forest Land* account for 3 per cent of the total area; and *5.A.2.5 Other land Converted to Forest Land* account for 2 per cent of the total area converted to forest. Additional disaggregation into soil types based on NFI data under each land use transition is also applied to enable the calculation of emissions from organic soils.

Previous land use 2000-2006

The percentage of previous land use between 2000 and 2006 were derived from interpolation of the 1990-2000 and 2006-2012 time series. This resulted in a constant decline in wetland conversion to forest land by 1 per cent of the total annual afforestation area, and increase in annual afforestation of grasslands by 1.3 per cent of the total area, a decrease in annual afforestation of croplands by 0.6 per cent of the total area, and a decrease in conversion of other land to forests by 0.1 per cent of the total area converted to forest in any year between 2000 and 2006.

7.3.2.6 Definition of carbon pools

Table 7.3.1. Definition of carbon pools used in LULUCF and KP-LULUCF reporting

LULUCF	KP LULUCF	Definition
Living biomass	Aboveground biomass	All biomass above stump height (1 % of tree height)
	Belowground biomass	Biomass below stump height including roots up to a diameter of 2mm
Dead organic matter	Deadwood	Standing deadwood, dead stumps, roots (min 2 mm) and logs (min 7cm diameter)
	Litter	Needles, leaves and branched up to a diameter of 7cm
Mineral soil	Mineral soil	SOC of less than 20% (reported to max depth of 30cm)
Organic soil	Organic soil	SOC of > 20% and depth > 30cm
Organo-mineral soil	Organo-mineral soil	Mineral soil with a top organic soil of depth < 30cm

7.3.3 Description of models used

7.3.3.1 CARBWARE

The CARBWARE model is used to derive net emissions/removals for all pools all forest categories since 2006. The CARBWARE system is initialised using individual tree data from the NFI and other activity data (See Figures 7.3.1 and 7.3.5. The growth and mortality model was developed using permanent sample plots established by Coillte in the 1950s. Following model parameterisation and extensive validation (see sections on uncertainty and QA/QC under each reporting category and Annex H), software was developed to facilitate reporting of pools using model functions and input activity data (Figure 7.3.5. The software system was developed as part of a QC initiative to reduce calculation errors when input data is formatted and processed. When the software was developed extensive testing and validation of the code functionally on different operating systems was carried out by FERS Ltd and an independent validator (PTR Ltd) under the COFORD funded CARBWARE project (2007-2012). The software is made available to the EPA and DAFM with a user manual.

The reporting system includes an on-going QA/QC system, whereby model outputs are validated against repeated NFI measurements on a 5 year rolling basis. Additional, external data checks on activity data are carried out by the data suppliers. The first repeat forest inventory on one-fifth of the forest area was completed 2011, with the remaining completed by the end of 2012.

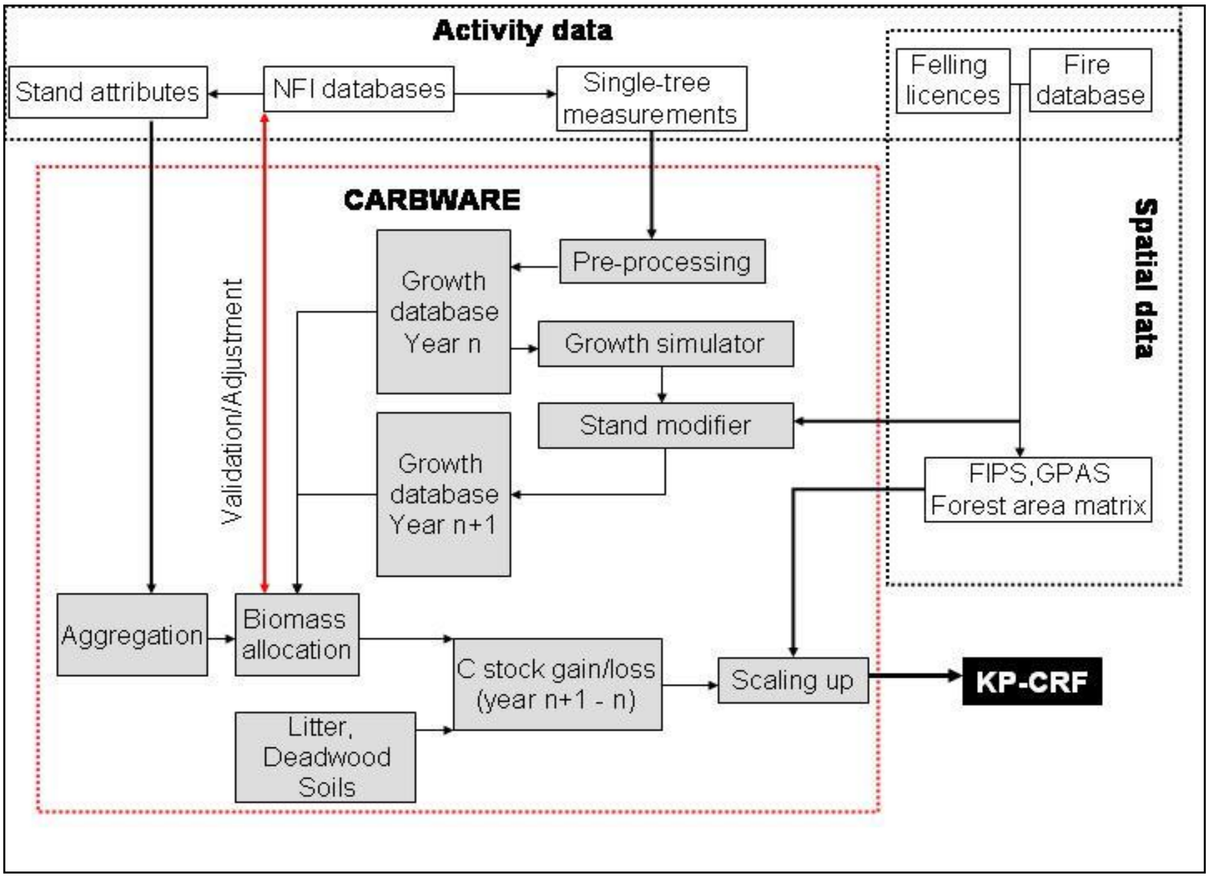


Figure 7.3.5 Schematic Overview of CARBWARE Functionality[3].

7.3.3.1.1 Pre-processing, Growth Simulator and Stand Modifier Modules

The pre-processing module carries out formatting of NFI input files in the Microsoft Access environment to ensure that individual tree and stand information can be used by the growth simulator and stand modifier module. The model itself comprises of a growth simulator (DBH increment model see Annex K), a modifier module (see Annex J), which facilitates inclusion of natural mortality and harvests and a biomass allocation module which facilitated carbon flow between different pools.

7.3.3.1.2 The Carbon Flow Sub-model

The total carbon stock changes for a given forest plot is calculated as the sum of the gains and losses in the above-ground biomass (AB), below-ground biomass (BB), Litter (Li), deadwood (DW) and soil (So) carbon pools (Equation 2.3 in Chapter 2 of the 2006 IPCC guidelines):

$$\Delta C_{lu} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{Li} + \Delta C_{Dw} + \Delta C_{So} \quad (7.3.1)$$

Biomass estimates include biomass for trees only, non-tree vegetation is assumed to be in steady state following canopy closure. The definition of C pools is the same for Convention and KP reporting. Below ground biomass includes all roots up to a diameter of 5cm. Litter is defined as deadwood with a diameter of less than 7cm. This includes abscised needles and leaves. The dead wood pool included all lying and standing deadwood, dead roots and stumps with a diameter greater than 7cm. organic and mineral/organic soils are reported.

[3] The red box indicates the operational domain. The white boxes represent input data sources and data bases and the grey boxes indicate software modules which carry out different procedures

a) Biomass Carbon gains and losses

Biomass carbon stock changes are calculated using a tier 3 gain and loss method, corresponding to the process-based approach given by equation 2.4 in Chapter 2 of the 2006 IPCC guidelines, which gives the net carbon stock change as the sum of carbon gains and carbon losses for each NFI PSP

$$\Delta C = \Delta C_G + \Delta C_L \quad (7.3.2)$$

The biomass carbon gains (ΔC_G) for both above-ground biomass (AB) and below-ground biomass (BB) are calculated for each NFI PSP using

$$\Delta C_G = GTOTAL \times CF \quad (7.3.3)$$

where GTOTAL is the biomass gain (t dm. ha^{-1} yr^{-1}) in a PSP and CF is the carbon fraction of biomass dry matter, which is taken as 50 per cent for all carbon pools (Black et al., 2007). GTOTAL is derived from the sum of all living individual tree components (i.e. AB or BB) within the NFI PSP, for example:

$$GTOTAL_{AB} = AB_n - AB_{n-1} \quad (7.3.4)$$

where n is the year of inventory. The GTOTAL value for each NFI permanent sample plot normalised to 1 ha. The AB and BB of individual trees were calculated using biomass algorithms for different species cohorts based on national research information (Annex K, Table K.1), where diameter at breast height (DBH) and tree height (H) are used as dependent variables. These variables are input data in the NFI 'individual tree table' for the first NFI (2005/6, See Figure 7.3.4). The increases in DBH and H of individual trees between NFI years were simulated in the single tree growth models (See K1-B and Table K1-B3 in Annex K). The stocking (number of trees in a plot) is adjusted after every growth simulation cycle using the stand modification module (Figure 7.3.4), which removes trees based on natural mortality models and harvest activity data (Annex K.2).

Biomass carbon losses from the above-ground biomass pool ($\Delta C_{L(AB)}$) were calculated based on harvest (L_{timber}), harvest residue (L_{HR}), litter fall (L_{LF}), above-ground losses due to mortality ($L_{mort(AB)}$) and fire (L_{fire}):

$$\Delta C_{L(AB)} = L_{timber} + L_{HR} + L_{LF} + L_{mort(AB)} + L_{fire} \quad (7..3.5)$$

L_{timber} is calculated based on the above-ground biomass removed from harvest, simulated in the stand modification module (Annex K.2). The allocation algorithms for timber based on harvested AB, H or DBH were derived from national research information (see Annex J, table J.1 and Figure 11.1). L_{HR} includes the harvest residue representing all stems and branches with a DBH less than 7cm and litter left on site after timber is removed:

$$L_{HR} = AG - L_{timber} \quad (7.3.6)$$

L_{LF} reflects the transfer of carbon from the AB pool to the litter pool. This is calculated in the allocation module (Figure 7.3.5), based on nationally derived leaf/needle biomass (LB) and the foliage turnover rates (F_t) (Tobin et al., 2006):

$$L_{LF} = LB \times F_t \quad (7.3.7)$$

Allometric equations and coefficients used for the calculation of LB for different species cohorts, with either AB or DBH as dependent variables, are shown in Annex J, Table J.1. The F_t rate was assumed to be 6.7 years (i.e. F_t = 0.15) for conifer crops and 1 year for broadleaf crops (Tobin et al., 2006). The mortality of trees is based on nationally derived single tree mortality models (Annex K.2).

The above-ground biomass loss from mortality ($L_{mort(AB)}$) was calculated using DBH and H as dependent variables in biomass algorithms (Annex K, Table K.1). The AB carbon losses associated with fires (L_{fire}) was determined as described in section 7.3.2. These losses are estimated in respect of total biomass burned and reported under a separate forest category in CRF Table 5(KP-II)5. The above-ground biomass gains in previously burned forest areas are assumed to be zero.

The biomass pools allocated to $L_{HR} + L_{LF} + L_{mort(AB)}$ pools are transferred to the litter and deadwood pools. Timber biomass harvested (L_{timber}) is assumed to be immediately oxidised in the year of harvest.

Biomass carbon losses from the below-ground biomass pool ($\Delta C_{L(BB)}$) were calculated as the sum of losses due to death of roots after harvest (L_{HRroot}), natural mortality of roots ($L_{mort(BB)}$) and root death following fire (L_{fire}):

$$\Delta C_{L(BB)} = L_{HRroot} + L_{mort(BB)} + L_{fire} \quad (7.3.8)$$

L_{HRroot} is the root biomass transferred to the deadwood pool following harvest as is $L_{mort(BB)}$ following tree death. All roots are assumed to die and decompose following harvest. The mortality of roots is assumed to follow that for trees, as estimated from nationally derived single tree mortality models (Annex K.2). The below-ground biomass loss from mortality ($L_{mort(BB)}$) was calculated using above-ground and total biomass algorithms (Annex J, Table J.1). The BB biomass losses associated with fires (L_{fire}) was determined in the same way as described above for AB losses due to fires and reported in Table 5(KP-II)5. The below-ground biomass gains in burned forest are assumed to be zero.

Carbon stock changes associated with deforestation reported in CRF and KP tables include those for the total standing biomass of all trees, including roots, removed at clear fell (i.e. all biomass carbon is assumed to be immediately oxidised). Since activity data and methods used to derive deforestation estimates are now based on NFI measurements, AB, BB, litter and deadwood C losses are directly estimated using allometric equations and C flow models in CARBWARE (Annex K and sections below).

Where NFI PSPs were deforested prior 2006 (i.e harvested before the NFI was set up), there was no plot data for estimating C stock before harvest. Therefore the carbon stock losses in the AB and BB pools for deforestation were calculated from an estimation of standing volume (V) of these NFI plots, as specified in the Coillte inventory, a basic density (D) in the range 0.35 to 0.55 (depending on tree species), a biomass expansion factor (BEF, total biomass to timber biomass see section 7) of 1.68 t/t^{-1}, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2 (Black et al., 2009), as follows

$$TOTAL_{(AB)} = (V \times D \times BEF \times CF) \times 1/(1-R) \quad (7.3.9)$$

$$TOTAL_{(BB)} = TOTAL_{(AB)} \times R \quad (7.3.10)$$

Volume (V) of stands was derived from a query of the Coiltle data for 2005-2006. The equations are similar to those used in the IPCC GPG (2006) eq. 2.8 PG 2.12 Chapter 2. However, the term (1-R) is included for above ground biomass because BEF is defined as the ratio of total biomass (including roots) to timber biomass. Similarly, the term R is included in the below ground biomass calculation.

There is no activity data for deforested areas before 2006, therefore the 2006-2012 mean AB (77.81 t C/ha), BB (20.48 tC/Ha), litter (4.11 t C/Ha) and deadwood (9.82 t C/Ha) C stock was applied as an IEF for these deforested areas.

b) Litter Carbon Stock Change

Net litter stock change (ΔC_{Li}) was calculated based on litter inputs (gains) due to litterfall (L_{LF}), as given by equation 7.3.7, harvest residue litter input (L_{HR}) in equation 7.3.6, mortality litter inputs (M_{li}), and losses associated with decomposition of the litter pool (L_{decomp}):

$$\Delta C_{Li} = (L_{LF} + L_{HR} + M_{Li}) - L_{decomp} \quad \text{.........(7.3.11)}$$

where M_{Li} is the input to the litter pool from natural mortality (i.e. all aboveground dead material with a diameter less than 7 cm). This is derived from the $L_{mort(AB)}$ minus the timber fraction of the new dead pool (L ($_{mort(tim)}$)):

$$M_{Li} = L_{mort(AB)} - L_{mort(tim)} \quad \text{.........(7.3.12)}$$

The decomposition losses of the new input litter (L_{decomp}) and existing litter pool (L_{old}) are calculated using decomposition factors of 0.14 taken from national research (Saiz et al. 2007; Black et al. 2009b):

$$L_{decomp} = 1 - \left[\sum [L_{LF}, L_{HR}, M_{Li}, L_{old}]^{-D_{Lt}} \right] \quad \text{......... (7.3.13)}$$

$$L_{old} = \sum [\{(L_{LF}, L_{HR}, M_{Li})_{n-1, n-2, n-x}), L_{ini}\}]^{-D_{LI}} \quad \text{......... (7.3.14)}$$

where, L_{ini} is the initial litter pool estimated following the completion of the first NFI in 2005 using constructed lookup stand attribute tables based on the FORECARB model. The remaining litter from the newly input litter, harvest residue and mortality pools from the previous years (n-1, n-2 etc) were accumulated following decomposition.
The accumulated litter pool was assumed to be immediately oxidised when deforestation occurs (i.e. reported as an emission in the CRF and KP tables):

$$\text{Deforested } \Delta C_{Li} = L_{old} \times -1 \quad \text{.........(7.3.15)}$$

The accumulated litter pool for these deforestation events is derived from the initial litter pool look up tables as described above.

c) Deadwood Carbon Stock Change

Net deadwood stock changes (ΔC_{DW}) were derived from carbon inputs associated with timber extraction residue (L_{tr}), timber from mortality (M_{timber}), dead roots from mortality ($L_{mort(BB)}$), roots from harvest (L_{HRroot}) and carbon loss due to decomposition of the new and previously existing deadwood pool (D_{DW}):

$$\Delta C_{DW} = (L_{tr} + M_{timber} + L_{mort(BB)} + L_{HRroot}) - D_{DW} \quad \text{.........(7.3.16)}$$

A small amount (approximately 4 per cent, Tarleton (PTR Ltd) personal communication) of harvested timber is assumed to be left on site following harvest and this is used to estimate L_{tr}:

$$L_{tr} = L_{timber} \times RF \quad \text{.........(7.3.17)}$$

The deadwood input from natural mortality (M_{timber}) is derived from allometric equations applied to the DBH and H of dead trees after mortality iterations (see Annex K), while $L_{mort(BB)}$ and L_{HRroot} are known from the analysis for the litter pool. The decomposition losses from the new input deadwood carbon pool, existing decaying logs (DL_{old}) and decaying stumps (DS_{old}) are calculated using equation 7.3.18 based on decomposition factors of 0.095 for stumps and 0.076 for roots (Tobin et al., 2007):

$$D_{DW} = 1 - \left[\sum [L_{tr}, M_{timber}, DL_{old}]^{-D_{\log} \times t} + \sum [L_{mort(BB)}, L_{HRroot}, DS_{old}]^{-D_{St}} \right] \quad \text{......... (7.3.18)}$$

The volume and decay class of logs and stumps, measured in permanent sample plots during the NFI in 2005 and 2006, are used to calculate the carbon stocks in the decaying deadwood pools DL_{old} and DS_{old}, respectively. In the case of decaying logs

$$DL_{old} = \sum_i \left[VL_i \times DDC_i \times CF\right]^{-D_{\log} \times t} + \left[\sum (L_{tr}, M_{timber}\right]^{-D_{\log}}_{(n-1, n-2, n-x)} \text{........................} \quad (7.3.19)$$

where VL is the log volume of the specific decay class (*i*, n=4), DDC is the density of the specific decay class (*i*) and CF is the carbon fraction (0.5). The density and decay classes described by Tobin et al (2007) were used to calculate the deadwood carbon pools in the NFI permanent sample plots (NFI, 2007b). L_{tr} and M_{timber} (n-1, n-2,..x) is the accumulated deadwood from the stand modifier functions (equation 7.3.16 and Figure 7.3.5) within the CARBWARE model for previous years (n). Similarly, decay class and volume functions were used to derive the carbon pool of decaying stumps in NFI sample plots (Tobin et al 2007, NFI, 2007b):

$$DS_{old} = \sum_j \left[VS_j \times DDC_j \times CF\right]^{-D_{St} \times t} + \sum \left[L_{mort(BB)}, L_{HRroot}\right]^{-D_{St}}_{(n-1, n-2, n-x)} \text{..................} (7.3.20)$$

where VS is the stump volume of the specific decay class (*j*, n=4), DDC is the density of the specific decay class (*i*) and CF is the carbon fraction (0.5). The density and decay classes described by Tobin et al (2007) were used to calculate the deadwood carbon pools in the NFI permanent sample plots (NFI, 2007b). $L_{mort(BB)}$ and L_{HRroot} (n-1, n-2,..x) is the accumulated deadwood from the stand modifier functions (equation 7.3.16 and Figure 7.3.5) within the CARBWARE model for previous years (n). The carbon stock of the deadwood pool in NFI plots were attributed to each permanent sample plot using a deadwood look up function in the stand attribute table of CARBWARE (Figure 7.3.4). The decomposition emissions of the old and new deadwood carbon pools was then calculated using decay constant described by Tobin et al. (2007).

The accumulated deadwood and litter pools (DS_{old} and DL_{old}) were assumed to be immediately oxidised when deforestation occurs so that

Deforested $\Delta C_{DW} = (DL_{old} + DS_{old}) \times -1$ ....(7.3.21)

The accumulated deadwood pool for these deforestation events is derived from the mean deadwood carbon pool of the forest category and age class, based on analysis of the NFI permanent sample plots.

d) Soils

Soils are classified into three major groups; mineral, peat and peaty/mineral soils. Peat soils are organic soils with a depth greater than 30 cm and peaty/mineral soils are a continuum between the peat and mineral categories. Current research information suggests that mineral soils in Ireland do not represent a source of carbon emissions, and therefore soil carbon stock changes are reported only for peats and peaty/mineral soils (see Ch 11). The emission for peat soils given by equation 7.3.22 is now based on new published data (Byrne and Farrell, 2005), but information on soil classification and peat depth available from the NFI is also taken into account.

$$\Delta C_{So} = \sum_i \left(A_i \times EF_{soil}\right) \text{...} (7.3.22)$$

The area (A_i) of the 0.05 ha plots with peat soils is multiplied by 20 to scale the measurement up to 1 ha. The EF_{soil} is 0.58 t C/ha^{-1}.yr^{-1} for the first 50 years following afforestation and is zero thereafter. Emissions from peaty/mineral soils are calculated in the same way (equation 7.23), but a soils depth function (SD) is applied to the emission factor to account for the smaller organic carbon pool available. If soil depth is less than 30 cm then,

$$\Delta C_{So} = \sum_j \left(A_j \times EF_{soil} \times SD \right) \text{ ....(7.3.23)}$$

and

$$SD = \frac{depth(cm)}{30cm} \text{ ....(7.3.24)}$$

Ireland uses a country specific emission factor for organic forest soils (Byrne and Farrell, 2005). This is calculated as the mean organic soil EF of 0.59 t C/ha/year over the first rotation (assumed to be 50 years for peatland forests). Byrne and Farrell (2005) demonstrate that organic soils are not a source following successive rotations. These EFs are based on total soil respiration measurements, which include respiratory inputs from autotrophic respiration and litter decomposition. Therefore, these EFs are considered to overestimate since autotrophic respiration is accounted for in NPP estimates (i.e. below ground biomass growth) and litter decomposition is accounted for in the litter pool. Other studies suggest that autotrophic respiration accounts for up to 40 per cent of total soils respiration (Siaz et al., 2007).There is currently no research information on the partitioning of soil respiration between heterotrophic and autotrophic processes in peatland soils. Therefore a conservative EF will be applied until new research information becomes available. While the EF rate is lower compared to the default rate of 0.68 t C/ha/year for organic soils in cold wet temperate conditions and the region specific value used in previous submissions of 4 t C/ha/year, the transition period is much longer than the previously used default periods. The accumulated default emission of 29.5 t/ha over 50 years is now more than 2 fold higher than the previously used methods (i.e. 13.6 t C/ha to Tier 1 and 14 t C/ha for previously used tier 2, (Hargreaves et al, 2003, NIR, 2011). A country specific transition period of fifty years is therefore considered appropriate to afforested areas on organic soils (See Byrne and Farrell, 2005). This EF is applied to all first rotation forests going back to 1940 assuming that 60 per cent of afforestation occurred on peat soils before 1990 (Black et al., 2009). All forest lands planted before 1940 are assumed to be second rotation crops or are older than 50 years by 1990 and organic soils emissions from these forests are deemed to be zero (Byrne and Farrell, 2005).

7.3.3.1.3 Scaling and Aggregation of PSP into Different Reporting Categories

Tree measurements within NFI plots were systematically sampled (see Figure 7.3.4), so all trees were not measured in a plot. The sampling method, in conjunction with an assumption of homogeneous spatial distribution of diameters within a stand, informs the calculation of a sampling weight or *expansion factor* (EXF) which is used to allow for the possibility that some trees on a given plot were not sampled. The expansion factor is inversely proportional to the prior probability that a given tree is included in the sample, based on the diameter class of the tree (see Figure 7.3.3). Each tree in the sample is thus replicated a number of times equal to its expansion factor. This replication is allowed for when calculating variables derived at plot level, such as density, by incorporating the expansion factor into the equations. For example, the estimated number of trees on a plot with a single sampled tree of greater than 70 mm is $(12.62/3)^2$. Figure 7.3.4 shows that trees of three diameter classes are only recorded if they are observed within a certain distance from the plot centre. The expansion factor used by the NFI assumes a random distribution for tree diameter in the plot. Because of that assumption, the weight assigned to a tree in the *i*th diameter class is:

$$\frac{R_3^2}{R_i^2} \text{ ....(7.3.25)}$$

where R_i denotes the radius of the concentric circle associated with the *i* th diameter class.

In practice, the expansion factor, or weight, is used to estimate plot-level features, e.g. basal area. In such calculations, the number of trees of the *i* th diameter class that were not included in the sample is estimated by $\frac{R_3^2}{R_i^2}$ x n_i, where n_i is the number of trees of the *i* th class that are included in the sample. The expansion factor therefore defines the relationship between each included tree and the estimated number of trees of the same class that were not included (Equation 7.3.25).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \quad \text{...(7.3.26)}$$

where n_{ij} _ EXF_{ij} is the product of the expansion factor for the *j* th tree in the *i* th class, and $\check{N}_{ij}$ is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 7.3.26 is the representative tree number. With minor and obvious changes to the equation, we can calculate other tree-level estimates, including representative basal area, and individual-tree estimates can be aggregated for the entire plot to give plot-level estimates, including representative density. For example the aboveground biomass carbon of a plot (t C/ha) $GTOTAL_{(AB)}$ of a plot is calculated as:

$$GTOTAL_{(AB)} = \frac{\sum [ABij \times EXFij] \times 20}{1000} \quad \text{...(7.3.27)}$$

where, 20 is the factor used to scale up to 1 ha and 1000 is used to convert kilogrammes of biomass carbon to tonnes.

For convention reporting the total gains or losses for each pool and soil category is calculated as the sum of the pool scales up using representative area of PSP within respective categories. A PSP represents 400 ha based on a 2 x 2 km grid sample. Since the NFI only detects forest areas at a 400 ha resolution the adjustment is done using the spatial GPAS data. The same adjustment is done for all other categories and KP tables.

So for example, if the area of organic soils under forest land remaining forest land is estimated to be 4.8 kha based NFI PSP (i.e. 12 plots out of 650 (representing a total of 260 kha) plots for the afforestation categories) and the total GPAS area is 260.47 kha, then the area is readjusted as follows:

New sub-category area (4.809 kha) $= (\frac{12}{650}) \times 260.47$

These calculations are carried out automatically by the CARBWARE software. The calculation steps were subject to QA/QC checks during the coding of the software.

7.3.3.1.4 Datasets Used to Develop the CARBWARE Models

a) Permanent Sample Plot

The pre-processing, growth and mortality model was calibrated on data extracted from the permanent sample plot record system of Coillte Teoranta (the Irish Forestry Board state commercial forestry company). Broad and Lynch (2006b) provide details of the dataset in the context of modelling plot volume. The database consists of records of many silvicultural and thinning trials. These longitudinal trials were established from the 1950s onwards, and were initially established as replicated and blocked experimental designs (Broad and Lynch, 2006a).

b) Pre-processing functions

Raw data in the single tree tables and stand attributes are pre-processed by the CARBWARE software to provide variables used in the growth and modification models. In some cases, not all required variables, such as tree height (H) and crown ration (CR) are measured. These missing values are estimated using functions described in Annex K.1.

c) Growth models

The availability of only one NFI cycle meant that that the CARBWARE model had to be developed and adapted to estimate carbon stock changes. This has been done by using diameter increment models for all trees with a DBH greater that 5cm and H increment models for trees with DBH less than 5cm (Annex K1-B). The generated DBH and H values, produced after each growth iteration, were then used to derive biomass estimates for a range of different biomass functions (Annex K, Table K.1).

d) Stand modification functions

The NFI permanent plots structure is modified at the end of each growth cycle to simulate the losses associated with natural mortality and harvest (see Annex K.2).

7.3.3.2 FORCARB

The FORCARB model is used to calculate CSC for the historic time series from 1990 to 2006. This is then adjusted (see figure 7.2.1) to ensure a time series consistency. The FORCARB model uses a similar C flow modelling approach as described for CARBWARE, but the main difference is that the growth, harvest and mortality is derived from stand level BFC yield tables as described by Black et al., 2012. The breakdown of species distributions was derived from and intersection of NFI and Coillte sub-compartments as described by Black et al., 2012. Species were grouped into cohorts and a representative species table was selected from the BFC yield tables to derive stand variables such as DBH, stocking etc.

Table 7.3.2. Breakdown of species used in the pre-1990 and post-1990 forest categories

Cohort	Species table	Proportion
Spruce	Sitka spruce	0.593
Pine	Lodgepole pine	0.307
Larch	Japanese Larch	0.081
FGB	Sycamore, Ash, Birch	0.004
SGB	Beech	0.016

The yield class categories, silviculture and rotation age for each species within the pre-1990 and post-1990 categories for the period 1990-1999 were derived from the FIPS 95 dataset, modified from Gallagher et al, (2004, see Table 7.3.28). The matrix was modified for the period 2000-2012 using NFI and Coillte sub-compartment information as described by Black et al, 2012 (Table 7.3.39).

Table 7.3.3. Yield class, silviculture and rotation criteria selected for periods 1990-1999 and 2000-2012

Period :1990-1999 (Source FIPS 95)

Species cohort	Yield class	Proportion of cohort	Silviculture	Rotation
Spruce	10	0.37	No thinning	MMAI
	16	0.26	No thinning	MMAI
	20	0.20	Thin	MMAI less 20%
	24	0.17	Thin	MMAI less 20%
Pines	10	1.00	Thin	MMAI
Larch	10	1.00	Thin	MMAI
FGB	6	1.00	Thin	MMAI
SBG	6	1.00	Thin	MMAI

Period :2000-2012 (Source NFI-Coillte intersect)

Spruce	10	0.37	No thinning	MMAI
	16	0.13	No thinning	MMAI
	20	0.20	Thin	MMAI less 20%
	24	0.17	Thin	MMAI less 20%
	16	0.13	No thinning	MMAI less 30%
Pines	10	0.30	No thinning	MMAI
	10	0.80	No thinning	30% less MMAI
Larch	10	1.00	Thin	MMAI
FGB	6	1.00	Thin	MMAI
SBG	6	1.00	Thin	MMAI

MMAI is maximum mean annual increment, which determines the age of clearfell.

The FORCARB growth model describes gains and losses in biomass pools on mean tree-level allometric functions (DBH and height, see annex K) and stand attributes (stocking) for representative species, according to Forestry Commission yield models (Edwards and Christy 1981, Black et al 2012). Stand attributes, such as age, mean DBH, top height, stocking and timber harvested, for five species cohorts (spruce, larch, pine, slow growing and fast growing broadleaves), were used as inputs for the calculation of cumulative stand biomass using species-specific allometric relationships (as described for CARBWARE models above). Harvest, thinning's and stocking changes associated with mortality are specified in the static yield class tables (Edwards and Christy 1981, Black et al 2012)..

A modified expo-linear growth function (Monteith 2000) was used to more accurately simulate biomass during the early years of the rotation and interpolate growth over time, since static models provide data at 5 year intervals and do not consider growth of young forest (<10 years old).

Stand biomass (*St*) was expressed as:

$$St = Mt\left[\frac{1-e^{-k_s(k_t-t)}}{1-e^{-k_s k_t t}}\right] \quad \text{.........(7.3.28)}$$

where:

$$Mt = \frac{Cm}{Rm}\ln\left[1+\frac{Co}{Cm}e^{Rmt}\right] \quad \text{.........(7.3.29)}$$

where:

Mt is Monteith's function, *Cm* is maximum growth rate, *C*o is initial absolute growth rate and *R*m is the initial relative growth rate and *t* is time (years). Parameters *Cm, Rm, Co,* k_s and k_t were fitted using the least squares optimisation method to estimated stand biomass values.

The current annual increment in above or below ground biomass for any given year was then calculated as:

$$\Delta C_b = St_{n+1} - St_n \quad \text{.........(7.3.30)}$$

The same C allocation models described in for the CARBWARE models were applied to simulate the biomass gains and losses and the transfer of C between pools. The resulting static tables with carbon gains, losses for biomass, net litter, deadwood pools and harvest volume were used to derive estimates of CSC from areas and age class distributions for reporting in categories *5.A.1 Forest Land Remaining Forest Land* and *5.A.2 Land Converted to Forest Land (see* section *7.3.4).*

Age class distributions were derived from afforestation records for the category *5.A.2 Land Converted to Forest Land.* For *5.A.1* For the *Forest Land Remaining Forest Land* category, age class distributions were initially derived from afforestation data before 1990 and felled/restocked areas. The age class distributions were then adjusted using optimisation procedures using the prescribed total harvest volume for each species cohort. The age class distributions were validated against data obtained age class distributions for 1998, 2006 and 2012 (see section 7.3.4).

For the time series adjustment of derived for C pools, the FORCARB model was run until 2012 and the 1990 to 2006 time series data was re-scaled using the CARBWARE 2006 to 2011 data (see section 7.3.4.1). Emissions form soils were not rescaled because this was derived directly using eq. 7.3.23 and 7.3.24 once areas on mineral, peaty mineral and peat soils was determined (see section 7.3.3.1.2).

7.3.4 Forest land remaining forest land (CRF 5.A.1)

Table 7.3.4 shows the net biomass, dead organic matter, soil C and to CO_2 emissions/removals for the time series 1990-2011 for forest land remaining forest land (i.e. all forest established before 1990 reported in CRF 5.A.1). For the historical time series 1990 to 2006, the adjusted FORCARB estimates reported. For the 2007 to 2012 time series, the CARBWARE model estimates are reported (Table 7.3.4).

Table 7.3.4. Time series for the forest category 5.A.1

Forests remaining forest (since 1990)

Year	Area (kHa)		CSC (Gg C)						Net CO_2 Gg	Harvests[1] (M m^3)	
			Living biomass			DOM	Mineral Soils	Organic soils	Total		
	Total	Organic	Gain	Loss	Net	Net	Net	Net		EUROSTAT	Modelled
1990	465.26	277.88	2628.45	-1633.17	995.28	-74.46	NO	-72.89	-3109.07	1.68	1.68
1991	465.24	277.86	2657.59	-1651.63	1005.96	-79.15	NO	-72.78	-3131.47	1.77	1.77
1992	465.22	277.85	2686.00	-1849.25	836.75	-106.40	NO	-72.67	-2411.49	2.08	2.08
1993	465.20	277.84	2703.29	-1767.39	935.91	-19.44	NO	-72.45	-3094.75	2.10	2.10
1994	465.18	277.83	2714.29	-1903.31	810.98	-42.05	NO	-72.33	-2554.19	2.29	2.28
1995	464.84	277.63	2724.43	-2016.14	708.29	-61.91	NO	-72.16	-2105.46	2.38	2.38
1996	464.51	277.43	2732.25	-2088.57	643.68	-72.85	NO	-71.86	-1829.58	2.46	2.46
1997	464.18	277.23	2743.65	-1920.54	823.11	23.82	NO	-71.39	-2843.61	2.32	2.31
1998	463.84	277.03	2765.65	-2129.50	636.15	-21.63	NO	-71.22	-1992.11	2.64	2.63
1999	463.51	276.83	2777.54	-2205.00	572.54	5.54	NO	-70.84	-1859.86	2.78	2.77
2000	462.65	276.32	2766.10	-2429.68	336.43	58.36	NO	-69.88	-1191.33	3.01	3.00
2001	461.79	275.81	2826.15	-2505.04	321.11	5.82	NO	-69.71	-943.10	2.84	2.82
2002	460.94	275.30	2778.41	-2582.06	196.35	-4.50	NO	-69.23	-449.58	2.91	2.90
2003	460.08	274.78	2766.18	-2508.17	258.02	60.11	NO	-67.76	-917.98	3.00	2.99
2004	459.22	274.27	2750.41	-2351.70	398.72	135.71	NO	-67.50	-1712.05	2.85	2.83
2005	458.37	273.76	2767.79	-2526.01	241.78	103.95	NO	-66.22	-1024.86	2.94	2.92
2006	456.37	272.57	2768.56	-2575.94	192.62	69.42	NO	-65.25	-721.55	2.97	2.95
2007	454.77	271.61	2789.64	-2529.67	259.98	126.47	NO	-64.21	-1181.55	2.90	2.86
2008	452.77	270.42	2816.55	-2229.10	587.45	74.22	NO	-62.20	-2198.07	2.46	2.21
2009	451.97	269.94	2831.88	-2320.25	511.63	99.55	NO	-61.43	-2015.73	2.46	2.68
2010	451.17	269.46	2864.00	-2668.44	195.56	149.08	NO	-59.90	-1044.08	2.74	3.04
2011	449.57	268.50	2802.58	-2682.68	119.91	130.12	NO	-57.93	-704.35	2.72	2.73
2012	449.57	268.50	2749.39	-2881.78	-132.39	195.11	NO	-56.00	-24.62	2.72	2.74

[1] The harvest volumes show a comparison of the EUROSTAT and modelled harvest using FORECARB and the CARBWARE model. Note: the harvest volumes from 2007 onwards are calculated as total harvest (EUROSTAT) minus post-1990 forest harvests

The FORCARB model (see 7.3.3.2) was initially run to determine net emissions/removals in pools for the entire time series. Since the initial age class distribution in 1990 and changes in age class could not be determined from the FIPS 95 data, age class was modelled using a partial least squares optimisation based on total harvest volume (EUROSTAT harvest volume). The optimisation essentially adjusts the age class distribution until the least difference between EUROSTAT and modelled FORCARB harvests is obtained (i.e. the minimum RMSE is obtained after at least 100 iterations). The optimisation procedure was initially performed on the 1990 data set, followed by repeated optimisation procedures in the following years. The priory age class distribution for 1990 (blue histograms) was based on and incomplete Coillte inventory for 1986 (Black et al., 2012, Figure 7.3.6). Figure 7.3.6 also shows the posterior age-class distribution (red histograms) following harvest optimisation for the year 1990. To ensure that the derived FORCARB age-class distributions over the entire time series were realistic, validations were made against independent age class data for 1998, 2006 and 2012 data (Black et al, 2012, see Figure 7.3.6).

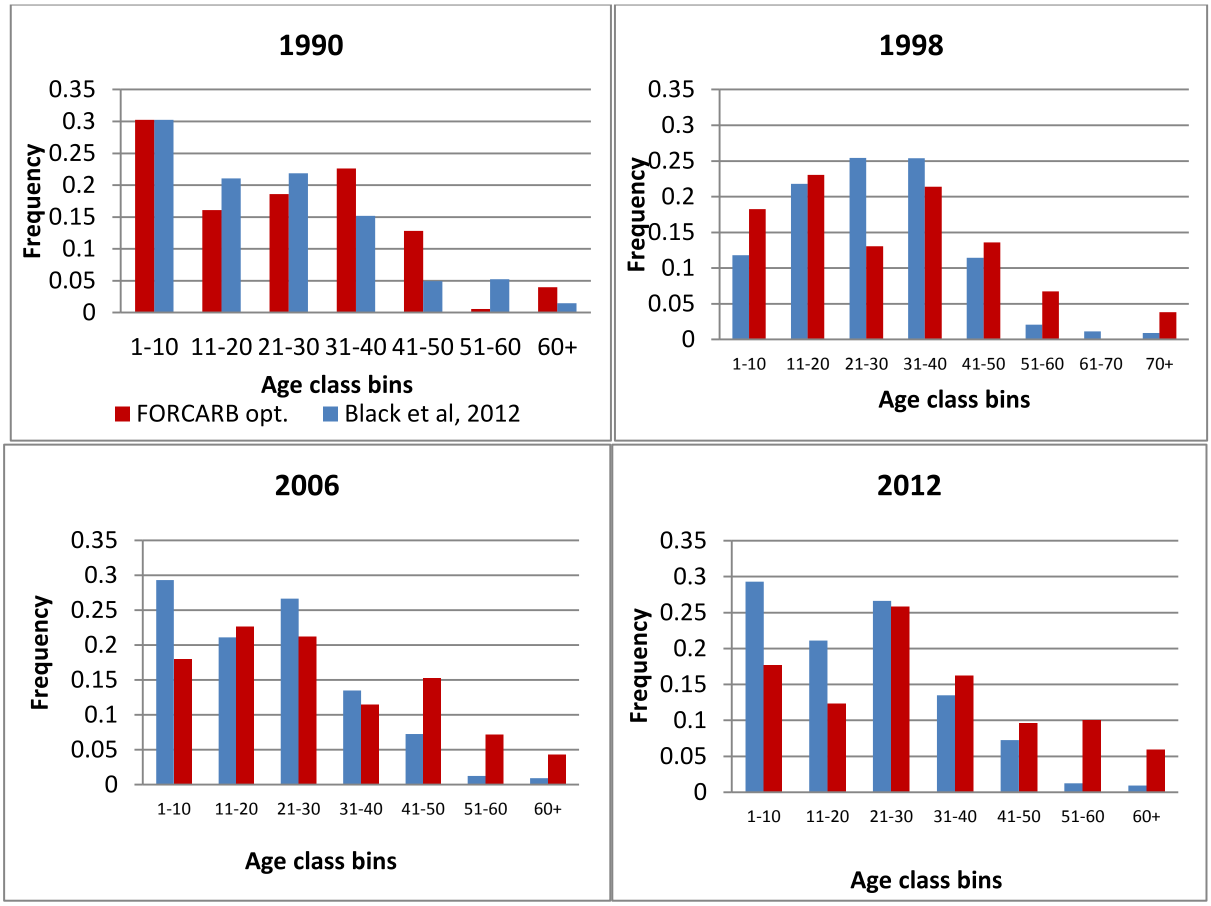


Figure 7.3.6 Validation of optimised age-class distributions

It can be seen from Figure 7.3.6 that both the FORCARB and published age-class distributions show the same trends over the time series. There is a right shift in the age-class distribution from 1990 to 1998, which suggest a transition from a younger to an older-aged forest estate. From 1998 to 2006, this trend is reversed because of a larger occurrence of clearfelling and restocking of sites. The slight reversed trends over the period 2006 to 2012 suggests and increase in mean age, which is consistent with a higher proportion of fillings coming from thinned stands (Black et al., 2012). These trends in combination with the increase harvest trends and higher emissions form harvest residues in the DOM pools over the time series appears to be the main driver of the observed decrease in removals by the pre-1990 forest category as suggested by Black et al., 2012.

7.3.4.1 Time Series Adjustment of Living Biomass and DOM Pools

To ensure that there is no bias introduced in estimates over the time series due to the use of the different models, the 1990 to 2006 FORCARB series was adjusted (Table 7.3.39) and rescaled using teir 1 IPCC GPG (2006) time series overlap approaches:

- Living biomass gains (*LBgian*, Gg C) from the 2007 to 2012 time series for the CARBWARE and FORCARB model outputs were compared. The ratio (2.19) of the total CARBWARE and FORCARB LBgain values for 2007-2012 was used to adjust the time series:
$$LB\ gain_{adj} = LB\ gain_{ini.} \times 2.19 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots \ldots \ldots \ldots (eq\ 7.3.31)$$
where, $LBgain_{adj}$ is the adjusted living biomass gain value and $LBgain_{ini}$ is initial FORCARB estimate. This method is consistent with eq 5.1 Ch5 of Time series in the 2006 GPG.

- The adjusted biomass losses (*LBloss*) were scaled using the ratio of living biomass gains to living biomass losses, derived for each year in the 1990-2006 time series. For example the adjustment for 1990 is:
$$LB\ loss_{adj(1990)} = LBgain_{adj(1990)} \times \frac{LB\ loss_{ini(1990)}}{LBgain_{ini(1990)}} \ldots \ldots \ldots \ldots . . \ldots \ldots (eq\ 7.3.32)$$

- For dead organic matter (DOM), the ratio (-1.51) of the average CARBWARE to average FORCARB values for 2007-2012 was used to adjust the time series:
$$DOM_{adj} = DOM_{ini.} \times -1.51 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (eq\ 7.3.33)$$

- There were no adjustments to the soil EF, since the FORCARB and CARBWARE estimates were identical

Figure 7.3.7 shows the initial FORCARB estimates (blue symbols) and the time series adjustment as (red symbols) reported in the CRF table 5.A.1 and Table 7.3.4. Both time series show the same trend but the adjusted values show a higher net removal of CO_2. This is due to fundamental differences in the model input variables and the spatial scale at with the FORCARB and CARBWARE models operate. There are also known underestimated biases in the FORCARB model introduced when BFC yield tables are used. These are introduced by:

- Use of prescribed thinning cycles and clearfell regimes which do not occur in practice. The CARBWARE model imposes harvest when this is indicated in the NFI or felling licence records, so gives a clear indication the land owner intends to harvest a site. Also rotation ages as prescribed in the BFC are generally higher that those imposed under current management practice (Black et al., 2007; 2012);

- Predefined stocking rates in the FORCARB model, which is generally under estimated, when compared to the real situation as evident from NFI data and national research (Black et al., 2007). This would result in an underestimation of LBgains when the FORCARB model is run;

- Differences in the current annual increment when BFC yield table (as used in FORCARB) are compared to NFI (CARBWARE) and national research information;

- The CARBWARE model provides a more accurate assessment of increment in younger stand than the FORCARB, BFC based model;

- Although the average yield class of the major species, Sitka spruce is similar for both the FORCARB and CARBWARE based estimates. The median is higher for the NFI based assessment, which would also result in a higher increment when compared to the FORCARB model.

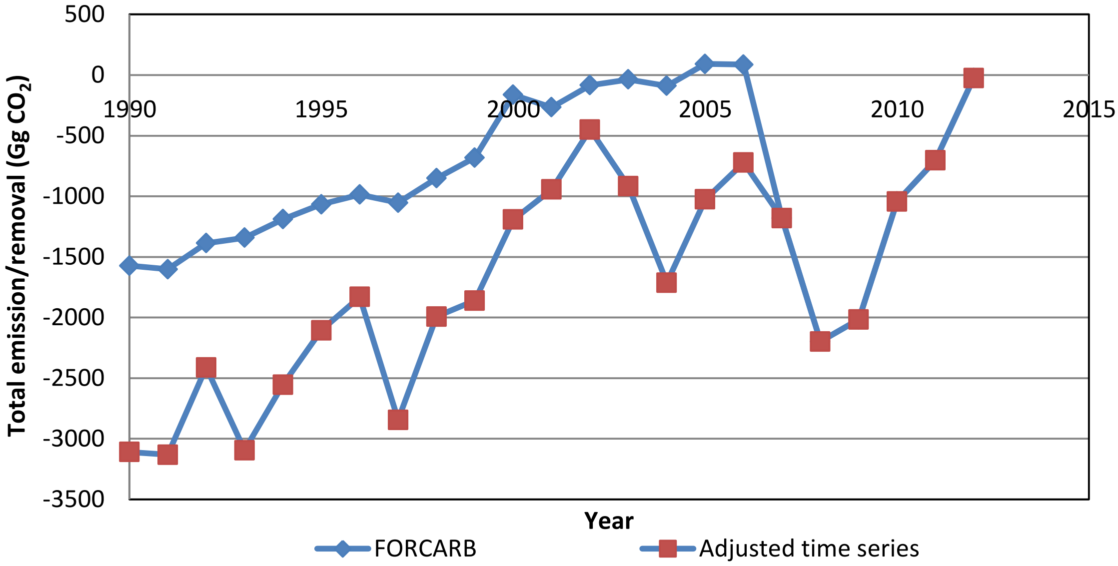


Figure 7.3.7 Adjusted time series[4] for forest category 5.A.1.

7.3.4.2 Mineral soils

The tier 1 approach is applied, which assumes that the carbon stock change (CSC) in mineral soil organic matter for category 5.A.1 Forest Land remaining Forest Land (FL-FL) is *zero.* Therefore, the notation key NO is therefore used for mineral soils under this land category in CRF Table 5.A.

[4] The final adjusted time series comprises of adjusted FORCARB estimates for the period 1990-2006 and CARBWARE estimated for the period 2007-2012.

Table 7.3.5. Area (in kha) and emissions from different organic soils types over the times series for forest land remaining forests

Year	Total Area[1]	Mineral	Organic	Open area [2]	Sites <50 years old (excl open area) [3]	Organic soils [4]	Organo-mineral soil [5]	Mineral soils [6]	Mineral tC	Orgainic tC	Orgaino-mineral tC	Total tC [7]	t CO_2
	(kHa)												
1990	465.3	187.4	277.9	41.4	302.9	107.6	28.8	80.0	NO	-63464.7	-9425.3	-72889.9	-267263.1
1991	465.2	187.4	277.9	41.4	302.4	107.4	28.8	79.6	NO	-63367.3	-9410.8	-72778.0	-266852.8
1992	465.2	187.4	277.9	41.4	301.9	107.2	28.7	79.2	NO	-63269.8	-9396.3	-72666.2	-266442.6
1993	465.2	187.4	277.8	41.5	301.0	106.9	28.6	78.3	NO	-63078.6	-9367.9	-72446.5	-265637.1
1994	465.2	187.3	277.8	41.5	300.5	106.7	28.6	77.8	NO	-62981.2	-9353.5	-72334.6	-265227.0
1995	464.8	187.2	277.6	41.5	299.8	106.5	28.5	77.3	NO	-62830.4	-9331.1	-72161.5	-264592.2
1996	464.5	187.1	277.4	41.0	298.6	106.0	28.4	76.1	NO	-62567.5	-9292.0	-71859.5	-263485.0
1997	464.2	186.9	277.2	41.1	297.4	105.3	28.3	75.5	NO	-62138.0	-9255.8	-71393.7	-261777.1
1998	463.8	186.8	277.0	41.1	296.7	105.1	28.2	75.0	NO	-61988.3	-9233.5	-71221.8	-261146.6
1999	463.5	186.7	276.8	41.2	295.1	104.5	28.1	73.6	NO	-61652.3	-9183.4	-70835.7	-259731.0
2000	462.7	186.3	276.3	41.3	292.6	103.0	27.8	72.4	NO	-60771.2	-9106.6	-69877.7	-256218.4
2001	461.8	186.0	275.8	41.5	291.9	102.8	27.8	72.2	NO	-60629.0	-9085.2	-69714.3	-255619.0
2002	460.9	185.6	275.3	41.6	289.9	102.1	27.6	70.8	NO	-60210.7	-9022.6	-69233.2	-253855.1
2003	460.1	185.3	274.8	41.7	285.3	99.8	27.1	67.5	NO	-58886.7	-8877.5	-67764.2	-248468.6
2004	459.2	185.0	274.3	41.8	284.1	99.4	27.0	67.0	NO	-58656.9	-8842.8	-67499.7	-247498.9
2005	458.4	184.6	273.8	42.0	279.5	97.5	26.6	63.5	NO	-57526.2	-8698.7	-66224.9	-242824.6
2006	456.4	183.8	272.6	42.3	275.8	96.2	25.9	61.5	NO	-56758.0	-8496.5	-65254.5	-239266.5
2007	454.8	183.2	271.6	42.4	272.4	94.7	25.3	59.9	NO	-55897.4	-8308.2	-64205.6	-235420.5
2008	452.8	182.4	270.4	42.7	267.4	91.9	24.3	58.2	NO	-54206.5	-7989.2	-62195.8	-228051.1
2009	452.0	182.0	269.9	42.9	265.1	90.8	23.8	57.2	NO	-53569.0	-7864.5	-61433.5	-225256.1
2010	451.2	181.7	269.5	43.0	261.5	88.5	23.2	55.8	NO	-52185.9	-7713.7	-59899.6	-219631.8
2011	449.6	181.1	268.5	43.2	254.7	85.6	22.3	51.7	NO	-50519.2	-7408.4	-57927.6	-212401.1
2012	449.6	181.1	268.5	43.2	249.6	82.8	21.4	49.1	NO	-48874.2	-7128.8	-56003.0	-205344.5

[1] Total area includes open areas

[2] Adjusted area for 10 % open area within forest areas (roads, extraction routes, biodiversity etc).

[3] No emissions from organic soils on sites older than 50 years old, (Data source NFI)

[4] Organic soils include all soils with a > 20% C and an organic layer greater than 30 cm (e.g. Blanket peats, fens, cutaway peats. All organic soils are assumed to be drained. These areas are used in eq 7.3..23.

[5] Organo-mineral soils are mineral soils with an organic overlay of < 30cm. These include peaty podsols and peaty gleys (Source NFI). These areas are used in eq 7.3.24

[6] Mineral soils are shown not to be a source so are reported as zero (NA). These include brown earths, podsols, gleys, brown podsolics, lithosols etc. (Source NFI).

[7] Area presented in CRF Tables. The total area of organic soils includes open areas and organic soils with forests older than 50 years old

7.3.4.3 Organic Soils

Emissions from the drainage of organic soils are reported using eq. 7.3.23 and 7.3.24, described in section 7.2. Forest soils[5] are classified as organic soils or (peats) if the peat depth is greater than 30 cm and the organic content is greater than 20 per cent. If the organic or peat layer is less than 30cm then the soils is classified as organo-mineral (or peaty-mineral) soils. For previous submissions, it was assumed that afforestation occurs on mineral and organic soils in the proportions 60 per cent and 40 per cent, respectively. The allocation to mineral, organo-mineral and organic soils is now determined separately for each year using PSP data from the 2006 and 2012 NFI , based on soil type and forest age attributes. The area of forest soils subjected to emissions/removals is obtained from a matrix of the three general soils types and the forest areas according to FIPS 07 and NFI information. The sample provides a breakdown in percentage of soil types in the FL-FL (pre-1990 forests younger than 50 years) and L-FL (post-1990 forest) areas. The total area is scaled up using the annual area in each category. The scaled up area is adjusted (i.e. reduced) to account for open areas in forest areas (10 per cent of the total area, NFI, 2007), since these are not planted or drained and emissions are assume to be zero. Forests older than 50 years old are assumed to be in steady state regardless of the soil type (see justifications in section 7.3.3.1.2, d) soils).

7.3.4.4 Emissions from Biomass Burning

Estimates of emissions from forest biomass burning in Ireland relate to forest wildfires. The estimates are recalculated in this submission based on new biomass, and DOM input estimates from the CARBWARE model for forest in 2012. In order to incorporate the effect of forest fires into CARBWARE, the following assumptions were made:

1) All fires are assumed to occur in all forest land classes under *5.A.1 Forest Land Remaining Forest Land* and *5.A.2 Land Converted to Forest Land*. However, because no geographically explicit data on fires are available to distinguish between fires occurring in these categories, these are equally distributed between the two categories based on the proportional area of these categories from 2007 onwards (Table 7.3.5). This assumption is made because there is evidence that fires generally only occur in forest at the pre-thicket stage of growth when there is enough woody biomass to act as a source for combustion by wild fires;

2) Emissions from the burning of forest biomass and DOM pools are calculated using equation 3.2.19 of the IPCC good practice guidance for LULUCF. A carbon release factor of 0.4 is used for wildfires (GPG Table 3A 1.12), with emission ratios for methane and nitrous oxide of 0.012 and 0.007, respectively (GPG Table 3 A 1.15). For nitrous oxide a C:N ratio of 0.01 is assumed;

3) Emissions directly resulting from fire (i.e. combustion) are included for all years from 1990 (Table 7.3.6). Data on forest areas were obtained from the Forest assessment reports, reconstitution grant data for grant aided forests and the state owned forest company (Coillte);

4) Biomass burned per ha includes all aboveground biomass, litter and deadwood. However, no activity data exists documenting the amount of timber or biomass burned. Therefore, for the forest land remaining forest land category, the average biomass input for combustion is based on an average aboveground biomass C stock for a YC 16 crop over a standard rotation- 74.2 tC ha^{-1}, equivalent to 149,450 kg biomass d.wt ha^{-1}. The average C stock for litter and deadwood is estimated to be

[5] The reported area under organic soils in the CRF tables include open areas and areas with forest cover which is older than 50 years

14.1 tC ha^{-1}, equivalent to 28,263 kg biomass d.wt ha^{-1}. For the land converted to forest land category, the average aboveground biomass C stock of a 18 year old YC 16 crop is 45.3 tC ha^{-1}, equivalent to 90,526 kg biomass d.wt ha^{-1}. The average C stock for litter and deadwood is estimated to be 6.5 tC ha^{-1}, equivalent to 12,959 kg biomass d.wt ha^{-1};

5) Emissions from soils are assumed to negligible and do not occur (NO);

6) The indirect effect of fires on carbon stock changes include those associated with loss of productivity of the area after fire and re-growth following re-planting, which is assumed to occur in the following year. It is assumed that changes in the area of forest remaining forest due to fire before 1995 were already captured by the FIPS 1995 data underlying the FORCARB model. Therefore, the indirect effects of fires and replanting on carbon stock changes, excluding the direct emission due to combustion, were only applied for the years from 1995 onwards. These are included in CRF Table 5.A.1 since they represent areas replanted.

Table 7.3.6. Area statistics and emission profiles over the time series 1990 to 2011 for wild fires in categories 5.A.1 and 5.A.2

	F-F land (pre-1990)							F-L land (post-1990)						
	Fire area	Prop area burned	biomass	CO_2	CH_4	N_20	$GgCO_2$ eq	Fire area	Prop area burned	biomass Mg	CO_2	CH_4	N_20	$GgCO_2$ eq
	Ha		Mg	Gg				Ha		Mg	Gg			
1990	389.00	1.00	69130.75	101.39	0.44	2.58E-03	111.48	NO	NO	NO	NO	NO	NO	NO
1991	250.00	1.00	44428.51	65.16	0.28	1.66E-03	71.65	NO	NO	NO	NO	NO	NO	NO
1992	160.70	1.00	28558.64	41.89	0.18	1.07E-03	46.05	NO	NO	NO	NO	NO	NO	NO
1993	324.00	1.00	57579.34	84.45	0.37	2.15E-03	92.85	NO	NO	NO	NO	NO	NO	NO
1994	372.00	1.00	66109.62	96.96	0.42	2.47E-03	106.61	NO	NO	NO	NO	NO	NO	NO
1995	508.00	1.00	90278.72	132.41	0.58	3.37E-03	145.59	NO	NO	NO	NO	NO	NO	NO
1996	565.00	1.00	100408.42	147.27	0.64	3.75E-03	161.92	NO	NO	NO	NO	NO	NO	NO
1997	309.00	1.00	54913.63	80.54	0.35	2.05E-03	88.56	NO	NO	NO	NO	NO	NO	NO
1998	163.00	1.00	28967.39	42.49	0.19	1.08E-03	46.71	NO	NO	NO	NO	NO	NO	NO
1999	133.00	1.00	23635.96	34.67	0.15	8.82E-04	38.12	NO	NO	NO	NO	NO	NO	NO
2000	334.00	1.00	59356.48	87.06	0.38	2.22E-03	95.72	NO	NO	NO	NO	NO	NO	NO
2001	666.00	1.00	118357.54	173.59	0.76	4.42E-03	190.87	NO	NO	NO	NO	NO	NO	NO
2002	153.00	1.00	27190.25	39.88	0.17	1.02E-03	43.85	NO	NO	NO	NO	NO	NO	NO
2003	944.00	1.00	167762.04	246.05	1.07	6.26E-03	270.54	NO	NO	NO	NO	NO	NO	NO
2004	550.00	1.00	97742.71	143.36	0.63	3.65E-03	157.62	NO	NO	NO	NO	NO	NO	NO
2005	200.00	1.00	35542.80	52.13	0.23	1.33E-03	57.32	NO	NO	NO	NO	NO	NO	NO
2006	200.00	1.00	35542.80	52.13	0.23	1.33E-03	57.32	NO	NO	NO	NO	NO	NO	NO
2007	224.83	1.00	39955.44	58.60	0.26	1.49E-03	64.43	NO	NO	NO	NO	NO	NO	NO
2008	273.55	0.64	31056.17	45.55	0.20	1.16E-03	50.08	273.55	0.36	10223.96	15.00	0.07	3.82E-04	16.49
2009	154.48	0.63	17392.65	25.51	0.11	6.49E-04	28.05	154.48	0.37	5858.42	8.59	0.04	2.19E-04	9.45
2010	1013.09	0.63	113040.74	165.79	0.72	4.22E-03	182.29	1013.09	0.37	39014.69	57.22	0.25	1.46E-03	62.92
2011	375.55	0.63	42047.05	61.67	0.27	1.57E-03	67.81	375.55	0.37	14379.80	21.09	0.09	5.37E-04	23.19
2012	95.00	0.63	10636.18	15.60	0.07	3.97E-04	17.15	95.00	0.37	36375.02	5.34	0.02	1.36E-04	5.87

7.3.4.5 Emissions of N_2O from Fertilization

Ireland does not report separately the emissions of N_2O due to fertilizer use for *5.A Forest Land*. The amount of synthetic fertilizer used in forests is negligible compared to that used in agriculture and therefore all N_2O emissions from fertilizer applications are reported under agriculture. The notation key IE is therefore used in CRF Table 5(I).

7.3.4.6 Emissions of N_2O from Drainage

Tier 1 estimates of N_2O emissions due to the drainage of organic soils and mineral soils in forest lands were first reported in 2009. Nitrous oxide emission estimates for drained forest soils are now improved in the present submission. This is due to the re-analysis of National Forest Inventory (NFI) data released in 2006 (NFI 2007a and 2007b) for the time series change to pre-1990 and post 1990 forests. The NFI results are based on randomised systematic grid sample design, at a grid resolution of 2 x 2 km to provide the number of plots needed to estimate total standing volume with a precision of ±5 per cent at the 95 per cent confidence level. The grid generated 17,423 intersections, each representing 400 ha. A land use classification of each intersection point was undertaken to identify afforested areas using photo-interpretation of OSI aerial photographs, aided by supplementary databases such as the Coillte and the afforestation grant and premiums datasets. This resulted in the classification of 1,742 points as forest land. At each intersection point permanent sample plots, representing 400 ha, were set up. Each plot was visited and a wide range of growth, carbon stock, forest type, soil and other variables were assessed and electronically stored. Data collection began in November 2004 and was completed in November 2006. Data were quality controlled by independently assessing a sub-sample of the plots, and by inbuilt checks in the data collection software.

The NFI data was used to derive a breakdown of areas for drained mineral, rich organic and poor organic soils over the time-series to 2005, based on planting year, soil type and cultivation type. Soils were assumed not to be drained if there was no cultivation or if pit planting was employed during forest establishment. It is assumed that all organic soils are drained. This includes previously drained sites, such as cutaway peats, where drainage occurred before afforestation occurred. Sites were then further categorised in to mineral (soils with no organic layer), rich N organic (peaty-gleys) and poor N organic (all remaining peats and peaty mineral soils). The total area subjected to drainage excluded open areas within forest areas, where no drainage occurs. The proportion of the three tier 1 soil types subjected to drainage for the time-series are determined from this soil/drainage matrix (table 7.10). The default emission factors were used for mineral, poor organic and rich organic soils (IPCC GPG, LULUCF Appendix 3a.2; Table 3a.2.1 pp 3.275). The inclusion of N_2O emissions from forest soils contributes emissions of 23.1 to 22.2 Gg CO_2 equivalents for the years 1990 to 2012. The slight decrease in emission is due to the reduction of forest area in this category (Table 7.3.7) due to deforestation.

Estimates presented in CRF 5(V) include forest land remaining forest land and lands converted to forest land. There is no specific CRF table for N_2O emissions associated with the drainage of organic forest soils following conversion to forest land. Recent unpublished national research does show that there are N_2O emissions from mineral soils following afforestation. This may be due to increase mineralisation or drainage of lands being afforested. However, we adopt a conservative approach by assuming drainage of all forest soils following afforestation results in the emission of N_2O (Tables 7.3.7a and b).

Table 7.3.7.a. The area activity data and N_20 emissions from drainage of forest land remaining forest land

F-F (pre-1990)										
Year	Total Area	Open area	No drain	Mineral	Organic N-poor	Organic N-rich	Mineral	Organic N-poor	Organic N-rich	Total Organic
	Area (kHa)						Mg N20			
1990	465.3	41.4	65.0	105.4	221.5	31.8	**9.94**	34.81	30.02	**64.84**
1991	465.2	41.4	65.0	105.4	221.5	31.8	**9.94**	34.81	30.02	**64.83**
1992	465.2	41.4	65.0	105.4	221.5	31.8	**9.94**	34.81	30.02	**64.83**
1993	465.2	41.5	65.0	105.4	221.5	31.8	**9.94**	34.81	30.02	**64.83**
1994	465.2	41.5	65.0	105.4	221.5	31.8	**9.93**	34.81	30.02	**64.82**
1995	464.8	41.5	65.0	105.3	221.3	31.8	**9.93**	34.78	29.99	**64.76**
1996	464.5	41.0	65.0	105.3	221.4	31.8	**9.93**	34.79	30.00	**64.78**
1997	464.2	41.1	64.9	105.2	221.2	31.8	**9.92**	34.75	29.97	**64.72**
1998	463.8	41.1	64.9	105.1	221.0	31.8	**9.91**	34.72	29.94	**64.67**
1999	463.5	41.2	64.8	105.0	220.8	31.7	**9.90**	34.69	29.92	**64.61**
2000	462.7	41.3	64.6	104.8	220.2	31.7	**9.88**	34.61	29.85	**64.46**
2001	461.8	41.5	64.5	104.5	219.7	31.6	**9.86**	34.53	29.78	**64.31**
2002	460.9	41.6	64.3	104.3	219.2	31.5	**9.83**	34.45	29.71	**64.16**
2003	460.1	41.7	64.2	104.0	218.7	31.4	**9.81**	34.37	29.64	**64.00**
2004	459.2	41.8	64.0	103.8	218.2	31.4	**9.79**	34.29	29.57	**63.85**
2005	458.4	42.0	63.9	103.5	217.7	31.3	**9.76**	34.21	29.50	**63.70**
2006	456.4	42.3	63.5	103.0	216.5	31.1	**9.71**	34.02	29.33	**63.35**
2007	454.8	42.4	63.3	102.5	215.5	31.0	**9.67**	33.87	29.21	**63.08**
2008	452.8	42.7	62.9	102.0	214.3	30.8	**9.61**	33.68	29.05	**62.73**
2009	452.0	42.9	62.8	101.7	213.9	30.7	**9.59**	33.61	28.98	**62.59**
2010	451.2	43.0	62.6	101.5	213.4	30.7	**9.57**	33.53	28.92	**62.45**
2011	449.6	43.2	62.4	101.1	212.4	30.5	**9.53**	33.38	28.79	**62.17**
2012	449.6	43.2	62.4	101.1	212.4	30.5	**9.53**	33.38	28.79	**62.17**

Table 7.3.7.b. The area activity data and N_20 emissions from drainage of forest land converted to forest land

F-L(post-1990)										
Year	Total Area[1]	Open area	No drain	Mineral	Organic N-poor	Organic N-rich	Mineral	Organic N-poor	Organic N-rich	Total Organic
	Area (kHa)							Mg N20		
1990	15.8	1.9	1.6	3.6	7.7	1.1	**0.33**	1.20	1.03	**2.23**
1991	35.0	4.2	2.9	10.5	12.8	4.6	**0.99**	2.01	4.38	**6.39**
1992	51.7	6.1	2.7	15.2	23.2	4.5	**1.43**	3.65	4.21	**7.85**
1993	67.7	8.1	6.3	22.0	25.1	6.3	**2.07**	3.94	5.92	**9.86**
1994	87.1	10.4	9.4	24.8	40.1	2.4	**2.34**	6.31	2.23	**8.54**
1995	110.8	13.2	11.0	15.1	53.6	17.9	**1.43**	8.43	16.86	**25.28**
1996	131.8	15.7	12.4	39.4	56.0	8.3	**3.71**	8.80	7.82	**16.62**
1997	143.2	17.0	24.6	40.0	52.3	9.2	**3.77**	8.22	8.71	**16.93**
1998	156.2	18.6	18.1	47.1	54.3	18.1	**4.44**	8.53	17.07	**25.60**
1999	168.8	20.1	18.2	54.6	66.8	9.1	**5.15**	10.49	8.59	**19.08**
2000	184.5	22.0	15.3	64.4	58.3	24.5	**6.07**	9.16	23.14	**32.30**
2001	200.0	23.8	17.6	48.5	83.7	26.4	**4.57**	13.15	24.92	**38.07**
2002	215.1	25.6	36.7	67.2	67.2	18.3	**6.34**	10.56	17.29	**27.85**
2003	224.2	26.7	12.3	55.5	98.7	30.9	**5.24**	15.52	29.09	**44.61**
2004	233.9	27.8	15.1	70.4	90.5	30.2	**6.63**	14.22	28.43	**42.65**
2005	244.0	29.0	26.9	53.7	107.5	26.9	**5.07**	16.89	25.33	**42.22**
2006	252.0	31.4	25.1	69.5	101.2	25.0	**6.55**	15.90	23.52	**39.42**
2007	259.2	32.5	25.7	71.4	104.0	25.6	**6.73**	16.34	24.17	**40.51**
2008	265.4	33.4	26.3	73.1	106.4	26.2	**6.89**	16.72	24.74	**41.46**
2009	272.1	34.4	27.0	74.9	109.0	26.9	**7.06**	17.13	25.34	**42.47**
2010	280.4	35.6	27.8	77.1	112.2	27.7	**7.27**	17.63	26.10	**43.73**
2011	287.1	36.6	28.4	78.9	114.8	28.3	**7.44**	18.04	26.70	**44.74**
2012	292.9	37.6	29.0	80.4	117.0	28.9	**7.58**	18.39	27.22	**45.61**

7.3.4.7 Uncertainty Analysis for Category 5.A.1

Characterisation of uncertainties associated with individual activity and area information was obtained directly or derived from already published studies. If no estimates were available expert judgement was applied (Table 7.3.8). Some uncertainties cannot be quantified due to a lack of validation data. These include uncertainties associated with mortality models. However, mortality factors are selected where a tree has a 95 per cent probability of being dead (Annex K2_A). Other assumptions regarding the number of locations and amount of timber removed during harvest cannot be evaluated until the repeat NFI is completed in 2012/3.

The IPCC tier 1 approach is applied to estimate uncertainties for the Convention reporting and Article 3.3 activities described in this chapter using the methods for combining uncertainties given in section 6.3 of the IPCC good practice guidance for LULUCF. However, many of the input variables are auto correlated with each other, and therefore violate the basic assumption in this approach that inputs are statistically independent. For example, biomass and litter pools are derived from DBH increment models and biomass equations. However the simple tier 1 method is adopted until the capacity to develop Monte Carlo approaches in developed and reported in future submissions.

The percentage input uncertainties in the various methodological parameters used for the analysis of carbon stock change in the relevant carbon pools and for the emissions of non-CO_2 gases are listed in Table 7.3.9. The combined uncertainties of the products of the respective parameters associated with each component pool are calculated using equation 7..3.34 (equation 6.4 of the IPCC good practice guidance):

$$U_{total} = \sqrt{U_1^2 + U_2^2 + U_3^2 + U_n^2} \quad \ldots\ldots\ldots(7.3.34)$$

where U_{total} is the combined uncertainty of the product of the input values U_1, U_2, U_3 and U_n given table 7.3.7. The calculated percentage uncertainties for pools are given in Table 7.3.8which also indicates the associated input parameters whose uncertainties have been combined. The uncertainties in the reported carbon stock changes reported in the CRF tables are calculated in Table 7.3.15 as the sum of the uncertainties for carbon pools using equation 7.3.35 (equation 6.3 of the IPCC good practice guidance):

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + (U_n \times x_n)^2}}{|x_1 + x_2 + x_n|} \quad \ldots\ldots\ldots(7.3.35)$$

where U_{total} is the combined uncertainty, U_1, U_2 and U_n are the uncertainties of pool estimates (Table 7.3.9) and x_1, x_2 and x_n are the mean values for the respective pools reported in the CRF tables.

Table 7.3.8. Uncertainty estimates for individual activity and area data sets for forest land remaining forest land

Code	Component	Sub-category	% Uncertainty	Source
A	Biomass algorithms	AB and BB	12.00	Black et al 2007
B	C fraction	All biomass pools	0.87	Black et al 2007
C	DBH and H Increment	AB and BB	11.90	Black et al 2007, Black 2008, Black et al 2009 section 7.3.2
D	Area data	GPAS data	0.60	Derived from Black et al 2009a Table 2 Comparison of NFI and GPAS data
E	Litter	Li	3.10	Tobin et al, 2006
F	Deadwood	DW	22.00	Tobin et al, 2007
G	Peat soils	So	90.00	Assume same as Teir 1 (Table 2.3,2.3.1 CH2, AFULO GPG2006)
H	Fire C stocks	fire	15.00	95 % confidence interval for biomass stocks (NFI)
I	Areas burned	fire area	50.00	Expert Judgement, guess
J	re-scaling of FORECARB	LB	3.10	% sd of ration of CABWARE/FORECARB
K	re-scaling of FORECARB	DOM	28.50	% sd of ration of CABWARE/FORECARB
L	N_20	N20 area	12.30	confidence interval of NFI analysis
M	N_20	N20 emissions		not specified in Tier 1 GPG 2003

Table 7.3.9. Combined uncertainty estimates for forest land remaining forest land pools

Pool	Component	Equation in NIR	% Uncertainty	Uncertainty of combined products (code)
LB net	Biomass	Eq 7.3.34	17.20	A+B+C+D+E+J
DOM	DOM	Eq 7.3.34	22.20	D+E+F+K
SO	Soils	Eq 7.3.34	90.00	D+G
Fires	Fire	Eq 7.3.34	59.30	H+I
N_20	Drainage	Eq 7.3.35	12.30	

For deriving uncertainties for code C in Table 7.3.9, CARBWARE DBH and H growth models were validated using some of the repeated NFI permanent sample plot data taken in 2012. These represent repeat measurement of 350 plots taken at a 3-5 year interval. Since modelling errors include NFI measurement and sampling errors, specific consideration was focused towards identifying sampling errors associated with the methodology employed by the Forest service (NFI data providers) and assessing model error (both sources of error in assessing biomass stock changes):

a) Accuracy of repeated DBH measurements

An infield validation check was used to ensure the corresponding tree was measured in the repeat inventory based on a spatial query of mapped trees. Measurement error of diameter and height was not checked infield or validated before entry into the data base. This resulted in a significant occurrence of negative increment data (5 to12 per cent of data) was removed prior to model validation. In addition, trees with a DBH increment > 15 cm over 5 year cycle and with increment values higher than 2 times the plot standard deviation were removed from the database. Zero increments from harvested trees were also removed from the database to ensure Wilcoxon ranked tests could be interpreted properly (see validation section). However, no further attempts were made to clean data with erroneous measurements in the remaining data.

b) Partial sampling of trees within a plot

Data on trees within three diameter classes (<12, 12-20 and >20 cm) are recorded if they are observed within a certain distance from the plot centre in three concentric plots within the 0.5 ha plot. This represents an additional sampling area and increases the probability of a lower representative sample of smaller, compared to larger trees. Performance of model calibration was assessed using root mean squared error (RMSE), accuracy (a measure of bias), precision and theoretical excess error.

Data were further stratified to investigate reasons for the large variation in growth increment prediction residuals across different species cohorts, DBH size classes, forest types and management regimes. Comparisons of model accuracy, bias and precision across different species cohorts and size classes show poor performance of the model in some cases (Table 7.4.9). Stratified cohort groups all had lower empirical excess error (Table 7.3.10), when compared to the theoretical excess error except for the SGB cohort, suggesting that the variation in the NFI model residuals is smaller than the random theatrically expected variation in the calibration dataset.

For all DBH categories, Spruce, pines, OC and SGB shows good agreement with the model with no significant difference between observed and simulated values (P > 0.05). In contrast, FGB and Larch showed poor agreement with the model predictions significant differences between observed and predicted values (Table 7.3.10). Larch and FBG showed a 27 per cent lower and 128 per cent higher growth rate than the model prediction, respectively.

This analysis (Table 7.3.10) and the uncertainty of biomass equations (annex J Table J1) show that the largest uncertainty is associated with broadleaf cohorts. Current national research is being conducted to improve biomass gains and loss estimated for these cohorts.

Table 7.3.10. NFI external validation of CARBWARE models

Cohort	<12 cm	12-20 cm	20-30 cm	30-40 cm	>40 cm	All classes
Spruce						
Accuracy	-0.42	0.09	0.28	0.09	-0.73	0.17 (4.8%)
Precision	1.94	1.9	1.86	1.91	2.09	2.04
P-value	<0.01	0.37	0.14	0.55	0.03	0.36
E_{imp}						9.80%
N	204	1234	1092	226	48	2804
Pines						
Accuracy	-0.3	0.13	0.14	-0.59	ND	-0.21 (-9.4 %)
Precision	1.37	1.62	1.61	3.17	ND	2.25
P-value	0.037	0.23	0.52	<0.01	ND	0.29
E_{imp}						0.40%
N	56	342	379	44	6	827
Larch						
Accuracy	ND	-1.59	0.48	ND	ND	-0.88 (-27.8 %)
Precision	ND	2.13	1.38	ND	ND	2.14
P-value	ND	<0.001	0.05	ND	ND	<0.001
E_{imp}						7.90%
N	8	54	36	4	0	102
OC						
Accuracy %	ND	-0.21	-0.53	-1.14	ND	-0.51 (-21.4 %)
Precision	ND	1.34	1.69	1.83	ND	1.65
P-value	ND	0.544	0.05	0.02	ND	0.06
E_{imp}						14.70%
N	5	77	66	31	19	198
FGB						
Accuracy	<0.001	1.44	3.06	4.19	ND	2.0 (128.1 %)
Precision	1.49	1.85	1.87	2.47	ND	2.28
P-value	0.2	<0.001	<0.0001	<0.0001	ND	<0.0001
E_{imp}						8.70%
N	64	194	183	35	19	495
SGB						
Accuracy	ND	-0.28	-0.23	-0.67	-1.24	-0.50 (-30.5 %)
Precision	ND	1.27	1.73	1.7	1.91	1.68
P-value	ND	0.37	0.75	0.17	<0.001	0.11
E_{imp}						55.10%

Tier 1 time series trend analysis was also conducted as specified in section 6.3 of the IPCC good practice guidance for LULUCF (Table 7.3.11). The increased uncertainty in the trends based on the 1990 base year are associated with increase harvests and age class distribution shifts over the time series, as described in text relating to Table 7.3.2 and Figure 7.3.5.

Table 7.3.11. Uncertainty analysis for forest land remaining forest land since 1990 category[6]

Year	Category	Year emission/reductions (Gg CO2 eq)	Base year emission/reductions (Gg CO2eq)	Combined uncertainty in year (±%)	Contribution to total variance in year (fraction)	Mean trend in year in relation to base-year (% mean trend)
1990	CRF 5A.1	-3109.07	-3109.07	21.87	0.91	na
	CRF 5A II	23.18	23.18	12.30	0.00	na
	CRF5(V)	111.48	111.48	59.36	0.09	na
	Total	**-2,974.41**	**-2,974.41**	**20.04**	**1.00**	**na**
1991	CRF 5A.1	-3131.47	-3109.07	21.94	0.94	0.72
	CRF 5A II	23.18	23.18	12.30	0.00	-0.01
	CRF5(V)	71.65	111.48	59.36	0.06	-35.73
	Total	**-3,036.64**	**-2,974.41**	**19.96**	**1.00**	**2.09**
1992	CRF 5A.1	-2411.49	-3109.07	24.75	0.95	-22.44
	CRF 5A II	23.18	23.18	12.30	0.00	-0.01
	CRF5(V)	46.05	111.48	59.36	0.04	-58.69
	Total	**-2,342.25**	**-2,974.41**	**20.14**	**1.00**	**-21.25**
1993	CRF 5A.1	-3094.75	-3109.07	20.61	0.92	-0.46
	CRF 5A II	23.18	23.18	12.30	0.00	-0.02
	CRF5(V)	92.85	111.48	59.36	0.08	-16.71
	Total	**-2,978.72**	**-2,974.41**	**20.07**	**1.00**	**0.14**
1994	CRF 5A.1	-2554.19	-3109.07	22.22	0.90	-17.85
	CRF 5A II	23.17	23.17	12.30	0.00	0.00
	CRF5(V)	106.61	111.48	59.36	0.10	-4.37
	Total	**-2,424.41**	**-2,974.41**	**19.96**	**1.00**	**-18.49**
1995	CRF 5A.1	-2105.46	-3109.07	24.37	0.85	-32.28
	CRF 5A II	23.15	23.18	12.30	0.00	-0.11
	CRF5(V)	145.59	111.48	59.36	0.14	30.59
	Total	**-1,936.72**	**-2,974.41**	**20.52**	**1.00**	**-34.89**
1996	CRF 5A.1	-1829.58	-3109.07	26.25	0.83	-41.15
	CRF 5A II	23.16	23.18	12.30	0.00	-0.08
	CRF5(V)	161.92	111.48	59.36	0.17	45.24
	Total	**-1,644.49**	**-2,974.41**	**21.26**	**1.00**	**-44.71**
1997	CRF 5A.1	-2843.61	-3109.07	20.09	0.91	-8.54
	CRF 5A II	23.14	23.14	12.30	0.00	0.00
	CRF5(V)	88.56	111.48	59.36	0.08	-20.57
	Total	**-2,731.91**	**-2,974.45**	**20.01**	**1.00**	**-8.15**
1998	CRF 5A.1	-1992.11	-3109.07	23.40	0.94	-35.93
	CRF 5A II	23.12	23.18	12.30	0.01	-0.26
	CRF5(V)	46.71	111.48	59.36	0.06	-58.10
	Total	**-1,922.28**	**-2,974.41**	**19.90**	**1.00**	**-35.37**
1999	CRF 5A.1	-1859.86	-3109.07	23.14	0.94	-40.18
	CRF 5A II	23.10	23.18	12.30	0.01	-0.35
	CRF5(V)	38.12	111.48	59.36	0.05	-65.81
	Total	**-1,798.65**	**-2,974.41**	**19.92**	**1.00**	**-39.53**
2000	CRF 5A.1	-1191.33	-3109.07	27.10	0.84	-61.68
	CRF 5A II	23.04	23.18	12.30	0.01	-0.59
	CRF5(V)	95.72	111.48	59.36	0.15	-14.14
	Total	**-1,072.56**	**-2,974.41**	**20.51**	**1.00**	**-63.94**
2001	CRF 5A.1	-943.10	-3109.07	32.52	0.73	-69.67
	CRF 5A II	22.99	23.18	12.30	0.01	-0.82
	CRF5(V)	190.87	111.48	59.36	0.27	71.21
	Total	**-729.24**	**-2,974.41**	**26.86**	**1.00**	**-75.48**
2002	CRF 5A.1	-449.58	-3109.07	57.83	0.90	-85.54
	CRF 5A II	22.94	23.18	12.30	0.01	-1.05
	CRF5(V)	43.85	111.48	59.36	0.09	-60.67
	Total	**-382.80**	**-2,974.41**	**19.79**	**1.00**	**-87.13**

[6] Note that uncertainties for category 5A(II) and 5A(V) include land in the forest remaining forest land category only.

Table 7.3.11. Uncertainty analysis for forest land remaining forest land since 1990 category[7] (continued)

Year	Category	Year emission/reductions (Gg CO2 eq)	Base year emission/reductions (Gg CO2eq)	Combined uncertainty in year (±%)	Contribution to total variance in year (fraction)	Mean trend in year in relation to base-year (% mean trend)
2003	CRF 5A.1	-917.98	-3109.07	31.36	0.64	-70.47
	CRF 5A II	22.88	23.18	12.30	0.01	-1.28
	CRF5(V)	270.54	111.48	59.36	0.36	142.67
	Total	**-624.56**	**-2,974.41**	**31.20**	**1.00**	**-79.00**
2004	CRF 5A.1	-1712.05	-3109.07	22.27	0.80	-44.93
	CRF 5A II	22.83	23.18	12.30	0.01	-1.52
	CRF5(V)	157.62	111.48	59.36	0.20	41.39
	Total	**-1,531.60**	**-2,974.41**	**21.40**	**1.00**	**-48.51**
2005	CRF 5A.1	-1024.86	-3109.07	29.28	0.89	-67.04
	CRF 5A II	22.77	22.77	12.30	0.01	0.00
	CRF5(V)	-57.32	111.48	59.36	0.10	-151.41
	Total	**-1,059.41**	**-2,974.81**	**19.47**	**1.00**	**-64.39**
2006	CRF 5A.1	-721.55	-3109.07	36.57	0.88	-76.79
	CRF 5A II	22.65	23.18	12.30	0.01	-2.29
	CRF5(V)	57.32	111.48	59.36	0.11	-48.59
	Total	**-641.58**	**-2,974.41**	**19.85**	**1.00**	**-78.43**
2007	CRF 5A.1	-1181.55	-3109.07	24.30	0.88	-62.00
	CRF 5A II	22.55	23.18	12.30	0.01	-2.71
	CRF5(V)	64.43	111.48	59.36	0.12	-42.20
	Total	**-1,094.57**	**-2,974.41**	**19.60**	**1.00**	**-63.20**
2008	CRF 5A.1	-2198.07	-3109.07	19.48	0.93	-29.30
	CRF 5A II	22.43	23.18	12.30	0.01	-3.25
	CRF5(V)	50.08	111.48	59.36	0.06	-55.08
	Total	**-2,125.56**	**-2,974.41**	**20.01**	**1.00**	**-28.54**
2009	CRF 5A.1	-2015.73	-3109.07	19.34	0.95	-35.17
	CRF 5A II	22.38	23.18	12.30	0.01	-3.47
	CRF5(V)	-28.05	111.48	59.36	0.04	-125.16
	Total	**-2,021.41**	**-2,974.41**	**20.23**	**1.00**	**-32.04**
2010	CRF 5A.1	-1044.08	-3109.07	25.18	0.70	-66.42
	CRF 5A II	22.33	23.18	12.30	0.01	-3.69
	CRF5(V)	182.29	111.48	59.36	0.29	63.52
	Total	**-839.46**	**-2,974.41**	**25.52**	**1.00**	**-71.78**
2011	CRF 5A.1	-704.35	-3109.07	32.85	0.84	-77.35
	CRF 5A II	22.23	23.18	12.30	0.01	-4.12
	CRF5(V)	67.81	111.48	59.36	0.15	-39.18
	Total	**-614.32**	**-2,974.41**	**20.64**	**1.00**	**-79.35**
2012	CRF 5A.1	-24.62	-3109.07	1047.20	0.95	-99.21
	CRF 5A II	22.23	23.18	12.30	0.01	-4.12
	CRF5(V)	17.15	111.48	59.36	0.04	-84.61
	Total	**14.76**	**-2974.41**	**23.09**	**1.00**	**-100.50**

[7] Note that uncertainties for category 5A(II) and 5A(V) include land in the forest remaining forest land category only.

7.3.5 Land Converted to Forest Land (CRF 5.A.2)

Table 7.3.11 shows the net biomass, dead organic matter, soil C and net CO_2 emissions/removals for the time series 1990-2012 for lands converted to forest land (i.e. all forest established after 1990 reported in category 5.A.2). For the data time series pre 2006, the adjusted FORCARB estimates are reported. For the data time series 2007 to 2011, the CARBWARE model estimates are reported (Table 7.3.11). The methods used and values reported in category 5.A.2 and now fully consistent and comparable with KP emission/removals reported for AR activities, for the years 2008-2012 (see chapter 11).

The increase on removals by the post 1990 forest is due to an increase in forests area and productivity as new established forests mature. The slight decrease in the slope of the change in removals from 2007 onward is due to thinning harvests in productive forests at age 17 years old and onwards.

7.3.5.1 Time Series Adjustment of Living Biomass and DOM Pools

To ensure that there is no bias introduced in estimates over the time series due to the use of the different models, the 1990 to 2006 FORCARB series was adjusted (Table 7.3.11) and rescaled using tier 1 IPCC GPG (2006) time series overlap approaches:

- Living biomass gains (*LBgian*, Gg C) from the 2007 to 2012 time series for the CARBWARE and FORCARB model outputs were compared. The ratio (1.586) of the total CARBWARE and FORCARB LBgain values for 2007-2012 was used to adjust the time series:
  $$LB\ gain_{adj} = LB\ gain_{ini.} \times 1.58 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots (eq\ 7.3.36)$$
  where, $LBgain_{adj}$ is the adjusted living biomass gain value and $LBgain_{ini}$ is initial FORCARB estimate. This method is consistent with eq 5.1 Chapter 5 of time series in the 2006 GPG;

- The adjusted biomass losses (*LBloss*) were also determined using equation 7.3.36 but using a ratio of 1.585 scaled using the ratio of living biomass losses of the total CARBWARE and FORCARB LBloss values for 2007-2012. The ratio of gains to losses (as applied to forest land remaining forest land) was not used because there are no harvest losses for the FORCARB time series 1990-2007;

- For dead organic matter (DOM), the ratio (1.911) of the average CARBWARE to average FORCARB values for 2007-2012 was used to adjust the time series:
  $DOM_{adj} = DOM_{ini.} \times 1.911 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (eq\ 7.3.37)$;

- There were no adjustments to the soil EF, since the FORCARB and CARBWARE estimates were identical.

Table 7.3.12. Time series for forest category 5.A.2 [8]

Lands converted to forest land (since 1990)

Year	Area (kHa) Total	Organic	CSC (Gg C) Living biomass Gain	Loss	Net	DOM Net	Mineral Soils Net	Organic soils Net	Net CO_2 Gg Total	Harvests[1] (M m3) Thinnings	Modelled
1990	15.82	9.85	0.00	-0.26	-0.26	0.01	NO	-4.57	17.64	NO	
1991	34.96	20.72	19.37	-0.71	18.66	0.12	NO	-9.35	-34.58	NO	
1992	51.66	30.87	41.31	-1.29	40.02	0.32	NO	-14.09	-96.27	NO	
1993	67.66	39.30	61.14	-1.97	59.17	0.56	NO	-17.89	-153.41	NO	
1994	87.12	49.83	87.91	-4.85	83.06	5.42	NO	-22.92	-240.41	NO	
1995	110.83	66.96	123.62	-8.66	114.96	11.38	NO	-30.60	-351.02	NO	
1996	131.81	78.82	165.59	-12.72	152.88	16.78	NO	-36.39	-488.67	NO	
1997	143.25	84.16	209.17	-17.11	192.06	21.92	NO	-38.93	-641.85	NO	
1998	156.17	90.99	255.12	-22.49	232.62	27.96	NO	-41.86	-801.98	NO	
1999	168.84	97.12	305.77	-29.07	276.70	35.25	NO	-44.45	-980.84	NO	
2000	184.54	105.45	367.61	-36.13	331.48	41.85	NO	-48.04	-1192.72	NO	
2001	200.00	114.97	433.77	-42.73	391.03	45.76	NO	-52.16	-1410.31	NO	
2002	215.06	122.89	501.97	-58.30	443.67	58.81	NO	-55.56	-1638.70	NO	
2003	224.15	129.17	583.81	-66.17	517.64	62.07	NO	-58.49	-1911.14	NO	
2004	233.89	135.15	664.76	-87.96	576.80	77.16	NO	-61.25	-2173.29	NO	
2005	243.99	137.63	757.58	-95.80	661.78	78.65	NO	-64.08	-2479.97	NO	
2006	252.02	141.82	853.25	-140.81	712.45	97.45	NO	-64.04	-2734.82	NO	
2007	259.20	148.64	954.36	-238.41	715.95	116.08	NO	-64.96	-2812.58	0.08	0.08
2008	265.45	148.95	1073.96	-262.76	811.20	125.00	NO	-66.01	-3190.73	0.02	0.02
2009	272.10	152.84	1185.35	-350.33	835.02	170.73	NO	-67.82	-3439.07	0.21	0.22
2010	280.41	156.52	1285.32	-383.79	901.53	182.52	NO	-68.92	-3722.14	0.14	0.15
2011	287.06	159.77	1347.64	-438.09	909.55	201.97	NO	-71.18	-3814.60	0.18	0.18
2012	292.91	161.24	1377.42	-461.09	916.33	207.18	NO	-72.79	-3852.66	0.11	0.11

[8] The harvest volumes show a comparison of the EUROSTAT and modelled harvest using FORECARB and the CARBWARE model. Note: the thinning volumes from 2007 onwards are based on the felling licence and Coillte information applied to the CARBWARE model

Figure 7.3.8 shows the initial FORCARB estimates (blue symbols) and the time series adjustment as (red symbols) reported in the CRF table 5.A.2 and Table 7.3.12. Both time series show the same trend but the adjusted values show a higher net removal of CO_2. This is due to fundamental differences in the model input variables and the spatial scale at with the FORCARB and CARBWARE models operate. There are also known underestimated biases in the FORCARB model introduced when BFC yield tables are used. These are introduced by the same factors as those discussed under the forest land converted to forest land section. The final adjusted time series comprises of adjusted FORCARB estimates for the period 1990-2006 and CARBWARE estimated for the period 2007-2012.

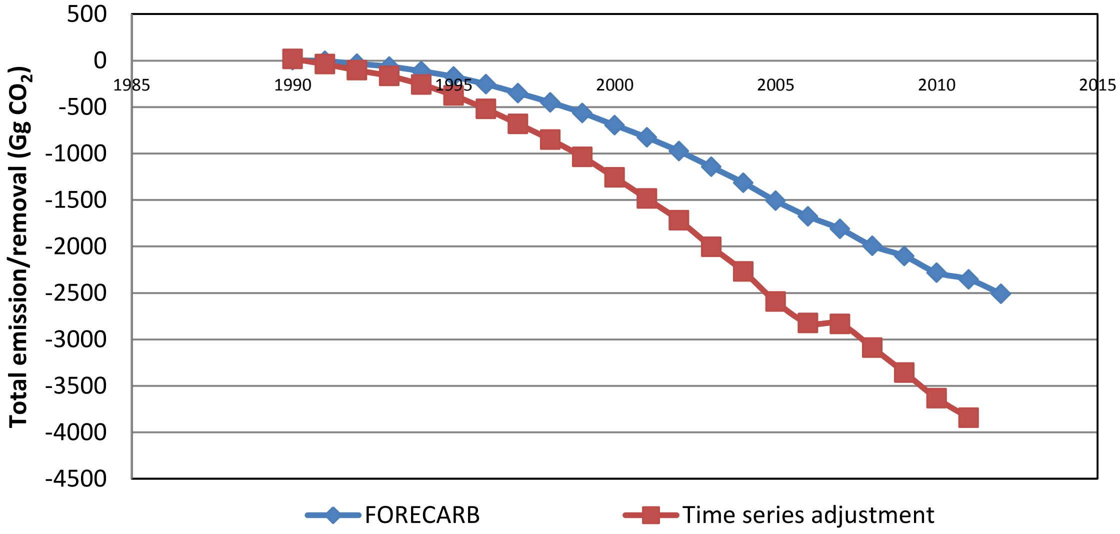


Figure 7.3.8The adjusted time series for forest category 5.A.2

7.3.5.2 Mineral Soils

Land converted to forest land (L-FL since 1990) on mineral soils are demonstrated not to be a source (see chapter 11.4), regardless of forest type and disturbance. Mineral CSC is reported as NO under this land category in CRF Table 5.A.

7.3.5.3 Organic Soils

The same approaches as described for forest land remaining forest land were used to estimate emissions from organic soils in lands converted to forest land since 1990 (sections 7.3.3.1.2 d) soils). However, there are no forests older than 50 years-old in the categories reported in 5.A.2, so this was not considered (Table 7.3.13). The allocation of emission estimates for the sub-categories CRF 5.A.2. 2.1 to 2.5 are based on the proportion of lands converted to forests described above.

Table 7.3.13 Area (in kha) and emissions from different organic soils types over the times series for land converted to forests

Year	Total Area[1]	Mineral	Organic	Open area[2]	Organic soils[3]	Organo-mineral soil[4]	Mineral soils[5]	tC Mineral	Orgainic tC	Organo-mineral tC	Total tC	Gg CO2
Area (kHa)												
1990	15.8	6.0	9.8	1.9	6.6	2.1	5.3	NO	-3878.1	-688.1	-4566.1	-16.7
1991	35.0	14.2	20.7	4.2	12.8	5.4	12.5	NO	-7572.5	-1772.7	-9345.2	-34.3
1992	51.7	20.8	30.9	6.1	19.8	7.4	18.3	NO	-11653.6	-2434.7	-14088.3	-51.7
1993	67.7	28.4	39.3	8.1	25.0	9.6	25.0	NO	-14742.8	-3151.4	-17894.2	-65.6
1994	87.1	37.3	49.8	10.4	32.6	11.3	32.9	NO	-19211.4	-3709.1	-22920.5	-84.0
1995	110.8	43.9	67.0	13.2	43.0	16.0	38.6	NO	-25375.1	-5228.4	-30603.5	-112.2
1996	131.8	53.0	78.8	15.7	52.0	17.4	46.7	NO	-30683.1	-5702.9	-36386.0	-133.4
1997	143.2	59.1	84.2	17.0	55.8	18.3	52.0	NO	-32939.6	-5992.6	-38932.3	-142.8
1998	156.2	65.2	91.0	18.6	59.5	20.7	57.4	NO	-35085.0	-6770.3	-41855.4	-153.5
1999	168.8	71.7	97.1	20.1	62.6	22.9	63.2	NO	-36943.6	-7507.4	-44451.0	-163.0
2000	184.5	79.1	105.4	22.0	67.2	25.7	69.7	NO	-39622.7	-8421.3	-48044.0	-176.2
2001	200.0	85.0	115.0	23.8	72.4	28.9	74.9	NO	-42709.1	-9453.6	-52162.6	-191.3
2002	215.1	92.2	122.9	25.6	76.6	31.6	81.2	NO	-45217.7	-10345.2	-55562.8	-203.7
2003	224.2	95.0	129.2	26.7	80.9	32.9	83.7	NO	-47723.8	-10766.6	-58490.4	-214.5
2004	233.9	98.7	135.2	27.8	84.8	34.3	87.0	NO	-50041.1	-11204.7	-61245.8	-224.6
2005	244.0	102.5	137.6	29.0	88.6	36.0	90.3	NO	-52297.7	-11779.7	-64077.4	-235.0
2006	252.0	110.2	141.8	31.4	88.8	39.1	92.7	NO	-52408.4	-11631.8	-64040.2	-234.8
2007	259.2	110.6	148.6	32.5	90.1	41.4	95.3	NO	-53140.6	-11821.2	-64961.8	-238.2
2008	265.4	116.5	149.0	33.4	90.8	43.7	97.5	NO	-53601.4	-12404.5	-66005.9	-242.0
2009	272.1	119.3	152.8	34.4	92.2	45.7	99.9	NO	-54385.6	-13431.2	-67816.7	-248.7
2010	280.4	123.9	156.5	35.6	94.3	47.7	102.8	NO	-55611.9	-13309.8	-68921.7	-252.7
2011	287.1	127.3	159.8	36.6	96.1	49.1	105.2	NO	-56702.2	-14474.9	-71177.1	-261.0
2012	292.9	131.7	161.2	37.6	97.8	50.2	107.2	NO	-57730.0	-15060.7	-72790.7	-266.9

[1] Total area includes open areas
[2] Open area within forest areas (roads, extraction routes, biodiversity etc).
[3] Organic soils include all soils with a > 20% C and an organic layer greater than 30 cm (e.g. Blanket peats, fens, cutaway peats. All organic soils are assumed to be drained. These areas are used in eq 7.3.23.
[4] Organo-mineral soils are mineral soils with an organic overlay of < 30cm. These include peaty podsols and peaty gleys (Source NFI). These areas are used in eq 7.3..24
[5] Mineral soils are shown not to be a source so are reported as zero (N0). These include brown earths, podsols, gleys, brown podsolics, lithosols etc. (Source NFI).

7.3.5.4 Emissions from Biomass Burning

The methodology for estimating emissions from biomass burning is discussed in category 5.A.1 (see section 7.3.4.4).

7.3.5.5 Emissions of N_2O from Fertilization

Ireland does not report separately the emissions of N_2O due to fertilizer use for *5.A Forest Land*. The amount of synthetic fertilizer used in forests is negligible compared to that used in agriculture and therefore all N_2O emissions from fertilizer applications are reported under agriculture. The notation key IE is therefore used in CRF Table 5(I).

7.3.5.6 Emissions of N_2O from Drainage

Reported under category 5.A.1 (see section 7.3.4.6).

7.3.5.7 Uncertainty Analysis for Category 5.A.2

The same uncertainty analysis was carried out for lands converted to forest land as was done for forests remaining forest land (Tables 7.3.14). However, the uncertainty relating to N_2O emission from drainage of soils is reported under the forest land remaining forest land category. The only different sources of uncertainty in this analysis (see Table 7.3.6 and 7.3.8) was the uncertainty due to re-adjustments, where the LB and DOM (Codes J and K Table 7.3.7), which were 3.7 and 9.0 per cent for lands converted to forest land.

Table 7.3.14. Uncertainty analysis of lands converted to forest land as reported in CRF 5.A.2

Year	Category	Year emission/reductions (Gg CO2 eq)	Base year emission/reductions (Gg CO2eq)	Combined uncertainty in year (±%)	Contribution to total variance in year (fraction)	Mean trend in year in relation to base-year (% mean trend)
1990	CRF 5A.1	17.90	17.90	84.21	1.00	na
	CRF 5A II	0.00	0.00	0.00	0.00	na
	CRF5(V)	0.00	0.00	0.00	0.00	na
	Total	**17.90**	**17.90**	**84.21**	**1.00**	**na**
1991	CRF 5A.1	-38.35	17.90	86.78	1.00	-314.30
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-38.35**	**17.90**	**36.43**	**1.00**	**-314.30**
1992	CRF 5A.1	-104.57	17.90	51.36	1.00	-684.30
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-104.57**	**17.90**	**51.36**	**1.00**	**-684.30**
1993	CRF 5A.1	-165.67	17.90	42.96	1.00	-1025.75
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-165.67**	**17.90**	**42.96**	**1.00**	**-1025.75**
1994	CRF 5A.1	-257.87	17.90	36.43	1.00	-1540.94
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-257.87**	**17.90**	**36.43**	**1.00**	**-1540.94**
1995	CRF 5A.1	-375.22	17.90	33.90	1.00	-2196.64
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-375.22**	**17.90**	**33.90**	**1.00**	**-2196.64**
1996	CRF 5A.1	-520.59	17.90	30.38	1.00	-3008.93
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-520.59**	**17.90**	**30.38**	**1.00**	**-3008.93**
1997	CRF 5A.1	-681.40	17.90	26.75	1.00	-3907.51
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-681.40**	**17.90**	**26.75**	**1.00**	**-3907.51**
1998	CRF 5A.1	-849.07	17.90	24.59	1.00	-4844.41
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-849.07**	**17.90**	**24.59**	**1.00**	**-4844.41**
1999	CRF 5A.1	-1035.85	17.90	22.89	1.00	-5888.09
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-1,035.85**	**17.90**	**22.89**	**1.00**	**-5888.09**
2000	CRF 5A.1	-1257.44	17.90	21.75	1.00	-7126.31
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-1,257.44**	**17.90**	**21.75**	**1.00**	**-7126.31**
2001	CRF 5A.1	-1485.12	17.90	21.13	1.00	-8398.49
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-1,485.12**	**17.90**	**21.13**	**1.00**	**-8398.49**
2002	CRF 5A.1	-1718.69	17.90	20.34	1.00	-9703.68
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-1,718.69**	**17.90**	**20.34**	**1.00**	**-9703.68**

Table 7.4.14. Uncertainty analysis of lands converted to forest land as reported in CRF 5A.2 (continued)

Year	Category	Year emission/reductions (Gg CO2 eq)	Base year emission/reductions (Gg CO2eq)	Combined uncertainty in year (±%)	Contribution to total variance in year (fraction)	Mean trend in year in relation to base-year (% mean trend)
2003	CRF 5A.1	-1911.14	17.64	20.17	1.00	-10933.06
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-1,911.14**	**17.64**	**20.17**	**1.00**	**-10933.06**
2004	CRF 5A.1	-2173.29	17.64	19.52	1.00	-12419.01
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-2,173.29**	**17.64**	**19.52**	**1.00**	**-12419.01**
2005	CRF 5A.1	-2479.97	17.64	19.20	1.00	-14157.40
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-2,479.97**	**17.64**	**19.20**	**1.00**	**-14157.40**
2006	CRF 5A.1	-2734.82	17.64	18.55	1.00	-15601.97
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-2,734.82**	**17.64**	**18.55**	**1.00**	**-15601.97**
2007	CRF 5A.1	-2812.58	17.64	18.26	1.00	-16042.74
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	Total	**-2,812.58**	**17.64**	**18.26**	**1.00**	**-16042.74**
2008	CRF 5A.1	-3190.73	17.64	17.89	0.99	-17986.26
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	16.49	0.00	52.20	0.01	
	Total	**-3,174.25**	**17.64**	**17.98**	**1.00**	**-18092.80**
2009	CRF 5A.1	-3439.07	17.64	17.32	0.99	-19593.94
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	9.45	0.00	52.20	0.01	
	Total	**-3,429.63**	**17.64**	**17.37**	**1.00**	**-19540.39**
2010	CRF 5A.1	-3722.14	17.64	17.13	0.95	-21198.46
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	62.92	0.00	52.20	0.05	
	Total	**-3,659.22**	**17.64**	**17.44**	**1.00**	**-20841.83**
2011	CRF 5A.1	-3814.60	17.64	17.02	0.98	-21722.55
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	23.19	0.00	52.20	0.02	
	Total	**-3,791.41**	**17.64**	**17.13**	**1.00**	**-21591.10**
2012	CRF 5A.1	-3852.66	17.64	17.03	1.00	-21938.31
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	5.87	0.00	52.20	0.00	
	Total	**-3,846.80**	**17.64**	**17.06**	**1.00**	**-21905.06**

Table 7.3.13 shows that the uncertainty of estimates for land converted to forest land was 85 per cent in 1990, decreasing to 17 per cent by 2012. This is because the net emission reduction in 1990 was close to zero, which makes the percentage uncertainty higher when the absolute uncertainty is much lower, when compared to other years. The same issue

arises when trend uncertainty compared to a base year is analysed. Hence the use of a base year, where absolute values are zero, or where values are very small, and expressing these as a percentage does not truly reflect the absolute uncertainty.

7.3.6 Deforestation Areas

This section describes deforestation areas reported under forest converted to other lands under sub-categories 5.B.2 to 5.E.2. In previous submissions, deforestation was reported only in respect of forest land converted to settlements, derived from CORINE data. Following the ERT team recommendations in the 2010 centralised review, Ireland has developed a new system to track deforestation trends going back to 1990. Historical deforestation trends show a marked increase in deforestation from 2000 to 2006 and a shift in the major land use transitions into grassland before 2000 and to settlements, wetlands and other land after 2000. These findings are consistent with a) an increase in building and infrastructural developments on forest land due to high economic growth in the late 1990s to mid-2000s; and b) an increase in deforestation of peatland forests following the introduction of EU life peatland restoration scheme in the 2004.

The new NFI data for 2012 allowed the recalculation of forest areas for 2006 to 2012. The development of the new methodology resulted in an increase in the reported area of deforestation from 1.38 to 12.512 kha in 2008, with a further 0.8 kha being deforested in 2009, 0.8 kha in 2010, 1.6 kha in 2011 and 0.8 kHa in 2012 (see chapter 11 and Table 7.3.15). The increase in conversion of forest land to other lands in after 2005 is associated with clearfelled forest land which was not replanted within a 5 year period as determined using the 2006 and 2012 NFI. The lands have not been converted any known land use but are classified as deforestation and reported as forest converted to other land.

The estimate of final land use after deforestation is based on an analysis of the CORINE land cover change from 1990 to 2000, the National Forest Inventory and the Forest Inventory and Planning Strategy, FIPS) data up to 2005. Post 2006 analysis is based on detailed information from the 2006 and 2012 NFI.

Table 7.3.15. The new deforestation, land use change and soil type matrix showing annual deforestation areas (ha/ year) associated with different land uses and soils categories

Area (kHa) of forest land converted 1990 to 2012 (SINCE 1ST Jan 1990)

	TOTAL Area		**Grassland**		**Settlement**		**Wetland**		**Other**	
	Total	Organic	Total	Organic	Total	Organic	Total	Organic	Total	Organic
1990	0.021	0.006	0.008	0.006	0.010	NO	NO	NO	0.002	NO
1991	0.041	0.012	0.016	0.012	0.020	NO	NO	NO	0.004	NO
1992	0.062	0.017	0.025	0.017	0.031	NO	NO	NO	0.007	NO
1993	0.082	0.023	0.033	0.023	0.041	NO	NO	NO	0.009	NO
1994	0.103	0.029	0.041	0.029	0.051	NO	NO	NO	0.011	NO
1995	0.436	0.029	0.308	0.029	0.051	NO	NO	NO	0.078	NO
1996	0.770	0.029	0.574	0.029	0.051	NO	NO	NO	0.144	NO
1997	1.103	0.029	0.841	0.029	0.051	NO	NO	NO	0.211	NO
1998	1.436	0.029	1.108	0.029	0.051	NO	NO	NO	0.277	NO
1999	1.770	0.029	1.375	0.029	0.051	NO	NO	NO	0.344	NO
2000	2.627	0.258	1.775	0.086	0.222	NO	0.171	0.114	0.459	0.057
2001	3.484	0.487	2.175	0.144	0.394	NO	0.341	0.228	0.574	0.115
2002	4.341	0.715	2.575	0.201	0.565	NO	0.512	0.342	0.688	0.172
2003	5.198	0.944	2.975	0.259	0.737	NO	0.682	0.456	0.803	0.230
2004	6.055	1.173	3.376	0.316	0.908	NO	0.853	0.570	0.918	0.287
2005	6.912	1.402	3.776	0.373	1.079	NO	1.024	0.684	1.033	0.344
2006	8.912	3.002	3.776	0.373	1.479	0.400	1.024	0.684	2.633	1.544
2007	10.512	4.202	3.776	0.373	2.679	1.200	1.424	1.084	2.633	1.544
2008	12.512	5.002	4.176	0.373	3.879	2.000	1.424	1.084	3.033	1.544
2009	13.312	5.402	4.576	0.373	3.879	2.000	1.824	1.484	3.033	1.544
2010	14.112	5.402	5.376	0.373	3.879	2.000	1.824	1.484	3.033	1.544
2011	15.712	5.802	6.576	0.373	3.879	2.000	2.224	1.884	3.033	1.544
2012	16.512	6.602	6.576	0.373	4.679	2.800	2.224	1.884	3.033	1.544

* No transition from forests to croplands were detected

7.3.6.1 Deforestation Losses

Carbon stock changes associated with deforestation reported in all CRF tables include those for the total standing biomass of all trees removed at clear fell (i.e. all biomass carbon is assumed to be immediately oxidised):

$$C_{L(Total)} = C_{L(AB)} + C_{L(BB)} = TOTAL_{(Biomass)} lost \qquad (7.3.38)$$

The carbon stock **losses (C_L)** in the **above ground** (AB) and **below ground** (BB) pools were calculated differently depending on the activity data available, but this was done in a hierarchical order:

1) Total biomass and DOM losses were directly determined from the NFI permanent sample plot tree data and allometric equations as described in section 7.3.3.1.2 above.
2) Where plots were clearfelled before 2006 from the standing volume (V) of the forest stand, as specified by Coillte plot queries, a basic density (D) in the range 0.35 to 0.55 (depending on tree species), a biomass expansion factor (BEF) of 1.68t/t^{-1}, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2, as described in Eq 7.3.9 and 7.3.10 above). A list of plot data from Coillte provided information of deforestation area (including open areas), species, age, standing volume before clearfell.
3) Where no deforestation data for clear-felled sites in 2006 could be derived, the biomass and DOM stock was based on the stock at rotation age for a YC 16 Sitka spruce crop. This equates to biomass stock of 230 t C ha^{-1} and a DOM stock of 15.6 t Cha^{-1}.
4) For all deforested sites before 2006 a mean biomass (98.29 tC/ha) and DOM (13.92 tC/ha) C stock for 2006-2012 was used (see section 7.3.3.1.2).

It is important to note that many deforested lands are not fully stocked before cleafell and land use change, with the exception of:

- Cleafelled non-regenerated land within a 5 year period (1600 ha since 2006 with a mean biomass stock of 230 t C ha^{-1}),
- EU life bog restoration projects in 2007 (400 ha , biomass stock of 176 t C ha^{-1}),
- Wind farm conversions in 2007 (400 ha, biomass stock of 230 t C ha^{-1}).
- Conversion to settlements (ESB lines) in 2008
- Grassland conversion in 2009

All other deforestation events over the period 2006-2012, representing 6400 ha of the total 9600 ha had a lower biomass stock ranging from 1.1 to 112 t C ha-1. These were younger aged crops, which were prematurely clearfelled for deforestation or scrub land forests converted to settlements.

The accumulated litter and DOM pool was assumed to be immediately oxidised when deforestation occurs. The approach adopted to apply an instantiations oxidation to litter and DOM (i.e. harvest residue, stumps and roots) in forests land converted to other land is based on the **conservativeness** principal. The rationale for this assumption is explained for the land use transitions for forestry indicated below:

A) *Forest conversion to wetlands*. Most forest conversion to wetland involves EU wetland conservation measures, where drains are blocked to encourage peat vegetation regeneration. This would create anaerobic condition for remaining harvest residues (stumps, lying deadwood and litter) resulting in very low decay at rates than those used in Ch11 for 1st rotation crops. In fact, based on the literature, one would assume that decay would be extremely slow or non-existent since ancient forest residues have been found in bog lands in the past. We would argue that instant oxidation of harvest residues in this instance is a **conservative over estimation of emissions**;

B) Recent evidence of forests conversion to grassland and settlements suggests that harvest residues are removed after harvest. The current common practice is to chip woody residues for bio-fuel or horticultural purposes (expert opinion, Forest Service). In this case, we would argue that instant oxidation should be applied since these are in essence harvested wood products and in the case of compost would decay relatively quickly. In some cases it is possible that forest residues are ploughed, piled up and left on site to decay over time. However, we have no data supporting this, so apply the conservative approach of instantiations oxidation.

Ireland has chosen not to account for carbon stock changes in mineral soils converted to grasslands. Verifiable information demonstrating that deforested grassland mineral soils are not a source of anthropogenic GHG is provided in chapter 11. The notation key NO is therefore used for mineral soils under this land category in CRF Table 5.B to E.

Mineral soils

For deforested settlement and other land categories we use a **conservative estimate**, as used for other countries (e.g. Finland), that 20% of SOC is emitted over a 20 year period in these soils. A mean SOC stock of 110 t C ha^{-1} was used based on best available soil data (see Figure 11.3, Ch 11). It should be noted that this is a conservative approach since:

- All deforested land allocated to the other land use category (Table H2 appendix H) are forest lands which have been clearfelled but not replanted within a 5 year period. These lands have not undergone a land use transition but are defined as deforestation to comply with the requirements set out in the annex to decision of 15CMP/1 (see CH 11);
- Land converted to settlement contains green areas which will not reduce SOC as a result of deforestation. However it is assumed that the total deforested area emits CO_2 form mineral soils because there is no activity data to determine the percentage green area in urban areas.

Organic soils

Emissions from organic soils converted to grassland, settlement and other land are assumed to continue using the EFs and methods outlined in reported using eq. 7.3.23 and 7.3.24, described in section 7.2. It is plausible, that drains are blocked and emission cease since land use conversion form forests into these categories, but it is **conservatively assumed** that emission form these soils continue following deforestation. Emissions form organic soils following forest conversion back to wetlands are assumed to not occur (NO) because peat soils are re-saturated since drainage does not occur on regenerated wetlands (as part of EU life peatland regeneration projects).

7.4 Cropland (5.B)

7.4.1 Soil Type and Soil Organic Carbon

For all non-forest land use categories, soil organic carbon (SOC) is the basic parameter in the default IPCC estimation methods for determining carbon stock changes in soils, which is a significant source of carbon emissions in land conversion categories in LULUCF. With the exception of forest soils, the organic carbon status of Irish soils under native vegetation is established from the soil type and the default reference soil organic carbon stocks (SOC_{ref}) for cold, temperate moist regions (Tables 3.2.4, 3.3.3 and 3.4.4 of the 1996 IPCC good practice guidance on LULUCF). The General Soil Map of Ireland (Gardiner and Radford, 1980) is the basic data source used in this analysis for soil type information in Ireland. Mineral soils as identified from the general soil map are allocated to the HAC (high activity clay), LAC (low activity clay), sandy and humic soil classes used by the IPCC, while peats are allocated to the IPCC wetlands class as shown on Table 7.4.1, based on detailed national assessment of soil carbon stocks in Ireland (Tomlinson, 2003). The values of SOC_{ref} appropriate to each soil association may then be assigned using the correspondence to IPCC classes given in Table 7.4.1. The distribution of CORINE Land Cover over IPCC soil classes was established in the same way to facilitate complete correspondence between land use, soil and SOC_{ref}.

Table 7.4.1. Soil Class Coverage and Soil Organic Carbon

General Soil Map Soil Association	Proportion of IPCC Soil Class					Proportion of Soil Association in Area of Ireland
	HAC	LAC	Peaty/ Humic	Sandy Soil	Wetlands Soil	
basin peat					0.34	0.06
brown earth		0.19				0.13
brown podzolic		0.21				0.15
gley		0.30			0.02	0.22
grey brown podzolic		0.30				0.21
lithosol			0.22	1.00		0.04
lowland blanket peat					0.31	0.05
podzol			0.78			0.08
Renzinas	1.00					0.01
upland blanket peat					0.33	0.06
Proportion of IPCC Soil Class in Area of Ireland	0.01	0.71	0.10	0.01	0.17	
SOC_{ref} (t C/ha)	95	85	115	71	87	

7.4.1.1 Estimation of Emissions from Soils

Mineral Soils

The annual change in SOC in mineral soils over the appropriate transition period determines the carbon emissions or removals for the various land-use conversion categories as follows:

$$\Delta C = A * (SOC_0 - SOC_{0-T}) / T \qquad (7.4.1)$$

$$SOC = SOC_{ref} * F_{LU} * F_{MG} * F_I$$

where

- ΔC = annual change in carbon stocks
- A = area of land converted from a former land use
- SOC_0 = soil organic carbon stock for current land use
- SOC_{0-T} = soil organic carbon stock for former land use

- SOC_{ref} = reference soil organic carbon under native vegetation for a given soil type in area A
- T = transition period
- F_{LU} = stock change factor for land use or land-use change type
- F_{MG} = stock change factor for management regime
- F_I = stock change factor for organic matter input

The factors F_{LU}, F_{MG} and F_I account for changes in SOC due to management practices that impact on soil carbon. Table 7.4.2 shows the adjustment factors derived from the product of F_{LU}, F_{MG} and F_I taken from Table 3.3.4 of the IPCC good practice guidance on LULUCF for the land uses defined for Ireland (Table 7.2.3). Equation 7.4.1 is the basic Tier 1 methodology used for estimating emissions from mineral soils for all land-use categories as described in the following sections. The default transition period of 20 years is applied for all mineral soils. The estimation procedure is performed following a simple approach that provides estimates of emissions from soils for the defined land uses in accordance with the IPCC good practice guidance for LULUCF and the available information for the country. It involves the identification and quantification of the land areas subject to a change of use, the application of the data in Table 7.4.1 to assign SOC_{ref} for the soil types in those land areas and the calculation of carbon stock change on the basis of the factors given in Table 7.4.2.

Table 7.4.2. Adjustment Factors for SOC

Land Use	F_{LU}	F_{MG}	F_I	Adjustment factor, AF
Cropland	0.71	1.09	1.11	0.86
Improved grassland	1.0	1.0	1.14	1.14
Unimproved grassland	1.0	1.0	NA	1.0
Rough grazing	1.0	0.95	NA	0.95
Other non-agricultural land (Native grassland)	1.0	1.0	NA	1.0

Organic Soils

The basic methodology for estimating emissions from organic soils is to assign a direct annual carbon loss rate that accounts for the oxidation of organic matter due to drainage, tillage or disturbance of the land area concerned. For example, the default emission factors of 0.25 t C/ha per year for managed grassland soils and 1 t C/ha per year for cultivated cropland soils in cold temperate climatic regions given in the IPCC good practice guidance for LULUCF are adopted for Ireland. Tier 2 EF are used for forest organic based on country specific information.

7.4.2 Cropland Areas

Cropland areas are based on CSO annual statistics for tillage crops, revised by the inventory agency to account for inconsistencies due to the impact of changes in total farmed area reported in 1997, as described in the 2007 NIR In 2010, the CSO revised the methodology for the estimation of Utilised Agricultural Areas under crops and grass. There was no discernible bias introduced in the reporting of areas under crops, with the areas for both 2010 2011 and 2012 consistent with previous trends and inter-annual variability within this sector.

Following discussion with the respective experts in agricultural practices and GIS analysis, it was agreed, pending the results of proposed research, to assume that no cultivation of histosols occurs. Therefore cropland organic soils are designated as “not occurring”, i.e. “NO” in the CRF tables.

Croplands are assumed to revert to unmanaged grassland during set-aside or fallow periods (the temporary exclusion of tillage areas from production) but stay within the category *5.B Croplands Remaining Croplands*, as a land parcel that is given over to set-aside in one year will likely be tilled in subsequent years. The Central Statistics Office data included set-aside areas within what is termed “Other Crops”. This area of Other Crops is used as the upper limit to give a conservative estimate of set-aside area. However, set-aside is no longer supported under the Single Farm Payment Scheme, and therefore the reported area under “Other Crops” has much decline since 2009. Therefore, where set-aside or fallow periods are part of the crop rotation scheme deployed by farmers, the specific area is no longer captured within the published CSO data. Consequently, these lands are likely reported as under grass by farmers to the CSO, and therefore included in the grassland land use category. New research and analysis of land management patterns has been funded by the EPA, which is aimed at addressing this potential misclassification of temporary grasslands. This is expected to have significant impact on the estimation of land use change within grasslands and croplands in future submissions.

It is only possible to estimate the net change in cropland area from the annual CSO statistics. This has a significant limitation in that possible under-lying dynamic of land conversion may not be captured. A simple example might be a conversion of 100 ha of cropland to Settlement in one location, and a 110 ha conversion of grassland to cropland in another location. The CSO data would only report a net 10 ha change in cropland. In order for the net change in cropland to correspond to that indicated by the CSO statistics, the cropland areas converted to *5.E Settlements* must be offset by new lands converted from *5.C Grassland*. Therefore, in this example, an additional conversion of 100 ha to cropland would be inferred. As indicated for category 5.A.2, a similar adjustment is made to account for the area of cropland which is converted to forestry and any small area of deforestation to cropland. This is achieved by adding those areas of cropland in transition to either forest lands or settlements to the area of land in transition to cropland, and deducting an equal amount from the area under *5.B.1 Croplands Remaining Croplands*. This is possible for transitions between Settlement, Wetland, Forest Land and Cropland, as there are independent estimates of the land use area within these categories. However, it is not possible to make a similar adjustment for Cropland and Grassland as both are based on the CSO data. Research is on-going to develop revised methodology to resolve this issue based on alternative, independent data sources.

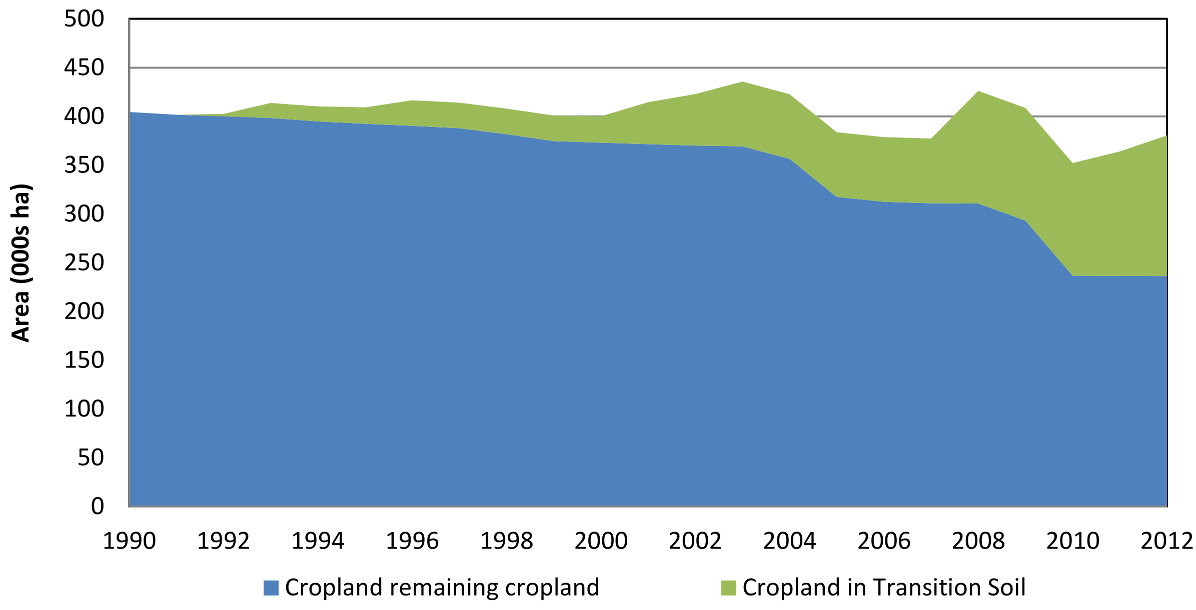


Figure 7.4.1a Time Series of Cropland from 1990-2012

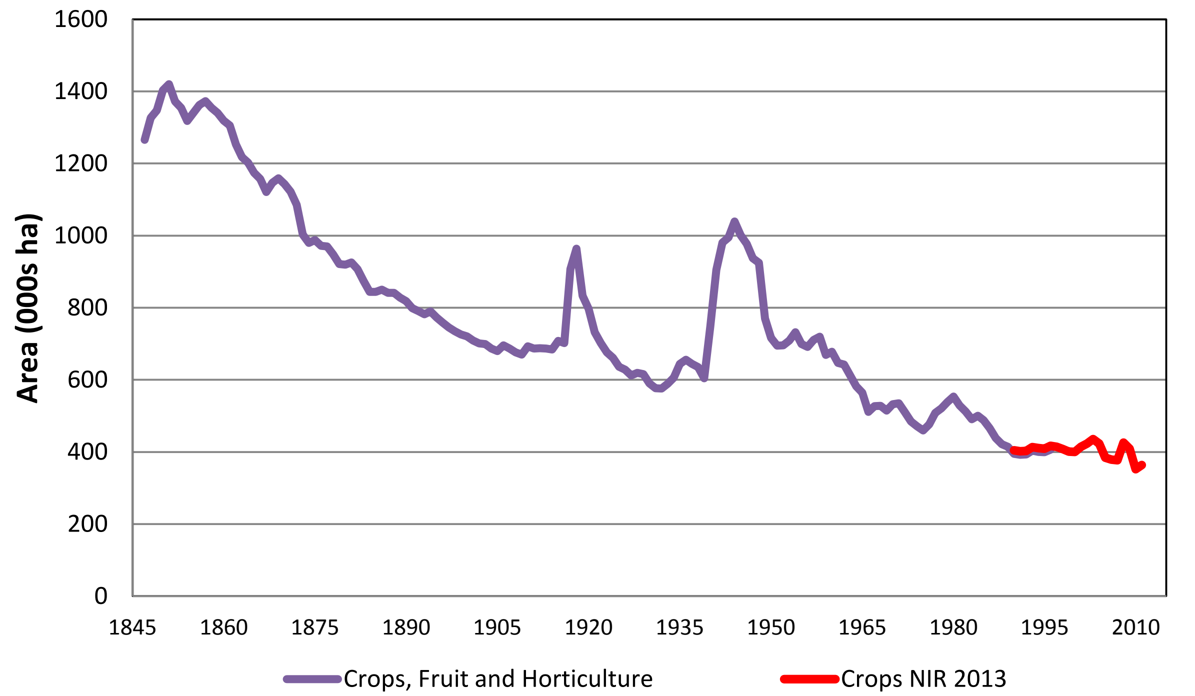


Figure 7.4.1b Historical Time Series of Croplands 1847-Present

The relevant emissions and removals are determined by net carbon stock changes in living biomass and soils for *5.B.2 Lands Converted to Cropland*.

Figure 7.4.12 shows the time series Cropland split between Cropland Remaining Cropland, and lands in transition to cropland. Figure 7.4.1b shows analysis of the long term trend in croplands in Ireland over the last century shows a steady decline in tillage area (with exceptional temporary reversal related to WW1 and WW2), and a consolidation of activity on most the suitable soil types and local climate zones. From the graph, this long term trend appears to have achieved a steady state, and it is reasonable to assume that no lands were in transition to cropland at the beginning of the reporting period, 1990. Since 1990, it is assume that all net increases in cropland, on an annual basis, represent a conversion of grassland to cropland, and all losses represent a permanent transition of land out of cropland. This is a conservative overestimate of the potential impact of interannual transitions between grassland and cropland.

7.4.3 Carbon Stock Change in Biomass

The stock change relates only to above-ground biomass and its estimation is based on the difference between initial and final carbon content of biomass for the lands converted. In the conversion of land to cropland, it is assumed under the Tier 1 approach that the dominant vegetation from the initial land use is removed entirely. The carbon stock change is then quantified as the net sum of carbon lost on conversion and the carbon added by the first year's growth of crops. Grassland is the only relevant land-use type undergoing conversion to cropland in Ireland. The dry matter content of grassland is taken as 12.0 tonnes/ha and the carbon content of dry matter is 0.5 per cent. The default value of 5 t C/ha from Table 3.3.8 of the IPCC good practice guidance for LULUCF is adopted for the carbon stock in crop biomass after one year. The carbon stock change in biomass on the area (A) converted to cropland is then calculated from Equation 3.3.8 of the IPCC good practice guidance as follows:

$$\Delta C = A * [(C_{after} - C_{before}) + \Delta C_{growth}] \qquad (7.4.2)$$

$$\Delta C = A * [(0.0 - 12.0 * 0.5) + 5.0]$$

7.4.4 Carbon Stock Change in Soils

The spatial distribution of cropland areas over IPCC soil class is derived from GIS analysis of the LPIS 2004 dataset provided by the Department of Agriculture, superimposed on the General Soil Association Map of Ireland (Gardiner and Radford, 1980). The GIS analysis shows that a very high proportion (98 per cent) of croplands are located on Low Activity Clay (LAC) soils. It is assumed that only grasslands on LAC soils are suitable for direct conversion to croplands, which is consistent with the requirement for cropland productivity. It is therefore reasonable to assume that all grassland areas converted to croplands are also on LAC soils and that no other land categories are converted to croplands. The research noted in 7.4.2 will also analyse the validity of this assumption.

Carbon stock changes in mineral soils are estimated using methodology outline in Section 7.4.1 and Equation 7.4.1. Farm management and input practices are assumed to have been constant over the inventory period for established croplands. Therefore the SOC will not have changed for mineral soils, with the exception of those lands going to set-aside for short periods. In line with expert option it is assumed that no cultivation occurs on organic soils, as discussed in 7.4.2.

7.4.5 N_2O Emissions in Cropland

Soil disturbance associated with land-use conversions to cropland result in minor emissions of N_2O. Emissions from this category were reported in the 2008 submission for the first time following recommendations from the in-country review conducted in 2007. Such emissions are estimated for mineral soils in category 5.B.2.2 Grassland Converted to Cropland and the estimates are included in CRF Table 5(III). The estimates are calculated from the change in soil organic carbon over the 20 year transition period, obtained using Equation 7.4.1 for the land-use and soil type converted to cropland, and the soil C: N ratio as follows:

$$N_2O = (\Delta C / R_{C:N}) * 44/28 \qquad (7.4.3)$$

where ΔC is the annual change in carbon stocks given by Equation 7.4.1 and $R_{C:N}$ is the C:N mass ratio in soil organic matter for which a default value of 15 is given in the IPCC good practice guidance.

7.5 Grassland (5.C)

7.5.1 Grassland Areas

Grassland is the dominant land-use category in Ireland. Area estimates are based principally on CSO annual agriculture statistics for improved grassland (pastures and areas harvested for silage and hay) and unimproved grassland, which refers to rough grazing. In 2011 the CSO initiated revised methodology for the estimation of utilised agricultural land. Due to this initiative, CSO estimates for 2010 grassland areas where not available for the 2012 submission. Therefore for the 2012 submission, grassland areas were based on an extrapolation of trends in grassland use established over the previous years. Data from the CSO are now available for 2010, 2011 and 2012. Whilst the revised methodology has no significant impact on estimate on CSO estimates of cropland, there is a significant impact on the CSO estimate of grassland areas within the improved grassland category, specifically pasture areas. There is no corroborating evidence that the increase in improved grassland area reported by the CSO reflects a real change in land use. Additional analysis of the revised CSO methodology is required to determine the best means to achieve continuity between the new methodology and areas published in previous years. In the 2014 submission, it has been decided to extrapolate the long trend trends observed in the pasture area to estimated area for 2010, 2011 and 2012. Figure 7.5.1 shows the original data and the impact of the adjustment. The research noted in section 7.4.1 will also analyse this issue.

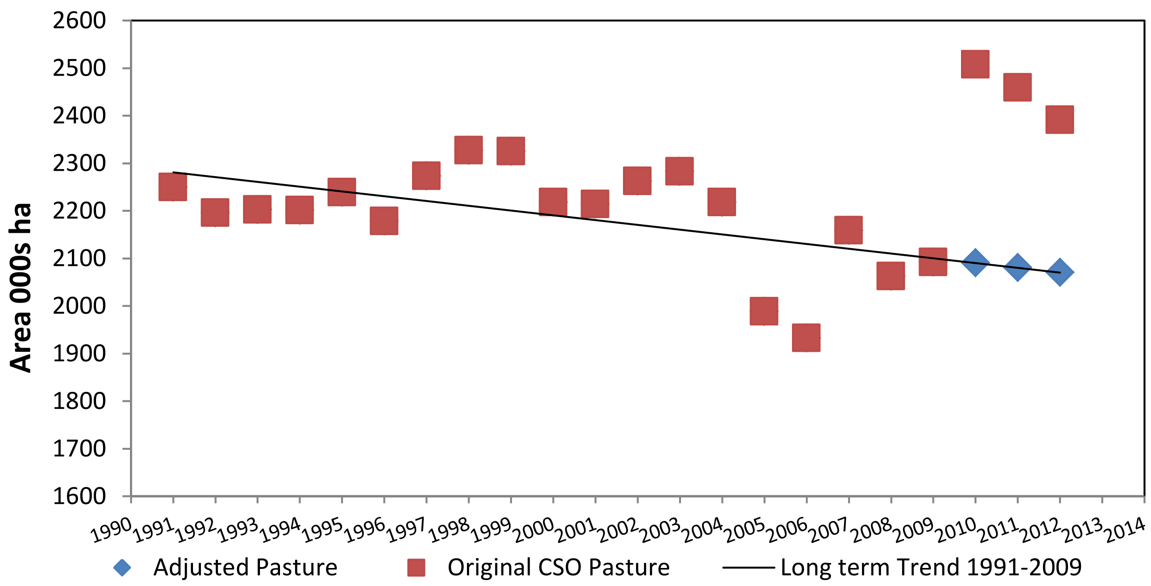


Figure 7.5.1 Plot of original CSO data for Pasture areas and adjusted data for 2010, 2011 and 2012 based on extrapolation of long term trend from 1991 to 2009

It is important to note that both improved and unimproved grassland areas are estimates of grasslands *in use* for agricultural purposes. Rough grazing areas *in use* are native grasslands that are unmanaged with regard to drainage or other factors, such as fertilizer application, but which are grazed by cattle or sheep. The CSO annual statistics for rough grazing exclude other areas of grassland not reported to be in use for agricultural purposes. These grasslands are assumed to be unmanaged natural grasslands, in a carbon-stable state, with no associated emission or sink activity. However, they do represent a reserve of lands available for conversion to other land uses.

In previous submissions, natural grasslands were included in the Other Land land use category. In response to comments from the ERT, it is agreed that this was inconsistent with IPCC guidelines. Therefore, in the 2014 submission, natural grassland areas are included in the Grassland land use category, with a baseline estimate for 1990 based on CORINE 1990 analysis of natural grassland classification types. When there is a demand for new agricultural grassland for use as rough grazing, it is met by a conversion from natural grassland.

Overall, the area of grassland has decreased slightly, see Figure 7.5.2. The area of improved pasture has been near steady state, while the area of rough grazing, or unimproved grassland, has been decreasing. The area of natural grassland has increased. This is probably in response to government policy for hill farming, which in recent years has sought to decrease over grazing on vulnerable commonage and mountain areas, and other policies and market drivers which encourage consolidation of livestock activities and more intense management of grasslands. Therefore, there has been a decline in the reported agricultural land area, with conversion to Forest Land and “abandonment” to natural grassland the principle drivers of trends. The grazing of unimproved grasslands leads to degradation of the soil, with consequent emission of carbon.

From the data available, it is difficult to estimate the changes in managed area within the category *5.C.1 Grassland Remaining Grassland*. The annual CSO figures refer to the areas of land that farmers have declared to be “in use” under the specified types of use. Given the economic investment required to maintain “improved” grassland, it is probable that the declared “in use” areas are a good indicator of the actual extent of well-maintained managed grasslands. Therefore, significant changes in the improved grassland areas do represent changes in land use, with lands either being neglected, or actively managed, depending on the potential for good economic return. The neglect of improved grasslands will cause the land to revert to the nominally unmanaged or native grassland state over time. The transition to rough grazing causes a degradation of the soil, leading to an emission of carbon. However, it is assumed that the average biomass remains constant. This is an underestimate of the effect of grazing, but insufficient analysis data exists to quantify the impact.

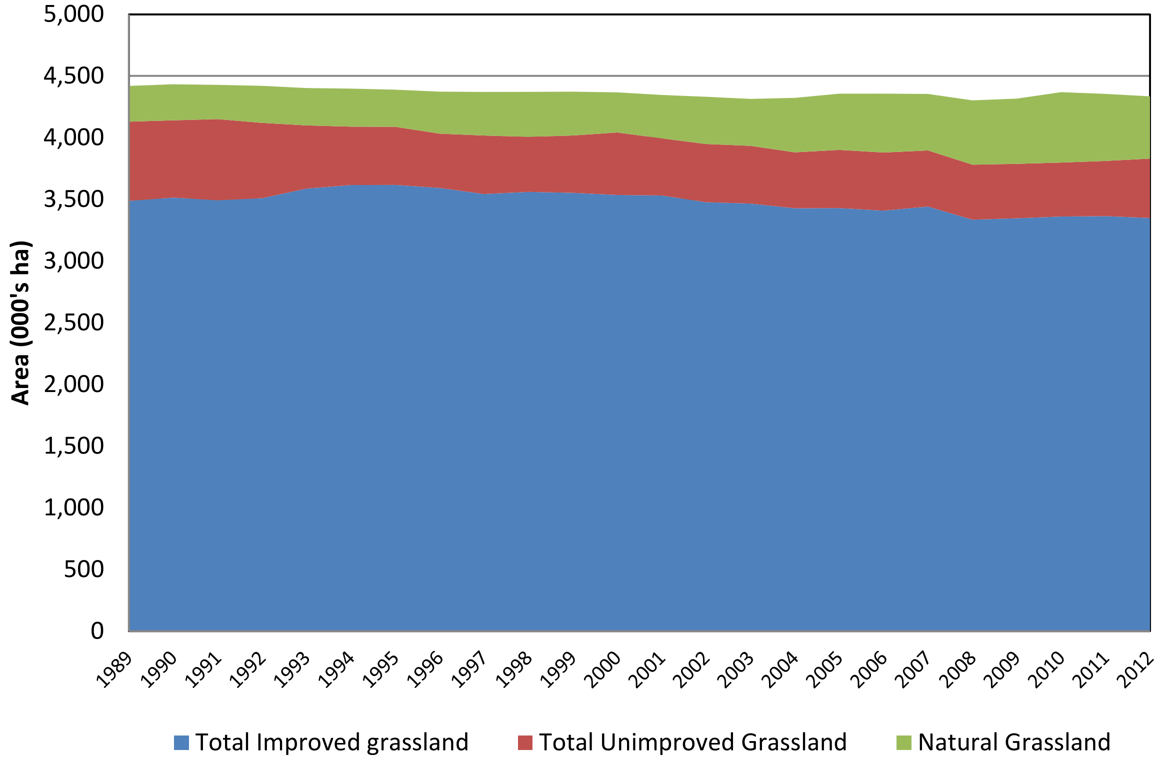


Figure7.5.2 Trends in Grassland use 1990-2012

There is a strong dynamic of lands moving between grassland and cropland (with a knock-on effect on the area assigned to other land). This is because of the nature of the CSO statistics, which record only the areas of grassland and cropland in a particular year. Under Irish conditions, conversion of cropland to grassland leads to a net gain of carbon from the soil, and also a gain in living biomass when the Tier 1 default methods are applied.

The research and analysis noted in 7.4.2 is expected to have significant impact on the estimation of land use change within grasslands and croplands.

7.5.2 Carbon Stock Changes in Grassland

The relevant carbon stock changes are for living biomass under *5.C.2 Land Converted to Grassland* and for soils under both *5.C.1 Grassland Remaining Grassland* and *5.C.2 Land Converted to Grassland.*

7.5.2.1 Carbon Stock Changes in Living Biomass

The Tier 1 methodology assumes that grassland remaining grassland has zero biomass carbon stock change under static management practices. This approach is adopted here and the notation NO is entered in CRF Table 5.C. The conversions from cropland to grassland are the dominant activities here, with some conversion of exhausted peatlands also occur. Carbon stock changes are estimated using the Tier 1 methodology in the same way as for land converted to cropland using Equation 7.4.2 above. The biomass value of cropland converted to grassland is taken to be 10 t/ha and the carbon stock increase due to growth in grasslands (ΔC growth) in the first year is 6 t C/ha from GPG Tables 3.4.2 and 3.4.3. In the case of peatlands there is no initial biomass at the time of conversion to grassland and therefore the carbon stock change is due only to the first year's growth at 6.0 t C/ha. The conversion of natural grassland for agricultural use is in effect the transition of unmanaged native grassland to improved or unimproved pasture, as indicated in section

7.5.1 above. There may be a change in carbon stock associated with conversion to improved grassland, as the land may be subject to ploughing and reseeding. This is accounted for through Equation 7.4.2. However, using the default values, a loss of 6.0 t C/ha for standing biomass followed by a gain of 6.0 t C/ha through growth in the first year[9].

Table 7.3.15 in section 7.3.6 above gives the area of forest land converted to grassland for the years 1990-2006. The immediate oxidation of biomass, litter and dead wood for years prior to 2006 were derived using the mean IEF for 2006 to 2009 (see section 7.3.3).

7.5.2.2 Carbon Stock Changes in Soils

The soil type distribution of grassland areas converted from other land uses over the IPCC soil classes is determined from GIS analysis of CORINE 1990 land cover data superimposed on the General Soil Association Map of Ireland (Gardiner and Radford, 1980). Mineral soils as identified from the general soil map were allocated to the five IPCC soil groups and their organic carbon status is established from the soil type and the default reference soil organic carbon stocks (Table 7.4.1). Table 7.4.2 shows the adjustment factors applied to the default SOC_{ref} to correct for land use and farming practice. The principal conversion affecting carbon stock change in soils is that from native grassland to rough grazing, which causes a decrease in soil carbon. Conversely, it can be seen from Table 7.4.2 that conversion from cropland to improved grassland implies an increase in the soil carbon. A significant secondary source of carbon emission is the use of wetland soil types as pasture. It is assumed here that the wetlands soils under pasture are to some extent artificially drained, and so encourages the emission of carbon from this organic soil type. The default emission rate of 0.25 t C/ha for drained organic soils under grassland has been applied.

New estimates have been provided for forest conversion to grassland organic soils for the period 1990 to 2009 using the tier 1 emission factor of 0.25 t C per ha per year, (see CRF 5C and 5 KP-1 A2). Emissions from peaty mineral soils are adjusted according to peat depth as described in equation 7.3.2.

7.5.3 Agricultural Lime Application

Much of the total emission of carbon for productive agricultural land derives from the use of lime applied to control soil acidity. Data on the annual amounts of lime applied to land are based on the sales of liming products obtained from the Irish Business and Employers Federation and the Department of Agriculture, Food and the Marine. Figure 7.5.6 shows the times for lime sales disaggregated between Grassland and Cropland based on relative proportion of land area under improved grasslands and crops.

Data on the type and composition of the lime amendments is not currently available, therefore is is assumed limestone is the standard form of the application. The CO_2 emissions are calculated using the default emission factor of 120 kg C/tonne lime. Estimates are calculated for both grassland and cropland areas assuming equal rates of application on both improved agricultural grassland and cropland. The estimates are reported in CRF Table 5(IV) rather than in CRF Tables 5.B and 5.C, the carbon stock change tables for cropland and grassland, respectively.

[9] There appears to be some inconsistency between default biomass carbon stocks given in Table 3.4.9 and those derived from Tables 3.4.2 and 3.4.3 of the IPCC good practice guidance on LULUCF. The inventory agency believes that the value of 13.6 tonnes DM/ha for the cold wet temperate climate zone should be 12 tonnes DM/ha.

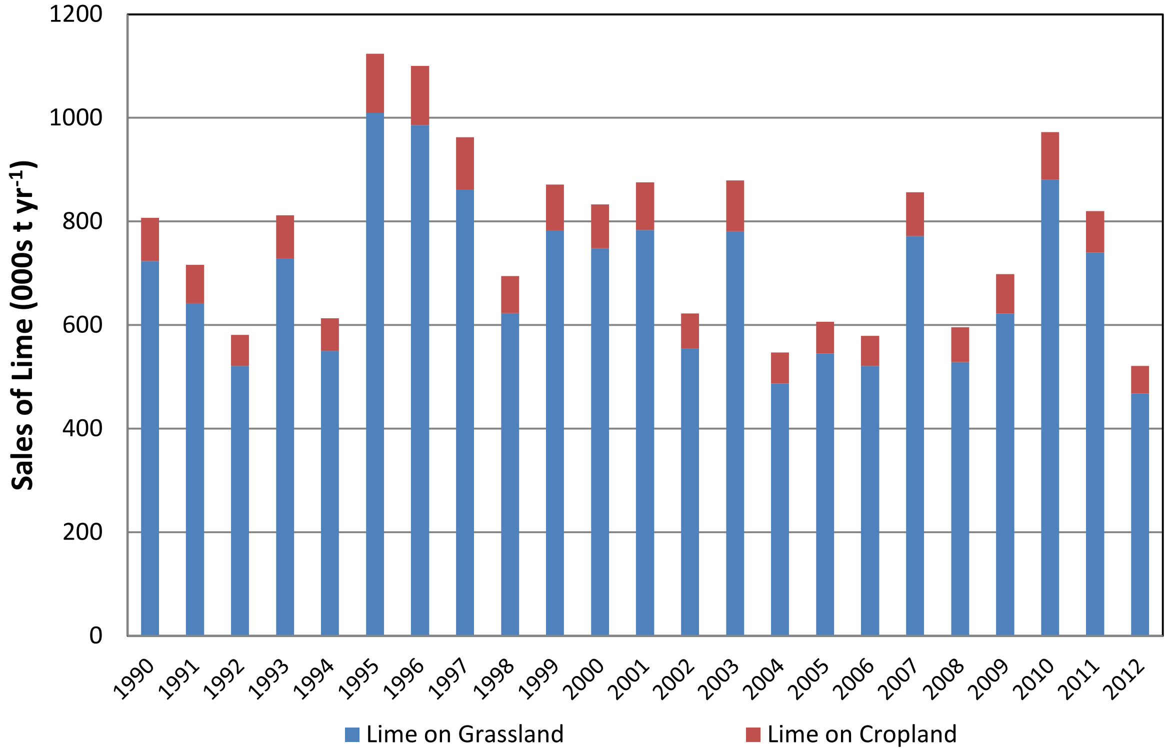


Figure 7.5.6 Lime Sales from 1990-2012 disaggregated between Grassland and Cropland

7.6 Wetlands (5.D)

7.6.1 Wetland Areas

The term Wetlands as applied to Ireland refer to natural unexploited wetlands and peatlands, which are those wetland areas drained for the purpose of commercial exploitation and harvesting of peat. The national wetland area is therefore split into two types, unmanaged wetland and managed peatland (Table 7.2.3). Previously, unmanaged wetlands areas were not reported to the UNFCCC In the 2012 submission, *5.D.1 Wetlands Remaining Wetlands* have been subdivided into two categories: Exploited Wetlands Remaining Wetlands and Unexploited Wetlands Remaining Wetlands.

In this analysis, Wetlands in Ireland are characterised as either natural unexploited wetlands or managed peatlands. Managed peatlands are those wetland areas drained for the purpose of commercial exploitation and harvesting of peat for use in energy or horticulture. The national wetland area is therefore split into two types, unmanaged wetland and managed peatland (Table 7.2.3). In the 2013 submission, *5.D.1 Wetlands Remaining Wetlands* were subdivided into two categories: Exploited Wetlands Remaining Wetlands and Unexploited Wetlands Remaining Wetlands. In the previous submission, unmanaged wetlands had been included in the “Other Land” category.

7.6.1.1 Unexploited Wetland Areas

The initial 1990 unexploited wetland area is based on the total area of peatland (excluding exploited areas) estimated from the CORINE 1990 land cover map. The main land use change out of unexploited wetlands has been demand from forestry. A small area of land is reported as converted to unexploited wetland due to the deforestation. It is assumed natural regeneration of biomass occurs over a period of five years to a maximum biomass of 3 t C ha-1, (see Table 7.3.15 section 7.6.2).

7.6.1.2 Exploited Wetland Areas

The commercial exploitation of wetlands as peatlands by Bord na Mona (the Irish Peat Board) according to the land-use definition in Table 7.2.3 proceeds is three separate stages, all of which may lead to changes in carbon stocks. Drainage is the first management activity, followed after several years by removal of the top layers of plant growth in the first season of peat extraction and then by the industrial extraction and harvesting of a layer of 10 to 15 cm of peat annually. The average working life of commercially developed Irish peatland is of the order of 30-50 years. Conversion to grasslands or forest land has been the historically favoured use of cutaway peatland. However, in recent years wetland restoration has been investigated, and achieved with some success. The areas reported under category *5.D.1 Wetlands Remaining Wetlands* refer to all lands drained, whether the peat remains covered by vegetation or is exposed. Bord na Mona manages its peat reserves to meet present demand and is therefore progressing to extract peat from new sites only when an older field is exhausted. It is assumed that the decrease in reserves of peatland indicate new extraction areas, and therefore they are an estimate of the area from which biomass has been removed. Until recently, Bord na Mona held a small area of un-drained wetlands in reserved. However, these lands have been transferred to the National Parks and Wildlife Service for conservation.

Also, a small area of exploited wetland has been restored to ecosystem function through drainage management and rewetting. This has led to an uptake of carbon in the revitalised biomass.

Bord na Mona supplies the area estimates for the company's commercial peat harvesting activities. The data for Bord na Mona commercial peat extraction areas are given as totals for consecutive five-year periods for a variety of peatland categories (Table 7.6.1). The annual average value obtained from this total is used for each of the five years to obtain the full time series. Domestic harvesting of peat bogs by private landowners for their own household use is a strong tradition in many parts of Ireland, and although well documented in a social and cultural context, the amount of such peat extraction is poorly quantified. Previously estimates of the land area devoted to private harvesting of peat was estimated to be in the region of 400 ha per year based on the assumption that the area under private commercial and domestic use was of the order of one eighth that of Bord na Mona lands. For the 2010 submission a refined estimate has been made using the value of residential peat use in the national energy balance and a bulk density estimate of 0.25 t/m^3 for peat m^{-3} (McGoff et al. 2007). This new approach ensures consistency between the quantities of peat combusted in *1.A.3.b Residential* and the area of private peat exploitation in LULUCF. More recent data is not available beyond 2009 activity, however, discussion with Bord na Mona concurred with the decision to project activity in the period 2006-2008 into 2012.

Table 7.6.1 Area Statistics for Peatlands (ha)

Peatland Category	1985-1990	1991-1995	1996-2000	2001-2005	2006-2008	Vegetation Cover
Active Production Bog	49,715	48,961	46,319	43,761	43,642	None
Production Reserve (Drained)	16,250	14,100	12,772	5,930	4,693	Heather
Fringe Bog (Undrained)	8,300	8,300	8,300	8,300	8,300	Heather dominated Bog Vegetation
Partially Drained	3,090	3,090	3,090	3,090	3,090	Typical Bog vegetation
Undrained Intact Bog	4,150	2,508	-	-	0	Intact Bog vegetation
Cutaway Areas						
Forestry (Plantation)	2,500	4,000	4,000	4,200		Conifers
Forestry (Natural)	-	100	800	2,235	4,200	Birch / Willow
Wetland (Acidic)	483	483	2,703	9,044	2,635	Eriophorum, Carex, Sphagnum
Wetland (Alkaline)	250	1,250	2,150	3,200	9,735	Typha, Phragmites, Open water
Lands Sold/Transferred	2,541	1,946	2,658	374	3,200	
Total owned (at end of period)	**84,738**	**82,792**	**80,134**	**79,760**	**79,495**	

7.6.2 Carbon Stock Changes in Wetland

7.6.2.1 Biomass

Carbon stock changes in biomass are determined by the balance between carbon loss due to the removal of vegetation on preparation for peat harvesting and gain on areas of restored peatland. These changes have been estimated on the basis that the entire cover of vegetation is removed to prepare for peat harvesting and that an equivalent amount of biomass is returned on restoration of cutaway areas. In the 2006 NIR, it was assumed that the restoration of biomass occurred in the year of conversion. However, discussions with experts from Bord na Mona suggest a more appropriate biomass transition period of 5 years.

The area from which vegetation is removed is taken to be the amount of peatland reserve that is drained to come under production annually and the restoration area is taken as the annual increase in cutaway wetland given by Table 7.6.1. The vegetation is typically heather-dominated bog or heathland cover for which a biomass carbon content of 3 t C/ha is adopted (Cruickshank et al, 2000).

Table 7.3.15 in section 7.3.7 above gives the area of forest land converted to wetlands for the years 1990-2012. The immediate oxidation of biomass, litter and dead wood for years prior to 2006 were derived using the mean IEF for 2006 to 2010 (see section 7.3.3). Thereafter, it is assumed that natural vegetation cover will gradually recover over a period of five years at the rate of 0.6 t C $ha^{-1}yr^{-1}$ up to a equilibrium of 3 t C ha^{-1}.

7.6.2.2 Soils

The CO_2 emissions associated with the combustion of peat are accounted for in the *Energy* sector. An additional loss of carbon is associated with drainage and the exposure of the new peat surface annually after harvesting takes place. The annual activity data are the active production areas of Bord na Mona bog (Table 7.6.1), together with the areas of peatland in use by private commercial enterprises and by domestic users. All such peatlands are nutrient-poor raised bogs or rain-fed blanket bogs for which the appropriate carbon emission factor is 0.2 t C/ha, given for boreal and temperate climatic regions in the IPCC good practice guidance. The activity land area in respect of the soils carbon pool is the value that appears in CRF Table 5.D. This area is significantly larger than that relevant to the estimation of carbon stock change in biomass above.

7.6.3 Emissions of Non-CO_2 Gases

In the submissions prior to 2006, no estimate was reported for N_2O emissions associated with the drainage of peatlands for commercial exploitation, as this is an optional reporting category in the LULUCF sector, therefore the notation key NA was used in CRF Table 5 (II). This position was reviewed following the in-country review of Ireland's GHG inventory in 2007. Emissions of N_2O due to the drainage of peatlands are now reported and utilise the IPCC Tier 1 approach.

7.7 Settlements (Category 5.E)

7.7.1 Areas of Settlements

The area of settlements in 1990 is that given by CORINE 1990. Land converted to settlements is the area taken up by new road building, available from the National Roads Authority, and the area covered by new residential, commercial and industrial construction based on CSO annual statistics, which are extracted from floor area records for permitted development. An incomplete time series of housing types (for the years 1995-2010) was used to estimate the residential building footprint from floor area. It was assumed that approximately 50 per cent of the planning permits granted for construction were for green-field sites previously not part of the urban fabric, based on the proportion of dwelling types completed in the given year.

With the exception of *Forest converted to Settlement*, the identification of previous land use from which settlement areas are converted is based on an analysis of the distribution of land use classes given by CORINE 1990. The extent of deforestation associated with conversion to settlement has been independently assessed, and is outlined in section 7.3.7 with the exclusion of wetland, water bodies, existing continuous urban fabric and other marginal lands unsuitable for development. The remaining change in Settlement area is assumed to have occurred in proportion to the respective categories in CORINE 1990.

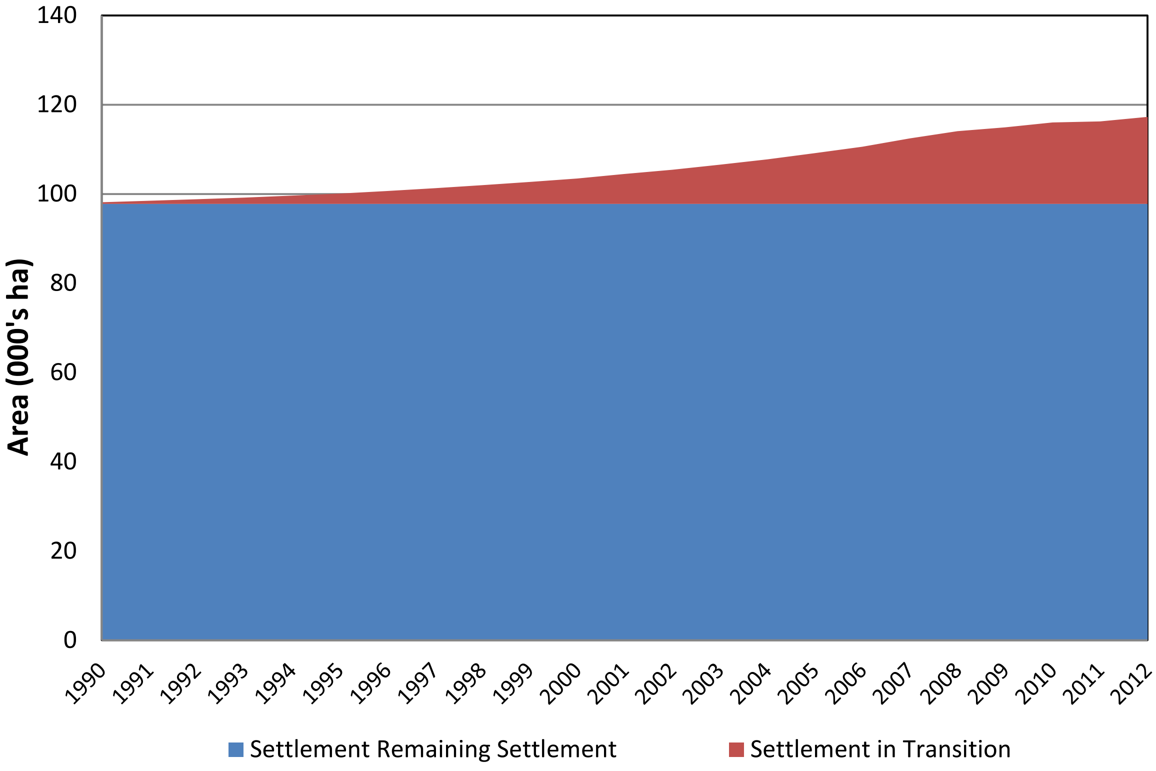


Figure 7.7.1 Estimated Area of Settlements[1] 1990 to 2012

[1] It is assumed Settlement remaining Settlement is constant since 1990. All new settlement activity is categorised as "in transition".

7.7.2 Carbon Stock Changes in Settlements

The assumption is made of complete removal of biomass in the year of conversion. The biomass loss from grassland and cropland is as per guidelines using the Tier 1 approach. It is assumed that those lands converted from "Other Land" had a biomass equivalent to natural vegetation. The relative loss of biomass from forest per hectare is large. No account has been made of the potential increased carbon stock in biomass in urban areas, e.g. in parks or roadside planting. This may be a significant carbon sink, especially under the policy of actively encouraging urban tree planting along new roads and in new housing developments, but no data is available.

Table 7.3.15 in section 7.3.7 above gives the area of forest land converted to settlements for the years 1990-2009. The immediate oxidation of biomass, litter and dead wood for years prior to 2006 were derived using the mean IEF for 2006 to 2009 (see section 7.3.3). It is assumed there is no recovery of biomass in these areas deforested to Settlement.

7.7.2.1 Soils

With the exception of *Forest converted to Settlement* the estimate of change in soil carbon during conversion to settlement is based on a review of approaches taken by other reporting parties. The revised 2006 IPCC guidelines also provide some additional insight into this potential source of emissions. It is assumed that 50% of the soil carbon present in the soil prior to conversion to Settlement is lost to the atmosphere, and this occurs in the year of conversion. A 100% uncertainty is attached to this emission factor. The methodology applied to *Forest converted to Settlement* is outlined in section 7.3.6.

The estimate of soil types under settlement is based on the national distribution of soil types associated with the previous land use. It is assumed that Wetland is unsuitable for conversion to dwelling and commercial settlement, and therefore conversion does not occur. The soil carbon content prior to conversion to Settlement is based on the land management factors and soil organic carbon reference values given in Tables 7.4.1 and 7.4.2.

7.8 Other Land (Category 5.F)

7.8.1 Areas of Other Land

The category *5.F Other Land* includes all lands not classified under the categories 5.A through 5.E. It represents the difference between the sum of categories 5.A through 5.E and the total land area of Ireland. A large part of *5.F Other Land* is not relevant in terms of its potential for emissions or removals. With the inclusion of unmanaged natural grassland areas in LULUCF reporting in this submission (see Section 7.5), the previous assumption that significant areas of afforestation occurred on “Other Land” has been revised. Much of this afforestation is now, more accurately, attributed to conversion from grasslands. Therefore, there has been a significant revision in the area of “Other Land Remaining Other Land”.

7.8.2 Carbon Stock Changes in Other Land

The degradation of lands reverting to rough grazing not in use, results in carbon losses from the soil. The soil classes are identified for *5.F.2.3 Grassland Converted to Other Land* in the same way as for other land-use categories. For mineral soils, SOC_{ref} is assigned according to Table 7.4.1 while Table 7.4.2 is used to apply the SOC adjustment factors and the carbon stock change is calculated using Equation 7.4.1. The default emission factor of 0.25 t C/ha is used to calculate carbon loss from organic soils.

Table 7.3.15 in show the transition of forest land to other land, which are not classified as crop, grassland, settlements or wetlands for the years 1990-2010.. These forest conversions are small areas being converted to quarries or telecommunication masks. More recently, these areas also include forest conversions into windfarms, but these are only the areas for roads and turbine platforms. Areas in the turbulence zone are generally clearfelled and replanted.

The immediate oxidation of biomass, litter and dead wood for years prior to 2006 were derived using the mean IEF for 2006 to 2009 (see section 7.3.3). It is assumed that these deforested lands revert to a natural grassland state, and recover an above ground biomass of the order of 6 t C ha^{-1} in the year of conversion.

7.9 Uncertainty in non-Forest LUULCF categories

The purpose uncertainty analysis is to identify those key categories which contribute significantly to the uncertainty in the overall estimate emissions and removals. The results of the formal Tier 1 approach to uncertainty analysis are presented in Table 7.9.1. These are consistent with the findings of the qualitative discussion provided here.

Categories of land use can be identified as potential key categories for uncertainty in the estimate of greenhouse gas emissions within LULUCF by virtue of uncertainty in the activity data or uncertainty in the emission factor, or a combination of both.

7.9.1 Uncertainty in Cropland

The dominant contribution to the 2012 uncertainty is estimate of emissions and removals within the Cropland category is uncertainty in the emission factor for the loss of carbon due to conversion to Cropland from other land uses, most notably conversion from Improved Grassland, accounting for approximately 90% of the overall uncertainty in this category. However this analysis does not include a number of quantified elements which may prove to just as significant.

- Tier 1 methodology for croplands remaining cropland assumes zero net emissions of carbon where the land management practices are well established. In general, cropland land use area in Ireland is decreasing, with croplands concentrated in well defined regions. This supports the assumption that the lands on which crops are grown are well established within this farming system, and takes place on the most suitable, productive soils and therefore the assumption of zero emissions is reasonable. It is difficult to quantify the uncertainty associated with this assumption.
- The area of cropland in Ireland has shown a downward long term trend. The proportion of reported agricultural land under croplands in of the order of 10%, this also shows a long term downward trend. The main uncertainty in the total area of cropland is the area of non-permanent grassland which should be included in the cropland category in the context of typical crop rotation practices. In previous years, an area of “Setaside“ was a major component of the area reported by the CSO under “Other Crops”. However, due to changes in the EU Area Payment Scheme, this statistic is no longer a reliable measure of “Setaside”. In addition, the practice of land leasing gives cropland farmers access to additional land resources which allows them to respond to market drivers, and the leads to the temporary conversion of land use between cropland and grassland. This dynamic cannot be quantified with current activity data. It is difficult to quantify the uncertainty associated with this limitation within existing activity data. Ireland has untaken a research study to examine this issue, using high spatial and temporal resolution data to attempt to identify a suite of representative crop rotation and farming practices which would characterise the dynamic land use pattern associated with cropland regions.
- According to national expert opinion, the drainage and cultivation of organic soils for crops does not occur in Ireland. However, independent GIS analysis indicates a small area may be cultivated, contrary to the expert opinion. It is thought probable that the GIS analysis findings are, in fact, an artefact due to the overlay of mismatching spatial layers, which may not have the necessary resolution to accurately determine the common area. This introduces and uncertainty in the areal extent equal to the estimate of cultivated organic soils at least equal to the area identified by the GIS analysis, of the order of 1,500ha. The magnitude of the emission factors associated with drainage of organic soils is such that it is important to address this potential underestimate of emissions. Additional research is required to resolve the issue; this research was commenced in 2013.

7.9.2 Uncertainty in Grassland

Grassland has the potential for large uncertainty by virtue of large areal extent, and estimates for drainage of organic soils in this category. The dominant sources for uncertainty in this category are the activity data and emission factors associated with the use of drained organic soils within agriculture.

- Grass based agriculture accounts for 90% of agricultural area in Ireland. The area of permanent grasslands is very stable over time, with known afforestation accounting for a high proportion of the observed decrease in reported grassland area. Reported grassland areas include both utilised agricultural areas and natural grassland. Carbon stock changes are estimated using Tier 1 methodologies is based on interannual changes in reported areas.

- The area of drained organic soils under grassland is based on the proportion of agricultural grassland land cover overlaid on a soil map. There are the usual issues of matching mapping scale and interpretation of land use from land cover. Additional analysis is required to confirm these findings and the uncertainty is high.

- Country specific emission factors for grasslands on drained organic soils are the subject of on-going research. Findings from which will be published in 2014. Preliminary findings indicate that the default IPCC Tier 1 emission factor may be as much as an order of magnitude in too low under conditions in Ireland. This introduces considerable uncertainty in the analysis of emissions, which cannot be quantified at this time. We welcome the publication of the IPCC 2013 Wetlands Supplement, to complement the country specific research, to help inform the analysis. Pending publication and review of this research, the 1996 IPCC GPG default factor is applied, with the recognition that the reported emissions from this activity are likely to be underestimated, and the associated uncertainty is very high.

- Tier 1 methodology for grassland remaining grassland on mineral soils assumes zero net emissions where management practices are well established. There is emerging research which indicates that improved grasslands on mineral soils in Ireland continue to act as a sink of carbon. This appears to be a sustained impact of increased intensity of land management (fertiliser usage and manure management, grazing practice). However additional analysis required to confirm this result on a national scale and link it to activity data related to management practices. However, the analysis to date is sufficient to demonstrate that Grassland remaining Grassland on mineral soils is “not a source”, but the quantitative uncertainty in this assessment is high. Khalil et al. (2012), Peichl, et al (2011). Kiely et al (2009). Byrne, and Kiely (2006).

7.9.3 Uncertainty in Wetlands

Drainage of organic soils within Wetland land use category is significant by virtue of uncertainty in areal extent and emission factors. Uncertainty analysis reveals these two components to contribute in equal measure to overall uncertainty. However, there is concern over the appropriateness of the 1996 IPCC GPG default emission factor for Ireland.

- The area of peatland drained for peat extraction is dominated by the activities of the semi state commercial company Bord na Mona (BnM) which owns approximately 80kha of land of which 60kha is currently in production. There are a number of smaller commercial enterprises, mainly involved in peat extraction for horticulture which compete in the export market with BnM. BnM estimate these players have 12% of the market. This is consistent with proxy data from sales export figures from Central Statistics Office. There is uncertainty in the conversion of volume of sales of peat to an equivalent area of drained lands to meet this product demand. It is assumed that the competitive operators employ similar extraction methods as BnM and therefore require an area of land in proportion to their market share. This is likely an overestimate of area drained as the extraction methods deployed are likely to be more vigorous than the approach taken by BnM. A similar issue arising with the use of proxy data from the energy sector to estimate the area of peatland drained to meet demand for residential heating by private, non-commercial sector.

- The default emission factor for drained wetlands for peat extraction is significantly less than the country specific factors for other land uses adopted by a number of other European countries. Whilst this is evidence the default EF results in an underestimated of emissions, there is insufficient data to adopted a revised country specific EF. We welcome the publication of the IPCC 2013 Wetlands Supplement, which coupled with to inform the analysis.

7.9.4 Uncertainty in Settlements

The area of settlement in the 1990 base year is based on the CORINE 1990 estimate of urban, industrial and other manmade environments. Change in settlement area since 1990 is based on construction statistics, national road infrastructure development and specific deforestation activities identified earlier.

There is a critical assumption which limits the potential for carbon stock change to only the specific footprint of the buildings, i.e. the sealed area, as captured in the planning permission declarations, with additional assumptions with respect to minimum new paving requirements and hedgerow removal required for new builds. This means there is an implicit assumption of no carbon stock change in lands adjacent to new constructions (green areas, etc.) relative to previous land use. Additional analysis is required to address this issue, however it is unlikely that this analysis would elevate land use change to Settlement to key category status. It is worth noting that these lands are reported as part of the “Other Land” category by default as they would not be captured in Agricultural, Forestry or Wetland statistics.

Reporting of potential change in soil carbon during conversion to settlement is based on a review of approaches taken by other reporting parties. The revised 2006 IPCC guidelines also provide some additional insight into this potential source of emissions. It is assumed that 50% of the soil carbon present in the soil prior to conversion to Settlement is lost to the atmosphere, and this occurs in the year of conversion. A 100% uncertainty is attached to this emission factor.

7.9.5 Uncertainty in Other Land

In the absence of a “wall to wall” land use mapping system in Ireland, the Other Land area is estimated from the residual area required to maintain a reporting of constant total national land area once estimates for all other land use categories have been taken into account. As such, this category will be subject to the cascade of uncertainty in estimates of land use area from the other land use categories.

Table 7.9.1 Activity Data and emission Factor Uncertainties for LULUCF)

	IPCC Source Category	Gas	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Reference Activity Data	Reference Emission Factor
	Category/ Sub-category		**%**	**%**		
5.A	Forest land	CO_2	51.00	114.00	See Sections 7.3.4.7 and 7.3.5.7	Country Specific value cf Chapter 7.3
5.B.1	Cropland Remaining Cropland	CO_2	22.57	69.15	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008	Default value from IPCC GPG
5.B.2	Cropland In Transition	CO_2	18.61	69.15	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008, Trend analysis of CSO UAA areas	Default value from IPCC GPG
5.C.1	Grassland remaining Grassland	CO_2	12.22	90.00	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008	Default value from IPCC GPG
5.C.2	Grassland in Transition	CO_2	43.95	101.11	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008, Trend analysis of CSO UAA data	Default value from IPCC GPG
5.D.1	Wetlands remaining wetlands	CO_2	21.49	101.45	CORINE 2000, BnM Expert opinion	Default value from IPCC GPG
5.D.2	Land Converted to Wetland	CO_2	2.50	50.00	Deforestation data, Chapter 7.3	Country Specific value cf Chapter 7.3
5.E.1	Settlement remaining Settlement	CO_2	39.97	75.00	Expert assessment of Dept of Environment Construction figures and National Road Authority infrastructure activity	Default value from IPCC GPG
5.E.2	Settlement in Transition	CO_2	39.97	81.83	Expert assessment of Dept of Environment Construction figures and National Road Authority infrastructure activity	Default value from IPCC GPG
5.F.1	Other Land remaining Other Land	CO_2	30.91	90.00	Uncertainty in Other Land Area based on combined uncertainty of land use change in other land use categories	Default value from IPCC GPG
5.F.2	Lands converted to Other Land	CO_2	51.93	75.00	Uncertainty in Other Land Area based on combined uncertainty of land use change in other land use categories	Default value from IPCC GPG
5.A	Forest Land	CH_4	30.00	100.00		
5.A	Forest Land	N_2O	30.00	100.00		
5.B.2	Cropland In Transition	N_2O	30.00	100.00	From LULUCF GPG. Page 3.50	Default value from IPCC GPG
5.C.2	N20 from drained Organic Soils under grassland	N_2O	90.80	100.00	Combined uncertainty in carbon loss from drained organic soils under grassland. The uncertainty from the carbon estimate cascades to the Activity Data Uncertainty in this approach	Default value from IPCC GPG
5.D.2	N2O from Drained Wetlands	N_2O	92.20	100.00	Combined uncertainty in carbon loss from drained organic soils within Wetlands. The uncertainty from the carbon estimate cascades to the Activity Data Uncertainty in this approach	Default value from IPCC GPG

7.10 Quality Assurance and Quality Control

The entire compilation for this submission for both LULUCF (Chapter 7) and activities under Article 3.3 of the Kyoto Protocol (Chapter 11) were reviewed externally by an independent consultant, qualified as a UNFCCC expert reviewer for LULUCF/KP-LULUCF in March 2012. This provides an important element of quality assurance for this 2012 submission. Following the findings of this independent peer review, both chapter 7 and 11 of this report have been substantially improved to provide additional transparency and consistency between Convention and KP reporting for LULUCF.

7.10.1 Category specific QA/QC for Forest Lands

Category specific QA/QC plans and documentation for forest land are carried out by FERS Ltd on behalf of the DAFM and EPA using IPCC GPG 2006 (Chapter 6), these include.

7.10.1.1 QC plan for Activity Data

- Evaluation of required data from external sources (Forest service, Collite);

- Set up of memoranda of understanding between DAFM, EPA and data providers including:
    - Deadlines for data delivery;
    - Internalised QA/QC checks and procedures;
    - Metadata;
    - Notification of changes to methods used for collecting activity data;
    - Identification of contact points and responsible parties.

- Correspondence with data providers 2 months before agreed delivery dates to notify of new requirements, request notification of changes to any activity data and to remind providers of deadlines;

- QC checks of reference sources for national activity data by evaluation of documentation with regard to activity data. For example, is data collection or sampling regimes adequate and un-bias? Does the agency have any information on uncertainties?
- Comparisons of input data with independent data sets such as harvest statistics (FAO/Eurostat), land cover data such as CORINE (see Black et al., 2009a);

- Time series consistency checks of activity data;

- Collation and initial completeness checks of activity data required;

- Pre-processing activity data and compiling data bases to be used by CARBWARE.

7.10.1.2 Emission Factors, Models and Calculations

QC checks on the background data used to develop emission factors: assessment of the adequacy of the emission factors and the QA/QC performed during their development. (e.g. Byrne and Farrell, 2005-orgsanic soil emissions; Tobin et al 2007-litter turnover).

QC checks on Models**:** Both the FORCARB and CABEWARE models were developed specifically for GHG inventory reporting. When these models were designed and developed the following was considered;

- Appropriateness of model assumptions, extrapolations, interpolations;

- Model calibration: models have been calibrated (see Annex K) using historic (1950-2000) Irish forestry data (Hawkins et al., 2012);

- Calibration of the age class distributions used in the FORCARB model was checked against independently derived information (see Figure 7.3.6, Black et al., 2012);

- Model design specifically considered the activity data characteristics, and their applicability to the greenhouse gas inventory. For example, the key activity data for reporting is the NFI. The CARBWARE model was designed to specifically deal with single tree input data, and not stand-based data, because of NFI limitations (see Annex K);

- If model descriptions, assumptions, rationale, and scientific evidence and references supporting the approach and parameters used for modelling have not been published, detailed descriptions are supplied in the Annex (K) to the NIR;
- Models are re-evaluated and updated annually using any new research information or if uncertainty analysis and validations indicate large uncertainties of bias in the assessment of any pool of forest subcategory. For example, the improvement to litter flow and turnover rates in conifer crops for this submission, as identified by the NIR 2012;

- All pools are included in the models, so are complete in relation to the IPCC source/sink categories. Where categories or pools are not reported, this is justified in chapter 11.

QA/QC of calculations is facilitated by the software and database management system designed to run the CARBWARE model (see Figure 7.3.5, section 7.3.3.1). This reduces the risk of calculation errors or manual error over the time series. Correct coding and calculation QA/QC was carried out by three independent parties using identical data during development of the software under the COFORD funded CARBWARE project (2007-2011).

7.10.1.3 Completeness and error checks in compilation of the CRF tables

Transcription of data to the CRF reported and compilation of data in the required format can result in error of inconsistencies. A check on the final CRF table is performed on completion of data transcription.

Following recommendations from previous ARRs corrections or adjustments are made and documented in the NIR

A QA/QC check list is documented every year to record problems detected and corrective actions.

7.10.1.4 Validation and QA/QC Links to Uncertainty Analysis

Comparisons of emission factors between countries: this is carried out for forest remaining forest land and land converted to forests see tables 7.10.1 and 7.10.2.

Uncertainty analysis or validation is used to identify where improvements should be made to pool or categories estimates and methods. For example, improvements are planned following the identified issue bias in estimating broadleaf biomass changes (Table 7.15).

Uncertainty analysis includes trend analysis to determine if there are any time series inconsistencies.

Time series adjustments are applied if there are fundamental differences in the activity data being used or methods applied over a time series.

7.10.1.5 Validation of Reported Estimates (Category 5.A.1)

In addition to the DBH growth model uncertainty and model validations shown in Annex J, IEFs reported in the CRF table 5.A were compared to other countries with similar forest characteristics for the inventory year 2011 in the 2013 submission using the Locator Tool (Table 7.10.1).

Table 7.10.1. Comparison of 2010 inventory year IEFs reported for other countries and those reported by Ireland forest land remaining forest land

Pool	IEF (Mg/ha)			
	Ireland	**EU27**	**UK**	**Range**
LB net	0.58	0.57	0.24	16.1 to -0.07
DOM	-0.16	0.02	0.26	0.57 to -0.06
Soils	-0.22	-0.38	0.57	0.57 to -0.68
Fire CO_2	260.65	IE,NO,NA	Mg/kg biomass	159 to 8.3
Fire CH_4	1.14	IE,NO,NA	Mg/kg biomass	0.29 to 0.03
Fire N_20	0.01	IE,NO,NA	Mg/kg biomass	0.008 to <0.001
N_20 drainage	0.14	0.25	NE	0.6 to 0.08

All of the reported IEFs for all pools are within the ranges reported for other countries. Ireland is the second highest IEF for LB gains, higher that the UK but lower than Malta. Ireland has the higher LB losses than any other country.

It should be stressed that IEFs have been validated against other sources such as eddy covariance, NFI and research information and show good agreement (see Table 7.24). The research also shows that Irish forests have a higher NEP, NPP and GPP when compared to most published values in the literature (see Black et al., 2009a, Luyssaert et al 2007).
The higher biomass gains have been attributed to:

a) The mild oceanic climate in Ireland and the large percentage of high yielding Sitka spruce plantations-planted at high stocking rates (2500 stems per ha).
b) Yield classes experienced in Ireland are much higher than that in the UK. For example YC 28 to 30 m^3/ha/yr can be obtained on some mineral soils, compared to a max of 24 in the British yield class tables.

Models used in the UK are based on the BFC yield tables, we show that the individual tree model used in CARBWARE provide a better estimate than BFC models (see a comparison of FORECARB and CARBWARE in section 7.3.4.1). It should be stressed that the CARBWARE single tree model has been validated against a partial sample of the new NFI (see section 7.4.3.7 Table 7.14). In addition, the growth models were developed using a historic permanent sample data base going back to 1950 (i.e the Coillte PSP, see Annex K)

Although the IEF for net living biomass (LB) is higher than that reported by the UK, this can be explained by the higher productivity of the major species Sitka spruce growing in the mild oceanic climate experienced in Ireland. In addition, the IEF is lower when compared to Denmark (2.53 Mg/ha), which also has a high proportion of Sitka and Norway spruce forests. The IEFs for wildfires in Ireland is the highest reported value under the convention.

7.10.1.6 Validation of reported estimates (Category 5.A.2)

IEFs reported in the CRF table 5A2 were compared to other countries with similar forest characteristics for the inventory year 2010 in the 2012 submission (Table 7.10.2).

Table 7.10.2 Comparisons of 2010 inventory year IEFs reported for other countries and those reported by Ireland land converted forest land

Pool	IEF (Mg/ha)			
	Ireland	**EU27**	**UK**	**Range**
LB net	3.22	1.26	2.46	10.4 to 0.007
DOM	0.69	0.17	0.09	1.55 to -0.38
Soils	-0.44	-0.64	0.44	0.44 to -2.13
Fire CO_2	151.7	IE,NO,NA	Mg/kg biomass	159 to 8.3
Fire CH_4	0.66	IE,NO,NA	Mg/kg biomass	0.29 to 0.03
Fire N_20	0.003	IE,NO,NA	Mg/kg biomass	0.008 to <0.001

All of the reported IEFs for all pools are within the ranges reported for other countries. Additional validations of the CARBWARE growth and C flow models were carried out by comparisons to eddy covariance data (a micrometeorological measure of stand net carbon balance including all pools) from the COFORD funded CARBiFOR project. The eddy covariance measurements and standard inventory assessments, used as inputs in to the CARBWARE single tree growth and C flow model, were carried out for 2 chronosequences (Table 7.10.3):

a) A range of Sitka spruce stands on a mineral surface water gley soil, including 2 thinning cycles;
b) Two Ash sites aged 6 and 12 on brown earth soils.

Eddy covariance provides an estimate of net ecosystem exchange (NEE, positive values represent a net removal) excluding emissions related to immediate oxidation of harvested timber. For comparison to the CARBWARE estimated net biome productivity (i.e. NEE minus harvest losses) are shown in bold in Table 7.10.3 below.

Table 7.10.3 Validation of net biome productivity (NBP. i.e. net C emissions/removals) estimates using CARBWARE against eddy covariance derived estimates across 2 chronosequesnces2010 inventory year IEFs reported for other countries and those reported by Ireland land converted forest land

Species	Yield class	Silviculture	Forest age	Year	E.covariance	± Uncertainty	NEE - harvest	± Uncertainty	Carbware	± Uncertainty	Wlicoxin p-value
					NEE		NBP		NBP		
					(t C ha^{-1} yr^{-1})						
Sitka spruce	24	un-thinned	20	2006	8.81	1.09	**8.81**	1.09	**8.50**	1.09	<0.01
Sitka spruce	24	1st Thin	21	2007	10.33	1.41	**-3.09**	2.67	**-4.20**	3.60	<0.05
Sitka spruce	24	1st Thin	22	2008	6.75	1.19	**6.75**	1.19	**9.80**	0.50	0.12
Sitka spruce	24	2ndThin	23	2009	8.14	1.94	**-3.06**	1.90	**-3.90**	0.59	<0.08
Sitka spruce	24	2ndThin	24	2010	8.18	1.47	**8.18**	1.47	**7.80**	0.16	<0.01
Sitka spruce	24	2ndThin	25	2011	8.54	1.11	**8.54**	1.11	**9.30**	0.72	<0.05
Sitka spruce	24	un-thinned	14	2009	8.52	1.46	**8.52**	1.46	**7.15**	0.36	<0.05
Sitka spruce	24	un-thinned	7	2009	2.21	0.46	**2.21**	0.46	**3.58**	2.54	<0.05
Ash	6	un-thinned	6	2010	1.38	0.29	**1.38**	0.29	**-1.23**	1.97	0.25
Ash	12	un-thinned	10	2010	4.67	0.71	**4.67**	0.71	**2.14**	1.54	0.14

This analysis shows that there is good agreement between the CARBWARE and eddy covariance based estimates across different age classes, species and silvicultural treatments, as evident from the signed rank Wilcoxin p-value (p-values <0.05 include no significant difference between the two estimates). It is evident that there are, however, differences in the following cases:

- The NBP for Ash sites are underestimated by CARBWARE, when compared to the eddy covariance approach. This is due to:

    - The previously mentioned under-estimation of DBH increment for the fast growing broadleaf cohort (FGB), where DBH is < 12cm (see Table 7.3.9);

    - Overestimation of litter and mortality losses in the FGB cohort models. Future improvements to the CARBWARE model are planned once more research from the COFORD research programme;

    - CARBWARE assumes that there is no significant change in mineral soil stock changes following afforestation, but NEE based estimated include emissions/ removals from soils, which in some cases can represent an net removal of C over time, although this is not always significant (see chapter 11, justification for not reporting soil CSC);

    - Eddy covariance based estimates include non-forest vegetation gains and losses, which are not estimated in the CARBWARE model. It is feasible that non-forest biomass in the early stages of forest establishment can represent a net removal of C, but this assumed to be zero at steady state since non-forest vegetation is decomposed after canopy closure.

- In one of the Sitka spruce sites (22 year old stand, Table 7.10.2), CARBWARE overestimated NBP, when compared to eddy covariance. Research form the CARBiFOR project shows that the lower NBP for this site is due to climatic inter-annual variability, which is not captured by CARBWARE.

The CARBWARE models are being continually validated against NFI data and updated as new research information from the COFORD funded programme becomes available.

Planned improvements include:

- Re-evaluation of CSC in mineral soils and emission factors for organic soils (ForCRep project 2013-2016);

- Development of a remote sensing system for tracking deforestation and land use change from forests to other land (ForCRep project 2013-2016);

- Re-evaluation of FGB cohort model using information from the CARBiFOR project (2007-2013);

- Development of a remote sensing system to identify forest areas subjected to wild fires and improvement to currently used biomass combustion and EFs used in national reporting.

Validation and refinement of the CARBWARE model based on the 2006 and 2012 NFI, Betterfor project funded by DAFM and COFORD 2013 to 2015.

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7.10.1.6 Independent External Reviews

An external review of the CARBWARE system was completed in 2007 as part of the design and methodology development research programme, funded by COFORD.

7.11 Recalculations in LULUCF

The recalculations for LULUCF includes a complete revision of the time series, now based on land remaining a land use category for the periods before 1990 and lands converted to other land uses since 1990. This required a major methodological change for forest lands resulting mainly from wider use of the national forest inventory data in the CARBWARE model for forest land and its development to ensure consistency between the LULUCF submissions under the Convention and the Kyoto Protocol. The following are the principal items leading to recalculations for the years 1990-2011 due to methodological improvements and in response to recommendations made previous annual inventory review reports. The impact of these recalculations on total GHG emissions in the LULUCF sector is a net decrease in removals of 1.7 per cent. The other main recalculations took place in the following categories:

5.A. Forest lands CRF

- The major change is the latest submission is the use of the new NFI data for 2012. This has resulted in the following changes:
  - Changes in the harvest removed from land converted to forest land and forest land remaining forest land
  - Changes in the previous land use categories used for land converted to forest land (section 7.3.2.5)
  - Changes in the areas under categories 5A1 and 5A2 due to changes in the deforestation area between 2006 and 2012.
  - A complete recalculation for the time series adjustment for 1990 to 2006 due to the new NFI data

- A correction to dead organic pool calculations for forest land remaining forest land. This was due to the use of the incorrect sign (+ve instead of –ve) adjustment factor used for the time series adjustment (see section 7.3.4.1).

5.B.-5.E. Forests converted to other land uses

  - An increase in deforestation emissions in 2011 from 29 Gg in the previous submission to 332 Gg CO_2 in this submission.
  - Inclusion of emission estimated from mineral forest soils converted to settlement and other lands as recommended by previous ERT (ARR 2012, 2013).

5.C Grassland

- Natural, unmanaged, grasslands are included in the Grassland land use category for the first time. Previously these lands have been included in the Other Land category. The revision means there is increase in the total area of Grassland, and a corresponding decrease in area of Other Land. All previous transitions between Grassland and Other Land, and the GHG emissions associated with these, are now reported under Grassland Remaining Grassland. This revision was in response to the review process.

- A recalculation has also been undertaken due to revision of the estimate of area of improved grassland in 2011.

5.E Settlement

- Estimates of changes in soil carbon due to conversion from other land uses to Settlement are reported for the first time. This is in response to the Review Process.

5.F Other Land

- Recalculation for all years due to revision of methodology to delete natural grassland from Other Land category and include it in Grassland category. This is in response to the Review Process

The net effect of the recalculations is outlined are shown in Table 7.12.1.

7.12 Improvements in LULUCF

The coverage of sources of emissions and removals by Ireland in the LULUCF sector under the Convention is complete for the years 1990-2012. This submission also contains estimates for 2008-2012 in respect of activities under Article 3.3 of the Kyoto Protocol (chapter 11), which are now fully consistent with Convention reporting for LULUCF. Even though a rather simplified approach has had to be followed for many land-use categories due to the level of information available, the assessment of emissions and removals according to the reporting requirements of Decision 13/CP.9 has identified a number of important CO_2 emission sources, in addition to the well-known carbon sink in forests. Extensive further work has been conducted to improve completeness, methodologies and data treatment for this submission and to apply some refinements due to approaches taken for estimating emissions and removals for Article 3.3 activities. The inventory agency is continuing to collaborate with the bodies from which the key land-use and forestry datasets are obtained and has established formal arrangements for the provision of the data within the national system, in the same way as for other sectors. The agency's capacity on GIS continues to be developed, which facilitates the assessment and integration of available datasets. It is intended to apply this capacity in a more detailed treatment of soils for future submissions.

The results of the national forest inventory are now being applied more extensively in the LULUCF inventory and this submission reflects further improvements given by this data source and by supporting research projects on climate change and forestry being undertaken over the period from 2007 to 2012. The CARBWARE development project has improved forest carbon stock change reporting tools and software to make available an integrated system that meets the reporting needs of the Convention and the Kyoto Protocol with respect to forest land. It also draws on data from the now completed CARBiFOR II project and other related research projects, to continually refine estimates of carbon stock change for reporting purposes and for projecting carbon sinks into the future. A new research project ForCRep (2012-2016) has been funded by COFORD and the DAFM to specifically address reporting of emissions associated wild fires and further investigate soil stock changes in mineral following conversions to and from forestry. This new research project will also explore the development of methods to deforestation using a wall to wall approach based on new remote sensing products. This will be integrated with other EPA projects, using similar approached for tracking land use transitions in grasslands and crop lands.

There has also been extensive validation and verification of the models used for LULUCF and Kyoto reporting. This is part of an on-going QA/QC procedure. The LULUCF sector now adopts a tier 1 QA/QC system for LULUCF.

A new research project, funded by DAFM, has been initiated to track deforestation using a wall to wall approach based on new remote sensing products. This will be integrated with other EPA projects, using similar approached for tracking land use transitions in grasslands and crop lands.

On-going work on developing a single forest cover and attribute data set has been progressing in the Forest Service. The most recent data set has been compiled for 2010, apart from a subset of grant and premium data that needs to have species attributes input manually. Annual versions will include data on location, planting year, species area and open space area attributes, for all forest greater than 0.5 ha in area (with the post 1990 afforestation data for areas down to 0.1 ha). The Forest Service will have a system in place for access to and use of the data.

Research is on-going into the extent, and condition, of hedgerows in Ireland, which will be classified as settlement biomass in future submissions. Further research is required in this area. New research has been instigated to determine country specific emission factors associated with agricultural and forestry practices on drained organic soils. The land use conversion to settlements, particularly as regards new construction, remains a coarse estimate. Additional analysis is required to determine the real dynamic rate of conversion between grassland and croplands, and vice versa. This analysis will be undertaken in collaboration with the Department of Agriculture, Food and Marine.

In 2012, new research has been funded by the EPA to investigate the potential of the other data sources, especially the Land Parcel Information System, as a resource for more complete description of patterns of agricultural land use and land management in Ireland.

7.12.1 Planned Improvements for Forest Lands

- Re-evaluation of CSC in mineral soils and emission factors for organic soils (ForCRep project 2013-2016);

- Development of a remote sensing system for tracking deforestation and land use change from forests to other land (ForCRep project 2013-2016);

- Re-evaluation of FGB cohort model using information from the Betterfor project (2013-2015);

- Development of a remote sensing system to identify forest areas subjected to wild fires and improvement to currently used biomass combustion and EFs used in national reporting.

7.12.2 Planned Improvements for Other Categories

Specific issues which are to be addressed include:

- The identification of set-aside or fallow areas within the crop rotation schemes deployed by farmers. These lands are likely reported as under grass by farmers to the CSO, and therefore included in the grassland land use category;

- Previous land use and soil type analysis of areas converted to croplands, currently assumed to be LAC soils and that no other land categories are converted to croplands;

- Additional analysis of the revised CSO methodology is required to determine the best means to achieve continuity between the new methodology and areas published in previous years.

Table 7.12.1 Percentage Change in Emissions and Removals from LULUCF due to Recalculations 1990-2011

a) 2013 Submission (Gg CO_2 eq)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
										Estimates in 2012 Submission (Gg CO_2 eq.)													
5.A	**Forest Land**	**-3,235.6**	**-3,374.8**	**-2,895.0**	**-3,154.8**	**-2,815.3**	**-2,546.8**	**-2,461.4**	**-3,217.8**	**-2,813.1**	**-2,749.8**	**-2,001.3**	**-2,144.5**	**-2,095.9**	**-2,293.8**	**-3,081.2**	**-2,989.8**	**-3,111.4**	**-3,850.0**	**-3,424.3**	**-3,441.7**	**-4,417.8**	**-4,206.6**
5.A.1	Forest Land remaining Forest Land (CO_2)	-3,287.6	-3,368.4	-2,820.7	-3,024.4	-2,593.6	-2,216.2	-1985.0	-2,574.0	-2,000.7	-1,748.0	-787.5	-712.9	-414.7	-353.4	-865.5	-439.6	-329.9	-1,058.0	-395.4	-135.9	-902.8	-431.0
5.A.2	Land converted to Forest Land (CO_2)	17.9	-38.4	-104.6	-165.7	-257.9	-375.2	-520.6	-681.4	-849.1	-1,035.8	-1,257.4	-1,485.1	-1,718.7	-2,003.3	-2,268.1	-2,592.8	-2,823.8	-2,835.3	-3,072.8	-3,347.4	-3,575.9	-3,821.9
5.A	Biomass burning (CH_4 and N_2O)	10.1	6.5	4.2	8.4	9.7	13.2	14.7	8.0	4.2	3.5	8.7	17.3	4.0	24.5	14.3	5.2	5.2	5.8	6.0	3.4	22.2	8.2
5.A	Drainage of soils	24.0	25.5	26.1	26.9	26.5	31.4	29.5	29.6	32.4	30.6	34.9	36.2	33.5	38.3	38.1	37.4	37.1	37.5	37.8	38.2	38.7	38.1
5.B	**Cropland**	**20.0**	**21.2**	**25.6**	**25.6**	**-49.9**	**-21.9**	**43.9**	**78.4**	**24.8**	**0.4**	**46.7**	**136.1**	**130.8**	**178.2**	**136.7**	**162.8**	**109.3**	**133.3**	**445.4**	**256.8**	**291.7**	**377.7**
5.B.1	Cropland remaining Cropland	20.0	21.2	9.7	-58.9	-87.5	-62.9	-25.1	-20.1	-39.1	-63.6	-22.2	-28.2	-34.7	-35.3	-26.3	-0.1	-53.6	-29.6	-20.6	-27.3	7.7	16.9
5.B.2	Land converted to Cropland	NO	NO	15.3	80.8	33.9	36.9	62.7	92.1	57.6	57.6	62.4	153.9	152.6	197.3	146.7	146.7	146.7	146.7	437.6	255.7	255.7	329.3
5.B	Agricultural Lime Application[b]	36.7	32.5	26.3	37.0	27.5	50.3	50.3	44.3	31.4	38.9	37.2	40.5	29.7	43.2	26.4	26.8	25.5	37.2	29.7	33.4	36.5	32.0
5.B.2	Emissions from soil disturbance	NA,NO	NA,NO	0.6	3.7	3.7	4.1	6.4	6.4	6.4	6.4	6.6	10.5	12.9	16.2	16.2	16.2	16.2	16.2	28.3	28.3	28.3	31.4
5.C	**Grassland**	**493.6**	**568.2**	**441.2**	**355.0**	**409.1**	**706.4**	**698.0**	**661.4**	**468.6**	**568.8**	**611.9**	**557.9**	**511.9**	**577.0**	**409.5**	**248.2**	**306.4**	**351.3**	**338.2**	**243.2**	**118.5**	**220.2**
5.C.1	Grassland remaining Grassland	602.4	600.5	484.2	398.0	460.8	719.2	717.9	688.7	519.1	627.2	616.8	591.2	545.2	608.1	512.0	529.7	510.3	524.0	525.2	533.4	670.6	542.9
5.C.2	Land converted to Grassland	-108.8	-32.3	-43.0	-42.9	-51.7	-12.9	-19.9	-27.2	-50.5	-58.4	-4.9	-33.3	-33.2	-31.1	-102.5	-281.4	-204.0	-172.7	-187.0	-290.2	-552.1	-322.8
5.C	Agricultural Lime Application[b]	318.4	282.6	229.3	320.3	242.2	444.3	433.7	379.2	274.2	344.4	329.1	344.8	244.2	343.6	214.4	239.9	229.4	339.5	232.5	273.9	391.4	328.7
5.D	**Wetlands**	**50.7**	**49.0**	**49.1**	**47.4**	**45.4**	**43.8**	**41.5**	**39.9**	**38.5**	**49.3**	**63.4**	**61.5**	**58.8**	**56.1**	**42.5**	**45.7**	**74.4**	**71.4**	**40.8**	**39.4**	**39.7**	**35.8**
5.D.1	Wetlands remaining Wetlands	47.1	45.5	45.5	44.0	41.9	40.3	38.1	36.5	35.2	46.1	43.5	42.0	39.8	37.6	24.5	27.7	30.8	33.1	35.9	38.7	38.6	33.9
5.D.2	Land converted to Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	16.8	16.4	16.1	15.7	15.3	15.3	40.9	35.6	2.3	-1.9	-1.5	-0.8
5.D	Drainage of soils	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6
5.E	**Settlements**	**10.3**	**9.6**	**9.7**	**10.2**	**12.0**	**9.8**	**12.5**	**13.7**	**14.7**	**15.8**	**37.3**	**42.9**	**40.9**	**45.3**	**46.6**	**50.8**	**34.3**	**32.8**	**30.4**	**19.8**	**23.4**	**9.6**
5.E.1	Settlements remaining Settlements	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
5.E.2	Land converted to Settlements	10.3	9.6	9.7	10.2	12.0	9.8	12.5	13.7	14.7	15.8	37.3	42.9	40.9	45.3	46.6	50.8	34.3	32.8	30.4	19.8	23.4	9.6
5.F	**Other Land**	**-1.1**	**0.3**	**-13.2**	**-14.4**	**-17.5**	**-4.5**	**-28.1**	**-35.6**	**-42.0**	**-36.3**	**-11.7**	**-27.4**	**-46.1**	**-44.6**	**-81.6**	**-90.2**	**-117.5**	**-103.7**	**-138.1**	**-120.9**	**-167.9**	**-138.2**
5.F.1	Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.F.2	Land converted to Other Land	-1.1	0.3	-13.2	-14.4	-17.5	-4.5	-28.1	-35.6	-42.0	-36.3	-11.7	-27.4	-46.1	-44.6	-81.6	-90.2	-117.5	-103.7	-138.1	-120.9	-167.9	-138.2
5.G	**G. Other**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
5	**TOTAL LULUCF CO_2 (net emissions/removals)**	**-2,699.8**	**-2,762.0**	**-2,417.0**	**-2,773.4**	**-2,459.6**	**-1,865.3**	**-1,747.5**	**-2,507.3**	**-2,354.7**	**-2,195.5**	**-1,307.0**	**-1,440.6**	**-1,452.9**	**-1,563.6**	**-2,598.9**	**-2,633.9**	**-2,765.7**	**-3,427.0**	**-2,782.5**	**-3,075.9**	**-4,204.1**	**-3,781.9**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**-2,662.1**	**-2,726.5**	**-2,382.6**	**-2,730.9**	**-2,416.2**	**-1,813.2**	**-1,693.7**	**-2,460.1**	**-2,308.4**	**-2,151.8**	**-1,253.7**	**-1,373.6**	**-1,399.6**	**-1,481.7**	**-2,527.5**	**-2,572.4**	**-2,704.5**	**-3,364.8**	**-2,707.7**	**-3,003.4**	**-4,112.3**	**-3,701.6**

a) 2014 Submission (Gg CO_2 eq)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
		Estimates in 2013 Submission (Gg CO_2 eq.)																						
5.A	**Forest Land**	**-2,956.0**	**-3,068.9**	**-2,435.6**	**-3,128.4**	**-2,661.5**	**-2,279.5**	**-2,126.9**	**-3,367.3**	**-2,714.9**	**-2,772.0**	**-2,253.4**	**-2,126.3**	**-2,010.9**	**-2,520.2**	**-3,689.6**	**-3,410.1**	**-3,362.0**	**-3,892.8**	**-5,285.0**	**-5,379.9**	**-4,483.2**	**-4389.8**	**-3815.8**
5.A.1	Forest Land remaining Forest Land (CO_2)	-3,007.7	-3,066.3	-2,369.6	-3,010.3	-2,457.2	-1,973.1	-1,682.3	-2,763.1	-1,949.6	-1,825.2	-1,104.3	-769.5	-409.7	-671.9	-1,568.7	-972.7	-669.4	-1,122.9	-2,152.5	-1,990.2	-878.3	-642.7	-9.0
5.A.2	Land converted to Forest Land (CO_2)	17.6	-34.6	-96.3	-153.4	-240.4	-351.0	-488.7	-641.9	-802.0	-980.8	-1,192.7	-1410.3	-1638.7	-1,911.1	-2,173.3	-2,480.0	-2,734.8	-2,812.6	-3,175.7	-3,430.5	-3,664.9	-3793.5	-3847.3
5.A	Biomass burning (CH_4 and N_2O)	10.1	6.5	4.2	8.4	9.7	13.2	14.7	8.0	4.2	3.5	8.7	17.3	4.0	24.5	14.3	5.2	5.2	5.8	6.0	3.4	22.2	8.2	2.1
5.A	Drainage of soils	24.0	25.5	26.1	26.9	26.5	31.4	29.5	29.6	32.4	30.6	34.9	36.2	33.5	38.3	38.1	37.4	37.1	36.9	37.2	37.5	37.8	38.2	38.4
5.B	**Cropland**	**20.0**	**21.2**	**25.6**	**25.6**	**-49.9**	**-21.9**	**43.9**	**78.4**	**24.8**	**0.4**	**46.7**	**135.6**	**129.5**	**176.6**	**135.6**	**161.8**	**108.3**	**132.3**	**443.1**	**254.5**	**293.6**	**377.6**	**422.4**
5.B.1	Cropland remaining Cropland	20.0	21.2	9.7	-58.9	-87.5	-62.9	-25.1	-20.1	-39.1	-63.6	-22.2	-28.2	-34.7	-35.3	-26.3	-0.1	-53.6	-29.6	-20.6	-27.3	11.8	20.2	9.6
5.B.2	Land converted to Cropland	NO	NO	15.3	80.8	33.9	36.9	62.7	92.1	57.6	57.6	62.4	153.3	151.4	195.8	145.8	145.8	145.8	145.8	435.6	253.7	253.7	326.4	377.8
5.B	Agricultural Lime Application[b]	36.7	32.5	26.3	37.0	27.5	50.3	50.3	44.3	31.4	38.9	37.2	40.5	29.7	43.2	26.4	26.8	25.5	37.2	29.7	33.4	40.6	35.2	23.4
5.B.2	Emissions from soil disturbance	NA,NO	NA,NO	0.6	3.7	3.7	4.1	6.4	6.4	6.4	6.4	6.6	10.5	12.8	16.1	16.1	16.1	16.1	16.1	28.1	28.1	28.1	31.0	35.1
5.C	**Grassland**	**493.9**	**568.5**	**435.4**	**347.3**	**396.9**	**769.4**	**736.0**	**689.5**	**488.2**	**588.4**	**677.3**	**626.4**	**556.2**	**621.7**	**406.8**	**233.6**	**154.6**	**199.0**	**168.3**	**400.4**	**59.7**	**72.9**	**-52.2**
5.C.1	Grassland remaining Grassland	600.3	612.6	476.0	387.8	446.2	711.7	678.4	639.2	461.2	577.8	594.3	543.3	473.0	538.4	394.2	400.9	365.2	399.5	346.0	348.2	450.7	341.3	302.8
5.C.2	Land converted to Grassland	-106.4	-44.1	-40.6	-40.5	-49.3	57.6	57.6	50.3	27.1	10.6	82.9	83.0	83.1	83.2	12.5	-167.3	-210.5	-200.5	-177.7	52.2	-391.0	-268.4	-355.0
5.C	Agricultural Lime Application[b]	318.4	282.6	229.3	320.3	242.2	444.3	433.7	379.2	274.2	344.4	329.1	344.8	244.2	343.6	214.4	239.9	229.4	339.5	232.5	273.9	387.3	325.5	206.0
5.D	**Wetlands**	**50.7**	**49.0**	**49.1**	**47.4**	**45.4**	**43.8**	**41.5**	**39.9**	**38.5**	**49.3**	**457.8**	**455.8**	**453.1**	**450.4**	**436.8**	**440.1**	**32.0**	**292.2**	**36.9**	**42.8**	**39.4**	**235.7**	**34.9**
5.D.1	Wetlands remaining Wetlands	47.1	45.5	45.5	44.0	41.9	40.3	38.1	36.5	35.2	46.1	43.5	42.0	39.8	37.6	24.5	27.7	30.8	33.1	35.9	38.7	38.6	38.5	34.1
5.D.2	Land converted to Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	411.2	410.8	410.4	410.0	409.7	409.7	-1.5	256.4	-1.6	1.5	-1.8	194.6	-1.8
5.D	Drainage of soils	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.5
5.E	**Settlements**	**77.9**	**71.7**	**72.7**	**77.3**	**93.8**	**88.1**	**111.6**	**122.3**	**132.0**	**141.3**	**187.3**	**237.6**	**221.2**	**261.2**	**272.9**	**311.5**	**349.4**	**559.8**	**495.9**	**177.1**	**223.4**	**55.6**	**256.5**
5.E.1	Settlements remaining Settlements	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
5.E.2	Land converted to Settlements	77.9	71.7	72.7	77.3	93.8	88.1	111.6	122.3	132.0	141.3	187.3	237.6	221.2	261.2	272.9	311.5	349.4	559.8	495.9	177.1	223.4	55.6	256.5
5.F	**Other Land**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**26.3**	**27.1**	**27.4**	**27.7**	**27.9**	**46.5**	**47.9**	**48.2**	**48.6**	**48.9**	**49.3**	**1,413.4**	**7.7**	**9.1**	**9.3**	**9.3**	**9.3**	**9.3**
5.F.1	Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
5.F.2	Land converted to Other Land	0.9	0.9	0.9	0.9	0.9	26.3	27.1	27.4	27.7	27.9	46.5	47.9	48.2	48.6	48.9	49.3	1,413.4	7.7	9.1	9.3	9.3	9.3	9.3
5.G	**G. Other**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
5	**TOTAL LULUCF CO_2 (net emissions/removals)**	**-2,350.2**	**-2,393.1**	**-1,886.3**	**-2,672.4**	**-2,217.8**	**-1,426.0**	**-1,220.6**	**-2,457.1**	**-2,050.0**	**-2,008.3**	**-891.1**	**-690.1**	**-656.0**	**-1,043.6**	**-2,459.8**	**-2,275.3**	**-1,365.4**	**-2,763.2**	**-4,205.7**	**-4,567.3**	**-3,948.4**	**-3718.6**	**-3223.0**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**-2,312.6**	**-2,357.6**	**-1,852.0**	**-2,629.9**	**-2,174.4**	**-1,373.9**	**-1,166.7**	**-2,409.9**	**-2,003.7**	**-1,964.7**	**-837.9**	**-623.1**	**-602.7**	**-961.8**	**-2,388.5**	**-2,213.8**	**-1,304.3**	**-2,701.6**	**-4,131.7**	**-4,495.8**	**-3,857.8**	**-3638.6**	**-3144.9**

c) Percentage Change

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
											Percentage Change in Total Emissions due to Recalculations												
5.A	**Forest Land**	**-8.6**	**-9.1**	**-15.9**	**-0.8**	**-5.5**	**-10.5**	**-13.6**	**4.6**	**-3.5**	**0.8**	**12.6**	**-0.8**	**-4.1**	**9.9**	**19.7**	**14.1**	**8.1**	**1.1**	**54.3**	**56.3**	**1.5**	**4.4**
5.A.1	Forest Land remaining Forest Land (CO_2)	-8.5	-9.0	-16.0	-0.5	-5.3	-110	-15.2	7.3	-2.6	4.4	40.2	7.9	-12	90.2	812	1213	102.9	6.1	444.3	1,365.0	-2.7	49.1
5.A.2	Land converted to Forest Land (CO_2)	-14	-9.8	-7.9	-7.4	-6.8	-6.5	-6.1	-5.8	-5.5	-5.3	-5.1	-5.0	-4.7	-4.6	-4.2	-4.4	-3.1	-0.8	3.4	2.5	2.5	-0.7
5.A	Biomass burning (CH_4 and N_2O)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.A	Drainage of soils	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-14	-16	-18	-2.4	0.1
5.B	**Cropland**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-0.4**	**-1.0**	**-0.9**	**-0.8**	**-0.6**	**-0.9**	**-0.8**	**-0.5**	**-0.9**	**0.6**	**0.0**
5.B.1	Cropland remaining Cropland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.5	19.2
5.B.2	Land converted to Cropland	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.8	-0.8	-0.6	-0.6	-0.6	-0.6	-0.5	-0.8	-0.8	-0.9
5.B	Agricultural Lime Application[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	10.2
5.B.2	Emissions from soil disturbance	NA	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.5	-0.6	-0.6	-0.6	-0.6	-0.6	-0.8	-0.8	-0.8	-11
5.C	**Grassland**	**0.1**	**0.1**	**-1.3**	**-2.2**	**-3.0**	**8.9**	**5.4**	**4.3**	**4.2**	**3.4**	**10.7**	**12.3**	**8.6**	**7.7**	**-0.7**	**-5.9**	**-49.5**	**-43.3**	**-50.2**	**64.6**	**-49.6**	**-66.9**
5.C.1	Grassland remaining Grassland	-0.3	2.0	-17	-2.5	-3.2	-10	-5.5	-7.2	-11.2	-7.9	-3.7	-8.1	-13.2	-11.5	-23.0	-24.3	-28.4	-23.7	-34.1	-34.7	-32.8	-37.1
5.C.2	Land converted to Grassland	-2.2	36.2	-5.5	-5.6	-4.6	-548.3	-389.8	-284.5	-153.6	-118.2	-1,778.7	-349.2	-350.2	-367.9	-112.2	-40.5	3.2	16.1	-5.0	-118.0	-29.2	-16.9
5.C	Agricultural Lime Application[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-10	-10
5.D	**Wetlands**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**621.7**	**641.7**	**671.1**	**703.2**	**928.3**	**862.7**	**-57.0**	**309.0**	**-9.7**	**8.6**	**-0.8**	**559.2**
5.D.1	Wetlands remaining Wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5
5.D.2	Land converted to Wetlands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5.D	Drainage of soils	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.E	**Settlements**	**657.0**	**647.4**	**649.4**	**657.1**	**678.4**	**796.4**	**795.9**	**795.8**	**795.7**	**795.6**	**402.1**	**454.5**	**440.3**	**476.2**	**486.1**	**513.1**	**919.3**	**1,607.2**	**1,532.7**	**794.1**	**853.4**	**481.7**
5.E.1	Settlements remaining Settlements	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5.E.2	Land converted to Settlements	657.0	647.4	649.4	657.1	678.4	796.4	795.9	795.8	795.7	795.6	402.1	454.5	440.3	476.2	486.1	513.1	919.3	1,607.2	1,532.7	794.1	853.4	481.7
5.F	**Other Land**	**-183.8**	**NA**	**-106.9**	**-106.3**	**-105.1**	**NA**	**-196.4**	**-176.9**	**-165.8**	**NA**	**NA**	**-274.7**	**-204.6**	**NA**	**-160.0**	**-154.7**	**-1,303.1**	**NA**	**NA**	**NA**	**NA**	**NA**
5.F.1	Other Land remaining Other Land	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5.F.2	Land converted to Other Land	-183.8	NA	-106.9	-106.3	-105.1	NA	-196.4	-176.9	-165.8	NA	NA	-274.7	-204.6	NA	-160.0	-154.7	-1,303.1	NA	NA	NA	NA	NA
5.G	**G. Other**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
5	**TOTAL LULUCF CO_2 (net emissions/removals)**	**-12.9**	**-13.4**	**-22.0**	**-3.6**	**-9.8**	**-23.6**	**-30.2**	**-2.0**	**-12.9**	**-8.5**	**-31.8**	**-52.1**	**-54.9**	**-33.3**	**-5.4**	**-13.6**	**-50.6**	**-19.4**	**51.1**	**48.5**	**-6.1**	**-1.7**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**-13.1**	**-13.5**	**-22.3**	**-3.7**	**-10.0**	**-24.2**	**-31.1**	**-2.0**	**-13.2**	**-8.7**	**-33.2**	**-54.6**	**-56.9**	**-35.1**	**-5.5**	**-13.9**	**-51.8**	**-19.7**	**52.6**	**49.7**	**-6.2**	**-1.7**

Chapter Eight

Waste

8.1 Overview of Waste Sector

Solid waste disposal in landfill sites, *wastewater treatment* and *waste incineration* are the main activities that give rise to greenhouse gas emissions in the *Waste* sector (Table 8.1). The largest of these sources is usually solid waste disposal on land where CH_4 is the gas concerned. Landfills represent a key emission category in Ireland and the emission estimates of CH_4 are considered to be reasonably well quantified in the national inventory. The treatment of wastewaters in anaerobic systems may be an important source of CH_4 for some Parties, however in Ireland, all wastewater treatment is aerobic and consequently it is not a source of CH_4 emissions. The anaerobic treatment of sludge is a source of CH_4 emissions and is included in the inventory. N_2O emissions arising from the production of human sewage are also included. Emissions of CO_2, CH_4 and N_2O from the incineration of clinical wastes for all years from 1990-1997, when all hospital waste incinerators were closed and incineration of solvents or liquid/vapour destruction in thermal oxidisers at chemical or pharmaceutical plants for all years from 1990-2012 are estimated. The annual GHG inventory is fully consistent with air pollutant reporting under the Convention on Long Range Transboundary Air Pollution and implements a recommendation from of previous annual inventory review reports.

The 2014 submission shows total GHG emissions of 1,011.52 Gg CO_2 equivalent in the *Waste* sector in 2012, of which *6.A Solid waste disposal on land* accounts for 79.9 per cent, *6.B Waste water handling* 16.2 per cent and *6.C Waste incineration* 3.9 per cent. The latest estimates show that emissions in the *Waste* sector have decreased by 27.2 per cent from 1990 to 2012 mainly due to a 31.5 per cent decrease in CH_4 emissions from *6.A solid waste disposal on land*.

Ireland has only used waste incineration as a waste management since 2011. Ireland's first waste to energy municipal waste incinerator commenced operation in 2011 and emissions from this new plant have been reported under *public electricity and heat production (1.A.1.a)* in section 3.2.1.1 in chapter 3 in accordance with the IPCC guidelines.

Table 8.1. Level 3 Source Category and Gas Coverage for Waste

Waste	**CO_2**	**CH_4**	**N_2O**
A. Solid Waste Disposal on Land			
1. Managed Waste Disposal on Land	NA	All	NA
2. Unmanaged Waste Disposal Sites	NA	All	NA
3. Other	NO	NO	NO
B. Wastewater Handling			
1. Industrial Wastewater	NA	All	NO
2. Domestic and Commercial Wastewater	NA	All	All
3. Other	NO	NO	NO
C. Waste Incineration	All	All	All
D. Other	NO	NO	NO

All : all emission sources covered; NE : emissions not estimated; NO : activity not occurring; NA : not applicable (no emissions of the gas occur in the source category); IE : emissions included elsewhere

8.2 Solid Waste Disposal (6.A)

8.2.1 Methodological Issues

The development of a national waste management strategy for Ireland (DELG, 1998) recognised the need for comprehensive analysis of the CH_4 production potential of landfills, particularly in view of the need to reduce the amount of municipal solid waste being placed in landfills. A modified form of the IPCC Tier 2 First Order Decay (FOD) method was therefore adopted as the most appropriate basis on which to assess annual CH_4 emissions. This allowed reasonable predictions of emission estimates to be made and was used up to the 2009 submission. Since then, the more detailed methodology provided in the 2006 IPCC Guidelines has been adopted and is described in detail in Section 8.2.2.

8.2.2 Methodology for CH_4 Generation from Solid Waste Disposal

While the method previously (pre-2010 submission) used to estimate and report Ireland's CH_4 emissions from landfills stood up to scrutiny in the UNFCCC review process, the inventory team was aware that the simple approach used to estimate CH_4 generation could be improved. The previous method did not adequately reflect the major changes in landfill operation and management after 1998 (introduction of licences for landfill operation) and it did not allow for the use of all information available for landfills. The inventory team determined that more detailed analysis was needed to address the inadequate representation of the cumulative time-dependent production of CH_4 which was determined on the basis of total waste disposal – effectively as a single hypothetical landfill. Therefore, the inventory team, in its capacity as the national entity responsible for compiling GHG inventories, adopted the methodology for estimating CH_4 production given in the 2006 IPCC Guidelines for use in the 2010 and subsequent submissions.

The 2006 IPCC guidelines provide an improved methodology and an associated model for estimating CH_4 emissions from landfills. The model is a simple first-order decay spread sheet model that keeps a running total of the amount of degradable organic carbon (DOC) available in a landfill as the basis for calculating the amount of DOC converted to CH_4 and CO_2 annually. The model is applied on a multi-phase basis where data on waste composition from national waste statistics are used directly to quantify the amount of the various constituents that produce DOC. The model contains ranges of default values for DOC content and methane generation rate constant of the waste constituents from which values appropriate to national circumstances may be selected. A methane correction factor (MCF) is used to account for the effect of landfill type and level of management on CH_4 generation. In the 2006 IPCC guidelines, the MCF varies from 0.4 for shallow unmanaged landfills to 1.0 for fully anaerobic deep and managed landfills. Analyses undertaken, as part of the improved methodology introduced in the 2010 submission, for both individual sites and groups of landfills shows annual MCF values increasing over time to reflect the change from generally shallow, poorly-managed landfills before 1998 (and therefore pre-landfill licensing) to well controlled and engineered landfills in subsequent years.

The model from the 2006 IPCC guidelines was applied for the six largest landfills individually and to all other landfills by assigning them to seven separate groups according to annual waste amount and life cycle. Two additional model runs were used to account for sewage sludge and street cleanings (Table I.1 of Annex I). The application of the model to individual landfills and to groups of landfills with similar characteristics accounts for the known life cycle of landfills. This revised approach captures the time dependency of methane generation in a more representative manner than the previous approach which was based on all waste taken together in one hypothetical landfill. The revised approach adequately accounts for the closure of approximately 250 largely uncontrolled landfills of various sizes around 1998 as waste licensing came into effect under Directive 1999/31/EC (CEU, 1999). Five of the seven largest landfills and all landfills in four of the landfill groups selected for analysis are closed sites (Annex I.1). The seven largest landfills account for approximately 28.4 per cent of the municipal waste disposal in Ireland over the period 1990-2012. This means that the remaining 71.6 per cent of municipal waste disposal, which is accounted for in landfills assigned to one of seven separate groups, has a significant bearing on the estimates of CH_4 generation, particularly for the early years of the 1990-2012 time-series. Table I.1 of Annex I provides a compilation of the input data for the IPCC model runs.

Waste Quantity and Composition

The EPA commenced the development of the National Waste Database (NWD) in the early 1990s to address a severe lack of information on waste production and waste management practices in Ireland. The database was needed to support radical reform of national policy and legislation on waste pursuant to the Waste Management Act of 1996 and subsequent Government strategies on sustainable development (DELG, 1997) and waste management (DELG, 1998). National statistics generated from this database published on a three-year cycle, and interim reports published on a yearly basis since 2001 by the EPA (Carey et al, 1996; Crowe et al, 2000; Meaney et al, 2003; Collins et al, 2004a; Collins et al, 2004b; Collins et al, 2005; Le Bolloch et al, 2006; Le Bolloch et al, 2007; Le Bolloch et al, 2009; McCoole et al, 2009; McCoole et al, 2011; McCoole et al, 2012; McCoole et al, 2013) are the primary basis for establishing the historical time-series of municipal solid waste (MSW) placed in landfills from 1995 onwards. Identification and risk assessment of historical landfills under S.I. No. 524 of 2008 (DEHLG, 2008) serves as the main source of information on landfilling of waste prior to 1995. The results of other surveys undertaken in previous years (Boyle, 1987, ERL, 1993, MCOS, 1994 and DOE, 1994) have also been used to some extent in compiling the MSW time-series.

The NWD reports, published since 1995, provide a good starting point for assigning waste quantities to individual landfills and provide a representation of waste composition. However, assumptions on waste quantities and composition are still required to establish the basic historical information, given the extended time-frame that must be taken into account for a number of the models. The waste quantities for each of the 14 IPCC spread sheet model analyses are determined by adding up the amounts of household and commercial waste for the relevant landfills for each year where this is given by the NWD. The quantities of waste for other years, which are not available from the NWD, are estimated by using a variety of documents and published reports.

Waste paper products are the key determinant of degradable carbon in landfills. The NWD shows a significant decline in the proportion of waste paper products in waste going to landfills from 30.1 per cent in 1995 to 21.6 per cent in 2012, which reflects the increase in recycling of paper. The NWD is used to give the values for all years in the period 1995 to 2012. In the analysis for historical years, the paper content was fixed at 40 per cent for 1980 and previous years and decreases linearly from 40 per cent in 1980 to 30.1 per cent in 1995. The proportion of organics, the other principal constituent of waste, was estimated in the same way for each year.

In response to a recommendation from a previous review, organic waste is now separated into food and garden waste. Additional information on the composition of solid waste disposed at landfills is provided in Annex I, tables I.1 and I.2.

Degradable Organic Carbon (DOC)

The waste constituents of MSW that contribute to DOC, food waste, waste paper, wood, textiles and disposable nappies, are identified in the available NWD breakdown for 1995, 1998, 2001 through 2012. The IPCC default proportions of DOC content are used for all these constituents (Annex I). Street cleansing composition data is available from the NWD, and the DOC content is therefore calculated from its constituent components. In addition, a DOC content of 5 per cent has been assumed for sewage sludge.

Decay Rate Constant k

The 2006 IPCC Guidelines provide narrow ranges for the value of decay rate constant appropriate to the individual waste components under different climatic zones. Ireland has chosen the highest values given for the Western Europe wet temperate conditions for all waste constituents, as the value of the ratio MAP:PET (Mean Annual Precipitation: Potential Evapotranspiration) is greater than 2 in Ireland.

Degradable Carbon Fraction DOC_f

A value of 0.6 is considered appropriate for the fraction of organic carbon that ultimately decomposes in solid waste landfills in general in Ireland, given that decomposition is not significantly inhibited by lignin, (which is one of the most slowly decomposing components of vegetation such as wood). A higher value of 0.75 has been applied in the models for two major landfills that are less than 10 years old (Annex I) where site conditions and management are conducive to the enhanced degradation of organic carbon.

Methane Correction Factor MCF

The choice of MCF in each of the model runs is made by assigning the individual landfill or group of landfills to the IPCC management category considered to reflect the applicable level of management for each year of their lifetime. The licensing of landfill sites came into effect around 1998, which ultimately resulted in the closure of approximately 250 sites. All landfills that continued in operation under licence after 1998, together with all new sites, are assumed to come within the IPCC description of a managed site and the MCF of 1.0 applies. The larger landfills that were in existence prior to the introduction of waste licensing were subject to some level of management but not to the extent of fully managed licensed sites after 1998. These large sites are assigned to the IPCC category of unmanaged deep sites for the years up to 1998 with a MCF of 0.8 and to the managed category with a MCF of 1.0 for the remainder of their lifetime. The 250 sites that operated primarily as small open town dumps and shallow uncontrolled disposal sites with significant aerobic conditions up to the introduction of waste licensing are assigned to the IPCC category of unmanaged shallow sites up to 1998, for which the appropriate MCF is 0.4. A transition from unmanaged shallow classification in 1960 to one-third unmanaged shallow and two-thirds unmanaged deep sites in 1998 is applied to the remainder of sites, giving an increasing MCF from 0.4 to 0.67 over this period.

8.2.3 Methane Recovery at Solid Waste Disposal Sites

A detailed study was conducted on behalf of the inventory agency by Fehily Timoney Consultants of methane flaring and utilisation for the years 1996-2008 (Ireland's NIR 2010). Following this study, the inventory agency undertook a similar survey of landfill sites in 2010 to collect data for the years 2008 and 2009. The study was aimed at validating the values for 2008 as the data for that year was incomplete and collecting information on flaring and utilisation for 2009. The survey was sent to 49 sites (both open and closed sites) on which flaring and or utilisation of landfill gas is known to occur. Survey data were obtained in respect of all sites indicating a 100 per cent response rate. Clarifications on submitted data were sought directly from landfill operators. A similar, inventory agency designed survey was conducted in subsequent years to obtain data for 2010-2012 from all 49 sites.

Information on the number of flares in use, together with data relating to flare capacity, run time and performance was used to estimate the volume of landfill gas flared at each site. The tonnage of CH_4 flared was calculated from landfill gas volume by accounting for gas temperature (assumed to be ambient air temperature) and suction pressure (provided in survey returns) and by using methane destruction efficiencies of 50 per cent for open flares and 98 per cent for closed flares.

The study and the surveys found that there were 13 methane utilisation plants at landfills in Ireland in 2012 with a total of 30 engines. This has increased from 6 plants and 20 engines in 2008, 8 plants and 24 engines in 2009, 10 plants and 27 engines in 2010 and 12 plants and 27 engines in 2011. The amount of methane input to landfill gas utilisation plants is calculated from their known electricity outputs as obtained by SEAI from EIRGRID (Electricity Transmission System Operator) and validated against survey returns using an overall efficiency of 34.6 per cent for the engines, which is considered typical of the engine types in general use. The overall results of CH_4 production, utilisation and flaring are presented in Table 8.2.

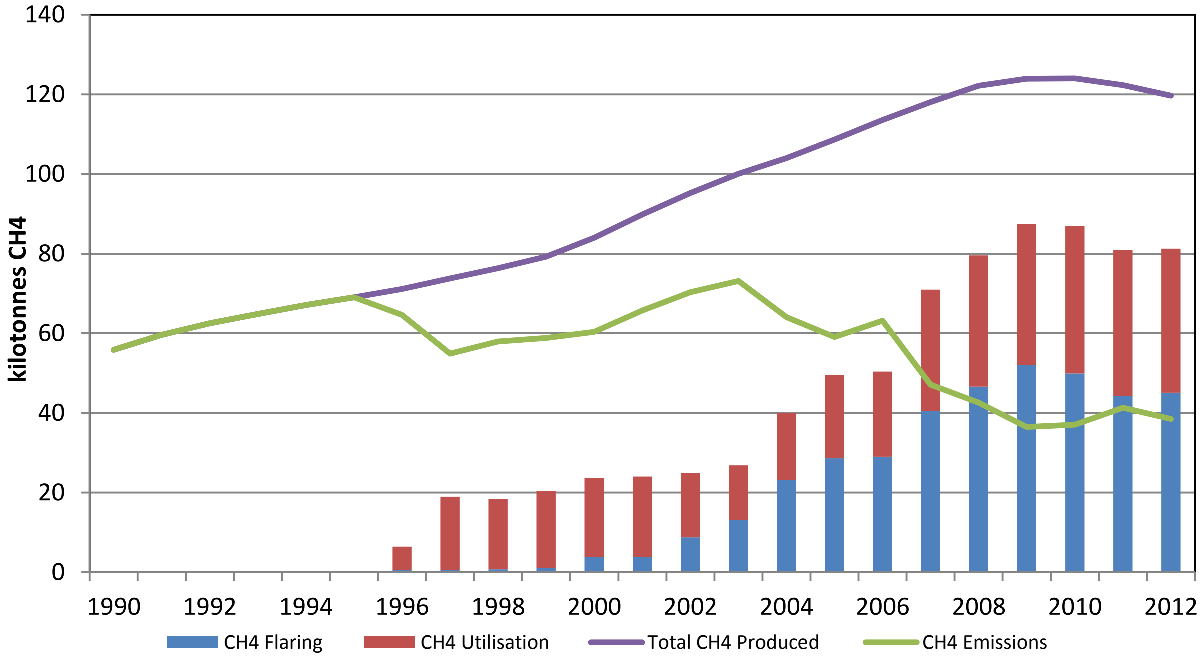

Figure 8.1. Methane Emissions from Solid Waste Disposal 1990-2012

Table 8.2. Methane Emissions from Solid Waste Disposal 1990-2012

	Methane Generation (Tonnes)	Methane Flaring (Tonnes)	Methane Utilisation (Tonnes)	Methane Recovery (Tonnes)	Per cent Methane Recovery	Methane Emissions (Tonnes)	Methane Emissions (Gg CO_2eq)
1990	55,859.50	-	-	-	-	55,859.50	1,173.05
1991	59,606.84	-	-	-	-	59,606.84	1,251.74
1992	62,498.51	-	-	-	-	62,498.51	1,312.47
1993	64,861.66	-	-	-	-	64,861.66	1,362.09
1994	67,141.19	-	-	-	-	67,141.19	1,409.97
1995	69,031.40	-	-	-	-	69,031.40	1,449.66
1996	71,113.99	598.85	5,877.35	6,476.19	9.11	64,637.80	1,357.39
1997	73,812.58	591.84	18,354.17	18,946.01	25.67	54,866.57	1,152.20
1998	76,362.13	770.11	17,632.04	18,402.15	24.10	57,959.98	1,217.16
1999	79,213.63	1,096.60	19,317.01	20,413.61	25.77	58,800.02	1,234.80
2000	83,999.70	3,855.11	19,818.49	23,673.60	28.18	60,326.11	1,266.85
2001	89,811.72	3,900.65	20,159.50	24,060.15	26.79	65,751.57	1,380.78
2002	95,239.63	8,773.44	16,107.54	24,880.98	26.12	70,358.65	1,477.53
2003	100,027.33	13,083.99	13,780.67	26,864.66	26.86	73,162.67	1,536.42
2004	103,982.83	23,180.45	16,749.43	39,929.88	38.40	64,052.94	1,345.11
2005	108,655.09	28,638.38	20,947.12	49,585.50	45.64	59,069.59	1,240.46
2006	113,567.46	29,033.88	21,346.10	50,379.98	44.36	63,187.48	1,326.94
2007	118,049.62	40,395.90	30,558.07	70,953.98	60.11	47,095.65	989.01
2008	122,136.81	46,639.68	32,908.74	79,548.42	65.13	42,588.39	894.36
2009	123,933.17	52,050.80	35,403.54	87,454.33	70.57	36,478.84	766.06
2010	124,029.11	49,886.65	37,090.88	86,977.53	70.13	37,051.57	778.08
2011	122,274.30	44,205.15	36,744.73	80,949.88	66.20	41,324.42	867.81
2012	119,694.11	45,121.03	36,102.70	81,223.72	67.86	38,470.39	807.88

Table 8.2 and Figure 8.1 present the results for methane emissions from *6.A Solid Waste Disposal*. These estimates of CH_4 generation obtained using the model in the IPCC 2006 Guidelines are considered more robust than estimates developed previous to the 2010 submission. The estimates show a steady increase in CH_4 production over the period 1990-2009, reflecting Ireland’s strong dependence on solid waste disposal to landfills. The utilisation of CH_4 remained generally constant up to 2006 since becoming established in 1996. The quantity of CH_4 utilised has subsequently almost doubled with the installation of engines at a number of the newer larger landfills and expansion at other sites. The quantity of CH_4 flared increased sharply from 2003 onwards. This reflects the proliferation of the use of enclosed flares as a means of odour control at landfills throughout the country, all of which operate under EPA licence and stringent environmental controls. Methane recovery through flaring and utilisation reached 70.6 per cent in 2009 after which there was a decrease to 66.2 per cent in 2011 and an increase to 67.9 per cent in 2012. Due to the rapidly increasing level of CH_4 flared after 2003, the emissions show a steady decline from the 2003 level of 1,536.42 Gg CO_2 eq to 766.06 Gg CO_2 eq in 2009. Emissions then increased to 867.81 in 2011, mainly due to a decrease in methane flaring and decreased again to reach 807.88 in 2012. Solid waste disposal emissions in 2012 accounted for 80.0 per cent of the total Waste sector emissions and were 31.1 per cent lower than in 1990.

8.3 Emissions from Wastewater Handling (6.B)

8.3.1. CH_4 Emissions from Wastewater and Sludge (6.B.1, 6.B.2)

The only source of emissions from wastewater handling in Ireland is the anaerobic treatment of sludge. Approximately two-thirds of the population in Ireland is served by urban wastewater treatment plants, which are based on aerobic systems with no emissions of CH_4.

The other one-third of the population uses septic tanks to treat wastewater mainly for individual houses in non-urban areas (Smith et al., 2004). CH_4 emissions from septic tanks are deemed not to occur in Ireland. Consequently the notation key “NO” is reported for CH_4 in *Domestic and Commercial Wastewater (6.B.2.a)*.

On-site domestic septic tanks consist of an underground tank (over 1 metre deep) and a percolation area for the treatment of the effluent. In Ireland, it is assumed that domestic chemicals, such as pesticides, paints, thinners, disinfectants, chemicals, water softeners and the use of cold water detergents are discharged in high enough volumes to hinder methanogenesis in on-site domestic septic tanks. In addition, prevailing soil temperatures at the depths where methanogenesis is assumed to occur (i.e. the bottom of the septic tank) rarely exceed 15°C in Ireland. Where the temperature is likely to exceed 15^{o}C, it is generally only for short periods of time and only in certain areas of the country. Thus, the combination of the use of modern domestic chemicals and low prevailing temperatures in septic tanks means that CH_4 emissions from septic tanks are deemed not to occur in Ireland.

Sludge is produced in all of the primary, secondary and tertiary stages of wastewater treatment. The anaerobic stabilisation of sludge makes it safe for disposal and is a source of CH_4 in Ireland. The amount of wastewater sludge produced in Ireland is available from biennial reports on urban wastewater treatment. It is reported that approximately three per cent of this sludge is treated anaerobically (O’ Leary et al. 1997, 2000; O’Leary and Carty, 1998; Smith et al. 2003; 2004, 2007; Monaghan et al. 2009). The average BOD of industrial wastewater sludge is 60 kg/t (40 per cent of the typical BOD content of treated industrial wastewater) and DOC is estimated as the product of average BOD content and tonnes of dry solids of sludge. The emission factor for CH_4 is derived from the Revised 1996 IPCC Guidelines (equation 11 on page 6.21) using the IPCC default value of 0.6 for B_o, 0.03 for the fraction of sludge treated and 1.0 for MCF.

The sludge arising from the secondary treatment of over half (58 per cent in 2012) of the population equivalent served by urban wastewater treatment plants is anaerobically digested. The CH_4 produced at these plants is used for electricity and heat generation for use on site since 2003. The quantities of CH_4 recovered are reported for the first time in the CRF tables 6.B for all years from 2003 to 2012 as recommended in the recent inventory review.

The remainder of domestic/commercial wastewater sludge, the DOC is calculated using 60g BOD/capita/day population equivalent[10] and SBF (the fraction of BOD that readily settles) of 0.395, which is a combination of 0.35 for conventional primary sedimentation and 0.045 for secondary sedimentation tanks. The emission factor for CH_4 is derived as for industrial sludge.

The sludge from wastewater treatment is disposed of in landfills, used as organic fertiliser on agricultural lands or in composting. The quantity of sludge that is disposed of in landfills contributes to CH_4 emissions from SWDS and is accounted for in emission estimates for CRF category *6.A.1 Solid Waste Disposal on Land*. The proportion of sludge disposed of in SWDS was 42 per cent of sludge produced (tonnes of dry solids) in 1990 and 54 per cent in 2000. Since then, the value has fallen substantially, to 5 per cent in 2006 and has remained at this proportion since then. The sludge applied to agricultural land contributes to N_2O emissions from soils and is included in emission estimates for CRF category *4.D.1 Direct soil emissions* as discussed in section 6.5.1 of this report. The proportion of sludge applied to agricultural lands has significantly increased in recent years from 12 per cent of both industrial and domestic sludge in 1990 to 83 and 70 per cent for industrial and domestic sludge respectively for all years since 2006.

[10] Population Equivalent is the BOD associated with the wastewater produced by one person and is established as 60g per day by Directive 91/271/EEC

8.3.2 N_2O Emissions from Human Sewage (6.B.2.b)

Human consumption of food results in the production of sewage, which is processed in septic tanks or in wastewater treatment facilities. This treated waste is disposed of directly onto land, into the soil through percolation areas or discharged to a water body. Nitrous oxide can be produced during these processes through nitrification and denitrification. This source of emissions was first included in inventory estimates as part of the recalculation exercise undertaken for the 2002 submission. Since then the methodology has improved with N_2O emission estimates derived using the IPCC methodology and the accompanying default values.

N_2O emissions are estimated by taking the IPCC default value of 0.16 for the nitrogen content in protein and applying the default emission factor of 0.01 (kg N_2O-N/ kg sewage produced) to obtain the quantity of nitrogen in sewage ultimately entering the atmosphere as N_2O. Emission estimates are provided in Table 8.3.

Table 8.3. Estimates of N_2O emissions from human sewage 1990-2012

Year	Protein (g/day)	Days	Pop (million)	N fraction (IPCC default)	EF (IPCC default)	N_2O * (Gg)
	A	B	C	D	E	
1990	112.0	365	3.506	0.16	0.01	0.360
1991	115.3	365	3.526	0.16	0.01	0.373
1992	112.9	366	3.555	0.16	0.01	0.369
1993	109.8	365	3.574	0.16	0.01	0.360
1994	106.5	365	3.586	0.16	0.01	0.350
1995	106.9	365	3.601	0.16	0.01	0.353
1996	109.7	366	3.626	0.16	0.01	0.366
1997	111.6	365	3.664	0.16	0.01	0.375
1998	114.7	365	3.703	0.16	0.01	0.390
1999	118.1	365	3.742	0.16	0.01	0.406
2000	115.6	366	3.790	0.16	0.01	0.403
2001	119.7	365	3.847	0.16	0.01	0.423
2002	115.9	365	3.917	0.16	0.01	0.417
2003	116.4	365	3.980	0.16	0.01	0.425
2004	115.2	366	4.045	0.16	0.01	0.429
2005	112.5	365	4.134	0.16	0.01	0.427
2006	112.6	365	4.233	0.16	0.01	0.437
2007	109.8	365	4.339	0.16	0.01	0.437
2008	110.6	366	4.422	0.16	0.01	0.450
2009	110.8	365	4.459	0.16	0.01	0.453
2010	110.8	365	4.471	0.16	0.01	0.455
2011	110.8	365	4.575	0.16	0.01	0.465
2012	110.8	365	4.585	0.16	0.01	0.466

*emissions calculated as A * B * C * D * E * 44 / 28000

8.4 Emissions from Waste Incineration (6.C)

Emissions of CO_2, CH_4 and N_2O from waste incineration are estimated for all years from 1990-2012. The annual GHG inventory is fully consistent with air pollutant reporting under the Convention on Long Range Transboundary Air Pollution and implements recommendations from previous annual inventory review reports.

8.4.1 Emissions from Clinical Waste Incineration (6.C.a), (6.C.b)

The incineration of Clinical Waste is no longer carried out in Ireland. The bulk of hazardous clinical waste in Ireland is now treated using non-incineration technologies (namely sterilisation and shredding), with the remaining waste disposed of through landfilling, exported for incineration or used as a fuel in cement kilns. In the early 1990s, the majority of hospitals operated on-site incinerator units where hazardous clinical waste was incinerated. A number of hospitals operated the practice of incinerating both hazardous and non-hazardous waste. Due to the implementation of stricter standards on incineration and the requirement for facilities to be licensed by the EPA, all incinerators were closed by the mid- to late-1990s. Prior to the closure of these facilities, a number of applications were made to the EPA in respect of IPPC licences. National reports and Government records also contain some information on the quantity of health-care waste incinerated during the period of operation of the incinerators. From these sources, it was determined that an estimated 4,000 tonnes of health-care waste was incinerated per annum. This value was used across the time series for the period 1990−1997, after which negligible quantities of health-care waste were incinerated up until the closure of the two remaining incinerators in 2000.

Emissions from Clinical Waste incineration (biogenic and non-biogenic) are estimated using the tier 1 method and equation 5.1 from the 2006 IPCC Guidelines. This equation is the same as equation 5.11 of the IPCC Good Practice Guidance.

$$CO_2 \text{ emissions} = \sum i \, (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$$

Where:

CO_2 emissions = CO_2 emissions in inventory year (Gg/yr)

SW_i = total amount of solid waste of type *I* (wet weight) incinerated, Gg/yr

dm_i = dry matter content in the waste (wet weight) incinerated, (fraction)

CF_i = fraction of carbon in the dry matter (total carbon content), (fraction)

FCF_i = fraction of fossil carbon in the total carbon, (fraction)

OF_i = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2

i = type of waste incinerated (CW: Clinical Waste)

Values for the above parameters were taken from Table 5.2 of the 2006 IPCC Guidelines, page 5.18. Methane (CH_4) and nitrous oxide (N_2O) emission factors were taken from Tables 5.3 and 5.4 of the 2006 IPCC Guidelines and are presented in Table 8.4. Additional information on emissions, EFs and parameters used is available in Table I.3 of Annex I.

Table 8.4. CH_4 and N_2O EFs for Clinical Waste Incineration

IPCC category	Waste	CH_4 kg/Gg waste	N_2O g/t waste	Reference
6.C.a	Clinical Waste	60.00	20.00	2006 IPCC Guidelines Table 5.3, pg 5.20 2006 IPCC Guidelines Table 5.4, pg 5.22 (Netherlands)

8.4.2 Emissions from Solvent (Liquid/Vapour destruction) Waste Incineration (6.C.b)

There is currently only a small number of facilities based in the pharmaceutical and chemical sectors that operate incinerators or thermal oxidisers for the treatment of hazardous waste, mainly for solvent or liquid/vapour destruction. The facilities that operate these units report emissions to the atmosphere to the EPA as part of IPPC licensing requirements. Estimates of the quantity of hazardous waste incinerated at the relevant facilities are determined from returns to the National Waste Database (Carey et al, 1996; Crowe et al, 2000; Meaney et al, 2003; Collins et al, 2004a; Collins et al, 2004b; Collins et al, 2005; Le Bolloch et al, 2006; Le Bolloch et al, 2007; Le Bolloch et al, 2008; McCoole et al, 2009; McCoole et al, 2010; McCoole et al, 2011; McCoole et al, 2012 ;McCoole et al, 2013 and McCoole et al, in prep).

Emissions from Solvent incineration are estimated using the tier 1 method and equation 5.1 from the 2006 IPCC Guidelines as described above. Methane (CH_4) and nitrous oxide (N_2O) emission factors were taken from Tables 5.3 and 5.6 of the 2006 IPCC Guidelines and are presented in Table 8.5. Additional information on emissions, EFs and parameters used is available in Table I.4 of Annex I.

Table 8.5. CH_4 and N_2O EFs for Solvent (Liquid/Vapour) Waste Incineration

IPCC category	Waste	CH_4 g/t waste	N_2O g/t waste	Reference
6.C.b	Solvent (Liquid/vapour) Waste	0.56	100.00	2006 IPCC Guidelines Table 5.3, pg. 5.20 2006 IPCC Guidelines Table 5.6, pg. 5.22

8.5 Uncertainties and Time-Series Consistency

The methodologies used in the derivation of emissions estimates from the waste sector are consistent over the time-series. In the case of category *6.A*, this consistency applies to all three components that determine the ultimate emissions, i.e. CH_4 generation, CH_4 flared and CH_4 utilised. Adoption of the model in the 2006 IPCC Guidelines is justified by the information available for its detailed application. In addition, this approach brings Ireland into line with other Parties using this methodology in advance of the expected mandatory use of these guidelines for inventory reporting post-2012.

Despite continuous improvements in national data, the overall uncertainty associated with estimating CH_4 emissions from source category *6.A* is high at 32.0 per cent. This uncertainty is primarily due to the length of the historical period that must be taken into account. Uncertainty estimates for the source category are calculated using equations 6.3 and 6.4 of the IPCC Good Practice Guidance. Uncertainties of 20 per cent are assumed in relation to the quantity of MSW, its composition and DOC contents, giving a combined uncertainty of 34.6 per cent for activity data using equation 6.4. The emission factor uncertainty is also 34.6 per cent, when 20 per cent is taken as the uncertainty for the fraction of DOC dissimilated, MCF and decay rate constant. This gives an uncertainty of 48.9 per cent for CH_4 generation again using equation 6.4, which is combined with uncertainties of 30 per cent and 10 per cent for CH_4 flaring and utilisation, respectively using equation 6.3 to give an uncertainty of 32.0 per cent for emissions. The Tier 1 uncertainty analysis is presented in Table 1.9 of this report.

Uncertainties in estimates of emissions from the source category *6.B* arise due to the quality of source data, wastewater production estimates, its chemical parameters in terms of COD or BOD, the methane producing capacity and its treatment. The only source of emissions from wastewater handling in Ireland is the anaerobic treatment of sludge, for which uncertainty estimates of 10 per cent and 30 per cent are assigned to the activity data and emission factor used, respectively.

8.6 Quality Assurance and Quality Control

As part of on-going QA/QC by the inventory team, emission estimates are reviewed on a round-robin basis so that the person who develops the estimates of emissions is not also the person undertaking the QC procedures. Activity data are drawn from various reports prepared in other EPA offices as outlined in the previous sections. Quality control procedures are undertaken by the teams involved in yearly reviews of data collection methods and through agreed collation and aggregation methodologies required to meet the relevant reporting requirements under the applicable legislation. In addition, where any anomalies exist in data compiled in such reports, revised data are published in the reports in following years and thus forms a basis for recalculations in emission estimates by the inventory team.

All survey returns with respect to landfill gas flaring and utilisation that was undertaken as part of this submission were reviewed by a member of the inventory team and clarifications were sought directly from landfill operators. The inventory team also maintains close collaboration with specialists and license inspectors in the EPA's waste licensing division who give advice or guidance as required.

8.7 Recalculations for Waste

A number of changes were implemented and the following recalculations took place in this submission:

- Methane emissions from solid waste disposal on land (6.A.1) have been revised for all years from 2004-2011 due to a disaggregation of organic waste into food and garden waste.
- Methane emissions from wastewater treatment of sludge were revised to account for a revision of population equivalent data for urban wastewater treatment plants.
- N_2O emissions from human sewage (6.B.2) were revised for 2011 due to a change in population statistics.
- Revised emissions of CO_2 from waste incineration of solvents (6.C.2) for 2011 due to a revision in waste statistics.

The total impact of all the changes above is an increase in GHG emissions from the Waste sector (CO_2 eq) of 2.4 per cent in 2011 and is shown in table 8.6 below. Additional information on recalculations is presented in Table 8.6 and CRF Table 8(b) for the relevant years.

8.8 Improvements in Waste

The inventory agency believes that the use of the model provided by the 2006 IPCC Guidelines, adopted since the 2010 submission, is justified as a robust estimation methodology where its flexibility in accommodating changes to input parameters to suit national circumstances is fully exploited. The application of the model to individual landfills and to groups of landfills with similar characteristics accounts for the known management and life cycle of landfills in Ireland as well as the quantity and composition of waste. This approach also captures the time dependency of methane generation in a more representative manner than the previous approach which was based on one hypothetical landfill site. The adoption of the refined methodology since the 2010 submission simplifies the task of the inventories team with regard to inventory preparation and during the UNFCCC review process. It also provides a convenient basis on which to incorporate further modifications in respect of particular data items or model parameters. In addition, it provides an efficient and improved mechanism for undertaking emissions projections in relation to landfills.

The inventory agency intends to continue its annual surveys of landfill operations to determine landfill gas flaring and utilisation statistics. This data is collated with other units involved in reporting within the EPA such as annual environmental reports and EPRTR and this collaboration ensures an element of consistency in environmental reporting in this area.

Table 8.6 .Recalculated Estimates for Waste 1990-2011

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
											Estimates in 2013 Submission (Gg CO2 eq.)											
6.A.1	Managed Waste Disposal on Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	901.2	951.5	1,083.4	1,197.4	1,275.7	1,104.6	1,014.3	1,115.4	796.3	714.9	591.5	602.4
6.A.2	Unmanaged Waste Disposal Sites	1,173.0	1,251.7	1,312.5	1,362.1	1,410.0	1,449.7	1,357.4	1,152.2	1,217.2	333.6	315.3	297.4	280.1	260.8	240.0	221.3	204.6	189.5	175.9	163.5	152.2
6.B.1.b	Industrial Wastewater	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.8	3.8	4.1	4.2	4.4	4.5	4.3	5.1	5.2	5.3	5.4	5.5	5.6	5.7
6.B.2.b	Domestic & Commercial Wastewater	12.8	12.8	12.9	13.0	13.1	12.7	12.8	16.5	16.7	17.7	18.0	18.6	19.0	18.1	18.4	9.3	9.5	9.7	9.9	10.1	10.3
6.B.2	Human Sewage	111.7	115.6	114.5	111.6	108.6	109.5	113.5	116.3	120.8	125.7	125.0	131.0	129.2	131.8	132.9	132.3	135.6	135.5	139.5	140.6	140.9
6.C	Waste Incineration	83.8	83.8	83.8	83.8	83.8	83.8	83.8	70.2	53.0	56.1	59.3	63.7	64.7	97.3	110.9	107.4	103.9	82.9	61.9	63.4	54.1
6	Total	1,383.3	1,466.0	1,525.7	1,572.6	1,617.5	1,657.7	1,569.5	1,359.0	1,411.5	1,438.5	1,473.3	1,598.5	1,694.8	1,787.9	1,612.0	1,489.9	1,574.3	1,219.4	1,107.7	974.6	965.7
											Recalculated Estimates in 2014 Submission (Gg CO2 eq.)											
6.A.1	Managed Waste Disposal on Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	901.2	951.5	1,083.4	1,197.4	1,275.7	1,105.1	1,019.1	1,122.3	799.5	718.5	602.6	625.8
6.A.2	Unmanaged Waste Disposal Sites	1,173.0	1,251.7	1,312.5	1,362.1	1,410.0	1,449.7	1,357.4	1,152.2	1,217.2	333.6	315.3	297.4	280.1	260.8	240.0	221.3	204.6	189.5	175.9	163.5	152.2
6.B.1.b	Industrial Wastewater	1.9	1.9	1.9	1.9	2.0	2.0	1.9	2.9	3.8	3.8	4.4	4.4	4.6	4.6	5.1	5.1	4.4	4.8	6.4	6.9	5.1
6.B.2.b	Domestic & Commercial Wastewater	12.8	12.8	12.9	13.0	13.1	13.1	12.8	12.8	16.7	16.7	18.0	18.0	18.8	16.7	15.6	16.0	10.0	12.3	15.3	15.8	14.6
6.B.2	Human Sewage	111.7	115.6	114.5	111.6	108.6	109.5	113.5	116.3	120.8	125.7	125.0	131.0	129.2	131.8	132.9	132.3	135.6	135.5	139.5	140.6	140.9
6.C	Waste Incineration	83.8	83.8	83.8	83.8	83.8	83.8	83.8	70.2	53.0	56.1	59.3	63.7	64.7	97.3	110.9	107.4	103.9	82.9	61.9	63.4	54.1
6	Total	1,383.3	1,466.0	1,525.7	1,572.5	1,617.5	1,658.0	1,569.4	1,354.5	1,411.5	1,437.2	1,473.5	1,597.9	1,694.7	1,786.8	1,609.7	1,501.2	1,580.8	1,224.5	1,117.6	992.8	992.7
											Percentage Change in Total Emissions due to Recalculations											
6.A.1	Managed Waste Disposal on Land	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.47	0.62	0.40	0.50	1.88	3.88
6.A.2	Unmanaged Waste Disposal Sites	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-
6.B.1.b	Industrial Wastewater	- 2.65	- 2.65	- 2.65	- 2.65	- 2.65	-	- 2.65	- 22.47	-	- 5.95	3.74	-	2.53	7.46	-	- 1.59	- 17.12	- 11.92	16.56	23.72	-11.60
6.B.2.b	Domestic & Commercial Wastewater	-	-	-	-	-	2.72	-	- 22.47	-	- 5.95	- 0.01	- 3.61	- 1.17	- 7.61	- 15.11	70.92	4.44	26.00	54.29	56.37	41.69
6.B.2	Human Sewage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6.C	Waste Incineration	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.00	0.00	0.00	-	-	0.00	-	0.00	0.00	-	-	0.00	-
6	Total	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.33	-	- 0.09	0.01	- 0.04	- 0.01	- 0.06	-0.14	0.76	0.41	0.42	0.89	1.86	2.80

Chapter Nine

Other Sources

The sector *Other* in the IPCC source sector classification (Table A.2, Annex A) that is the basis for the CRF reporting tables provides for the inclusion of greenhouse gas emission sources that may be particular to individual Parties. There are no such sources to report in Ireland.

Chapter Ten

Recalculations and Improvements

10.1 Introduction

On-going demands for more complete and more accurate estimates of greenhouse gas emissions means that the methodologies being used are subject to regular revision and refinement as inventory capacity is increased and better data become available. The general improvement in inventories over time may therefore introduce inconsistencies between the emissions estimates for recent years and those for years much earlier in the time-series. Recalculated estimates are often needed to eliminate these inconsistencies and to ensure that the inventories for all years in a time-series are directly comparable with respect to the sources and gases covered and that the methods, activity data and emission factors are applied in a transparent and consistent manner. In this way, the results can be used with greater confidence in identifying trends and in monitoring progress towards the commitments that have been defined with reference to emissions in the base year. The UNFCCC reporting guidelines provide for the reporting of recalculations as part of the annual submissions from Annex 1 Parties. Justification for the recalculations should be provided, as well as explanations of the changes that have been made and the numerical values of the original and revised estimates must be compared to show the impact of the changes.

10.2 Explanation and Justification for Recalculations

The foregoing chapters describe recalculations and improvements for the individual Level 1 source sectors of the inventory undertaken for the 2014 submission and they present the corresponding quantitative changes in emissions and removals within the individual sectors. The recalculations are either due to methodological refinement or methodological change, as defined by the IPCC good practice guidance. Table 10.1 records the major changes and where they are described in the 2014 NIR. This section summarises the recalculations and assesses their effect in relation to total national emissions to record the updates and the most recent emissions estimates as they appear in the 2014 submission CRF tables. The original and revised numerical values of the emissions estimates for the years 1990-2011, along with the changes related to methods, activity data and emission factors are detailed in the respective CRF Tables 8(a) and 8(b). The principal changes that that give rise to recalculated estimates for the years 1990-2011 included in the 2014 submission are outlined below (Table 10.2 and Figure 10.1).

10.2.1 Recalculations in Energy

The overall effect of recalculations on Energy sector emissions was a decrease by 0.13 per cent on average in the 1990-2011 trend. The biggest decrease was noted in the 2004-2007 period with 0.50 per cent reduction on average in those four years and a maximum decrease in the same period was by 0.78 per cent in 2007. In 2011 emissions were 0.19 per cent higher than those submitted in 2013 for the same year.

1.A.1 Energy Industries

- A revision to energy data in sub-category *1.A.1.c* for years 2005-2011: revised (increased) CO_2 emission factors (from ETS data) and revised peat consumption activity data from Energy Balance (decreased).

The impact has been a decrease in sector *1.A.1* emissions by 0.001 per cent (CO_2 eq.) on average in the same period.

1.A.2 Manufacturing Industries and Construction

- Revisions to sub-categories in *1.A.2 (a to f)*, were a result of revised fuel quantities in Energy Balance: natural gas (in 2004-2007 and 2011), petroleum coke (in 2003), fuel oil (in 2011) and coal (in 2009). Also there was new inclusion of peat in Energy Balance (2005 onwards, *1.A.2.e*) and revised natural gas CO_2 emission factors for 2004-2011.

Overall, all above changes to sector *1.A.2* resulted in emissions decreasing by 1.5 per cent (CO_2 eq.) on average between 2004 and 2011.

1.A.3 Transport

- Revisions to road transport, *1.A.3.b* sub-category are mainly due to methodological and emission factor change of implementing the most recent COPERT model (version 10.0), replacing version 9.1.

Specifically, this has decreased emissions of N_2O and CH_4 from road transport and resulted in total sector *1.A.3* emission decrease by 0.7 per cent (CO_2 eq.) on average between 1991 and 1998. The impact is more significant when looking at the individual GHGs, where the percentage decreases in the same period for N_2O and CH_4 are 23.4 per cent and 1.1 per cen, respectively. The revised estimates due to the COPERT model change are clearly sown in Tables 3.7 and 3.8 of chapter 3.

1.A.4 Other Sectors

- Revised fuel data, in particular, petroleum coke between 2003 and 2009 (in *1.A.4.a* and *1.A.4.b*), natural gas for years 2004-2007, 2009 and 2011 in *1.A.4.a*, bituminous coal between 2009-2011 in *1.A.4.b* plus revised natural gas CO_2 emission factors for 2006-2011 in both *1.A.4.a* and *1.A.4.b.*

These revisions have led to decrease in sector *1.A.4* emissions by 0.2 per cent (CO_2 eq.) on average between 2003 and 2011.

10.2.2 Recalculations in Industrial Processes

Recalculations in the *Industrial Processes* sector in this submission are confined to sub-categories *2.F*, HFC and SF_6 gases and are mainly due to a new F-gas study conducted in 2013 including revised activity data from new and existing supplier sources in sector *2.F.1, Refrigeration and stationary air conditioning*.

Revisions included HFC gases in sectors:

- *2.F.1 Refrigeration and Air-Conditioning (stationary)*
- *2.F.1 Mobile Air Conditioning (MAC)*
- *2.F.2 Foams,*
- *2.F.3 Fire extinguishers,*
- *2.F.4 Metered Dose Inhalers*
- *2.F.4 Aerosols*
- *2.F.7 Semiconductor manufacture*;

and also SF_6 gas in sectors:

- *2.F.9 Other – window soundproofing,*

- *2.F.9 Other - sporting goods,*
- *2.F.9 Other - gas-air tracer*.

The impact of these recalculations increased the subcategory *2.F* emissions by 18.5 per cent an average in the whole trend between 1990 and 2011 but their relative impact on total GHG emissions remained minor. Overall, total *Industrial Processes* sector recalculations resulted in increased emissions of 6.1 per cent on average for the years 1990 to 2011. The results of the recalculations are given by category and gas in Tables 4.4 (sector 2.F) and 4.5 (IPCC 2 sector) of chapter 4 and in CRF Tables 8(b) for the relevant years.

10.2.3 Recalculations in Solvent and Other Product Use

Recalculations for the *Solvent and Other Product Use* sector are minor and confined to the period 1999-2011 and are due to revised UK activity data used as a proxy for Irish emissions. Those recalculations decreased the IPCC category 3 emissions by 0.18 per cent on average between 1999 and 2011 but the relative impact on total GHG emissions remained negligible.

10.2.4 Recalculations in Agriculture

The following changes were implemented in the Agriculture sector in this inventory submission:

- Livestock numbers for several livestock categories were revised for 2010 and 2011, although the changes were small. For example, the total cattle in 2011 increased by 0.3 per cent. The revision to the livestock numbers also changes the amount of Nitrogen available for application to agricultural land, and hence also impacts on the emission estimates for *4.D.1 Direct Soil Emissions, 4.D.2 Pasture, Range and Paddock and 4.D.3 Indirect Emissions.*
- The amount of synthetic fertiliser applied to land was revised for 2011, and was decreased by 16.8 per cent.

The net effect of the revisions to livestock statistics and synthetic fertiliser application is an increase in agricultural CH_4 emissions of 0.2 per cent in 2011, and a decrease in agricultural N_2O emissions of 4.7 per cent in 2011.

Overall GHG emissions (CO_2 eq) from Agriculture in 2011 have decreased by 1.8 per cent. Additional information on recalculations is provided in the CRF Table 8(b) for the relevant years and in Table 6.5 in chapter 6.

10.2.5 Recalculations in LULUCF

The recalculations for LULUCF includes a complete revision of the time series, now based on land remaining a land use category for the periods before 1990 and lands converted to other land uses since 1990. This required a major methodological change for forest lands resulting mainly from wider use of the national forest inventory data in the CARBWARE model for forest land and its development to ensure consistency between the LULUCF submissions under the Convention and the Kyoto Protocol. The following are the principal items leading to recalculations for the years 1990-2011 due to methodological improvements and in response to recommendations made in previous annual review reports.

5.A. Forest lands CRF

The major change in this submission is the use of the new NFI data for 2012. This has resulted in the following changes:

- Changes in the harvest removed from land converted to forest land and forest land remaining forest land;
- Changes in the previous land use categories used for land converted to forest land (section 7.3.2.5);
- Changes in the areas under categories *5.A.1* and *5.A.2* due to changes in the deforestation area between 2006 and 2012;
- A complete recalculation for the time series adjustment for 1990 to 2006 due to the new NFI data;
- A correction to dead organic pool calculations for forest land remaining forest land. This was due to the use of the incorrect sign (+ve instead of –ve) adjustment factor used for the time series adjustment (see section 7.3.4.1).

5.B.-5.E. Forests converted to other land uses

- An increase in deforestation emissions in 2011 from 29 Gg in the previous submission to 332 Gg CO_2 in this submission;
- Inclusion of emission estimated from mineral forest soils converted to settlement and other lands as recommended by previous ERT (ARR 2012, 2013).

5.C Grassland

- Natural, unmanaged, grasslands are included in the Grassland land use category for the first time. Previously these lands have been included in the Other Land category. The revision means there is increase in the total area of Grassland, and a corresponding decrease in area of Other Land. All previous transitions between Grassland and Other Land, and the GHG emissions associated with these, are now reported under Grassland Remaining Grassland. This revision was in response to the review process;
- A recalculation has also been undertaken due to revision of the estimate of area of improved grassland in 2011.

5.E Settlement

- Estimates of changes in soil carbon due to conversion from other land uses to Settlement are reported for the first time. This is in response to the Review Process.

5.F Other Land

- Recalculations for all years due to a revision of the methodology to remove natural grassland from the *Other Land* category and include it in the *Grassland* category. This is in response to the UNFCCC review process.

The net effect of the recalculations is outlined in Table 7.23 and Table 10.2.

10.2.6 Recalculations in Waste

The following recalculations took place in this submission:

- Methane emissions from *solid waste disposal on land (6.A.1)* have been revised for all years from 2004-2011 due to a disaggregation of organic waste into food and garden waste;
- Methane emissions from wastewater treatment of sludge were revised to account for a revision of population equivalent data for urban wastewater treatment plants;
- N_2O emissions from human sewage *(6.B.2)* were revised for 2011 due to a change in population statistics;
- Revised emissions of CO_2 from waste incineration of solvents *(6.C.2)* for 2011 due to a revision in waste statistics.

The total impact of these changes is an increase in GHG emissions from the *Waste* sector (CO_2 eq) of 2.4 per cent in 2011.

Additional information on recalculations is presented in Table 8.6 and CRF Table 8(b) for the relevant years.

10.3 Effects on Emission Levels, Trends and Time-Series Consistency

Tables 10.2 and 10.3 outline the effect of recalculations for the years 1990-2010 according to greenhouse gas and the IPCC sectors, respectively. The overall effect on total emissions excluding LULUCF shows no change to estimates in 1990 and a decrease in 2011 emissions by 0.25 per cent. There is no significant impact on the trend in total emissions (Chapter Two). Emissions increased in the three consecutive years 2008-2009 by 0.15 per cent on average and decreased by 0.25 per cent in 2011, Table 10.2 (c). The recalculations improve time-series consistency and comparability and they take account of the inventory review process by implementing the major outstanding inventory-specific recommendations of the latest annual review reports. It may be said that fully consistent greenhouse gas inventories are available for the years 1990-2011 and that these annual inventories are complete with respect to the coverage of the six greenhouse gases and all IPCC source categories. The range of really important greenhouse gas emission sources in Ireland is quite small and the important elements of good practice are taken into account in the current approaches to estimating their emissions.

10.4 Response to the Review Process and Planned Improvements

Ireland recognises the need to deliver annual submissions in close conformity with the UNFCCC reporting guidelines on annual inventories to facilitate the work of expert review teams in conducting productive and efficient technical reviews of greenhouse gas inventories. Every attempt is made to participate in the UNFCCC review process and to facilitate the work of the UNFCCC secretariat, especially insofar as it impacts on the quality and transparency of the Irish estimates of emissions. The in-country review of Ireland's 2006 and 2013 submissions (UNFCCC, 2007, 2013) were an important development in this regard. The majority of the recommendations in the 2013 in-country review were implemented in this 2014 submission while further recommendations from the 2008 to 2012 centralised reviews of Ireland's inventory have also been addressed where feasible in the present submission. This involved greater application of country-specific information in a number of areas of the inventory and improved explanations and clarifications have been included in the 2014 NIR relating to the use of ETS data, which are used extensively in the *Energy* and *Industrial Processes* sectors. Also additional background information on the COPERT model for calculating emissions from road transport in *Transport* sector was included. Significant improvements have been made in this submission in relation to the F-gas emissions in *Industrial Processes* sector. Annex J summarises the issues raised in the 2010 to 2012 annual inventory review reports and Ireland's response to those issues through the 2013 submission and the current submission. It may be stated therefore that the inventory material being submitted in 2014 broadly meets the principles of transparency, completeness, consistency, comparability and accuracy laid down in the UNFCCC reporting guidelines.

Further general improvements to greenhouse gas inventories are taking place through consolidation and implementation of the national system, which has been fully operational since 2007, and through application of formal QA/QC procedures that have been put into effect as an integral part of the national system. Memoranda of Understanding (MOU) which define the data inputs between the inventory agency and all key data providers and which outline the responsibilities that are conferred to the data providers under the national system (Table 1.1) underpin the national system in Ireland and have improved the quality and timely delivery of the activity data. Their application has identified where additional MOUs may be useful, including some secondary MOUs incorporated in 2009. An updated national climate change strategy was published in 2007 providing a framework in which internal review of annual inventories takes place among all stakeholders to monitor progress on the strategy, thereby fulfilling another important requirement of national system implementation.

The implementation of comprehensive QA/QC procedures in this reporting cycle according to the plan supporting the national inventory system maintains and enhances the general improvement in quality of Irish greenhouse gas inventories. The QA/QC elements include a plan and procedures for QA/QC in data selection and acquisition, data processing and reporting to comply with international requirements under Decision 280/2004/EC and the Kyoto Protocol. The plan provides guidance on and templates for appropriate quality checking, documentation and traceability, the selection of appropriate source data and calculation methodologies. It extends to peer review and expert review of inventory data and outlines the annual requirements of a continuous improvement programme for the inventory. Participation in the internal review mechanisms within the EU as part of the QA/QC plan developed for the EU inventory under Decision 280/2004/EC provides an opportunity to engage with other Member States in the examination and assessment of individual IPCC sectors and particular issues relating to methodologies and country-specific approaches that could bring mutual benefits to their greenhouse gas inventories.

Table 10.1. Changes in Methodological Descriptions compared to 2013 NIR

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Categories where the 2014 NIR includes major changes in methodological descriptions compared to the 2013 NIR	Sub-categories where changes are reflected in recalculations of previous year estimates	Reference to sub-category, gas, pages in the NIR, Annex
Total (Net Emissions)			
1. Energy			
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries			
2. Manufacturing Ind & Const			
3. Transport	✓	✓	1A3b Road Transport CH_4 and N_2O. Revised model; COPERT 4 v9.1 to COPERT 4 v10.0
4. Other Sectors			
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas			
2. Industrial Processes			
A. Mineral Products			
B. Chemical Industry			
C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF6			
F. Consumption of Halocarbons and SF6	✓	✓	Revised HFCs in sectors: 2.F.1 Refrigeration and air-con, 2.F.2 Foams, 2.F.3 Fire extinguishers, 2.F.4 Aerosols, 2.F.4 MDI, 2.F.7 Semiconductor manufacture; and also SF_6 in sectors: 2.F.9 Other – window soundproofing, 2.F.9 Other - sporting goods, 2.F.9 Other - gas-air tracer.
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			
A. Enteric Fermentation			
B. Manure Management			
C. Rice Cultivation			
D. Agricultural Soils			
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues			
G. Other			
5. Land Use, Land-Use Change and Forestry	✓	✓	
A. Forest Land	✓	✓	Revision to NFI data for 2012
B. Cropland		✓	
C. Grassland	✓	✓	Natural grassland included in Grassland category. Previously reported under Other Land.
D. Wetlands			
E. Settlements	✓	✓	Changes in soil carbon due to conversion of lands to Settlement are estimated for the first time, for all years.
F. Other Land	✓	✓	Natural grassland no longer reported under Other Land.
G. Other			
6. Waste			
A. Solid Waste Disposal on Land			
B. Waste-water Handling		✓	Recovered CH_4 emissions from anaerobic digestion of wastewater sludge reported in CRF tables 6.B
C. Waste Incineration			
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			
Aviation			
Marine			
Multilateral Operations			
CO2 Emissions from Biomass			

Table 10.2. Recalculations by Gas 1990-2011

(a) Emissions by Gas 1990 –2011 reported in 2013 Submission (Gg CO_2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2 (inc net CO_2 from LULUCF)	29,724.21	30,444.34	30,657.14	30,433.39	31,962.72	33,367.24	35,092.42	35,748.36	37,916.06	39,711.57	43,382.25	45,657.82	44,223.31	43,591.44	43,454.88	45,145.29	44,632.72	44,151.89	44,236.11	38,650.63	37,137.53	33,882.54
CO_2 (exc net CO_2 from LULUCF)	32,423.99	33,206.32	33,074.16	33,206.81	34,422.32	35,232.54	36,839.95	38,255.68	40,270.73	41,907.05	44,689.23	47,098.40	45,676.21	45,155.04	46,053.76	47,779.22	47,398.46	47,578.90	47,018.64	41,726.52	41,341.62	37,664.48
CH_4 emissions (inc CH_4 from LULUCF)	13,683.42	13,852.85	13,967.17	13,982.62	13,911.20	13,931.81	14,190.65	14,204.22	14,422.52	13,959.47	13,420.17	13,474.94	13,399.30	13,961.32	13,168.30	12,814.38	12,889.26	12,364.64	12,233.72	11,932.93	11,717.53	11,636.40
CH_4 emissions (exc CH_4 from LULUCF)	13,674.13	13,846.87	13,963.33	13,974.88	13,902.32	13,919.68	14,177.15	14,196.84	14,418.62	13,956.29	13,412.20	13,459.04	13,395.64	13,938.77	13,155.16	12,809.60	12,884.48	12,359.27	12,228.17	11,929.81	11,697.10	11,628.82
N_2O emissions (inc N_2O from LULUCF)	9,140.50	8,949.60	8,942.61	9,139.25	9,418.87	9,660.69	9,785.06	9,736.21	10,345.58	9,983.55	9,528.06	9,021.37	8,648.47	8,571.60	8,391.34	8,174.63	8,040.98	7,794.68	7,702.86	7,612.73	7,896.40	7,693.86
N_2O emissions (exc N_2O from LULUCF)	9,112.13	8,920.07	8,912.07	9,104.48	9,384.36	9,620.70	9,744.70	9,696.33	10,303.17	9,943.09	9,482.75	8,970.28	8,598.81	8,512.25	8,333.13	8,117.83	7,984.55	7,737.83	7,633.62	7,543.38	7,825.02	7,621.12
HFCs	1.31	7.11	9.90	15.13	27.73	54.60	91.85	153.44	217.03	223.94	259.81	279.85	309.24	382.20	416.04	475.81	548.66	535.67	566.66	523.33	559.30	538.61
PFCs	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
SF_6	35.51	40.74	45.97	55.46	64.94	82.93	102.17	132.20	93.09	67.38	54.35	67.84	67.73	115.43	68.65	101.63	62.90	65.52	56.68	38.24	34.51	48.29
Total including LULUCF	52,585.05	53,302.25	53,637.94	53,656.06	55,430.73	57,172.65	59,365.22	60,105.26	63,056.15	64,141.84	66,950.04	68,797.81	66,860.45	66,850.77	65,681.64	66,880.07	66,322.84	65,042.97	64,902.23	58,823.42	57,382.30	53,812.90
Total excluding LULUCF	55,247.17	56,028.74	56,020.58	56,386.96	57,846.92	58,985.84	61,058.90	62,565.31	65,364.51	66,293.68	68,203.75	70,171.39	68,260.04	68,332.48	68,209.17	69,452.43	69,027.37	68,407.76	67,609.96	61,826.84	61,494.57	57,514.53

(b) Recalculated Emissions by Gas 1990 –2011 reported in 2014 Submission (Gg CO_2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO2 (inc net CO2 from LULUCF)	30,073.75	30,813.20	31,187.83	30,534.43	32,204.48	33,806.53	35,619.35	35,798.55	38,220.69	39,898.71	43,798.05	46,408.28	45,020.15	44,107.67	43,345.73	45,351.56	45,861.83	44,450.41	42,799.99	37,182.31	37,343.69	33,997.72
CO2 (exc net CO2 from LULUCF)	32,423.99	33,206.32	33,074.16	33,206.81	34,422.32	35,232.54	36,839.95	38,255.68	40,270.73	41,907.03	44,689.18	47,098.33	45,676.12	45,151.23	45,805.48	47,626.85	47,227.19	47,213.62	47,005.72	41,749.65	41,292.13	37,716.34
CH4 emissions (inc CH4 from LULUCF)	13,683.38	13,852.80	13,967.10	13,982.53	13,911.15	13,932.12	14,189.50	14,198.65	14,421.24	13,957.15	13,419.75	13,473.39	13,398.74	13,959.87	13,165.79	12,825.87	12,895.47	12,369.48	12,243.51	11,950.79	11,741.06	11,699.63
CH4 emissions (exc CH4 from LULUCF)	13,674.09	13,846.83	13,963.26	13,974.79	13,902.26	13,919.99	14,176.00	14,191.27	14,417.35	13,953.97	13,411.77	13,457.48	13,395.08	13,937.33	13,152.65	12,821.10	12,890.70	12,364.11	12,237.97	11,947.66	11,720.62	11,692.05
N2O emissions (inc N2O from LULUCF)	9,140.49	8,944.90	8,936.84	9,086.21	9,338.85	9,595.22	9,725.82	9,678.45	10,309.86	9,982.44	9,530.12	9,025.28	8,653.98	8,578.59	8,397.74	8,180.62	8,047.82	7,801.57	7,708.48	7,619.52	7,907.25	7,360.86
N2O emissions (exc N2O from LULUCF)	9,112.12	8,915.37	8,906.30	9,051.44	9,304.33	9,555.24	9,685.46	9,638.57	10,267.45	9,941.97	9,484.81	8,974.22	8,604.38	8,519.35	8,339.64	8,123.93	7,991.52	7,745.36	7,640.05	7,551.09	7,837.02	7,288.43
HFCs	0.47	0.60	1.46	4.00	13.26	37.13	94.57	161.83	206.99	215.60	270.82	313.65	381.97	514.99	635.44	813.46	844.63	850.89	973.06	957.12	973.37	992.28
PFCs	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32	130.58	106.20	65.57	37.02	13.20
SF6	35.51	40.74	45.97	55.46	64.94	82.93	102.17	132.20	93.09	67.38	54.35	67.84	67.74	115.43	68.83	101.98	63.40	66.18	57.50	41.17	34.74	47.66
Total including LULUCF	52,933.69	53,659.87	54,154.36	53,692.84	55,577.95	57,529.32	59,834.49	60,100.51	63,313.74	64,317.22	67,378.49	69,584.42	67,734.98	67,505.36	65,795.96	67,441.84	67,861.47	65,669.11	63,888.74	57,816.48	58,037.12	54,111.36
Total excluding LULUCF	55,246.27	56,017.48	56,006.31	56,322.71	57,752.38	58,903.21	61,001.23	62,510.37	65,317.47	66,281.89	68,216.34	70,207.50	68,337.70	68,467.13	68,184.47	69,655.66	69,165.75	68,370.74	68,020.49	62,312.26	61,894.90	57,749.96

(c) Percentage Change in Emissions by Gas 1990-2011

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO2 (inc net CO2 from LULUCF)	1.18%	1.21%	1.73%	0.33%	0.76%	1.32%	1.50%	0.14%	0.80%	0.47%	0.96%	1.64%	1.80%	1.18%	-0.25%	0.46%	2.75%	0.68%	-3.25%	-3.80%	0.56%	0.34%
CO2 (exc net CO2 from LULUCF)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.54%	-0.32%	-0.36%	-0.77%	-0.03%	0.06%	-0.12%	0.14%
CH4 emissions (inc CH4 from LULUCF)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.04%	-0.01%	-0.02%	0.00%	-0.01%	0.00%	-0.01%	-0.02%	0.09%	0.05%	0.04%	0.08%	0.15%	0.20%	0.54%
CH4 emissions (exc CH4 from LULUCF)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.04%	-0.01%	-0.02%	0.00%	-0.01%	0.00%	-0.01%	-0.02%	0.09%	0.05%	0.04%	0.08%	0.15%	0.20%	0.54%
N2O emissions (inc N2O from LULUCF)	0.00%	-0.05%	-0.06%	-0.58%	-0.85%	-0.68%	-0.61%	-0.59%	-0.35%	-0.01%	0.02%	0.04%	0.06%	0.08%	0.08%	0.07%	0.09%	0.09%	0.07%	0.09%	0.14%	-4.33%
N2O emissions (exc N2O from LULUCF)	0.00%	-0.05%	-0.06%	-0.58%	-0.85%	-0.68%	-0.61%	-0.60%	-0.35%	-0.01%	0.02%	0.04%	0.06%	0.08%	0.08%	0.08%	0.09%	0.10%	0.08%	0.10%	0.15%	-4.37%
HFCs	-64.22%	-91.51%	-85.27%	-73.57%	-52.17%	-32.01%	2.97%	5.47%	-4.63%	-3.72%	4.24%	12.0%	23.5%	34.7%	52.7%	70.9%	53.9%	58.8%	71.72%	82.89%	74.03%	84.23%
PFCs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SF6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.26%	0.35%	0.80%	1.01%	1.45%	7.67%	0.65%	-1.30%
Total including LULUCF	0.66%	0.67%	0.96%	0.07%	0.27%	0.62%	0.79%	-0.01%	0.41%	0.27%	0.64%	1.14%	1.31%	0.98%	0.17%	0.84%	2.32%	0.96%	-1.56%	-1.71%	1.14%	0.55%
Total excluding LULUCF	0.00%	-0.02%	-0.03%	-0.11%	-0.16%	-0.14%	-0.09%	-0.09%	-0.07%	-0.02%	0.02%	0.05%	0.11%	0.20%	-0.04%	0.29%	0.20%	-0.05%	0.61%	0.79%	0.65%	0.41%

Table 10.3. Recalculations by IPCC Sector 1990-2011

(a) Emissions by IPCC Sector 1990 –2011 reported in 2013 Submission (Gg CO_2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1. Energy	30,970.47	31,832.89	31,730.32	31,957.05	32,959.66	33,845.38	35,433.16	36,574.83	38,822.07	40,156.84	42,458.12	44,569.56	43,355.14	43,890.73	44,034.04	45,732.42	45,355.60	45,516.25	45,249.87	40,735.36	40,530.48	36,938.87
2. Industrial Processes	3,179.27	2,890.63	2,820.01	2,810.56	3,088.71	3,082.98	3,230.78	3,686.96	3,531.12	3,595.98	4,223.10	4,330.65	3,755.83	3,069.03	3,174.18	3,298.58	3,298.62	3,312.20	3,031.12	1,929.88	1,929.88	1,767.37
3. Solvent and Other Product Use	80.03	81.78	82.25	82.62	83.67	85.39	85.39	85.88	86.63	83.73	79.04	77.91	75.60	74.39	73.92	74.07	75.10	75.67	74.30	71.88	71.66	72.49
4. Agriculture	19,634.08	19,757.40	19,862.29	19,964.15	20,097.37	20,314.40	20,740.09	20,858.61	21,513.18	21,018.65	19,970.19	19,594.75	19,378.62	19,510.45	19,315.01	18,857.48	18,723.70	18,284.27	18,146.98	17,932.52	17,996.85	17,693.21
5. LULUCF	-2,662.12	-2,726.49	-2,382.64	-2,730.90	-2,416.19	-1,813.19	-1,693.68	-2,460.06	-2,308.36	-2,151.83	-1,253.70	-1,373.59	-1,399.58	-1,481.71	-2,527.53	-2,572.36	-2,704.53	-3,364.79	-2,707.74	-3,003.42	-4,112.27	-3,701.62
6. Waste	1,383.32	1,466.04	1,525.72	1,572.59	1,617.51	1,657.68	1,569.47	1,359.04	1,411.52	1,438.48	1,473.30	1,598.52	1,694.85	1,787.87	1,612.01	1,489.89	1,574.34	1,219.38	1,107.69	974.62	965.69	1,042.58
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total exc LULUCF	**55,247.17**	**56,028.74**	**56,020.58**	**56,386.96**	**57,846.92**	**58,985.84**	**61,058.90**	**62,565.31**	**65,364.51**	**66,293.68**	**68,203.75**	**70,171.39**	**68,260.04**	**68,332.48**	**68,209.17**	**69,452.43**	**69,027.37**	**68,407.76**	**67,609.96**	**61,826.84**	**61,494.57**	**57,514.53**

(b) Recalculated Emissions by IPCC Sector 1990 –2011 reported in 2014 Submission (Gg CO_2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1. Energy	30,970.48	31,828.22	31,724.57	31,904.00	32,879.65	33,779.89	35,372.83	36,516.42	38,785.07	40,154.93	42,459.41	44,572.60	43,360.07	43,893.17	43,792.23	45,586.61	45,193.15	45,159.51	45,240.08	40,761.57	40,482.32	37,008.94
2. Industrial Processes	3,178.43	2,884.12	2,811.56	2,799.43	3,074.24	3,065.51	3,233.51	3,695.35	3,521.08	3,587.64	4,234.11	4,364.45	3,828.57	3,201.84	3,393.76	3,636.58	3,595.10	3,628.08	3,438.34	2,549.19	2,344.17	2,220.41
3. Solvent and Other Product Use	80.03	81.78	82.25	82.62	83.67	85.39	85.39	85.88	86.63	83.71	78.99	77.84	75.51	74.28	73.78	73.92	74.89	75.45	73.94	71.37	71.16	72.07
4. Agriculture	19,634.06	19,757.37	19,862.27	19,964.13	20,097.35	20,314.39	20,740.08	20,858.26	21,513.18	21,018.44	19,970.38	19,594.76	19,378.81	19,511.03	19,315.01	18,857.31	18,721.86	18,283.22	18,150.58	17,937.38	18,004.52	17,380.55
5. LULUCF	-2,312.58	-2,357.62	-1,851.95	-2,629.87	-2,174.43	-1,373.89	-1,166.74	-2,409.86	-2,003.73	-1,964.67	-837.85	-623.08	-602.73	-961.77	-2,388.51	-2,213.83	-1,304.28	-2,701.63	-4,131.75	-4,495.78	-3,857.78	-3,638.60
6. Waste	1,383.27	1,465.99	1,525.67	1,572.54	1,617.46	1,658.03	1,569.42	1,354.47	1,411.52	1,437.18	1,473.45	1,597.85	1,694.74	1,786.81	1,609.69	1,501.24	1,580.76	1,224.48	1,117.56	992.75	992.73	1,067.99
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total exc LULUCF	**55,246.27**	**56,017.48**	**56,006.31**	**56,322.71**	**57,752.38**	**58,903.21**	**61,001.23**	**62,510.37**	**65,317.47**	**66,281.89**	**68,216.34**	**70,207.50**	**68,337.70**	**68,467.13**	**68,184.47**	**69,655.66**	**69,165.75**	**68,370.74**	**68,020.49**	**62,312.26**	**61,894.90**	**57,749.96**

(c) Percentage Change in Emissions by Sector 1990-2011

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1. Energy	0.0%	0.0%	0.0%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.5%	-0.3%	-0.4%	-0.8%	0.0%	0.1%	-0.1%	0.2%
2. Industrial Processes	0.0%	-0.2%	-0.3%	-0.4%	-0.5%	-0.6%	0.1%	0.2%	-0.3%	-0.2%	0.3%	0.8%	1.9%	4.3%	6.9%	10.2%	9.0%	9.5%	13.4%	32.1%	21.5%	25.6%
3. Solvent and Other Product Use	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.2%	-0.3%	-0.3%	-0.5%	-0.7%	-0.7%	-0.6%
4. Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-1.8%
5. LULUCF	-13.1%	-13.5%	-22.3%	-3.7%	-10.0%	-24.2%	-31.1%	-2.0%	-13.2%	-8.7%	-33.2%	-54.6%	-56.9%	-35.1%	-5.5%	-13.9%	-51.8%	-19.7%	52.6%	49.7%	-6.2%	-1.7%
6. Waste	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.3%	0.0%	-0.1%	0.0%	0.0%	0.0%	-0.1%	-0.1%	0.8%	0.4%	0.4%	0.9%	1.9%	2.8%	2.4%
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total exc LULUCF	0.0%	0.0%	0.0%	-0.1%	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.1%	0.1%	0.2%	0.0%	0.3%	0.2%	-0.1%	0.6%	0.8%	0.7%	0.4%

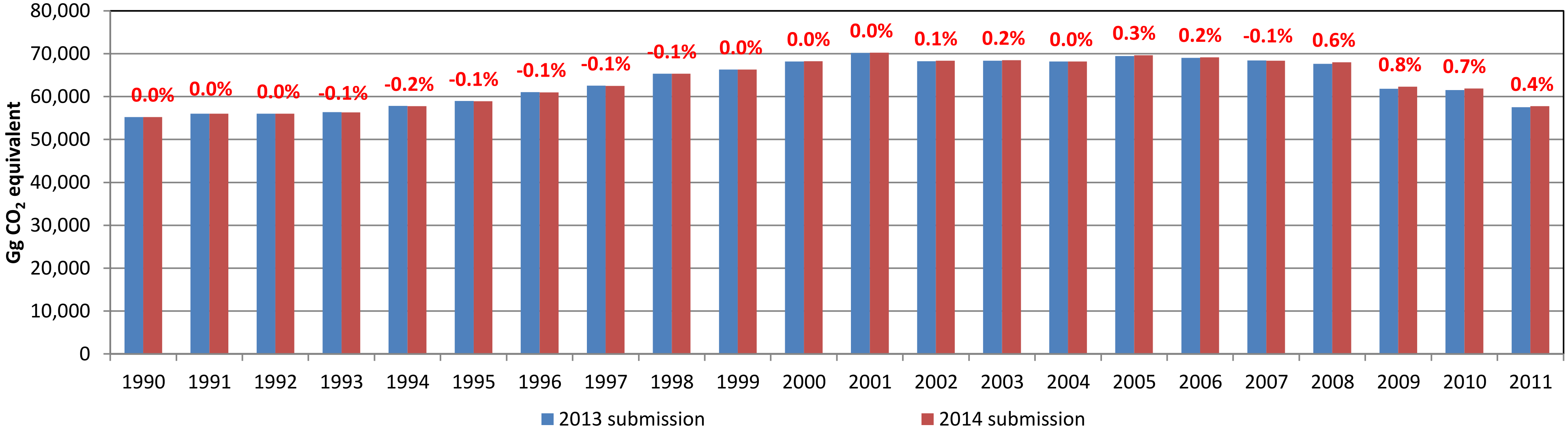

Figure 10.1 Impact of Recalculations between annual Submissions 1990-2011

PART II
SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1 OF THE KYOTO PROTOCOL

Chapter 11

Emissions and Removals from LULUCF Activities under Article 3.3 of the Kyoto Protocol

11.1 General Information

11.1.1 Introduction

The major item of supplementary information required under Article 7.1 of the Kyoto Protocol is the estimation of anthropogenic emissions by sources and removals by sinks from land use land-use change and forestry activities under Article 3 paragraph 3 and any activities that a Party has elected under Article 3 paragraph 4 of the Kyoto Protocol. These estimates must be reported for afforestation, reforestation and deforestation activities since 1990 under Article 3.3 and in respect of any of those activities from forest management, cropland management, grazing land management and revegetation under Article 3.4 for which a Party has elected to account in the Kyoto Protocol commitment period 2008-2012. Ireland has not elected to account for any activity under Article 3.4 of the Protocol in this period and therefore the information provided in this chapter relates to emissions and removals in 2008 to 2012 associated with afforestation, reforestation and deforestation in Ireland since 1990. The estimates of emissions and removals for these activities are compiled in supplementary CRF tables similar to those used for submitting the GHG inventory under the Convention as described in Part I of this NIR. The reported net removals of CO_2 in 2012 on 286.26 kha of lands subject to afforestation/reforestation since 1990 is estimated at 3,846.80 Gg CO_2 eq while there were net emissions of 224.45 Gg CO_2 eq on a deforested area of 16.51 kha. The overall forest sink for Article 3.3 forest decreased from 3,713.19 Gg CO_2eq in 2008 to 3,622.35 Gg CO_2eq in 2011, primarily due to deforestation. However the sink for afforested lands increased due to an increase in the afforested area and higher productivity associated with an increase in age class distribution. The accounted net removal from Afforestation, Reforestation and Deforestation (ARD) activities since 1990 to 2012 is 16,291.15 CO_2eq (Table 11.4). The approaches employed for data collection and the methodologies used to derive the estimates for Article 3.3 activities are described in Chapter 7, since the same approaches and time series are used for both Convention and KP reporting.

11.1.2 Institutional Arrangements

The inventory for Article 3.3 activities is prepared by FERS Ltd, a consultant working to COFORD/DAFM (Council for Forest Research and Development) which in turn delivers the information to the inventory agency under an agreed Memorandum of Understanding (Table 1.1). The reporting system adopts an activity based approach using the tier 3 CARBWARE national model that is applied specifically to report on Article 3.3 activities. To ensure consistency in reporting for *Lands converted to Forest Land* in the LULUCF inventory under the Convention (Chapter 7) and Afforestation and Reforestation under Kyoto Protocol, a new time series and methodological approach using the CARBWARE model has been developed and reported for the first time (see Chapter 7).

Table 11.1 shows the reported activities and pools. The definition of carbon pools is presented in Table 7.3.1 in section 7.3.2.6 of Chapter 7.

Table 11.1. Reported Activities and Pools (CRF Table NIR 1)

Activity		Change in carbon pool reported[1]					Greenhouse gas sources reported[2]						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil	Fertilization[3]	Drainage of soils under forest management	Disturbance associated with land-use conversion to croplands	Liming	Biomass burning[4]		
							N_2O	N_2O	N_2O	CO_2	CO_2	CH_4	N_2O
Article 3.3 activities	Afforestation and Reforestation	R	R	R	R	R	IE			NO	R	R	R
	Deforestation	R	R	R	R	R			NO	R	NO	NO	NO
Article 3.4 activities	Forest Management	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA
	Cropland Management	NA	NA	NA	NA	NA			NA	NA	NA	NA	NA
	Grazing Land Management	NA	NA	NA	NA	NA				NA	NA	NA	NA
	Revegetation	NA	NA	NA	NA	NA				NA	NA	NA	NA

R indicates the reported carbon pools and emissions from biomass burning;
IE (included elsewhere) is used to show that emissions from fertilisation of soils are included under Agriculture
Only organo-mineral and organic soils are reported. Mineral soils are shown not to be "a source", so are not reported.

Table 11.2. Land Transition Matrix (CRF Table NIR 2) for inventory year 2012

To current inventory / From previous inventory year		Article 3.3 activities		Article 3.4 activities				Other[5]	Total area at the beginning of the current inventory year[6]
		Afforestation and Reforestation	Deforestation	Forest Management (if elected)	Cropland Management (if elected)	Grazing Land Management (if elected)	Revegetation (if elected)		
		(kha)							
Article 3.3 activities	Afforestation and Reforestation	286.263	0.800						287.063
	Deforestation		15.712						15.712
Article 3.4 activities	Forest Management (if elected)		NA	NA					NA
	Cropland Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation[4] (if elected)	NA			NA	NA	NA		NA
Other[5]		6.652	0.000	NA	NA	NA	NA	6,802.359	6,809.011
Total area at the end of the current inventory year		292.915	16.512	NA	NA	NA	NA	6,802.359	7,111.786

Areas and changes in areas between the previous and the current inventory year

Table 11.3. Key Categories for Article 3.3 Activities (CRF Table NIR 3)

KEY CATEGORIES OF EMISSIONS AND REMOVALS	GAS	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			COMMENTS[3]
		Associated category in UNFCCC inventory[1] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory[1], [4] (including LULUCF)	Other[2]	
Specify key categories according to the national level of disaggregation used[1]					
Afforestation and Reforestation	CO2	Conversion to forest land	Yes	No	Level assessment

Table 11.4. Information Table on Accounting for Activities under Articles 3.3 and 3.4 of the Kyoto Protocol

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	BY(5)	Net emissions/removals(1)						Accounting Parameters(7)	Accounting Quantity (8)
		2008	2009	2010	2011	2012	Total(6)		
	($Gg\ CO_2$ equivalent)								
A. Article 3.3 activities									
A.1. Afforestation and Reforestation									-17,901.300
A.1.1. Units of land not harvested since the beginning of the commitment period(2)		-3,180.517	-3,473.380	-3,630.307	-3,713.286	-3,693.064	-17,690.554		-17,690.554
A.1.2. Units of land harvested since the beginning of the commitment period(2)									-210.745
Ireland		6.271	43.754	-28.916	-78.122	-153.732	-210.745		-210.745
All Harvested AR land (101-114)		IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO		IE,NO
A.2. Deforestation		461.062	381.870	210.066	332.702	224.447	1,610.147		1,610.147
B. Article 3.4 activities									
B.1. Forest Management (if elected)		NA	NA	NA	NA	NA	NA		NA
3.3 offset(3)								0.000	NA
FM cap(4)								916.667	NA
B.2. Cropland Management (if elected)	0.000	NA	NA	NA	NA	NA	NA	0.000	0.000
B.3. Grazing Land Management (if elected)	0.000	NA	NA	NA	NA	NA	NA	0.000	0.000
B.4. Revegetation (if elected)	0.000	NA	NA	NA	NA	NA	NA	0.000	0.000

11.1.3 Forest Definition and Application

The definition of forest is the same as that adopted for the LULUCF inventory under the Convention. Forest land has a minimum area of 0.1 hectare, a minimum width of 20 m, trees higher than 5 m and a canopy cover of more than 20 per cent within the forest boundary, or trees able to reach these thresholds in situ. The following attributes are also relevant to the definition:

- A tree is a woody perennial of a species forming a single main stem or several stems, and having a definitive crown;
- A forest includes windbreaks, shelterbelts and corridors of trees with an area of more than 0.1 ha and minimum width of 20 m;
- Forest is determined both by the presence of trees/stumps and the absence of other predominant land-uses. Areas under re-establishment (following clearfell) that have not yet reached but are expected to reach a canopy cover of 20 per cent and a minimum tree height of 5 m are included, as are temporarily un-stocked areas, resulting from human intervention, which are expected to be restocked;
- The forest area is determined by the forest boundary. The term forest boundary is defined by any man-made boundary enclosing the forest area or, in the absence of such boundary feature, the boundary of the forest is determined by extending out 1 m from the position of the pith-line of the outermost trees (NFI, 2007a);
- The forest area includes forest roads, firebreaks and other open areas on forest land; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest;
- The forest area excludes tree stands in agricultural production systems, for example in fruit plantations and Christmas tree plantations;
- The term forest also includes trees in urban parks and gardens, provided these areas satisfy the forest definition.

Reforestation activities do not occur in Ireland and the relevant activities under Article 3.3 are limited to afforestation and deforestation. All afforested areas are the result of planting and establishment of forest areas of 5 ha or greater under guidelines of the Forest Service Grant and Premiums Scheme (Forest Service, 2003). All of these forest areas are consistent with the forest definition. The scheme was introduced under European Commission Council Regulation 2080/92 to support afforestation of agricultural land as part of accompanying measures to reform the Common Agricultural Policy. The afforestation grant and premiums dataset captures all areas afforested following successful grant application. Afforestation areas recorded by the Forest Service are verified using a strict control and referrals process, following a post-establishment site visit by a forestry inspector (Forest Service, 2003). All deforestation areas are derived from legally-binding licence applications under the Forestry Act. These provisions fulfil the requirement to demonstrate that afforestation (i.e. planting of non-forest land with trees for development of the forest sector) and deforestation began on or after1 January 1990 and are directly human-induced, which is necessary for the accounting of emissions and removals for activities under Article 3.3. These datasets were primarily digitised using the 1:12560 and 1:2500 Ordnance Survey Ireland (OSI) raster maps (see section 7.3.2 in Chapter 7).

Ireland provides information on how lands subject to harvest or disturbance followed by re-establishment is distinguished from deforestation as required under paragraph 8 of the annex to the decision 15/CMP.1. A forest area is classified as deforested when there is clear indication of a specific land use change for that area or if clearfelled areas have not been replanted within a period of 5 years. Whilst different methodologies have been used to detect deforestation over time (Sections 7.3.2.4, and 7.3.6 in Chapter 7 and Annex H), this definition of deforestation has been applied consistently in developing the 1990 to 2012 area time-series. In addition, a consistent time series has been recalculated for deforested areas (Section 7.3 in Chapter 7), based on new activity data obtained from the 2006 and 2012 NFIs.

11.2 Land Area Information

11.2.1 Spatial Assessment Unit

Ireland uses a combination of approaches 2 and 3 defined in Chapter 2, section 2.3.2 of the IPPC good practice guidance for LULUCF for the representation of land areas for Article 3.3 activities. This is in accordance with requirements under paragraph 6 of the annex to the decision 15/CMP.1. Un-harvested and harvested afforestation and deforestation areas are reported within the entire territory of Ireland, with further sub division into species strata (Table 11.5) within internal national boundaries. Afforestation areas are tracked on a spatially explicit basis (IPCC Approach 3) while deforestation areas are identifiable but not spatially explicit (IPCC Approach 2). Both approaches can detect a land use change at a resolution consistent with the forest definition area of 0.1 ha. Forest areas under Article 3.3 shown in CRF table NIR-2 are sub categorised into forest categories in order to transparently report and compare implied carbon stock change factors for different forest and soil types (Tables 5(KP-I)A.1.1 and 5(KP-I)A.1.2). For deforestation activities, (5(KP-I)A.1.2) areas are stratified according to land use activities converted form forest area. This is consistent with forests converted to non-forest lands in LULUCF Convention reporting (CRF 5 B, C, D and E).

Forest stand attributes from the NFI were also collected to classify forest age, rotation stage (i.e. thicket, pre thinning, thinning cycle or rotation cycle), and management status so that inventories plots could be disaggregated into appropriate KP forest categories (see KP CRF 5 (KPI) A1.1/2). The activity data was used to derive different forest categories depicting the different productive capacity and C stock pool changes to improve transparency and comparability (Table 11.5).

Table 11.5. Forest category codes used in CRF Tables 5 (KP1)

Forest_Category_Code	Forest_Category_Description
1	Spruce (Pure). Mainly Sitka and Norway spruce
2	Pine (Pure). Prodominantly Scots and lodgepole pine
3	Larch (Pure)
4	Other conifers (Pure)
5	Fast growing broadleaves (Pure) such as ask, Alder, Sycamore, Birch
6	Slow growing broadleaves (Pure) such as Oak and Beech
7	Conifer mixes
8	Broadleaf mix
9	Conifer/Boradleaf mix
10	Open areas including biodiversity areas, roads within the forest boundary
11	Blown areas subjected to windthrow
12	Scrub, felled or failed areas (planted and unplanted)
13	New afforestation after 2006
14	Natural succession and regenreating land
101 to 115	Harvested areas. E.g 101 are harvested spruce areas
200	Burned areas

Forest stands were considered to be pure if one species represents 80 % or more of the canopy

Note: Categories 12 and 14 do not qualify as afforestation or reforestation under Article 3.3 of the KP, so are reported as NO in the CRF tables. Open areas are planned open areas in afforested areas for extraction roads of biodiversity enhancement. These are, however, assumed to be in steady state and reported as NO.

11.2.2 Methodology for Land Transition Matrix

The main drivers for producing reliable and up-to-date forest cover statistics and related spatial data in Ireland are carbon accounting under the Kyoto Protocol and the need for spatial data related to environmental modelling and monitoring under the Water Framework Directive. A number of data sources were used to derive land use change statistics for afforestation and deforestation areas for input into the CARBWARE system (see sections 7.3.2 and 7.3.6 in Chapter 7).

11.2.2.1 Afforestation Areas (Approach 3)

See Chapter 7, sections 7.2.2, 7.3.2 and 7.3.5.

11.2.2.2 Deforestation Areas (Approach 2/3)

See Chapter 7, sections 7.2.2, and 7.3.2.4, 7.3.6 and Annex H.

11.2.2.3 Forest Fire Areas (Approach 2)

Areas of forest subjected to wild fires were obtained from Forest Service statistics (see section 7.3.4.4 and Table 7.3.6 in Chapter 7). These areas were assumed to be proportionally distributed between the Kyoto Protocol forestry categories afforestation/reforestation and forest management. For example, in 2008 the AR area in Table 11.1 represented 36 per cent of the total forest area, so it was assumed that 36 per cent of areas experiencing wild fires in 2008 are in the AR category. This determines the area for estimating biomass burned, reported in CRF Table 5(KP II)5. The same assumptions are applied to years subsequent to 2008.

11.2.3 Activity Data for Afforestation Areas

Activity data inputs into the CARBWARE system for all activities reported as non-harvested afforested land up to 2006 (CRF Table 5(KP-I)A.1.1) were derived from National Forest Inventory statistics and the IFORIS database (see sections 7.3.2.2 and 7.3.2.3 in Chapter 7).

11.2.3.1 Harvest Activity Data

All harvests occurring on afforested land since 1990 are carried out as first thinnings of more productive conifer crops. Activity data relating to the removal of timber was based on the NFI permanent sample plots was obtained in 2006 and 2012. Additional information is obtained from the Coillte forest sub-compartment forecast inventory for State forests (see section 7.3.2.4 in Chapter 7).

11.2.3.2 Deforestation Activity Information

Information for deforested areas supplied with the limited felling license application provides details of the species, areas, volume of timber clear felled and an indication of the applicable land use transition category (see CRF 5(KP-I)A.2) from the following:

Forest land to Grassland **(F-Grassland (01))**

Forest land to Cropland **(F-Cropland (02))**

Forest land to Wetland **(F-Wetland (03))**

Forest land to Settlement **(F-Settlement (04))**

Forest land to Other land **(F-Other (05)).**

These areas include areas not specified above such as clear felled forest land not replanted within a period of 5 years.

Biomass, litter and deadwood pools for deforestation land were assumed to be immediately oxidised in the year deforestation occurs (see Chapter 7). The changes in biomass and deadwood C pools stock for these deforested lands converted to other land uses in the subsequent years is assumed to be zero and reported as NO. This is because all forest C pools have been oxidised in the previous year and we assume there is no biomass stock change in the converted land use (e.g. grasslands). The approach adopted in this case is **conservative** because biomass stock changes in grasslands and croplands represents a sink in the 1st year following conversion of 6 and 5 t C ha^{-1}, respectively (see section 7.3.4.4 and according tier 1 IPCC GPG).

11.3 Activity-Specific Information

Refer to section 7.2 and 7.3 for detailed description of methods, assumption and description of the CARBWARE system. The models have been validated using external data (see uncertainty and QA/QC sections in Chapter 7).

11.3.1 Additional information – Lime Application

Emissions from lime application to deforested land converted to grasslands are accounted for by applying the following assumptions:

1) Only deforested land converted to grassland is treated with lime as limestone. The area of forest land converted to grassland was 4.178 ha, 4.576 ha, 5.367 ha, 5.576 and 5.576 ha in the years 2008, 2009, 2010, 20122 and 2011 respectively;

2) The application rate is equivalent to the national average rate applied to grasslands. This is calculated based on data supplied in CRF table 5 (IV). This was 0.139 Mg/ limestone per ha in 2008, 0.164 Mg/ha in 2009, 0.231 Mg/ha in 2010, 0.194 Mg/ha in 2010 and 0.123 Mg/ha in 2012;

3) The tier 1 EF of 120 kg/tonne of lime was applied to calculate emissions.

11.4 Justification for Omitting a Carbon Pool

This section provides detailed information that demonstrates that the mineral soil pool is not a net source of anthropogenic GHG emissions; therefore, the mineral soil pool is not accounted for and reported as NO. If a pool is not reported and demonstrated that it is not a net source then the approach is consistent with requirements under paragraph 6(e) of the annex to the decision 15/CMP.1.

11.4.1 Mineral Soils for grassland, cropland and forest land transitions

Demonstration that soils are not a source is based on numerous research data, which have been subject to rigorous statistical analyses using different approaches. **The working null hypothesis is that mineral soils are a source when lands are converted to forest land, and visa-versa. The null hypothesis can be rejected if statistical tests prove that mineral soils are not a source. Therefore, we demonstrate that mineral soils for cropland and grassland conversion to and from forestry by rejecting the null hypothesis.**

Changes in mineral soil C pools over time (ΔC_{so}) are not reported because of all current information confirms that it is not a source. These findings are based on three research approaches, but this is re-evaluated every submission year following review of national research. There is also a new project ForCRep (2012-2016) specifically initiated to further develop a method for reporting mineral soils stock changes.

a) A chronosequence approach:

National research information does suggest that mineral soils are a sink for a minimum of 50 years following afforestation (Black et al., 2009b). These authors show that SOC is higher when a 9 year old stand was compared to year 0 (i.e. an un-forested grassland in the chronosequence). Other information from 30 different afforested sites, previously located on grasslands, suggest that there is *no significant* change (P>0.1) of mineral soil C stocks over time following afforestation (Black, 2008 see Figure 11.1). If anything the data suggest an increased SOC stocks over time, suggesting that afforestation of mineral soils results in a net sink, albeit not significant. Therefore, we opt not to report stock changes for mineral soils because we can **reject the null hypothesis and demonstrate that the pool is not a source**. However, this can only be applied to grassland/forestland conversions, so additional data and analysis was required.

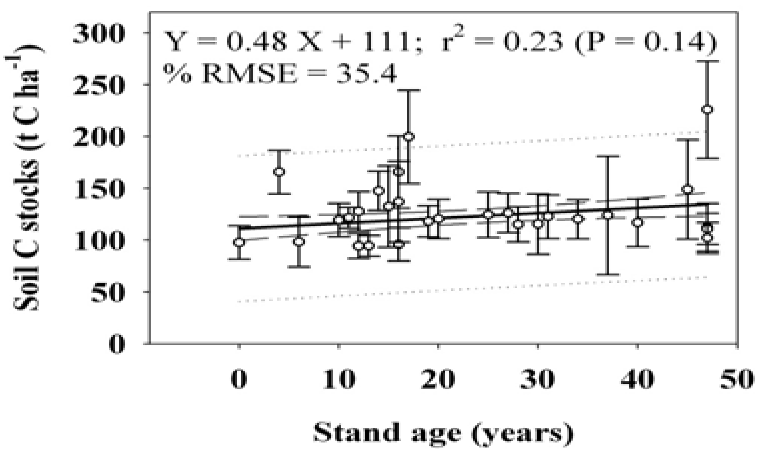

Figure 11.1 Variation in mineral soil carbon stocks and estimation of □C_{so} using the nationally derived data (n = 30).

The solid line represents the linear change on C stock over time. The dashed and dotted lines represent the 95% confidence and prediction intervals

b) A paired plot approach:

A National forest research (FORESTSOIL C and CARBiFOR2 projects 2007-2012) designed a soil carbon monitoring system for Ireland using country-specific land use and soil carbon information. The system is based on a stratified NFI sample of the country by soil type and land use. This element of the work concentrated on a paired plot approach to assess soil C stock changes due to afforestation and deforestation activities. The sampling strategy was designed to augment NFI plot measurements, but included an additional, paired plot, samples from adjacent non-forest land uses. The overall concept applies the assumption that changes in soil C stocks, due to transition from one land use to another, is a function of the difference between the forest and non-forest plot soil carbon pools and that both soil pools are in steady state. For this reason, all land use samples were assessed to have not undergone land use transitions in the past 20 to 50 years.

The following assumptions and conditions were applied:

- The analysis only applies to mineral soils. Organic soils stock changes are determined using emission factors. This includes organo-mineral soils, such as peaty-gley soils (see equations 7.3.23 and 7.3.24 in section 7.3.3.1.2(d) in Chapter 7);
- Carbon stock changes in mineral soils for all sample plots were at steady state when sampled;
- The age at steady state (i.e. the mean age of the land use or soil type) is equivalent to the transition time for soil C stocks to reach steady state;
- The land use transitions did not include wetlands or croplands because transitions between forestry and these land uses (and vice versa) because they were not detected in the random stratified sample grid of 60 out of 1762 NFI sample plots.(section 7.3.2.4 and Annex H). In addition there are very few mineral soils in wetlands;
- Settlement and other land soils were not sampled because of technical difficulties in obtaining soil samples. Deforestation and transition to settlements and other land does occur in Ireland but the soils stocks are assumed to be a source and are reported (see section 11.4.1.1). No paired settlement or other land plots were identified in the random stratified sample taken in this study;
- This analysis is primarily concerned with transitions between forestry, scrub, un-managed grassland and managed grassland. Scrub in this case refers to land uses dominated by non-tree species such as gorse or bramble. These in effect are degraded or disused grasslands (un-managed grasslands), previously used for rough grazing;
- Changes in soil C stocks due to land use change is assumed to occur only if the difference between the forest and non-forest pair, within a given soil group is found to be significantly different following statistical analysis.

To quantify the relative importance of the different factors on Ireland's soil C stocks, and to test the null hypothesis for different land use and soil strata, we carried out a hierarchical analysis of variance and multiple regression analysis using SPSS statistical package.

Table 11.6. Record sample plots taken from mineral soils sites

Soil	Land use	Transition time (years)	Number of plots	Number of soil profiles
Gleys	Forest	30	10	50
	Un-managed grassland	30	4	20
	Managed grassland	30	4	20
	Scrub grassland	30	2	10
Brown earths	Forest	35	10	50
	Un-managed grassland	35	6	30
	Managed grassland	35	4	20
	Scrub grassland			
Brown podsols	Forest	50	10	50
	Un-managed grassland	50	6	30
	Managed grassland	50	4	20
	Scrub grassland	50		
Podsols	Forest	39	10	50
	Un-managed grassland	39	5	25
	Managed grassland	39	4	20
	Scrub grassland	39	1	5
Total			80	400

Land uses were first categorized as shown in Table 11.6, and then re-classified either as forest or grassland (Grassland/Forest pair). The forest grassland pair was categorised because there no significant difference soils stock or changes in the different grassland types.

Table 11.7. Results from the hierarchical analysis of variance on soils C at a depth of 0-30cm

Source	SS	MS	F	P
Between soils	763902	254634	3.49	<0.01
Land use within soils	29663	2963	1.24	0.34
Grassland/Forest within soils	20215	4043	0.81	0.48

Based the hierarchical analysis of variance on soils C at a depth of 0-30 cm, it was evident that there was a significant difference in soils C stock when soil types were compared. However, there was no difference in the soil C stock when the different land use classes were compared (Table 11.7). Therefore, the null hypothesis is rejected (i.e. the p value for the Land-use source of variance is >0.05). **This confirms that mineral soils are not a source since there is no difference in the soil C stock when forests, un-managed grasslands, managed grasslands and scrublands are compare**d.

To further illustrate this point, Figure 11.2 shows that the mean soil C stock was significantly different within soil types for combined data from forests and grasslands (left panel Figure 11.2). Although there were marginal differences between the mean soil C stocks when forest and grassland plots are compared within the soil categories, these were not significantly different (right panel in Figure 11.2).

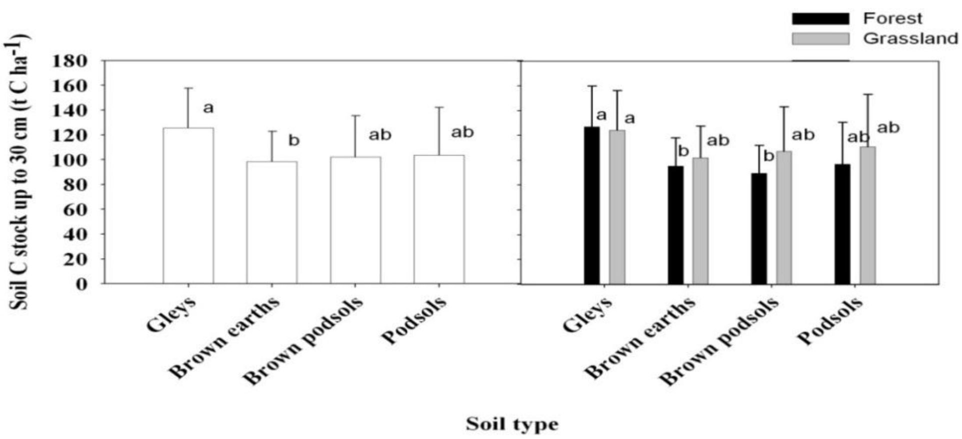

Figure 11.2 Mean soil C reference values for forest and grasslands at steady state across different mineral soil types. Histogram bars with different letters are significantly different at P < 0.05

Based on these analyses and the chronosequence soil stock changes (Black et al., 2009; NIR, 2010) it is evident that there is no significant change in soil C stocks for up to 30 years following transitions between all grassland types and forest land. Therefore **the null hypothesis is rejected and we clearly demonstrate that this pool is not a source for grassland/forest land transitions.** Similar results have been reported by Davis et al (2002) and Scott et al (2002) for studies conducted in New Zealand, where many more plots were sampled.

Based on these conclusions and related publications (Wellock et al., 2011) Ireland has elected not to account for mineral soil C stock changes following afforestation and deforestation from and into grassland uses, because we demonstrate that this pool is not a source across different mineral soil types. However, more research was required to demonstrate this for cropland/forest land conversions.

b) A new SOC database from the For CRep project:

In 2013, the ForCRep project (2012-2016) compiled a national database using all available SOC survey data sampled from mineral soils representing major land use categories in the republic of Ireland. The mineral soil database comprises of a total of 227 sample sites obtained from the Soil C project (Wellock et al., 2011), the Irish national soil database of Ireland (NCD, see Xu et al., 2011), the An Foras Taluntas project (Creamer, R., unpublished data), and the CARBiFOR project (Black et al 2009a). For this study it is not yet possible to make comparisons across different soil types because detailed soil profile data is still being processed and collected. However, a preliminary analysis was conducted to test the null hypothesis if mineral soils are a source across all cropland/ grassland and forest land transitions.

Analysis of variance confirmed that the **null hypothesis can be rejected for cropland to forest land conversions**. The SOC in forest mineral soils is significantly higher (37%), when compared to croplands, confirming that these soils are a sink (Figure 11.3). In the **case of forest land conversions to cropland, the null hypothesis can be accepted** since mineral soils could represent a significant loss of SOC (i.e. a source). However, there are no deforestation activities and conversion to cropland in Ireland (see CRF table KP.A.2). This is primarily due to the poorer quality of land under forestry, which is not suitable of cropland production. Cropland conversions to forestry have declined in recent years because previous transitions represented marginal land not suitable for cropland production.

Based on a comparison of mean SOC values for all grasslands and forest land, there was no statistical difference in the mean SOC for these land categories (Figure 11.3). Therefore, **the null hypothesis is rejected and SOC in following grassland/forest land transitions are demonstrated not to be a source**.

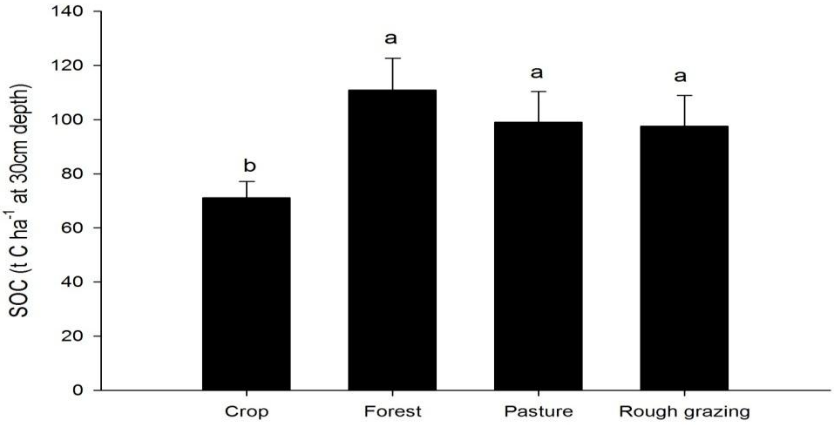

Figure 11.3 Comparison of mean SOC values (histograms) and standard deviations (error bars) across different land use categories. Mean values with different alphabetical characters indicate a significant difference ($p<0.05$)

11.4.1.1 Emissions of mineral soils in Settlement and Other lands

A previous annual inventory review report (paragraph 88, ARR 2011) provides recommendations and guidance for reporting of soil stock changes for forest conversion to settlements and other lands. However, this recommendation is not supported by any documentation in the IPCC GPG:

- Settlements: IPCC GPG 2003 provides no guidance on soil stock changes resulting from conversion from forest land to settlements;
- Other land: For other lands the GPG on page 3.147 states: *"The conversion of land to "Other Land", especially to bare soils, could result in the release of carbon previously held in soil on the land. On land converted to "Other Land" inventory compilers should estimate the change in carbon stocks in mineral soils under the initial land uses. The resulting carbon stocks in mineral soils for "Other Land" can be assumed as zero for many situations. It is also assumed that the change in carbon stocks in organic soils is not relevant in this section";*
- According to IPCC GPG for LULUCF page 4.60: *"Carbon stock changes on lands subject to deforestation activities during the commitment period can be estimated by determining the carbon stocks in all pools prior to and after the deforestation event".* However, no guidance is provided for settlements or other lands By definition these are not bare soils but are essentially infrastructures with cement based on top of the previous soils layer.

Based on the evidence presented and the lack of any information of soil stock changes for deforestation to settlement and other land categories we now use a **conservative estimate**, as used for other countries (e.g. Finland). We assume that:

- 20% of SOC is emitted over a 20 year period in these land uses following deforestation. A mean SOC stock of 110 t C ha^{-1} for forest soils was used based on best available soil data (see Figure 11.3, Chapter 11). It should be noted that this is a conservative approach since;
    - All deforested land allocated to the other land use category (Table H.2 Annex H) are forest lands which have been clearfelled but not replanted within a 5

year period. These lands have not undergone a land use transition but are defined as deforestation to comply with the requirements set out in the annex to decision of 15CMP/1 (see CH 11);

- Land converted to settlement contains green areas which will not reduce SOC as a result of deforestation. However, it is assumed that the total deforested area emits CO_2 from mineral soils because there is no activity data to determine the percentage green area in urban areas.

11.5 Factoring out Indirect and non-human induced emission/reductions

Ireland considers that all emissions/removals from Article 3.3 activities are directly human induced, since they are activities resulting from silvicultural intervention. No factoring out of indirect human-induced activities is considered in this submission due to a cited poor understanding of these influences (see Ainsworth and Long, 2005).

11.6 Uncertainty Analysis

Characterisation of uncertainties associated with individual activity and area information was obtained directly or derived from already published studies. If no estimates were available expert judgement was applied (Table 11.8). Some uncertainties cannot be quantified due to a lack of validation data. These include uncertainties associated with mortality models. However, mortality factors are selected where a tree has a 95 per cent probability of being dead (Annex K2-A).
The IPCC tier 1 approach is applied to estimate uncertainties for the Article 3.3 activities described in this chapter using the methods for combining uncertainties given in section 6.3 of the IPCC good practice guidance for LULUCF (see equations 7.3.34 and 7.3.35 in section 7.3.4.7 in Chapter 7).

The percentage input uncertainties in the various methodological parameters used for the analysis of carbon stock change in the relevant carbon pools and for the emissions of non-CO_2 gases are listed in Table 11.8. The combined uncertainties of the products of the respective parameters associated with each component pools are given table 11.9. The calculated percentage uncertainties for pools are given in Table 11.9 which also indicates the associated input parameters whose uncertainties have been combined (see equation 7.3.34 in section 7.3.4.7 in Chapter 7). The uncertainties in the reported carbon stock changes reported in the CRF tables are calculated in Table 11.10 as the sum of the uncertainties for carbon pools using equation 7.3.35 in section 7.3.4.7.

Table 11.8. Uncertainty estimates for individual activity and area data sets

Code	Parameter	Sub-category [a]	% uncertainty [b]	Source
A	Biomass algorithms	AB and BB, SB, NB, LT	12.0	Black et al., 2007
B	Carbon fraction	CF all pools	0.87	Black et al., 2007
C	DBH, H increment models	AB, BB	11.80	Validations on NFI data (see section 7.3 and paper in preparation for publication)
D	Area data	GPAS (11.2.2)	0.60	Derived from Black et al, 2009a[c]
D	Deforestation area	NFI, CORINE, I OSI (section 7.3.7)	50.01	Sample strata uncertainty analysis using new deforestation methods
E	Litter	Li	3.10	Tobin et al., 2006
F	Deadwood	DW	22.00	Tobin et al., 2007
G	Biomass C stock	AG and BB deforestation	30.10	Black, 2008; Black et al., 2009b
H	Litter C stock	DLold	30.00	Black, 2008; Black et al., 2009b
I	Deadwood C stock	DSold	30.00	Black, 2008; Black et al., 2009b
J	Peat soil emission	EFsoil	90.00	Assume Tier 1 (Table 2.3.2.3.1 Chapter AFOLU 2006 IPCC GLs)
K	Fire C stocks	Fires	15.00	95 % conf. interval for biomass stocks (NFI)
L	Areas burned	Fires	50.00	Expert judgement

a refer to methodology section 7.3.
b Uncertainties (no sign) are expressed as SEE at 95 % confidence interval
c Comparison of NFI area and GPAS data sources (see Table 2 in publication)

Table 11.9. Uncertainty estimates of major C pools

Code	Component	% Uncertainty* equation 7.3.35	Individual parameter codes from Table 11.8
TB	Biomass		
TBA		16.9	A, B, C, D
TBD		58.45	B, D, G
Li	Litter		
LiA		3.28	B, D, E
LiD		58.4	B, D, H
DW	Deadwood		
DWA		22.03	B, D, F
DWD		58.4	B, D, I
So	Soils	90.0	D, J
FI	Fire	52.2	K, L

Table 11.10 .Combined uncertainties of reported values in the KP-CRF tables

	% Uncertainty by year				
CRF table	**2008**	**2009**	**2010**	**2011**	**2012**
5(KP1)A1.1	17.32	16.80	16.38	16.28	16.11
5(KP1)A1.2	89.61	53.44	7.64	7.65	15.87
5(KP1)A2	55.78	60.14	54.93	45.05	48.82
5(KP2)5	52.20	52.20	52.20	52.20	52.20
Total	**22.50**	**20.64**	**17.88**	**18.11**	**17.08**

Uncertainties were re-evaluated for the 2008, 2009, 2010 and 2011 inventory years due to the modification to activity data and methods due to the new NFi in 2012.

11.7 Other Information for Article 3.3 Activities

The following information is provided to assist in checking for compliance under paragraphs 6 to 9 of annex to Decision 15/CMP.1. The definition of reporting boundaries and their geographical locations for afforestation and deforestation areas are reported within the entire territory of Ireland, with further sub division of species strata within internal national boundaries. Afforestation areas are tracked on a spatially explicit basis (IPCC Approach 3) while deforestation areas are identifiable but not spatially explicit (IPCC Approach 2). Both approaches can detect a land use change at a resolution consistent with the forest definition area of 0.1 ha. All afforested areas are a result of direct planting and establishing forest areas under guidelines of the Forest Service Grant and Premiums Scheme since the beginning of 1990 (Forest Service, 2003). The afforestation grant and premiums scheme was introduced under European Commission Council Regulation 2080/92 to support afforestation of agricultural land as part of accompanying measures to reform the Common Agricultural Policy. The afforestation grant and premiums dataset captures all areas afforested following successful grant application. All afforestation areas recorded by the Forest Service are verified using a strict control and referrals process, following a post establishment site visit by a forestry inspector (Forest Service 2003).

The national geographic area is the boundary for reported deforestation events. If deforestation is detected in the NFI and it has not been previously reported, the area represented by the permanent sample plot grid (400 ha or a 2 km grid) is assumed to be the representative deforested area. In these cases the uncertainty regarding the estimation of deforested areas is large (see Table 11.8 and 11.10).

The new NFI 2012 enables the detection of all deforestation events including illegal deforestation and failure to replant felled areas within 5 years. The NFI completes an inventory of all forest areas every 5 years on a rotation basis. ***If a clearfelled area has not been planted with a successive crop within one NFI cycle (i.e. 5 years), the area is classified under deforestation***. These areas are to be reported for the year deforestation is detected. Under the felling licence rules all replanted crop must be inspected after 5 years to ensure a 95 per cent survival rate. Crop is then considered to be successfully established for the next rotation.

11.8 Quality Assurance and Quality Control (QA\QC)

The same QA/QC procedures were carried out for KP LULUCF as reported for forest lands under section 7.10. The entire compilation for this submission for both LULUCF (Chapter 7) and activities under Article 3.3 of the Kyoto Protocol (Chapter 11) were reviewed externally by an independent consultant, qualified as a UNFCCC expert reviewer for LULUCF/KP-LULUCF in March 2012. This provides an important element of quality assurance for this 2014 submission. Following the findings of this independent peer review, both chapter 7 and 11 of this report have been substantially improved to provide additional transparency and consistency between Convention and KP reporting for LULUCF.

11.9 Recalculations in KP LULUCF

Numerous changes have been implemented to the KP LULUCF 2008, 2009, 2010 and 2011 inventories following comments from the UNFCCC expert reviewers, availability of new activity data and internal QA/QC checks, these include:

1) Emissions from deforested areas now include mineral soil emissions for other lands and settlements. All mineral soils in this category are assumed to lose 20% of the SOC over a 20 year. A mean SOC values for mineral soils is assumed to be 110 t C/ha based on results presented in section 11.4.1.
2) The deforested areas have been re-estimated using the latest NFI 2012. This has resulted in an increase in deforestation area in 2011 from 8.5 kHa in the previous submission, to 15.712 kHa in this submission.
3) Emissions from application of lime to deforested grasslands have been recalculated due to changes in the deforestation areas as determined using the NFI 2006 and 2012
4) The deforestation emissions from forest biomass, litter and deadwood have also been recalculated using the latest NFI information. As a result these changes, and the three points listed above, the emissions associated with deforestation for 2011 have increased from 29.76 to 332.70 Gg CO_2 eq. when the 2013 and latest submissions are compared.
5) Harvest data for AR land has been re-estimated using the latest NFI information. As a result the total harvest volume and area harvested has decreased, resulting in lower harvest losses and biomass gains in the sub-category KP.A1.2.
6) The areas under sub-category KP.A.1.1 has changed due to use of new activity data from the NFI 2006 and 2012 and the allocation of areas between sub-categories KP.A1.1, A1.2 and A.2 as a result. The total area for units of land not harvested since 1990 (KP.A.1.1) for 2011 has increased from 270kHa in the 2013 submission, compared to 282 kHa in this submission. Therefore the net sink for biomass, litter, deadwood and soils increase from 3,687 to 3,736 Gg CO_2 in this submission.

Chapter Twelve

Information on Accounting of Kyoto Units

12.1 Background Information

Ireland's Standard Electronic Format report for the 2013 reported year, which contains the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically –

SEF_IE_2014_1_16-13-40 10-1-2014.xls

The contents of the SEF report (R1) can also be found in Appendix 1 – *SIAR Supplementary Information* of this document.

12.2 Summary of Information Reported in the SEF Tables

There was 292,232,752 AAUs in Ireland's domain of the Union Registry at the end of the year 2013, of which 223,701,906 units were in the Party holding accounts; 1,810,375 units in the entity holding accounts; 735 units in the other cancellation accounts and 66,719,736 units in the retirement account.

There was 8,964,017 CERs in the registry at the end of 2013: 903,808 CERS were in the Party holding accounts; 5,277,156 CERs were held in the entity holding accounts; 2059 in the other cancellation accounts and 2,780,994 CERs were held in the retirement account.

There was 2,953,285 ERUs in the registry at the end of 2013; 1,635,668 ERUs were in the Party holding accounts; 78,734 ERUs were held on the entity holding accounts and 1,238,883 ERUs were held in the retirement account.

There was 1,051,429 t-CERs in the registry at the end of 2013; all of which were held on the entity holding accounts. The registry did not contain any RMUs or I-CERs.

There were no units in the Article 6 issuance and conversion accounts; no units in the Article 3.3 and Article 3.4 issuance or cancellation accounts and no units in the Article 12 afforestation and reforestation accounts.

The total amount of the units in the registry corresponded to 305,201,483 tonnes CO_2 eq.

Ireland's assigned amount is 314,184,272 tonnes CO_2eq.

Table 12.1. Information on the SEF tables

Annual Submission Item	Reported for 2012
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	Ireland's Standard Electronic Format report for 2013 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically. SEF_IE_2014_1_16-13-40 10-1-2014.xls The contents of the SEF report (R1) can also be found in Appendix 1 – *SIAR Supplementary Information.*

12.3 Discrepancies and notifications

There were no discrepant transactions, no CDM notifications, no non-replacements and no invalid units in 2013 (Table 12.2).

Table 12.2. Discrepancies and notifications

Annual Submission Item	Reported for 2013
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions, pursuant of 15/CMP.1 annex I.E paragraph 12, occurred in the 2013 reporting period. The contents of the report R2 can also be found in the Appendix 1 – SIAR Supplementary Information of this document. Refer to Separate Electronic Attachment "SIAR Reports 2014-IE v 1.0.xls" Worksheet R2.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications were received during the 2013 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14. The contents of the Report R3 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment "SIAR Reports 2014-IE v 1.0.xls" Worksheet R3.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred during the 2013 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15. The contents of the Report R4 can be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment "SIAR Reports 2014-IE v 1.0.xls" Worksheet R4.

Annual Submission Item	Reported for 2013
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2013, pursuant of 15/CMP.1 annex I.E paragraph 16. The contents of the Report R5 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment "SIAR Reports 2014-IE v 1.0.xls" Worksheet R5.

12.4 Publicly Accessible Information

The public has access via the registry website to information on registry account types and account holders, information regarding Article 6 projects (currently no Article 6 projects in Ireland), information on transactions and the list of account holders authorised to hold Kyoto units in their account (Table 12.3).

Table 12.3. Publicly Accessible Information

Annual Submission Item	Reported for 2013
15/CMP.1 annex I.E Publicly accessible information	There was no change regarding publicly accessible information during 2013. The following information is publicly accessible and is available via the homepage of Ireland's domain on the Union Registry – https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml See also: http://www.epa.ie/climate/emissionstrading/union%20registry/publicreports/ In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below.
	Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48) For security reasons and in accordance with Article 110.1 of the Commission Regulation No 389/2013, it is considered that the representative identification information (name, representative identifier and contact information) (required by paragraph 45) is held as confidential. For similar security reasons, it is considered that the legal entity/account holder contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report. The most up-to-date account information may be accessed from the EUTL public website: http://ec.europa.eu/environment/ets/

Table 12.3 (Continued) Publicly Accessible Information

<table>
<tr><th>Annual Submission Item</th><th>Reported in 2013</th></tr>
<tr><td></td><td>JI projects in Ireland (Paragraph 46)

Note that no Article 6 (Joint Implementation) projects are reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period. In line with the Ireland's National Climate Change Strategy 2008-2012, Ireland does not host JI projects.</td></tr>
<tr><td></td><td>Holding and transaction information of units (Paragraph 47)

Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by Commission Regulation.

Article 110.1 of the Commission Regulation No 389/2013, provides that

"Information, including the holdings of all accounts, all transactions made, the unique unit identification code of the allowances and the unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction, held in the EUTL, the Union Registry and any other KP registry shall be considered confidential except as otherwise required by Union law, or by provisions of national law that pursue a legitimate objective compatible with this Regulation and are proportionate".</td></tr>
<tr><td>15/CMP.1 annex I.E

Publicly accessible information</td><td><u>Paragraph 47c</u>
Ireland does not host JI projects in line with the National Climate Change Strategy.

<u>Paragraph 47e</u>
Ireland does not perform LULUCF activities and therefore does not issue RMUs

<u>Paragraph 47g</u>
No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date.

<u>Paragraph 47h</u>
No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date.

<u>Paragraph 47j</u>
No ERUs, CERs, AAUs and RMUs have been retired to date

<u>Paragraph 47k</u>
There is no previous commitment period to carry ERUs, CERs, and AAUs over from.</td></tr>
</table>

12.5 Calculation of the Commitment Period Reserve

The commitment period reserve (CPR) is the lower of the two values given by 90 per cent of the assigned amount and five times the estimate of total emissions in the most recently reviewed inventory. The inventory for 2011 submitted on 27 September 2013 is the most recently reviewed inventory for Ireland (FCCC/ARR/2013/IRL). The total emissions in 2011 amounted to 57,514,525 tonnes *CO_2 equivalent* and five times this estimate is 287,572,627 tonnes CO_2 equivalent. This value is greater than 90 per cent of the assigned amount (282,765,845 tonnes *CO_2 equivalent*) determined in the review of Ireland's initial report *(*FCCC/IRR/2007/IRL*)* and therefore the commitment period reserve is 282,765,845 tonnes *CO_2 equivalent*.

12.6 Accounting for Activities under Article 3.3

In the initial report under the Kyoto Protocol *(*FCCC/IRR/2007/IRL*)*, Ireland elected to account for all activities under Article 3.3 of the Kyoto Protocol on the basis of commitment period accounting. No information on the accounting of KP-LULUCF is therefore included in the SEF tables.

Chapter 13

Changes in National System

13.1 Changes in National System since previous submission

Ireland's national system is described in section 1.2 of Chapter 1. There were no changes in the institutions or resources involved in the national system during the current reporting cycle.

Chapter 14

Changes in National Registry

14.1 Introduction

The national registry of Ireland is described in the initial report under the Kyoto Protocol (FCCC/IRR/2007/IRL). Ireland's national registry was established initially for the implementation of Directive 2003/87/EC (EP and CEU, 2003) on emissions trading. The registry software was purchased from the Department of the Environment, Food and Rural Affairs in the UK and has been developed in consultation with other Member States that also purchased this software as part of the GRETA group. 2012 saw the transition from the national registry using the GRETA registry software to the Consolidated System of EU Registries (CSEUR).

The following changes to the national registry of IRELAND have occurred in 2013.

These changes are summarised in this chapter and further details are provided in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR.

14.2 Information on Changes in National Registry

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change in the name or contact information of the registry administrator occurred during the 2013 reporting period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reporting period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	An updated diagram of the database structure is attached as **Annex A** in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR. Iteration 5 of the national registry released in January 2013 and Iteration 6 of the national registry released in June 2013 introduces changes in the structure of the database. Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. However, each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see **Annex B**) in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR. Annex H testing was carried out in February 2014 and the successful test report has been attached in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR. No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
5/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change of security measures occurred during the reporting period

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	There was no change regarding publicly accessible information during 2013. The following information is publicly accessible and is available via the homepage of Ireland's domain on the Union Registry – https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml See also: http://www.epa.ie/climate/emissionstrading/union%20registry/publicreports/ In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below.
	Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48) For security reasons and in accordance with Article 110.1 of the Commission Regulation No 389/2013, it is considered that the representative identification information (name, representative identifier and contact information) (required by paragraph 45) is held as confidential. For similar security reasons, it is considered that the legal entity/account holder contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report. The most up-to-date account information may be accessed from the EUTL public website: http://ec.europa.eu/environment/ets/
	JI projects in Ireland (Paragraph 46) Note that no Article 6 (Joint Implementation) projects are reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period. In line with the Ireland's National Climate Change Strategy 2008-2012, Ireland does not host JI projects.

Reporting Item	Description
	Holding and transaction information of units (Paragraph 47) Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by Commission Regulation. Article 110.1 of the Commission Regulation No 389/2013, provides that *"Information, including the holdings of all accounts, all transactions made, the unique unit identification code of the allowances and the unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction, held in the EUTL, the Union Registry and any other KP registry shall be considered confidential except as otherwise required by Union law, or by provisions of national law that pursue a legitimate objective compatible with this Regulation and are proportionate".*
	Paragraph 47c Ireland does not host JI projects in line with the National Climate Change Strategy. Paragraph 47e Ireland does not perform LULUCF activities and therefore does not issue RMUs. Paragraph 47g No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date. Paragraph 47j No ERUs, CERs, AAUs and RMUs have been retired to date Paragraph 47k There is no previous commitment period to carry ERUs, CERs, and AAUs over from.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period. Ireland's domain of the Union Registry can be found at this link: https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as **Annex B**. Annex H testing was carried out in February 2014 and the successful test report has been attached.

In response to the previous Annual Review Recommendations, the following document was submitted as a second addendum to Chapter 14: '*Information on Changes in National Registry*' of the Annual Inventory Submission for the reporting year 2012.

Reference	Recommendation description	Response
2.3.3	The assessor recommends that following major changes, the party provide a data model which contains all DES required entities complete with descriptions in its annual NIR.	The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. Since the successful certification of the registry on 1 June 2012, Iteration 4 of the registry, introduced in October 2012, added a limited number of new entities, none of them relating to DES entities. A data model was attached which more clearly shows the relevant entities "RECONCILIATIONS", "NOTIFICATIONS", "RESPONSES"," INTERNAL AUDIT LOG" and "MESSAGE LOG." As specified in the DES (Section VII. Data Logging Specifications/E. Message Archive), a copy of messages sent and received is stored in standalone files in one of two managed servers in the hosting environment. For that reason, the Message Archive is not shown in the

		model. The "MESSAGE LOG" object holds the location of the entire message, for each Message_ID. Since the successful certification of the registry on 1 June 2012, there has been no change in the capacity of the registry or change of its infrastructure.
2.3.10	The assessor strongly recommends that the Party test each release thoroughly against the DES as part of each major release cycle and provide the results of such tests in its annual NIR.	The consolidated EU system of registries successfully completed a full certification procedure in June 2012. Notably, this procedure includes connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). This included a full Annex H test. All tests were executed successfully and led to successful certification on 1 June 2012. The October 2012 release (version 4.0) was only a minor iteration and changes were limited to EU ETS functionality and had no impact on Kyoto Protocol functions in the registry. The test script previously provided reflects this. However, each major release of the registry is subject to both regression testing and tests related to new functionality. These tests include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production.

Chapter 15

Minimisation of Adverse Impacts under Article 3.14

15.1 Introduction

Article 3.14 of the Kyoto Protocol requires that Annex I Parties shall strive to meet their commitments under Article 3.1 of the Kyoto Protocol in such a way as to minimize adverse social environmental and economic impacts on developing country Parties, particularly those Parties identified in Article 4 paragraphs 8 and 9 of the Convention. Information on how commitments under Article 3.14 are being implemented is to be prioritised under a number of actions as set down in section H of the annex to guidelines for the preparation of supplementary information required under Article 7.1 of the Kyoto Protocol (Decision 15/CMP.1). These requirements are addressed in this chapter. There has been no change to the information provided since the previous inventory submission.

15.2 Context

As a Member State of the European Union, Ireland's commitments under the Kyoto Protocol are being implemented under Decision 2005/166/EC, governing joint fulfilment under Article 4, and Decision 280/2004/EC, which covers specific emissions monitoring and reporting requirements. In this context, the minimization of adverse impacts on developing countries is also largely dictated by the European Commission's policy on climate change and by its policies and programmes affecting developing countries. Regulation at the European level also controls or influences market conditions, fiscal incentives, tax and duty exemptions and subsidies in all economic sectors in Member States.

The impact assessment of new policy initiatives has been established in the European Union, which allows their potential adverse social, environmental and economic impacts on various stakeholders, including developing country Parties, to be identified and limited at an early stage within the legislative process. Impact Assessment Guidelines specifically address impacts on third countries and also issues related to international relations. This provides a framework in which Member States like Ireland can also ensure a high level of protection of the environment and contribute to the integration of environmental considerations into the preparation and adoption of specified plans and programmes with a view to promoting sustainable development.

15.3 Specific Elements

a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities

Ireland's electricity market has been deregulated and the levy supporting the use of peat for electricity generation under a Public Service Agreement has been discontinued. Tax incentives contributed to the development of Ireland's most recent gas field off the west coast but such incentives will be severely curtailed for any similar developments in the future under new legislation. Reforms of the Common Agricultural Policy have resulted in changes to subsidies in agriculture, which are now linked to environmental, food safety and animal welfare standards. The EU Emissions Trading Scheme is a market-based emissions control measure which applies to major combustion and process emission sources of CO_2 and a carbon tax is being introduced for fossil fuel use outside the ETS.

b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies

Environmentally unsound and unsafe technologies may be regarded as technologies that would not conform to the concept of sustainable development and the objective and principles of the UNFCCC. The EC has addressed this issue by developing legislation to ensure that the price for coal produced in Member States is not lower than the price of coal of similar quality available from third countries and by phasing out subsidies on fossil fuel production and consumption by 2010. No environmentally unsound or unsafe technologies are in operation in Ireland.

c) Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end

The Irish Government is represented on the energy and environment strands of the Seventh Framework Programme (FP7) for Research and Technological Development (RTD). This representation includes the FP7 Energy Programme Committees that focuses on developing and agreeing the annual work programme and strategic vision for the FP7 Energy Work programme 2007–2013. Much of the focus of this (energy theme) initiative is on energy mitigation through supporting technological development and transfer through joint collaborations and calls with emerging economies including India, Russia and Brazil.

The International Energy Agency (IEA) is the energy forum and think-tank for 26 OECD countries. The Irish Government is a Party to four Renewable Energy Implementing Agreements of the IEA on Bioenergy, Ocean, Wind and RE Technology Deployment (RETD). Ireland provides national delegates to the executive committees of the Implementing Agreements and nominates and supports country experts to a number of tasks. The Government also sits on the Committee for Energy research and technology (CERT). Ireland is a member of the EU Expert Group on Technology, which supports the EC in climate negotiations. This expert group is focused on the transfer of technology to reduce the impacts of climate change and on supporting developing countries to this end.

d) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort

The EU collaborates with other Annex I and Non-Annex I Parties (Brazil, Saudi Arabia, China, Colombia, India, Korea, Mexico and South Africa) in the Carbon Sequestration Leadership Forum (CSLF). The CSLF is a ministerial-level international climate change initiative that is focused on the development of improved cost-effective technologies for the capture transport and long-term safe storage of CO_2. The mission of the CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles. The CSLF will also promote awareness and champion legal, regulatory, financial, and institutional environments conducive to such technologies.

Ireland began its support to the Renewable Energy and Energy Efficiency Partnership (REEEP) in 2005. Following the decision by the Irish Government in 2007 to offset all its carbon emissions from official travel, REEEP was chosen as its implementing partner. REEEP is a Public-Private partnership and was launched by the United Kingdom along with other partners at the Johannesburg World Summit on Sustainable Development in August 2002. By providing opportunities for concerted collaboration among its partners, REEEP aims to accelerate the marketplace for renewable energy and energy efficiency. Funding from Ireland is being prioritised for projects in its programme countries of Ethiopia, Lesotho, Mozambique, Tanzania, Uganda, Zambia and Malawi.

Ireland provides development assistance in line with the priorities expressed by partner countries. To date requests for assistance in the area of technology are primarily in connection with water supply, transport infrastructure and agriculture. An innovative programme in Ethiopia carries out operational participatory research with farmers, extension workers and government officials to identify, develop, and disseminate new agricultural technologies. Some of the successful technologies are based on traditional practices, for example soil conservation techniques. Other new technologies are related to new crop varieties and irrigation. In addition to ODA, private companies also provide technology and advice to developing countries, particularly in the energy sector. Due to the range of funding sources no precise figure is available for funding attributed to technology development and transfer. Ireland’s support to REEEP is worth mentioning again here as an example of Ireland’s support for technology transfer. REEEP brings the private and public sectors together to facilitate the financing, development and transfer of renewable energy technologies. Ireland believes that this type of public-private collaboration is essential for the development of appropriate and environmentally sound technologies and to facilitate their application and use in developing countries.

e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities

The EU contributes to strengthening the capacities of countries engaged in the export of fossil fuels through the work of the Energy Expert Group of the Gulf Cooperation Council (GCC), in particular under the working sub-group on energy efficiency. As part of the EU’s research programme, a project called “EUROGULF” was launched with the objective of to analyse The European Commission’s planned e-network on clean energy technologies, is aiming to promote research and technical development of clean energy technologies in the GCC countries.

Ireland currently holds the Programme Chair of Renewable Energy and Energy Efficiency Partnership, a Type 2 International NGO. The Renewable Energy and Energy Efficiency Partnership (REEEP) is a global partnership that works to reduce the barriers in policy, regulatory and financial structures that bar and limit the uptake of renewable-energy and energy-efficiency technologies and projects. This Partnership focuses on deployment of projects in sub-Saharan Africa, Asia and Latin America. Ireland is actively involved in the partnership, alongside energy-related organisations from Australia, Austria, Canada, Germany, Italy, Spain, the Netherlands, New Zealand, Norway, the UK, the USA and the European Commission.

Ireland is a founding member of the UNEP SEFI Public Finance Alliance, or ‘SEF Alliance’. This is a member-driven coalition of public and publicly backed organisations that finance sustainable-energy markets in various countries, including emerging and developing economies. . Members use the platform to exchange best practices, pool resources, launch joint projects and assist other governments in establishing new or similar financing models. The SEF Alliance is under the remit of the Sustainable Energy Finance Initiative (SEFI) of the United Nations Environment Programme (UNEP) but is governed directly by its members and pursues activities according to their interests. In 2008, the Alliance published Public Finance for Climate Change Mitigation, which provided an overview of mechanisms being used by the public sector to help scale up the climate mitigation markets, with a particular focus on the clean energy sector. In 2008, the SEF Alliance also published a Public Venture Capital Study which examined current clean-energy venture financing, focusing on the role of public sector-sponsored venture capital.

f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies

Ireland supports a range of EU activities aimed at reducing dependence on the consumption of fossil fuels, in particular those EU support programmes for the promotion of renewable energies and energy efficiency in developing countries. Renewable energy cooperation with Mediterranean and Gulf countries which led to the Mediterranean Solar Plan, endorsed in 2008 with the objective of installing 20 GW of new generation capacity in solar and other renewable energy sources around the Mediterranean Sea by 2020. Another objective is to create a sub-regional electricity market between Morocco, Tunisia and Algeria and to progressively integrate it with the electricity market of the EU. Important initiatives which target energy efficiency and renewable energy projects in South America, Africa and Asia include the Africa, Caribbean and the Pacific (ACP-E) Energy Facility, the Latin America Investment Facility (LAIF), the Euro-Solar Programme in Latin America and the Global Energy Efficiency and Renewable Energy Fund (GEEREF).

Glossary

Annex 1 Parties	Countries listed in Annex I to the United Nations Framework Convention on Climate Change
Base year	The year or period under the Kyoto Protocol on which quantified emission limitation or reduction commitments in the commitment period are based.
BOD	Biochemical Oxygen Demand
CARBWARE	A forest model to calculate carbon stock change and growth increment for Irish forests
CFCs	Chlorofluorocarbons
CH_4	Methane
CHP	Combined Heat and Power.
CMMS	Cattle Movement and Monitoring System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2 equivalent	The equivalent mass as CO_2 of other greenhouse gases converted on the basis of their global warming potential (GWP)
COFORD	National Council for Forest Research and Development
Commitment Period	The years 2008 to 2012 inclusive for which quantified emission limitation or reduction commitments are established under the Kyoto Protocol
COP	Conference of the Parties
CORINAIR	Co-ordinated Information on the environment in the European Community-AIR. CORINAIR was one of several collaborative exercises initiated under the CORINE programme to harmonise the collection and dissemination of information on the environment in the EU.
CRF	Common Reporting Format
DAF	Department of Agriculture and Food
DAFM	Department of Agriculture, Food and the Marine
DCENR	Department of Communications, Energy and Natural Resources
DEHLG	Department of Environment Heritage and Local Government
DNDC	DeNitrification-DeComposition, is a computer simulation model of carbon and nitrogen biogeochemistry in agri-ecosystems
EMEP	European Monitoring and Evaluation Programme, a co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe
Emission	(of a greenhouse gas). The release of greenhouse gases into the atmosphere.
Enteric Fermentation	The digestive process in ruminant animals (e.g cattle and sheep) where bacteria convert the feed to a usable form of energy for the animal, producing CH_4 as a by product
EUROSTAT	Statistical Agency of the European Union
FAO	Food and Agriculture Organisation of the United Nations
FFS	Farm Facilities Survey
FIPS	Forest Inventory and Planning System
Fluorinated Gases	HFCs, PFCs and SF_6
Fossil Fuel	Peat, coal, oil and natural gas and associated derivatives
FTA	Fraction of BOD in sludge that degrades anaerobically
GDP	Gross Domestic Product
Gg	Gigagram (10^9 g) = kilo tonne = 1,000 tonnes

Greenhouse Gas	A gas in the atmosphere that allows solar radiation through to the earth's surface, but traps some of the heat radiated back from the earth's surface
GWP	The cumulative warming over a specified time period, e.g. 100 years, resulting from a unit mass of a greenhouse gas emitted at the beginning of that time period, expressed relative to an absolute GWP of 1 for CO_2
HCFCs	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbons
HGV	Heavy Goods Vehicle
IEA	International Energy Agency
IEF	Implied Emission Factor
IPC	Integrated Pollution Control
IPCC	Intergovernmental Panel on Climate Change
IUCC	Information Unit on Climate Change
kt	kilo tonne (1,000 tonnes)
Kyoto Protocol	The Protocol to the UNFCCC adopted by Decision 1/CP.3 under which industrialised countries agreed to reduce their combined greenhouse gas emissions in 1990 by at least 5 per cent by the period 2008-2012
LTO	Landing and Take-off cycle
Montreal Protocol	Protocol on substances that deplete the ozone layer
Mt	million tonnes or mega tonnes
N_2O	Nitrous Oxide
NBP	Net Biome Productivity
NEE	Net Ecosystem Exchange
NIR	National Inventory Report
NMVOC	Non Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
NRA	National Roads Authority
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
PFCs	Perfluorocarbons
SBSTA	Subsidiary Body for Scientific and Technological Advice
SEAI	Sustainable Energy Authority of Ireland
SF_6	Sulphur Hexafluoride
Sink	The reservoir or pool in which sequestered carbon is stored; the process of sequestration
SO_2	Sulphur Dioxide
Teagasc	Irish Agriculture and Food Development Authority
TPER	Total Primary Energy Requirement
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compounds

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Annex A

Greenhouse Gases GWP and IPCC Reporting Format

Table A.1 Greenhouse Gases and GWP Values

Greenhouse Gas	**Chemical Formula**	**IPCC GWP (1995)[a]**
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrous Oxide	N_2O	310
Hydrofluorocarbons (HFC)		
HFC-23	CHF_3	11700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134	$C_2H_2F_4(CHF_2CHF_2)$	1000
HFC-134a	$C_2H_2F_4(CH_2FCF_3)$	1300
HFC-152a	$C_2H_4F_2(CH_3CHF_2)$	140
HFC-143	$C_2H_3F_3(CHF_2CH_2F)$	300
HFC-143a	$C_2H_3F_3(CF_3CH_3)$	3800
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-245ca	$C_3H_3F_5$	560
Perfluorocarbons(PFC)		
Perfluoromethane	CF_4	6500
Perfluoroethane	C_2F_6	9200
Perfluoropropane	C_3F_8	7000
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	c-C_4F_8	8700
Perfluoropentane	C_5F_{12}	7500
Perfluorohexane	C_6F_{14}	7400
Sulphur Hexafluoride	SF_6	23900

(a) GWP (global warming potential) as provided by the IPCC in its Second Assessment Report

Table A.2 IPCC Reporting Format (Level 1 and Level 2)

IPCC SOURCE and SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	PFC	SF6
1. Energy						
A. Fuel Combustion (Sectoral Approach)						
1. Energy Industries						
2. Manufacturing Industries and Construction						
3. Transport						
4. Other Sectors						
5. Other						
B. Fugitive Emissions from Fuels						
1. Solid Fuels						
2. Oil and Natural Gas						
2. Industrial Processes						
A. Mineral Products						
B. Chemical Industry						
C. Metal Production						
D. Other Production						
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6						
G. Other						
3. Solvent and Other Product Use						
A. Paint Application						
B. Degreasing and Dry Cleaning						
C. Chemical Products Manufacture & Processing						
D. Other						
4. Agriculture						
A. Enteric Fermentation						
B. Manure Management						
C. Rice Cultivation						
D. Agricultural Soils						
E. Prescribed Burning of Savannas						
F. Field Burning of Agricultural Residues						
G. Other						
5. Land-Use Change and Forestry						
A. Forestry						
B. Cropland						
C. Grassland						
D. Wetland						
E. Settlements						
F. Other Land						
G. Other						
6. Waste						
A. Solid Waste Disposal on Land						
B. Wastewater Handling						
C. Waste Incineration						
D. Other						
7. Other						
Memo Items:						
International Bunkers						
Multilateral Operations						
CO_2 Emissions from Biomass						

The grey cells indicate sources/sinks where no emissions/removals of the various gases are expected

Annex B

Key Category Analyses

B.1 2012 Key Category Analysis Level Assessment excluding LULUCF

B.2 2012 Key Category Analysis Level Assessment including LULUCF

B.3 2012 Key Category Analysis Trend Assessment excluding LULUCF

B.4 2012 Key Category Analysis Trend Assessment including LULUCF

Table B.1 2012 Key Category Analysis Level Assessment excluding LULUCF

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10322.82	17.64	17.64
2	1.A.1	Energy Industries - Solid Fuels	CO2	7332.86	12.53	30.16
3	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5513.55	9.42	39.58
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	4771.00	8.15	47.74
5	1.A.4.b	Residential - Liquid Fuels	CO2	2734.28	4.67	52.41
6	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2686.52	4.59	57.00
7	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2606.20	4.45	61.45
8	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2516.45	4.30	65.75
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2239.71	3.83	69.58
10	1.A.4.b	Residential - Solid Fuels	CO2	1874.34	3.20	72.78
11	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1619.42	2.77	75.54
12	1.A.4.b	Residential - Gaseous Fuels	CO2	1429.72	2.44	77.99
13	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1250.72	2.14	80.12
14	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1183.90	2.02	82.15
15	2.A.1	Cement Production	CO2	1177.02	2.01	84.16
16	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1101.99	1.88	86.04
17	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	999.40	1.71	87.75
18	2.F	Consumption of Halocarbons & SF6	HFC	982.01	1.68	89.43
19	6.A	Waste - Solid Waste Disposal on land	CH4	803.62	1.37	90.80
20	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	690.01	1.18	91.98
21	4.A.3	Enteric Fermentation - Sheep	CH4	612.22	1.05	93.02
22	4.B.1	Manure Management - Dairy Cattle	CH4	481.09	0.82	93.85
23	1.A.1	Energy Industries - Liquid Fuels	CO2	449.46	0.77	94.61
24	4.B.8	Manure Management - Pigs	CH4	408.91	0.70	95.31
25	4.B.13	Manure Management - Solid Storage	N2O	398.52	0.68	95.99
26	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	338.89	0.58	96.57
27	2.A.2	Lime Production	CO2	214.39	0.37	96.94
28	1.A.3.d	Navigation - Liquid Fuels	CO2	181.69	0.31	97.25
29	4.B.9	Manure Management - Poultry	CH4	145.52	0.25	97.50
30	6.B	Waste - Waste Water Handling	N2O	144.54	0.25	97.74
31	1.A.3.e	Other Transport - Gaseous Fuels	CO2	142.00	0.24	97.99
32	1.A.4.b	Residential - Solid Fuels	CH4	119.55	0.20	98.19
33	1.A.3.c	Rail Transport - Liquid Fuels	CO2	118.04	0.20	98.39
34	1.A.1	Energy Industries - Other Fuels	CO2	93.55	0.16	98.55
35	1.A.3.b	Road Transport - Liquid Fuels	N2O	90.76	0.16	98.71
36	1.A.1	Energy Industries - Gaseous Fuels	N2O	75.73	0.13	98.84

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
37	3	Solvent and Other Product Use	CO2	72.72	0.12	98.96
38	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	68.33	0.12	99.08
39	4.B.12	Manure Management - Liquid Systems	N2O	65.51	0.11	99.19
40	1.A.1	Energy Industries - Solid Fuels	N2O	57.90	0.10	99.29
41	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	56.96	0.10	99.39
42	4.A.6	Enteric Fermentation - Horses	CH4	42.00	0.07	99.46
43	6.C	Waste - Waste Incineration	CO2	39.26	0.07	99.52
44	2.F	Consumption of Halocarbons & SF6	SF6	39.21	0.07	99.59
45	4.A.8	Enteric Fermentation - Pigs	CH4	34.10	0.06	99.65
46	1.B.2.b	Fugitive emissions - Natural gas	CH4	23.73	0.04	99.69
47	6.B	Waste - Waste Water Handling	CH4	19.42	0.03	99.72
48	4.B.3	Manure Management - Sheep	CH4	15.60	0.03	99.75
49	1.A.3.b	Road Transport - Liquid Fuels	CH4	15.49	0.03	99.78
50	1.A.3.c	Rail Transport - Liquid Fuels	N2O	14.28	0.02	99.80
51	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	11.32	0.02	99.82
52	1.A.4.b	Residential - Solid Fuels	N2O	8.55	0.01	99.84
53	2.F	Consumption of Halocarbons & SF6	PFC	8.03	0.01	99.85
54	1.A.4.b	Residential - Liquid Fuels	CH4	7.86	0.01	99.86
55	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	7.72	0.01	99.88
56	1.A.4.b	Residential - Biomass	CH4	7.34	0.01	99.89
57	1.A.4.b	Residential - Liquid Fuels	N2O	6.87	0.01	99.90
58	1.A.1	Energy Industries - Biomass	N2O	6.25	0.01	99.91
59	1.A.4.a	Commercial/Institutional - Biomass	CH4	5.13	0.01	99.92
60	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	3.92	0.01	99.93
61	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	3.38	0.01	99.93
62	4.B.6	Manure Management - Horses	CH4	3.27	0.01	99.94
63	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	3.13	0.01	99.94
64	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	2.75	0.00	99.95
65	1.A.4.b	Residential - Gaseous Fuels	CH4	2.64	0.00	99.95
66	1.A.1	Energy Industries - Solid Fuels	CH4	2.20	0.00	99.96
67	4.A.7	Enteric Fermentation - Mules & Asses	CH4	2.06	0.00	99.96
68	1.A.1	Energy Industries - Gaseous Fuels	CH4	1.95	0.00	99.96
69	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	1.85	0.00	99.97
70	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	1.67	0.00	99.97
71	1.A.3.e	Other Transport - Gaseous Fuels	N2O	1.55	0.00	99.97
72	1.A.3.d	Navigation - Liquid Fuels	N2O	1.54	0.00	99.97
73	1.A.4.b	Residential - Biomass	N2O	1.43	0.00	99.98
74	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	1.22	0.00	99.98

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
75	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.19	0.00	99.98
76	4.A.4	Enteric Fermentation - Goats	CH4	1.08	0.00	99.98
77	1.A.1	Energy Industries - Biomass	CH4	1.04	0.00	99.98
78	1.A.4.a	Commercial/Institutional - Biomass	N2O	1.01	0.00	99.99
79	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.98	0.00	99.99
80	1.A.1	Energy Industries - Other Fuels	N2O	0.95	0.00	99.99
81	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.83	0.00	99.99
82	1.A.4.b	Residential - Gaseous Fuels	N2O	0.78	0.00	99.99
83	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	0.75	0.00	99.99
84	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.54	0.00	99.99
85	1.A.1	Energy Industries - Other Fuels	CH4	0.48	0.00	99.99
86	2.A.3	Limestone Use	CO2	0.44	0.00	100.00
87	6.C	Waste - Waste Incineration	N2O	0.41	0.00	100.00
88	1.A.3.d	Navigation - Liquid Fuels	CH4	0.36	0.00	100.00
89	1.A.1	Energy Industries - Liquid Fuels	N2O	0.33	0.00	100.00
90	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.27	0.00	100.00
91	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.26	0.00	100.00
92	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.20	0.00	100.00
93	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.18	0.00	100.00
94	4.B.7	Manure Management - Mules and Asses	CH4	0.16	0.00	100.00
95	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.14	0.00	100.00
96	1.A.1	Energy Industries - Liquid Fuels	CH4	0.13	0.00	100.00
97	2.A.4	Soda Ash Production and Use	CO2	0.09	0.00	100.00
98	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.07	0.00	100.00
99	2.A.7	Bricks & Ceramics	CO2	0.03	0.00	100.00
100	4.B.4	Manure Management - Goats	CH4	0.03	0.00	100.00
101	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.01	0.00	100.00
102	6.C	Waste - Waste Incineration	CH4	0.00	0.00	100.00
103	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	0.00	0.00	100.00
104	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.00	0.00	100.00
105	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.00	0.00	100.00
106	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	100.00
107	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	100.00
108	2.A.7	Glass Production	CO2	0.00	0.00	100.00
109	2.B	Chemical Industry	N2O	0.00	0.00	100.00
110	2.B	Chemical Industry	CO2	0.00	0.00	100.00

Table B.2 2012 Key Category Analysis Level Assessment including LULUCF

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10322.82	16.18	16.18
2	1.A.1	Energy Industries - Solid Fuels	CO2	7332.86	11.49	27.67
3	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5513.55	8.64	36.31
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	4771.00	7.48	43.78
5	5.A.2	LULUCF - Land converted to Forest Land	CO2	3847.33	6.03	49.81
6	1.A.4.b	Residential - Liquid Fuels	CO2	2734.28	4.28	54.10
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2686.52	4.21	58.31
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2606.20	4.08	62.39
9	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2516.45	3.94	66.34
10	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2239.71	3.51	69.85
11	1.A.4.b	Residential - Solid Fuels	CO2	1874.34	2.94	72.78
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1619.42	2.54	75.32
13	1.A.4.b	Residential - Gaseous Fuels	CO2	1429.72	2.24	77.56
14	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1250.72	1.96	79.52
15	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1183.90	1.86	81.38
16	2.A.1	Cement Production	CO2	1177.02	1.84	83.22
17	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1101.99	1.73	84.95
18	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	999.40	1.57	86.51
19	2.F	Consumption of Halocarbons & SF6	HFC	982.01	1.54	88.05
20	6.A	Waste - Solid Waste Disposal on land	CH4	803.62	1.26	89.31
21	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	690.01	1.08	90.39
22	4.A.3	Enteric Fermentation - Sheep	CH4	612.22	0.96	91.35
23	4.B.1	Manure Management - Dairy Cattle	CH4	481.09	0.75	92.11
24	1.A.1	Energy Industries - Liquid Fuels	CO2	449.46	0.70	92.81
25	4.B.8	Manure Management - Pigs	CH4	408.91	0.64	93.45
26	4.B.13	Manure Management - Solid Storage	N2O	398.52	0.62	94.08
27	5.B.2	LULUCF - Land converted to Cropland	CO2	377.75	0.59	94.67
28	5.C.2	LULUCF - Land converted to Grassland	CO2	354.97	0.56	95.23
29	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	338.89	0.53	95.76
30	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	302.80	0.47	96.23
31	5.E.2	LULUCF - Land converted to Settlements	CO2	256.47	0.40	96.63
32	2.A.2	Lime Production	CO2	214.39	0.34	96.97
33	1.A.3.d	Navigation - Liquid Fuels	CO2	181.69	0.28	97.25
34	4.B.9	Manure Management - Poultry	CH4	145.52	0.23	97.48
35	6.B	Waste - Waste Water Handling	N2O	144.54	0.23	97.71
36	1.A.3.e	Other Transport - Gaseous Fuels	CO2	142.00	0.22	97.93

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
37	1.A.4.b	Residential - Solid Fuels	CH4	119.55	0.19	98.12
38	1.A.3.c	Rail Transport - Liquid Fuels	CO2	118.04	0.18	98.30
39	1.A.1	Energy Industries - Other Fuels	CO2	93.55	0.15	98.45
40	1.A.3.b	Road Transport - Liquid Fuels	N2O	90.76	0.14	98.59
41	1.A.1	Energy Industries - Gaseous Fuels	N2O	75.73	0.12	98.71
42	3	Solvent and Other Product Use	CO2	72.72	0.11	98.82
43	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	68.33	0.11	98.93
44	4.B.12	Manure Management - Liquid Systems	N2O	65.51	0.10	99.03
45	1.A.1	Energy Industries - Solid Fuels	N2O	57.90	0.09	99.12
46	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	56.96	0.09	99.21
47	4.A.6	Enteric Fermentation - Horses	CH4	42.00	0.07	99.28
48	6.C	Waste - Waste Incineration	CO2	39.26	0.06	99.34
49	2.F	Consumption of Halocarbons & SF6	SF6	39.21	0.06	99.40
50	5.A.1	LULUCF - Forest land Remaining Forest Land	N2O	38.57	0.06	99.46
51	5.B.2	LULUCF - Land converted to Cropland	N2O	35.07	0.05	99.52
52	5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	34.14	0.05	99.57
53	4.A.8	Enteric Fermentation - Pigs	CH4	34.10	0.05	99.63
54	1.B.2.b	Fugitive emissions - Natural gas	CH4	23.73	0.04	99.66
55	6.B	Waste - Waste Water Handling	CH4	19.42	0.03	99.69
56	4.B.3	Manure Management - Sheep	CH4	15.60	0.02	99.72
57	1.A.3.b	Road Transport - Liquid Fuels	CH4	15.49	0.02	99.74
58	1.A.3.c	Rail Transport - Liquid Fuels	N2O	14.28	0.02	99.76
59	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	11.32	0.02	99.78
60	5.B.1	LULUCF - Cropland remaining Cropland	CO2	9.60	0.02	99.80
61	5.F.2	LULUCF - Land Converted to Other Land	CO2	9.32	0.01	99.81
62	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	9.02	0.01	99.83
63	1.A.4.b	Residential - Solid Fuels	N2O	8.55	0.01	99.84
64	2.F	Consumption of Halocarbons & SF6	PFC	8.03	0.01	99.85
65	1.A.4.b	Residential - Liquid Fuels	CH4	7.86	0.01	99.86
66	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	7.72	0.01	99.88
67	1.A.4.b	Residential - Biomass	CH4	7.34	0.01	99.89
68	1.A.4.b	Residential - Liquid Fuels	N2O	6.87	0.01	99.90
69	1.A.1	Energy Industries - Biomass	N2O	6.25	0.01	99.91
70	1.A.4.a	Commercial/Institutional - Biomass	CH4	5.13	0.01	99.92
71	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	3.92	0.01	99.92
72	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	3.38	0.01	99.93
73	4.B.6	Manure Management - Horses	CH4	3.27	0.01	99.93
74	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	3.13	0.00	99.94

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
75	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	2.75	0.00	99.94
76	1.A.4.b	Residential - Gaseous Fuels	CH4	2.64	0.00	99.95
77	5.D.2	LULUCF - Land Converted to Wetlands	N2O	2.54	0.00	99.95
78	1.A.1	Energy Industries - Solid Fuels	CH4	2.20	0.00	99.95
79	4.A.7	Enteric Fermentation - Mules & Asses	CH4	2.06	0.00	99.96
80	1.A.1	Energy Industries - Gaseous Fuels	CH4	1.95	0.00	99.96
81	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	1.85	0.00	99.96
82	5.D.2	LULUCF - Land Converted to Wetlands	CO2	1.76	0.00	99.97
83	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	1.67	0.00	99.97
84	1.A.3.e	Other Transport - Gaseous Fuels	N2O	1.55	0.00	99.97
85	1.A.3.d	Navigation - Liquid Fuels	N2O	1.54	0.00	99.97
86	1.A.4.b	Residential - Biomass	N2O	1.43	0.00	99.98
87	5.A.1	LULUCF - Forest land Remaining Forest Land	CH4	1.43	0.00	99.98
88	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	1.22	0.00	99.98
89	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.19	0.00	99.98
90	4.A.4	Enteric Fermentation - Goats	CH4	1.08	0.00	99.98
91	1.A.1	Energy Industries - Biomass	CH4	1.04	0.00	99.98
92	1.A.4.a	Commercial/Institutional - Biomass	N2O	1.01	0.00	99.99
93	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.98	0.00	99.99
94	1.A.1	Energy Industries - Other Fuels	N2O	0.95	0.00	99.99
95	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.83	0.00	99.99
96	1.A.4.b	Residential - Gaseous Fuels	N2O	0.78	0.00	99.99
97	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	0.75	0.00	99.99
98	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.54	0.00	99.99
99	5.A.2	LULUCF - Land converted to Forest Land	CH4	0.49	0.00	99.99
100	1.A.1	Energy Industries - Other Fuels	CH4	0.48	0.00	100.00
101	2.A.3	Limestone Use	CO2	0.44	0.00	100.00
102	6.C	Waste - Waste Incineration	N2O	0.41	0.00	100.00
103	1.A.3.d	Navigation - Liquid Fuels	CH4	0.36	0.00	100.00
104	1.A.1	Energy Industries - Liquid Fuels	N2O	0.33	0.00	100.00
105	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.27	0.00	100.00
106	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.26	0.00	100.00
107	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.20	0.00	100.00
108	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.18	0.00	100.00
109	4.B.7	Manure Management - Mules and Asses	CH4	0.16	0.00	100.00
110	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.14	0.00	100.00
111	1.A.1	Energy Industries - Liquid Fuels	CH4	0.13	0.00	100.00
112	2.A.4	Soda Ash Production and Use	CO2	0.09	0.00	100.00

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2012 Level assessment %	Cumulative Total %
113	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.07	0.00	100.00
114	5.A.2	LULUCF - Land converted to Forest Land	N2O	0.04	0.00	100.00
115	2.A.7	Bricks & Ceramics	CO2	0.03	0.00	100.00
116	4.B.4	Manure Management - Goats	CH4	0.03	0.00	100.00
117	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.01	0.00	100.00
118	6.C	Waste - Waste Incineration	CH4	0.00	0.00	100.00
119	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	0.00	0.00	100.00
120	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.00	0.00	100.00
121	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.00	0.00	100.00
122	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	100.00
123	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	100.00
124	2.A.7	Glass Production	CO2	0.00	0.00	100.00
125	2.B	Chemical Industry	N2O	0.00	0.00	100.00
126	2.B	Chemical Industry	CO2	0.00	0.00	100.00

Table B.3 2012 Key Category Analysis Trend Assessment excluding LULUCF

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4690.42	10322.82	17.64	19.78	19.78
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	1874.34	3.20	15.02	34.80
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	1880.66	4771.00	8.15	10.27	45.07
4	1.A.4.b	Residential - Liquid Fuels	CO2	1175.35	2734.28	4.67	5.50	50.57
5	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2239.71	3.83	4.86	55.43
6	1.A.1	Energy Industries - Solid Fuels	CO2	8009.44	7332.86	12.53	4.26	59.69
7	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1429.72	2.44	4.23	63.91
8	2.F	Consumption of Halocarbons & SF6	HFC	0.47	982.01	1.68	3.63	67.54
9	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1957.00	1101.99	1.88	3.59	71.13
10	1.A.1	Energy Industries - Liquid Fuels	CO2	1268.51	449.46	0.77	3.30	74.43
11	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	999.40	1.71	2.82	77.25
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.38	1619.42	2.77	2.62	79.87
13	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3021.84	2516.45	4.30	2.53	82.40
14	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	338.89	0.58	2.16	84.56
15	4.A.3	Enteric Fermentation - Sheep	CH4	1032.48	612.22	1.05	1.78	86.34
16	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5630.17	5513.55	9.42	1.67	88.01
17	6.A	Waste - Solid Waste Disposal on land	CH4	1173.05	803.62	1.37	1.62	89.63
18	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2854.99	2606.20	4.45	1.55	91.18
19	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2868.35	2686.52	4.59	1.30	92.48
20	1.A.4.b	Residential - Solid Fuels	CH4	356.29	119.55	0.20	0.95	93.43
21	2.A.1	Cement Production	CO2	884.00	1177.02	2.01	0.89	94.32
22	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1381.01	1250.72	2.14	0.78	95.11
23	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1279.75	1183.90	2.02	0.64	95.74
24	4.B.1	Manure Management - Dairy Cattle	CH4	608.23	481.09	0.82	0.60	96.34
25	1.B.2.b	Fugitive emissions - Natural gas	CH4	131.08	23.73	0.04	0.43	96.77
26	1.A.1	Energy Industries - Other Fuels	CO2	0.00	93.55	0.16	0.35	97.12
27	1.A.3.d	Navigation - Liquid Fuels	CO2	84.90	181.69	0.31	0.34	97.45
28	1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	142.00	0.24	0.28	97.74
29	1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	75.73	0.13	0.24	97.97
30	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	0.00	56.96	0.10	0.21	98.19
31	4.B.8	Manure Management - Pigs	CH4	332.33	408.91	0.70	0.21	98.40
32	6.C	Waste - Waste Incineration	CO2	82.97	39.26	0.07	0.18	98.57
33	1.A.3.b	Road Transport - Liquid Fuels	N2O	44.39	90.76	0.16	0.16	98.74
34	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	51.13	11.32	0.02	0.16	98.89
35	4.B.9	Manure Management - Poultry	CH4	105.20	145.52	0.25	0.13	99.02
36	6.B	Waste - Waste Water Handling	N2O	111.71	144.54	0.25	0.10	99.12

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
37	1.A.3.b	Road Transport - Liquid Fuels	CH4	36.82	15.49	0.03	0.09	99.20
38	1.A.3.c	Rail Transport - Liquid Fuels	CO2	133.19	118.04	0.20	0.09	99.29
39	1.A.4.b	Residential - Solid Fuels	N2O	25.36	8.55	0.01	0.07	99.36
40	4.A.6	Enteric Fermentation - Horses	CH4	23.28	42.00	0.07	0.06	99.42
41	2.A.2	Lime Production	CO2	214.08	214.39	0.37	0.05	99.47
42	4.B.3	Manure Management - Sheep	CH4	26.13	15.60	0.03	0.04	99.51
43	3	Solvent and Other Product Use	CO2	80.03	72.72	0.12	0.04	99.56
44	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	690.01	1.18	0.04	99.59
45	1.A.1	Energy Industries - Solid Fuels	N2O	62.22	57.90	0.10	0.03	99.62
46	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	68.33	0.12	0.03	99.65
47	2.F	Consumption of Halocarbons & SF6	PFC	0.09	8.03	0.01	0.03	99.68
48	1.A.1	Energy Industries - Biomass	N2O	0.00	6.25	0.01	0.02	99.70
49	2.A.7	Bricks & Ceramics	CO2	5.07	0.03	0.00	0.02	99.72
50	4.B.13	Manure Management - Solid Storage	N2O	371.24	398.52	0.68	0.02	99.74
51	1.A.4.b	Residential - Biomass	CH4	11.83	7.34	0.01	0.02	99.76
52	1.A.4.a	Commercial/Institutional - Biomass	CH4	0.00	5.13	0.01	0.02	99.78
53	1.A.4.b	Residential - Liquid Fuels	CH4	3.12	7.86	0.01	0.02	99.80
54	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	3.16	7.72	0.01	0.02	99.81
55	1.A.4.b	Residential - Liquid Fuels	N2O	2.58	6.87	0.01	0.02	99.83
56	6.B	Waste - Waste Water Handling	CH4	14.68	19.42	0.03	0.01	99.84
57	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	4.28	1.67	0.00	0.01	99.85
58	1.A.3.c	Rail Transport - Liquid Fuels	N2O	16.11	14.28	0.02	0.01	99.86
59	4.A.8	Enteric Fermentation - Pigs	CH4	29.61	34.10	0.06	0.01	99.87
60	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	5.53	3.13	0.01	0.01	99.88
61	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	4.87	2.75	0.00	0.01	99.89
62	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	1.61	3.92	0.01	0.01	99.90
63	4.B.12	Manure Management - Liquid Systems	N2O	63.87	65.51	0.11	0.01	99.91
64	1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.64	0.00	0.01	99.92
65	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	5.02	3.38	0.01	0.01	99.92
66	2.F	Consumption of Halocarbons & SF6	SF6	35.51	39.21	0.07	0.01	99.93
67	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	0.43	1.85	0.00	0.01	99.94
68	4.B.6	Manure Management - Horses	CH4	1.81	3.27	0.01	0.00	99.94
69	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	1.93	0.75	0.00	0.00	99.94
70	1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	0.00	0.00	99.95
71	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	1.95	0.00	0.00	99.95
72	1.A.1	Energy Industries - Biomass	CH4	0.00	1.04	0.00	0.00	99.96
73	1.A.4.b	Residential - Biomass	N2O	2.32	1.43	0.00	0.00	99.96

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
74	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.00	1.01	0.00	0.00	99.96
75	1.A.1	Energy Industries - Other Fuels	N2O	0.00	0.95	0.00	0.00	99.97
76	4.A.4	Enteric Fermentation - Goats	CH4	1.83	1.08	0.00	0.00	99.97
77	1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.55	0.00	0.00	99.97
78	1.A.3.d	Navigation - Liquid Fuels	N2O	0.70	1.54	0.00	0.00	99.98
79	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	0.49	1.22	0.00	0.00	99.98
80	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.73	1.19	0.00	0.00	99.98
81	1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.78	0.00	0.00	99.98
82	6.C	Waste - Waste Incineration	N2O	0.86	0.41	0.00	0.00	99.99
83	1.A.1	Energy Industries - Other Fuels	CH4	0.00	0.48	0.00	0.00	99.99
84	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.33	0.83	0.00	0.00	99.99
85	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.58	0.18	0.00	0.00	99.99
86	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.13	0.54	0.00	0.00	99.99
87	1.A.1	Energy Industries - Solid Fuels	CH4	2.36	2.20	0.00	0.00	99.99
88	2.A.3	Limestone Use	CO2	0.15	0.44	0.00	0.00	100.00
89	1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.13	0.00	0.00	100.00
90	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.74	2.06	0.00	0.00	100.00
91	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.00	0.20	0.00	0.00	100.00
92	1.A.3.d	Navigation - Liquid Fuels	CH4	0.17	0.36	0.00	0.00	100.00
93	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.26	0.00	0.00	100.00
94	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.18	0.27	0.00	0.00	100.00
95	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.00	0.07	0.00	0.00	100.00
96	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	0.98	0.00	0.00	100.00
97	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.16	0.14	0.00	0.00	100.00
98	4.B.4	Manure Management - Goats	CH4	0.04	0.03	0.00	0.00	100.00
99	4.B.7	Manure Management - Mules and Asses	CH4	0.13	0.16	0.00	0.00	100.00
100	2.A.4	Soda Ash Production and Use	CO2	0.10	0.09	0.00	0.00	100.00
101	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.02	0.01	0.00	0.00	100.00
102	6.C	Waste - Waste Incineration	CH4	0.01	0.00	0.00	0.00	100.00
103	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	138.29	0.00	0.00	0.00	100.00
104	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.29	0.00	0.00	0.00	100.00
105	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.59	0.00	0.00	0.00	100.00
106	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	0.00	0.00	100.00
107	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	0.00	0.00	100.00
108	2.A.7	Glass Production	CO2	13.33	0.00	0.00	0.00	100.00
109	2.B	Chemical Industry	N2O	1035.40	0.00	0.00	0.00	100.00
110	2.B	Chemical Industry	CO2	990.23	0.00	0.00	0.00	100.00

Table B.4 2012 Key Category Analysis Trend Assessment including LULUCF

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4690.42	10322.82	16.18	14.03	14.03
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	1874.34	2.94	11.16	25.19
3	5.A.2	LULUCF - Land converted to Forest Land	CO2	17.64	3847.33	6.03	10.22	35.41
4	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	3007.68	9.02	0.01	8.65	44.06
5	1.A.1	Energy Industries - Gaseous Fuels	CO2	1880.66	4771.00	7.48	7.31	51.37
6	1.A.4.b	Residential - Liquid Fuels	CO2	1175.35	2734.28	4.28	3.91	55.28
7	1.A.1	Energy Industries - Solid Fuels	CO2	8009.44	7332.86	11.49	3.52	58.80
8	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2239.71	3.51	3.46	62.26
9	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1429.72	2.24	3.04	65.30
10	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1957.00	1101.99	1.73	2.70	68.00
11	5.E.2	LULUCF - Land converted to Settlements	CO2	1173.05	256.47	0.40	2.70	70.70
12	2.F	Consumption of Halocarbons & SF6	HFC	0.47	982.01	1.54	2.62	73.32
13	1.A.1	Energy Industries - Liquid Fuels	CO2	1268.51	449.46	0.70	2.46	75.77
14	6.A	Waste - Solid Waste Disposal on land	CH4	14.68	803.62	1.26	2.10	77.88
15	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	999.40	1.57	2.02	79.90
16	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.38	1619.42	2.54	2.02	81.91
17	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3021.84	2516.45	3.94	2.00	83.91
18	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	338.89	0.53	1.61	85.52
19	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5630.17	5513.55	8.64	1.52	87.03
20	4.A.3	Enteric Fermentation - Sheep	CH4	1032.48	612.22	0.96	1.34	88.38
21	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2854.99	2606.20	4.08	1.27	89.65
22	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2868.35	2686.52	4.21	1.10	90.75
23	5.C.2	LULUCF - Land converted to Grassland	CO2	0.00	354.97	0.56	0.95	91.70
24	5.B.2	LULUCF - Land converted to Cropland	CO2	600.29	377.75	0.59	0.72	92.42
25	1.A.4.b	Residential - Solid Fuels	CH4	356.29	119.55	0.19	0.71	93.13
26	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	47.10	302.80	0.47	0.67	93.80
27	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1381.01	1250.72	1.96	0.64	94.44
28	2.A.1	Cement Production	CO2	884.00	1177.02	1.84	0.59	95.04
29	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1279.75	1183.90	1.86	0.53	95.56
30	4.B.1	Manure Management - Dairy Cattle	CH4	608.23	481.09	0.75	0.47	96.03
31	6.B	Waste - Waste Water Handling	N2O	0.00	144.54	0.23	0.39	96.42
32	1.B.2.b	Fugitive emissions - Natural gas	CH4	131.08	23.73	0.04	0.31	96.73
33	5.F.2	LULUCF - Land Converted to Other Land	CO2	111.71	9.32	0.01	0.30	97.03
34	1.A.1	Energy Industries - Other Fuels	CO2	0.00	93.55	0.15	0.25	97.28
35	1.A.3.d	Navigation - Liquid Fuels	CO2	84.90	181.69	0.28	0.24	97.52

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
36	5.D.2	LULUCF - Land Converted to Wetlands	CO2	77.94	1.76	0.00	0.22	97.74
37	5.B.2	LULUCF - Land converted to Cropland	N2O	106.41	35.07	0.05	0.21	97.95
38	1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	142.00	0.22	0.20	98.16
39	1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	75.73	0.12	0.17	98.33
40	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	0.00	56.96	0.09	0.15	98.48
41	4.B.8	Manure Management - Pigs	CH4	332.33	408.91	0.64	0.13	98.61
42	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	51.13	11.32	0.02	0.12	98.73
43	1.A.3.b	Road Transport - Liquid Fuels	N2O	44.39	90.76	0.14	0.11	98.84
44	6.C	Waste - Waste Incineration	CO2	0.00	39.26	0.06	0.10	98.95
45	4.B.9	Manure Management - Poultry	CH4	105.20	145.52	0.23	0.09	99.03
46	5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	3.59	34.14	0.05	0.08	99.11
47	1.A.3.c	Rail Transport - Liquid Fuels	CO2	133.19	118.04	0.18	0.07	99.18
48	1.A.3.b	Road Transport - Liquid Fuels	CH4	36.82	15.49	0.02	0.06	99.25
49	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	690.01	1.08	0.06	99.31
50	5.A.2	LULUCF - Land converted to Forest Land	CH4	20.00	0.49	0.00	0.06	99.37
51	6.B	Waste - Waste Water Handling	CH4	0.00	19.42	0.03	0.05	99.42
52	1.A.4.b	Residential - Solid Fuels	N2O	25.36	8.55	0.01	0.05	99.47
53	4.A.6	Enteric Fermentation - Horses	CH4	23.28	42.00	0.07	0.04	99.51
54	2.A.2	Lime Production	CO2	214.08	214.39	0.34	0.04	99.56
55	3	Solvent and Other Product Use	CO2	80.03	72.72	0.11	0.04	99.59
56	4.B.3	Manure Management - Sheep	CH4	26.13	15.60	0.02	0.03	99.63
57	5.A.1	LULUCF - Forest land Remaining Forest Land	N2O	24.78	38.57	0.06	0.03	99.66
58	5.B.1	LULUCF - Cropland remaining Cropland	CO2	0.00	9.60	0.02	0.03	99.69
59	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	68.33	0.11	0.03	99.71
60	1.A.1	Energy Industries - Solid Fuels	N2O	62.22	57.90	0.09	0.02	99.74
61	5.A.1	LULUCF - Forest land Remaining Forest Land	CH4	9.29	1.43	0.00	0.02	99.76
62	2.F	Consumption of Halocarbons & SF6	PFC	0.09	8.03	0.01	0.02	99.78
63	1.A.1	Energy Industries - Biomass	N2O	0.00	6.25	0.01	0.02	99.80
64	2.A.7	Bricks & Ceramics	CO2	5.07	0.03	0.00	0.01	99.81
65	1.A.4.b	Residential - Biomass	CH4	11.83	7.34	0.01	0.01	99.83
66	1.A.4.a	Commercial/Institutional - Biomass	CH4	0.00	5.13	0.01	0.01	99.84
67	1.A.4.b	Residential - Liquid Fuels	CH4	3.12	7.86	0.01	0.01	99.85
68	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	3.16	7.72	0.01	0.01	99.86
69	1.A.4.b	Residential - Liquid Fuels	N2O	2.58	6.87	0.01	0.01	99.87
70	4.B.12	Manure Management - Liquid Systems	N2O	63.87	65.51	0.10	0.01	99.88
71	1.A.3.c	Rail Transport - Liquid Fuels	N2O	16.11	14.28	0.02	0.01	99.89
72	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	4.28	1.67	0.00	0.01	99.90

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
73	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	5.53	3.13	0.00	0.01	99.91
74	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	4.87	2.75	0.00	0.01	99.91
75	4.B.13	Manure Management - Solid Storage	N2O	371.24	398.52	0.62	0.01	99.92
76	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	1.61	3.92	0.01	0.01	99.93
77	4.A.8	Enteric Fermentation - Pigs	CH4	29.61	34.10	0.05	0.01	99.93
78	1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.64	0.00	0.01	99.94
79	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	5.02	3.38	0.01	0.01	99.94
80	5.D.2	LULUCF - Land Converted to Wetlands	N2O	0.89	2.54	0.00	0.00	99.95
81	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	0.43	1.85	0.00	0.00	99.95
82	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	1.93	0.75	0.00	0.00	99.95
83	1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	0.00	0.00	99.96
84	4.B.6	Manure Management - Horses	CH4	1.81	3.27	0.01	0.00	99.96
85	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	1.95	0.00	0.00	99.96
86	1.A.4.b	Residential - Biomass	N2O	2.32	1.43	0.00	0.00	99.97
87	1.A.1	Energy Industries - Biomass	CH4	0.00	1.04	0.00	0.00	99.97
88	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.00	1.01	0.00	0.00	99.97
89	1.A.1	Energy Industries - Other Fuels	N2O	0.00	0.95	0.00	0.00	99.98
90	4.A.4	Enteric Fermentation - Goats	CH4	1.83	1.08	0.00	0.00	99.98
91	2.F	Consumption of Halocarbons & SF6	SF6	35.51	39.21	0.06	0.00	99.98
92	1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.55	0.00	0.00	99.98
93	1.A.3.d	Navigation - Liquid Fuels	N2O	0.70	1.54	0.00	0.00	99.98
94	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	0.49	1.22	0.00	0.00	99.99
95	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.73	1.19	0.00	0.00	99.99
96	1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.78	0.00	0.00	99.99
97	1.A.1	Energy Industries - Other Fuels	CH4	0.00	0.48	0.00	0.00	99.99
98	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.33	0.83	0.00	0.00	99.99
99	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.58	0.18	0.00	0.00	99.99
100	6.C	Waste - Waste Incineration	N2O	0.00	0.41	0.00	0.00	99.99
101	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.13	0.54	0.00	0.00	100.00
102	1.A.1	Energy Industries - Solid Fuels	CH4	2.36	2.20	0.00	0.00	100.00
103	2.A.3	Limestone Use	CO2	0.15	0.44	0.00	0.00	100.00
104	1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.13	0.00	0.00	100.00
105	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.00	0.20	0.00	0.00	100.00
106	1.A.3.d	Navigation - Liquid Fuels	CH4	0.17	0.36	0.00	0.00	100.00
107	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.74	2.06	0.00	0.00	100.00
108	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.26	0.00	0.00	100.00
109	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.18	0.27	0.00	0.00	100.00

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2012 Emissions (Gg CO2eq)	2012 Level assessment (%)	2012 Trend assessment (%)	Cumulative Total (%)
110	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.00	0.07	0.00	0.00	100.00
111	5.A.2	LULUCF - Land converted to Forest Land	N2O	0.00	0.04	0.00	0.00	100.00
112	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.16	0.14	0.00	0.00	100.00
113	4.B.4	Manure Management - Goats	CH4	0.04	0.03	0.00	0.00	100.00
114	2.A.4	Soda Ash Production and Use	CO2	0.10	0.09	0.00	0.00	100.00
115	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.02	0.01	0.00	0.00	100.00
116	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	0.98	0.00	0.00	100.00
117	4.B.7	Manure Management - Mules and Asses	CH4	0.13	0.16	0.00	0.00	100.00
118	6.C	Waste - Waste Incineration	CH4	0.00	0.00	0.00	0.00	100.00
119	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	138.29	0.00	0.00	0.00	100.00
120	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.29	0.00	0.00	0.00	100.00
121	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.59	0.00	0.00	0.00	100.00
122	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	0.00	0.00	100.00
123	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	0.00	0.00	100.00
124	2.A.7	Glass Production	CO2	13.33	0.00	0.00	0.00	100.00
125	2.B	Chemical Industry	N2O	1035.40	0.00	0.00	0.00	100.00
126	2.B	Chemical Industry	CO2	990.23	0.00	0.00	0.00	100.00

Annex C

Ireland’s Energy Balance 1990-2012

C.1 Ireland’s Energy Balance - Stakeholders, Surveys and Sources

C.2 Expanded Energy Balance sheets for 2012

C.3 Country specific carbon emission factors – fossil fuels

Sustainable Energy Authority of Ireland (SEAI)

The Sustainable Energy Authority of Ireland was established as Ireland's national energy authority under the Sustainable Energy Act 2002. SEAI's mission is to play a leading role in transforming Ireland into a society based on sustainable energy structures, technologies and practices. To fulfil this mission SEAI aims to provide well-timed and informed advice to Government, and deliver a range of programmes efficiently and effectively, while engaging and motivating a wide range of stakeholders and showing continuing flexibility and innovation in all activities.

SEAI has a lead role in developing and maintaining comprehensive national and sectoral statistics for energy production, transformation and end use. This data is a vital input in meeting international reporting obligations, for advising policy makers and informing investment decisions. The Energy Policy Statistical Support Unit (EPSSU) is SEAI's specialist statistics team.

Its core functions are to:

- Collect, process and publish energy statistics to support policy analysis and development in line with national needs and international obligations;
- Conduct statistical and economic analyses of energy services sectors and sustainable energy options;
- Contribute to the development and promulgation of appropriate sustainability indicators.

National Legislation

- Sustainable Energy Act 2002.
  http://www.irishstatutebook.ie/pdf/2002/en.act.2002.0002.pdf

- European Communities (Energy End-use Efficiency and Energy Services) Regulations 2009, (S.I. No. 542 of 2009).
  http://www.irishstatutebook.ie/pdf/2009/en.si.2009.0542.pdf

- Sulphur Content of Heavy Fuel, Gas Oil, and Marine Fuel Regulations 2008, (S.I. 119 of 2008). http://www.irishstatutebook.ie/pdf/2008/en.si.2008.0119.pdf

EU Legislative Requirements

- Under the European Energy Statistics Regulation of 2008, no.1099, Ireland is legally obliged to submit energy statistics to Eurostat. The Regulation came into force on 1 January 2009 and SEAI are collecting data on behalf of Ireland from this date. SEAI submit annual and monthly energy statistics to Eurostat on energy supply, transformation and end-use for solid fuels, natural gas, electricity & heat and renewables & wastes (Oil statistics are supplied by DCENR). This data is also used for Ireland's Energy Balance.
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1099:EN:NOT

- Information regarding gas and electricity prices is sent to Eurostat twice a year under the EU Gas and Electricity Price Transparency Directive 90/377/EEC. http://europa.eu/legislation_summaries/other/l27002_en.htm

Department of Communications, Energy and Natural Resources (DCENR) - Oil Security Division

The Oil Security Division of the Department of Communications, Energy and Natural Resources is responsible for the development and implementation of Ireland's strategic oil supply policy, with particular regard to the areas of contingency planning and Ireland's obligations under the EU and International Energy Agency (IEA), in order to ensure an effective system of security of supply at times of physical oil supply disruption.

The National Oil Reserves Agency (NORA) is responsible for holding Ireland's strategic oil stocks for use in the event of a supply disruption. NORA is funded by a levy on disposals of petroleum products currently 2 cents per litre.

Oil Security Division collects monthly returns from oil companies and consumers on disposals of petroleum products and calculates the levy liability of each company. This is done under the NORA Act 2007 and associated returns and levy Regulations. A full list of legislation is available on the NORA website at www.nora.ie

Oil Security Division also provides Monthly Oil Statistics to the IEA and Eurostat.

National Legislation

- National Oil Reserves Agency Act 2007.
  http://www.oireachtas.ie/documents/bills28/acts/2007/a707.pdf
- National Oil Reserves Agency Act 2007 (Returns and ?Levy) Regulations 2007
  http://www.irishstatutebook.ie/pdf/2007/en.si.2007.0567.pdf
- National Oil Reserves Agency Levy Amendments Regulation 2009
  http://www.irishstatutebook.ie/pdf/2009/en.si.2009.0220.pdf

EU Legislative Requirements

- EU Council Directive 2009/119/EC of 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products.
  http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:265:0009:0023:EN:PDF

- European Union (Oil Reserves) Regulations 2012, transposes the 2009 EU Directive into Irish Law, SI 541 of 2012.
  http://www.irishstatutebook.ie/pdf/2012/en.si.2012.0541.pdf

Solid Fuels & Petroleum Coke

Fuels

- Bituminous Coal
- Anthracite
- Manufactured Ovoids
- Lignite
- Milled & Sod Peat
- Peat Briquettes
- Petroleum Coke

Frequency

Monthly solid fuel survey

Annual CHP Survey

Data Sources

This data collection is a monthly survey of solid fuel imports and producers to obtain solid fuel statistics as required under the European Energy Statistics Regulation of 2008, no.1099. This data is aggregated for the annual Energy Balance.

In the Energy Balance, anthracite and manufactured ovoids are combined to protect confidentiality.

Estimations

Smaller solid fuel distributors are not surveyed. To cover these smaller units, a technique was developed in 2009 to estimate the total data for the smaller units. The estimation method used data from Ireland's National Statistical Institute (CSO) monthly trade statistics publication to identify overall solid fuel imports which in turn highlighted areas that were missing.

Sod Peat is currently estimated.

Validation

These data are validated against the Emissions Trading Scheme data once it becomes available and there is a data point match. If there is a discrepancy between the ETS figure and the survey figure, the ETS figure is used as this has been audited by the Environmental Protection Agency.

Sectoral Breakdown

The sectoral breakdown is sourced from the monthly solid fuel surveys, except for industry where this is sourced from ETS data for bituminous coal, milled peat and petroleum coke.

Oil and Biofuels

Fuels

- Crude Oil
- Refinery Gas
- Gasoline
- Kerosene
- Jet Kerosene
- Heavy Fuel Oil
- LPG
- Gasoil/Diesel/DERV
- Liquid Biofuel
    - Bioethanol
    - Biodiesel

Frequency

Monthly oil & biofuels survey

Annual CHP Survey

Data Sources

Oil data is collected monthly by the Department of Communications, Environment and Natural Resources (DCENR). Oil companies are required to report to DCENR under the National Oil Reserves Agency Act 2007 (No. 7 of 2007) and the National Oil Reserves Agency Act 2007 (Returns and Levy) Regulations 2007 (S.I. 567 of 2007). Each oil company sends their monthly return to DCENR in a prescribed Microsoft Excel format. This data is then analysed and manually transferred to a single monthly Excel sheet called the OCS system. All fuels are collected in litres, except for LPG which is collected in tonnes. In March each year, DCENR provide SEAI with all twelve OCS Excel sheets from the previous year. From the 2013 data collection a new online database, OLA, was rolled out to all companies. Data will be drawn from the OLA system rather than the OCS Excel spreadsheets and will be provided to SEAI on this basis.

Liquid Biofuel data is collected monthly by DCENR under the Biofuel Obligation Scheme introduced in the Energy (Biofuel Obligation and Miscellaneous Provisions) Act 2010 and is provided to SEAI on an annual basis.

Revenue excise data on oil (litres) is provided on a monthly basis to SEAI.

Validation

Oil data are validated against the Emissions Trading Scheme data once it becomes available and there is a data point match. If there is a discrepancy between the ETS figure and the survey figure, the ETS figure is used as this has been audited by the Environmental Protection Agency.

Sectoral Breakdown

Census of Industrial Production (CIP) data may be used for the industry breakdown. A joint CSO/SEAI Business Energy Use Survey (BEUS) was introduced recently in order to address energy consumption in the commercial and industry sectors. The survey results are not available yet but will eventually replace the CIP when calculating the breakdown of the industry sub-sectors.

The Total Final Consumption (TFC) is split further as follows:

Gasoline

- Total TFC sourced from Revenue excise data
- Transport
  - Road Private Car – calculated from vehicle stock and average annual consumption
  - Public Passenger Services – calculated from vehicle stock and average annual consumption
  - Domestic Aviation – sourced from Revenue excise data
  - Fuel Tourism - estimates provided by the Department of the Environment, Community & Local Government
  - Unspecified - remainder

Kerosene

- Total TFC sourced from Revenue excise data
- Industry
  - Estimated as 10 per cent of TFC
  - Industry sub sectors are calculated using the Heavy Fuel Oil split from the 2009 CIP
  - The new BEUS will improve on this estimate
- Residential
  - Estimated as 90 per cent of TFC
  - The new BEUS will improve on this estimate

Jet Kerosene

- Total TFC sourced from OCS system
- Transport
  - Domestic Aviation – split based on EPA tier 3 methodology
  - International Aviation – split based on EPA tier 3 methodology

Fueloil

- Total TFC sourced from Revenue excise data plus ETS data
- Industry – total less 10 kilotonnes used in Commercial/Public Services sector
    - Total basic metals and fabricated metal comes from ETS data.
    - The remaining sub sectors are calculated using the Heavy Fuel Oil split from the 2009 CIP after subtracting basic metals
    - The new BEUS will improve on this estimate
- Commercial/Public Services – estimated as 10 kilotonnes

LPG

- Total TFC sourced from OCS system
- Industry
    - Total industry based on supplier split from OCS sheets
    - Industry sub sectors calculated using the Derived Gas split from the 2009 CIP
- Transport
    - Sourced from Revenue data as a differential excise duty is charged
- Residential
    - Total residential based on supplier split from OCS sheets
- Commercial/Public Services
    - Total commercial/public services based on supplier split from OCS sheets

Gasoil/Diesel/Derv

- Industry
    - Total industry estimated based on 1990 sector split (15 per cent of Revenue gasoil less fuel input for electricity generation)
    - Industry sub sectors are calculated using the Gas Oil split from the 2009 CIP
    - The new BEUS will improve on this estimate
- Transport
    - Road Freight – calculated from CSO tonne kilometres and European data on energy use per tonne kilometre
    - Road Private Car – calculated from vehicle stock and average annual consumption
    - Public Passenger Services – calculated from vehicle stock and average annual consumption plus Revenue excise data for buses
    - Rail – Provided by the rail network operator
    - Fuel Tourism - estimates provided by the Department of the Environment, Community & Local Government
    - Sourced from Revenue data as a differential excise duty is charged
    - Unspecified - remainder
- Residential
    - Total residential estimated based on 1990 sector split (19 per cent of Revenue gasoil)
    - The new BEUS will improve on this estimate
- Commercial/Public Services
    - Total commercial/public services estimated based on 1990 sector split (44 per cent of Revenue gasoil), less navigation and fisheries
    - The new BEUS will improve on this estimate
- Agriculture
    - Total agriculture estimated based on 1990 sector split (21 per cent of Revenue gasoil)
- Fisheries
    - Sourced from Revenue data as a differential excise duty is charged

Natural Gas

Frequency

Monthly and annual surveys of Bord Gáis Networks

Annual CHP Survey

Data Sources

Natural gas data is collected monthly and annually from Bord Gáis Networks. Bord Gáis Networks own, operate, build and maintain the natural gas network in Ireland and connect all customers to the network.

Supply data are collected in cubic metres and in gross energy units, Terajoules (TJ). Data on the demand side are received in TJ only.

Validation

Data are validated against the Emissions Trading Scheme data once it becomes available and there is a data point match. If there is a discrepancy between the ETS figure and the survey figure, the ETS figure is used as this has been audited by the Environmental Protection Agency.

Sectoral Breakdown

Census of Industrial Production data are used for the industry breakdown. A joint CSO/SEAI Business Energy Use Survey was introduced recently in order to address energy consumption in the commercial and industry sectors. The survey results are not available yet but will eventually replace the CIP when calculating the breakdown of the industry sub-sectors.

Renewables & Non-Renewable Waste

Fuels

- Wind
- Hydro
- Biomass
- Renewable Waste
- Landfill Gas
- Biogas
- Solar
    - Thermal
    - Photovoltaic
- Geothermal
- Non-Renewable Waste

Frequency

Annual renewable surveys

Annual CHP survey

Data Sources

Wind & Hydro

- Sourced from monthly electricity surveys – see electricity data collection

Wind (auto generation)

- Wind auto production data is sourced from annual surveys of the auto producers.

Biomass, Renewable Waste & Non-Renewable Waste

- Wood suppliers are surveyed annually; however there is usually a high non-response rate.
- Residential non-traded wood is calculated using estimation techniques.
- Boardmills and the major sawmills that use wood waste for energy are also surveyed. The remaining smaller sawmills are estimated.
- The Environmental Protection Agency provides administrative data on some renewable and non-renewable waste.
- The Department of Agriculture, Food and the Marine provide administrative data on tallow used for energy purposes.
- Biomass and waste data are validated against the Emissions Trading Scheme data once it becomes available and there is a data point match. If there is a discrepancy between the ETS figure and the survey figure, the ETS figure is used as this has been audited by the Environmental Protection Agency.

Landfill Gas

- Landfill Gas data is sourced from annual surveys of landfill gas operators and from administrative data provided by the Environmental Protection Agency.

Biogas

- Biogas data is sourced from annual surveys of sludge biogas installations and other biogas installations in Ireland

Solar

- Solar thermal contribution to energy in Ireland is calculated on an annual basis from administrative data. Data for retrofits on older buildings comes from government grant schemes administered by SEAI since 2006 both for residential and commercial properties. Solar statistics on new residential buildings in Ireland is sourced from the Building Energy Rating system which is also administered by SEAI.

Geothermal

- Geothermal contribution to energy in Ireland is calculated on an annual basis from administrative data. Data for retrofits on older buildings comes from government grant schemes administered by SEAI since 2006 both for residential and commercial properties. However, the residential grants ended in 2011 and SEAI have been working on a new source for this data.

Electricity

Frequency

Monthly electricity generator survey

Monthly TSO survey

Quarterly electricity retail market reports

Data Sources

Electricity Supply data is collected through a monthly survey of all electricity generators and the Transmission System Operator (Eirgrid) as required under the European Energy Statistics Regulation of 2008, no.1099. This data is aggregated for the annual Energy Balance.

The electricity generator survey is a business survey of all of the main activity electricity producers in Ireland. The Transmission System Operator survey is an administrative survey as this is data collected or generated by the TSO.

Since 2012, electricity consumption data is sourced from the quarterly Electricity and Gas Retail Markets Annual Report which is published by the Commission for Energy Regulation. Prior to this, each electricity supplier was surveyed annually for consumption data.

Validation

The electricity generator data are validated against the Emissions Trading Scheme data on fuel inputs once available. If there is a discrepancy between the ETS figure and the survey figure, the ETS figure is used as this has been audited by the Environmental Protection Agency.

Sectoral Breakdown

Census of Industrial Production data are used for the industry breakdown. A joint CSO/SEAI Business Energy Use Survey was introduced recently in order to address energy consumption in the commercial and industry sectors. The survey results are not available yet but will eventually replace the CIP when calculating the breakdown of the industry sub-sectors.

Table C.2 Expanded Energy Balance Sheet 2012

2012 Units = ktoe	Coal	Bituminous Coal	Anthracite + Manufactured Ovoids	Coke	Lignite	Peat	Milled Peat	Sod Peat	Briquettes	Oil	Crude	Refinery Gas	Gasoline	Kerosene	Jet Kerosene	Fueloil	LPG	Gasoil / Diesel /DERV	Petroleum Coke	Naphtha	Bitumen	White Spirit	Lubricants	Natural Gas	Renewables	Hydro	Wind	Biomass & Renewable Waste	Landfill Gas	Biogas	Liquid Biofuel	Solar	Geothermal	Non-Renewable Waste	Electricity	Heat	TOTAL
Indigenous Production	**0**	**0**				**760**	600	161		**0**														**285**	**742**	61	377	198	44	14	24	8	18	14			1,801
Imports	**1,423**	**1,372**	**40**		11	**0**				**8,776**	2,954	51	1,238	630	916	261	110	2,253	74	0	251	1	37	**3,853**	**84**			13			71				63		14,198
Exports	**8**	**0**	**7**		0	**9**			9	**1,602**			271	2	0	1,065	34	202	0	21	1	1	6	**0**	**1**			1			0				21		1,641
Mar. Bunkers	**0**					**0**				**108**						22		86							**0**												108
Stock Change	**-152**	**-154**	2		0	**10**	19	-2	-7	**35**	36		5	9	-16	4	-2	-7	3	4	0	0	0	**1**	**5**			0			5						-100
Primary Energy Supply (incl non-energy)	**1,264**	**1,218**	**36**	**0**	**11**	**761**	**619**	**158**	**-17**	**7,101**	**2,990**	**51**	**972**	**637**	**900**	**-823**	**74**	**1,958**	**77**	**-17**	**250**	**0**	**31**	**4,138**	**831**	**61**	**377**	**210**	**44**	**14**	**100**	**8**	**18**	**14**	**42**	**0**	**14,151**
Primary Energy Requirement (excl. non-energy)	**1,264**	**1,218**	**36**	**0**	**11**	**761**	**619**	**158**	**-17**	**6,820**	**2,990**	**51**	**972**	**637**	**900**	**-823**	**74**	**1,958**	**77**	**-17**	**0**	**0**	**0**	**4,138**	831	**61**	**377**	**210**	**44**	**14**	**100**	**8**	**18**	**14**	**42**	**0**	**13,869**
Transformation Input	**913**	**913**	**0**	**0**	**0**	**576**	**576**	**0**	**0**	**3,044**	**2,990**	**6**	**0**	**0**	**0**	**40**	**0**	**8**	**0**	**0**	**0**	**0**	**0**	**2,506**	**79**	**0**	**0**	**30**	**44**	**4**	**0**	**0**	**0**	**0**	**19**	**0**	**7,136**
Public Thermal Power Plants	**913**	913				**473**	473	0		**48**						40		8						**2,254**	**71**			27	44								3,759
Combined Heat and Power Plants	**0**	0				**7**	7			**7**		6				0	0	0						**246**	**8**			3		4							267
Pumped Storage Consumption																																			0		0
Briquetting Plants	**0**					**96**	96			**0**															**0**												96
Oil Refineries & other energy sector	**0**					**0**				**2,990**	2,990													**6**	**0**										18		3,014
Transformation Output	**0**	**0**	**0**	**0**	**0**	**85**	**0**	**0**	**85**	**3,015**	**0**	**40**	**549**	**124**	**0**	**1,048**	**75**	**1,161**	**0**	**18**	**0**	**0**	**0**	**0**	**29**	**0**	**0**	**12**	**16**	**2**	**0**	**0**	**0**	**0**	**1,900**	**0**	**5,029**
Public Thermal Power Plants	**0**					**0**				**0**															**26**			10	16						1,730		1,756
Combined Heat and Power Plants - Electricity	**0**					**0**				**0**															**3**			1		2					169		173
Combined Heat and Power Plants - Heat																									**0**												0
Pumped Storage Generation																																			0		0
Briquetting Plants						**85**			85	**0**															**0**												85
Oil Refineries						**0**				**3,015**		40	549	124	0	1,048	75	1,161		18					**0**												3,015

Table C.2 Expanded Energy Balance Sheet 2012 (continued)

Exchanges and transfers	19	-12	31	0	0	0	0	0	0	-19	0	0	0	176	-176	1	0	-1	-19	0	0	0	0	0	-467	-61	-377	-12	-16	-2	0	0	0	0	467	0	0
Electricity																									-467	-61	-377	-12	-16	-2					467		0
Heat																																					0
Other	19	-12	31							-19			0	176	-176	1		-1	-19						0												0
Own Use and Distribution Losses	0					18	18			95		82				0	11	1						66	0										272		451
Available Final Energy Consumption	370	292	67	0	11	252	25	158	69	6,958	0	3	1,522	937	724	186	137	3,109	58	1	250	0	31	1,566	315	0	0	180	0	9	100	8	18	14	2,118	0	11,593
Non-Energy Consumption	0	0	0	0	0	0	0	0	0	281	0	0	0	0	0	0	0	0	0		250	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	281
Final non-Energy Consumption (Feedstocks)	0					0				281											250	0	31	0	0												281
Total Final Energy Consumption	328	250	67	0	11	241	0	163	79	6,558	0	0	1,425	887	699	180	142	3,166	58	0	0	0	0	1,558	315	0	0	183	0	9	98	8	18	14	2,140	0	11,154
Industry*	95	95	0			0	0	0	0	558	0	0	0	89	0	171	99	150	49	0	0	0	0	624	150	0	0	144		5	0	0	0	14	816	0	2,257
Non-Energy Mining	0					0				58				3		1	0	36	19					12	0										59		130
Food & beverages	16	16				0				130				52		15	28	34	0					110	41			36		5					174		470
Textiles and textile products	0					0				3				1		0	0	1	0					1	0										10		14
Wood and wood products	0					0				3				0		0	0	2	0					2	93			93							35		133
Pulp, paper, publishing and printing	0					0				3				1		0	0	2	0					4	0										19		26
Chemicals & man-made fibres	0					0				28				12		4	3	10	0					68	0			0							148		244
Rubber and plastic products	0					0				9				0		0	5	4	0					5	0										36		50
Other non-metallic mineral products	80	80				0				89				8		2	1	47	30					18	16			16						14	52		268
Basic metals and fabricated metal products	0					0				152				0		144	5	3	0					262	0										64		478
Machinery and equipment n.e.c.	0					0				6				0		0	2	3	0					6	0										21		32
Electrical and optical equipment	0					0				37				0		0	34	2	0					129	0										101		266
Transport equipment manufacture	0					0				4				0		0	3	1	0					2	0										17		23
Other manufacturing	0					0			0	35				9		3	18	6	0					7	0										79		121

Table C.2 Expanded Energy Balance Sheet 2012 (continued)

Transport	0	0	0	0	0	0	0	0	0	4,346	0	0	1,425	0	699	0	1	2,221	0	0	0	0	0	0	98	0	0	0	0	0	98	0	0	0	4	0	4,448
Road Freight	0					0				637								637							20						20						657
Road Private Car	0					0				1,843			1,117				1	726							46						46						1,890
Public Passenger Services	0					0				167			38					129							5						5						171
Rail	0					0				40								40							0						0				4		44
Domestic Aviation	0					0				6			1		6										0												6
International Aviation	0					0				694					694										0												694
Fuel Tourism	0					0				305			133					172							8						8						313
Navigation	0					0				56								56							0												56
Unspecified	0					0				599			137			0		462							18						18						616
Residential	232	154	67		11	241		163	79	1,035			0	799		0	34	193	9					569	46			23				8	15		712		2,836
Commercial/Public Services	0	0	0	0	0	0	0	0	0	386	0	0	0	0	0	10	7	369	0	0	0	0	0	365	22	0	0	16	0	4	0	0	2	0	560	0	1,333
Commercial Services	0	0	0		0	0				250				0		1	6	244	0					160	18			16				0	2		401		829
Public Services	0					0		0	0	136						9	2	125						205	4					4					158		504
Agricultural	0	0				0				212			0	0			0	212						0	0										48		260
Fisheries	0					0				20								20							0												20
Statistical Difference	42	43	-1	0	0	10	25	-4	-10	119	0	3	97	50	24	6	-4	-57	0	1	0	0	0	8	-1	0	0	-3	0	0	2	0	0	0	-22	0	157

Table C.3 Country specific carbon emission factors – fossil fuels

Fuel	NCV (toe/t)	NCV (MJ kg^{-1})	CO2 (t/TJ)	Density (kg l^{-1})
Liquid fuels				
Crude Oil	1.0226	42.814	73.333	
Refinery Gas	1.1941	49.995	52.652	
LPG	1.1263	47.156	63.700	
Naphtha	1.0510	44.003	73.333	
Motor Gasoline	1.0650	44.589	69.960	0.7550
Aviation Gasoline	1.0650	44.589	69.960	0.7550
Jet Kerosene	1.0533	44.100	71.401	
Other Kerosene	1.0556	44.196	71.400	0.8000
DERV (Road Gasoil)	1.0344	43.308	73.300	
Heating and Other Gasoil	1.0344	43.308	73.300	0.8450
Residual Fuel Oil	0.9849	41.236	76.000	0.9416
Residual Fuel Oil (Electricity Generation)	0.9694	40.587	78.896	
Fuel Oil – Low Sulphur content	0.9849	41.236	76.000	0.9416
Fuel Oil – High Sulphur content	0.9849	41.236	76.000	0.9416
White Spirits	1.0510	44.003	73.333	
Lubricants	1.0100	42.287	73.333	
Petroleum Coke	0.7767	32.518	92.871	
Bitumen (including Orimulsion)	0.9004	37.698	80.667	
Solid Fuels				
Coal (electricity generation)	0.5890	24.661	93.784	
Other Bituminous Coal (imports)	0.6649	25.199	94.600	
Other Bituminous Coal (default)	0.6650	25.199	94.600	
Anthracite	0.6650	27.842	98.260	
Lignite/Brown Coal	0.4733	19.816	101.200	
Patent Fuels (Manufactured Ovoids)	0.7643	32.000	98.260	
Milled Peat	0.1798	7.527	116.089	
Sod Peat	0.3130	13.105	104.000	
BKB/Peat Briquettes	0.4430	18.548	98.860	
	NCV (MJ m^{-3})	**NCV (MJ kg^{-1})**	**CO2 (t/TJ)**	**Density (kg m^{-3})**
Gaseous fuels				
Natural Gas-Indigeneous	34.7840	47.780	55.232	0.7280
Natural Gas-Imported	35.7930	46.250	56.945	0.7739
Natural Gas- weighted average			56.867	

Annex D

Energy (IPCC Sector 1)

D.1 – D.2 Calculation Sheets for Energy 2012

D.3 – D.5 Comparison of Reference and Sectoral Approach

D.6 – D.8 Time-Series of Implied Emission Factors (IEFs) in Categories 1.A.1 and 1.A.2

Table D.1 Calculation Sheet for Emissions from Fuel Combustion 2012 (continued on following pages)

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			**Emission Factors**			**Emissions**		
				CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**
	Sector/Fuel	**kTOE**	**TJ**	**kg/TJ**	**kg/TJ**	**kg/TJ**	**Gg**	**Mg**	**Mg**
	1A1a Public Electricity								
1	Coal	1160.11	48571.51	93784	0.7	0.5	4555.25	34.00	24.29
2	Peat	550.00	23027.37	116089	3.0	7.0	2673.22	69.08	161.19
3	Fuel Oil and Gas Oil	46.65	1953.25	78133	0.8	0.3	152.61	1.56	0.59
4	Natural Gas	1994.50	83505.73	56937	1.1	2.9	4754.55	92.85	244.28
5	Biomass (LFG, Wood & MSW biomass)	106.26	4448.90	84553	4.2	3.6	376.17	18.50	16.02
6	MSW (renewable and non-renewable, fossil)	15.94	667.34	140182	80.9	10.8	93.55	53.97	7.20
	Public Electricity Total	**3873.46**	**162174.09**				**12229.19**	**269.97**	**453.57**
	1A1b Refinery Fuel								
7	Refinery Gas	102.37	4285.87	68794	1.0	0.1	294.84	4.29	0.43
8	Natural Gas	4.72	197.63	83215	1.0	0.1	16.45	0.20	0.02
9	LPG	10.32	432.03	3340	1.0	0.1	1.44	0.43	0.04
10	Gasoil/Diesel/DERV	0.14	5.89	95744	3.0	0.6	0.56	0.02	0.00
	Refinery Total	**117.55**	**4921.42**				**313.30**	**4.93**	**0.50**
	1A1c Manufacture of Briquettes								
11	Peat	**20.70**	**866.87**	120419	2.0	1.5	**104.39**	**1.73**	**1.30**
	1A2a-1A2f Industry Fuel								
12	Bituminous Coals	84.79	3549.83	94600	10.0	1.5	335.81	35.50	5.32
13	Briquettes	0.74	31.09	98860	2.0	1.5	3.07	0.06	0.05
14	Kerosene	75.84	3175.19	71400	3.0	0.6	226.71	9.53	1.91
15	Fuel Oil	108.53	4544.02	76000	3.0	0.6	345.35	13.63	2.73
16	LPG	95.81	4011.41	63700	1.0	0.1	255.53	4.01	0.40
17	Gasoil/Diesel/DERV	143.03	5988.43	73300	3.0	0.6	438.95	17.97	3.59
18	Pet Coke	90.75	3799.72	92871	3.0	0.6	352.88	11.40	2.28
19	Naphta	0.00	0.00	74330	3.0	0.6	0.00	0.00	0.00
20	Natural Gas	940.70	39385.24	56867	1.0	0.1	2239.71	39.39	3.94
21	Biomass (solid)	148.54	6218.91	110000	30.0	4.0	684.08	186.57	24.88
22	Biomass (gas)	4.96	207.61	54600	1.0	0.1	11.34	0.21	0.02
23	Non Renewable wastes	25.48	1066.98	53383	3.0	0.6	56.96	3.20	0.64
	Industry Total	**1719.17**	**71978.41**				**4254.97**	**321.45**	**45.75**

Table D.1 Calculation Sheet for Emissions from Fuel Combustion 2012 (continued from previous page)

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
				CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
	Sector/Fuel	**kTOE**	**TJ**	**kg/TJ**	**kg/TJ**	**kg/TJ**	**Gg**	**Mg**	**Mg**
	1A3a Aviation								
24	Civil Aviation Kerosene	3.80	159.17	71117	2.0	3.6	11.32	0.32	0.57
	1A3b Road Transport Fuel								
25	Gasoline	1294.89	54214.55	69960	11.8	1.76	3792.85	641.28	93.45
26	Gasoil/Diesel/DERV	2126.90	89049.15	73300	0.9	2.21	6527.30	79.76	192.21
27	LPG	1.00	41.86	63700	10.56	2.41	2.67	0.44	0.10
28	Liquid Biofuels	84.75	3548.24	69316	4.52	1.98	245.95	16.02	7.02
	Road Transport Total	**3507.54**	**146853.81**				**10322.82**	**737.51**	**292.77**
	1A3c-1A3e Other Transport Fuel								
29	Railway Diesel	38.46	1610.34	73300	4.2	28.6	118.04	6.68	46.06
30	Navigation Fuel Oil	0.00	0.00	76000	7.0	2.0	0.00	0.00	0.00
31	Navigation Gasoil	59.20	2478.67	73300	7.0	2.0	181.69	17.35	4.96
32	Gas Distribution Use (Natural Gas)	59.64	2497.03	56867	5.0	2.0	142.00	12.49	4.99
33	Railway Biofuel	0.00	0.00	70800	4.2	28.6	0.00	0.00	0.00
	Other Transport Total	**157.30**	**6586.04**				**441.72**	**36.52**	**56.01**
	1A4a Commercial/Institutional Fuel								
34	Bituminous Coal	-	-	94600	10.0	1.5	-	-	-
35	Anthracite + Manufactured Ovoids	-	-	98260	10.0	1.5	-	-	-
36	Lignite	-	-	101200	10.0	1.5	-	-	-
37	Briquettes	-	-	98860	10.0	1.4	-	-	-
38	Fuel Oil	9.85	412.36	76000	10.0	0.6	31.34	4.12	0.25
39	LPG	7.14	298.90	63700	5.0	0.1	19.04	1.49	0.03
40	Gasoil / Diesel/ DERV	342.66	14346.59	73300	10.0	0.6	1051.60	143.47	8.61
41	Pet Coke	0.0004	0.02	92871	10.0	0.6	0.00	0.00	0.00
42	Natural Gas	419.76	17574.33	56867	5.0	0.1	999.40	87.87	1.76
43	Biomass	19.37	811.14	110000	300.0	4.0	89.23	243.34	3.24
44	Biogas	3.91	163.77	54600	5.0	0.1	8.94	0.82	0.02
	Commercial/Institutional Total	**802.69**	**33607.11**				**2101.38**	**481.12**	**13.90**

Table D.1 Calculation Sheet for Emissions from Fuel Combustion 2012

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
				CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
	Sector/Fuel	**kTOE**	**TJ**	**kg/TJ**	**kg/TJ**	**kg/TJ**	**Gg**	**Mg**	**Mg**
	1A4b Residential Fuel								
45	Bituminous Coal	161.04	6742.54	94600	300.0	1.5	637.84	2022.76	10.11
46	Anthracite + Manufactured Ovoids	64.91	2717.70	98260	300.0	1.5	267.04	815.31	4.08
47	Lignite	12.75	533.67	101200	300.0	1.5	54.01	160.10	0.80
48	Sod Peat	127.70	5346.71	104000	300.0	1.4	556.06	1604.01	7.49
49	Briquettes	86.83	3635.31	98860	300.0	1.4	359.39	1090.59	5.09
50	Kerosene	682.54	28576.68	71400	10.0	0.6	2040.37	285.77	17.15
51	LPG	33.06	1384.02	63700	5.0	0.1	88.16	6.92	0.14
52	Gasoil / Diesel/ DERV	184.44	7721.93	73300	10.0	0.6	566.02	77.22	4.63
53	Petroleum Coke	10.22	427.79	92871	10.0	0.6	39.73	4.28	0.26
54	Natural Gas	600.49	25141.48	56867	5.0	0.1	1429.72	125.71	2.51
55	Biomass	27.99	1171.75	110032	298.3	3.9	128.93	349.49	4.63
	Residential Total	**1991.96**	**83399.58**				**6038.34**	**6542.16**	**56.88**
	1A4c Agriculture/Forestry/Fishing Fuel								
56	Gasoil	224.84	9413.54	73300	5.0	23.4	690.01	46.71	220.42
57	Biomass	-	-	110000	300.0	4.0	-	-	-
	Agriculture Total	**224.84**	**9413.54**				**690.01**	**46.71**	**220.42**
	Total Energy	**12419.03**	**519960.03**				**36507.44**	**8442.42**	**1141.67**

Table D.2 Emissions from Fuel Combustion Allocated by IPCC Source Category 2012

	GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA	IMPLIED EMISSION FACTORS			EMISSIONS		
		Consumption	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
		(TJ)	(t/TJ)	(kg/TJ)	(kg/TJ)	(Gg)		
A	**1.A.1. Energy Industries**	**167,962.3816**				**12,646.8708**	**0.2766**	**0.4554**
B	Solid Fuels	72,465.7418	101.1907	1.4464	2.5775	7,332.8579	0.1048	0.1868
C	Liquid Fuels	6,677.0447	67.3146	0.9433	0.1589	449.4628	0.0063	0.0011
D	Gaseous Fuels	83,703.3560	56.9989	1.1117	2.9187	4,771.0008	0.0931	0.2443
E	Biomass	4,448.8963	84.5530	4.1572	3.6015	376.1674	0.0185	0.0160
F	Other Fuels	667.3428	140.1819	80.8753	10.7834	93.5493	0.0540	0.0072
G	**1.A.2 Manufacturing Industries and Construction**	**71,978.4124**				**4,254.9749**	**0.3215**	**0.0458**
H	Solid Fuels	3,580.9174	94.6370	9.9305	1.5000	338.8872	0.0356	0.0054
I	Liquid Fuels	21,518.7636	75.2560	2.6272	0.5068	1,619.4168	0.0565	0.0109
J	Gaseous Fuels	39,385.2374	56.8668	1.0000	0.1000	2,239.7127	0.0394	0.0039
K	Biomass	6,426.5180	108.2103	29.0631	3.8740	695.4153	0.1868	0.0249
L	Other Fuels	1,066.9760	53.3827	3.0000	0.6000	56.9581	0.0032	0.0006
M	**1.A.3 Transport**	**153,599.0162**				**10,775.8618**	**0.7743**	**0.3493**
N	Solid Fuels	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
O	Liquid Fuels	147,553.7492	72.0677	5.0547	2.2862	10,633.8639	0.7458	0.3373
P	Gaseous Fuels	2,497.0263	56.8668	5.0000	2.0000	141.9979	0.0125	0.0050
Q	Biomass	3,548.2407	69.3161	4.5158	1.9777	245.9501	0.0160	0.0070
R	**1.A.4 Other Sectors**	**126,420.2083**				**8,829.7292**	**7.0700**	**0.2912**
S	Solid Fuels	18,975.9315	98.7745	300.0000	1.4527	1,874.3376	5.6928	0.0276
T	Liquid Fuels	62,581.7929	72.3258	9.1077	4.0185	4,526.2794	0.5700	0.2515
U	Gaseous Fuels	42,715.8165	56.8668	5.0000	0.1000	2,429.1121	0.2136	0.0043
V	Biomass	2,146.6674	105.7908	276.5443	3.6740	227.0977	0.5936	0.0079
W	**1.A.5 Other *(Not specified elsewhere)*[(6)]**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
X	**1.A. Fuel Combustion**	**519,960.0185**				**36,507.4367**	**8.4424**	**1.1417**
	Memo Items							
Y	Aviation Bunkers	29,051.0729	71.4000	0.2934	2.3375	2,074.2466	0.0085	0.0679
Z	Marine Bunkers	4,524.5819	73.8584	7.0000	2.0000	334.1784	0.0317	0.0090
AA	CO_2 from Biomass	16,570.3224	93.2167			1,544.6306	NA	NA

Table D.3 Correspondence between National Disaggregation of Sources and IPCC Combustion Source Categories

	IPCC Source Category/Fuel Groups from Table D.2	National Disaggregated Sources from Table D.1
A	**1.A.1 Energy Industries (A = B+C+D+E+F)**	
B	(a) Solid Fuels	1+2+11
C	(b) Liquid Fuels	3+7+9+10
D	(c) Gaseous Fuels	4+8
E	(d) Biomass	5
F	(e) Other Fuels	6
G	**1.A.2 Manufacturing Industries (G = H+I+J+K+L)**	
H	(a) Solid Fuels	12+13
I	(b) Liquid Fuels	14+15+16+17+18+19
J	(c) Gaseous Fuels	20
K	(d) Biomass	21+22
L	(e) Other Fuels	23
M	**1.A.3 Transport (M = N+O+P+Q)**	
N	(a) Solid Fuels	NO
O	(b) Liquid Fuels	24+25+26+27+29+30+31
P	(c) Gaseous Fuels	32
Q	(d) Biomass	28+33
R	**1.A.4 Other Sectors (R = S+T+U+V)**	
S	(a) Solid Fuels	34+35+36+37+45+46+47+48+49
T	(b) Liquid Fuels	38+39+40+41+50+51+52+53+56
U	(c) Gaseous Fuels	42+54
V	(d) Biomass	43+44+55+57
W	**1.A.5 Other**	**NO**
X	**1.A Fuel Combustion (X = A+G+M+R+W)**	

Table D.4 Emissions of CO_2 from the Reference Approach in 2012 [CRF 2012 Table 1.A(b)]

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit)	NCV/ GCV (1)	Apparent consumption (TJ)	Carbon emission factor (t C/TJ)	Carbon content (Gg C)	Carbon stored (Gg C)	Net carbon emissions (Gg C)	Fraction of carbon oxidized	Actual CO_2 emissions (Gg CO_2)
Liquid Fossil	Primary Fuels	Crude Oil	kt	NO	2,684.605	NO		-73.097	2,757.702	42.814	NCV	118,068.803	20.000	2,361.376	NA	2,361.376	1.000	8,658.379
		Orimulsion		NO	NO	NO		NO	NO	41.868	NCV	NO	NO	NO	NO	NO	NO	NO
		Natural Gas Liquids	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
	Secondary Fuels	Gasoline	kt		1,032.980	414.837	NO	-11.370	629.513	44.589	NCV	28,069.592	19.080	535.568	NA	535.568	1.000	1,963.749
		Jet Kerosene	kt		724.805	0.453	551.635	-2.008	174.725	44.100	NCV	7,705.298	19.473	150.045	NA	150.045	1.000	550.166
		Other Kerosene	kt		504.656	5.673	NO	31.256	467.728	44.196	NCV	20,671.643	19.473	402.533	NA	402.533	1.000	1,475.953
		Shale Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Gas / Diesel Oil	kt		2,110.281	305.896	101.356	-19.660	1,722.689	43.308	NCV	74,606.735	19.991	1,491.456	NA	1,491.456	1.000	5,468.671
		Residual Fuel Oil	kt		199.451	977.210	24.060	-34.428	-767.391	41.236	NCV	-31,643.983	20.727	-655.891	NA	-655.891	1.000	-2,404.934
		Liquefied Petroleum Gas (LPG)	kt		92.831	33.494		0.366	58.971	47.156	NCV	2,780.847	17.373	48.311	NA	48.311	1.000	177.140
		Ethane			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Naphtha	kt		NO	8.579		5.158	-13.737	44.003	NCV	-604.468	20.000	-12.089	NO	-12.089	1.000	-44.328
		Bitumen	kt		255.400	0.019		NO	255.381	37.698	NCV	9,627.327	22.000	211.801	211.801	0.000	1.000	0.000
		Lubricants	kt		35.051	5.911	NO	NO	29.140	42.287	NCV	1,232.234	20.000	24.645	12.322	12.322	1.000	45.182
		Petroleum Coke	kt		161.396	0.286		14.297	146.813	32.518	NCV	4,774.131	25.328	120.922	NO	120.922	1.000	443.379
		Refinery Feedstocks	kt		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Other Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Other Liquid Fossil												39.383		0.788	0.788	0.000		0.000
Aviation Gasoline			kt	NO	NO	NO	NO	NO	NO	44.589	NCV	NO	19.080	NO	NO	NO	1.000	NO
Other non-specified			kt	NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NA	NA,NO
White Spirit			kt	NO	0.899	0.004	NO	NO	0.895	44.003	NCV	39.383	20.000	0.788	0.788	0.000	1.000	0.000
Liquid Fossil Totals												235,327.542		4,679.463	224.911	4,454.552		16,333.357
Solid Fossil	Primary Fuels	Anthracite (2)	kt	NO	41.209	0.187		-3.183	44.205	27.842	NCV	1,230.755	26.798	32.982	NO	32.982	1.000	120.934
		Coking Coal	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Other Bituminous Coal	kt	NO	2,155.503	11.182	NO	-226.242	2,370.563	25.199	NCV	59,734.842	25.724	1,536.613	NA	1,536.613	1.000	5,634.246
		Sub-bituminous Coal		NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Lignite	kt	NO	24.665	0.470		-2.520	26.715	19.816	NCV	529.383	27.600	14.611	NO	14.611	1.000	53.574
		Oil Shale		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Peat	kt	1,043.782	NO	NO		-2,715.511	3,759.293	7.787	NCV	29,275.122	29.863	874.243	NA	874.243	1.000	3,205.558
	Secondary Fuels	BKB (3) and Patent Fuel	kt		NO	20.022		-16.394	-3.628	18.548	NCV	-67.290	26.962	-1.814	NA	-1.814	1.000	-6.652
		Coke Oven/Gas Coke			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Other Solid Fossil												5,603.831		158.542	NO	158.542		581.322
Manufactured Ovoids			kt	NO	13.486	11.492	NO	-6.041	8.035	32.000	NCV	257.113	26.798	6.890	NO	6.890	1.000	25.264
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Sod Peat			kt	408.000	NO	NO	NO	NO	408.000	13.105	NCV	5,346.718	28.364	151.652	NO	151.652	1.000	556.058
Solid Fossil Totals												96,306.643		2,615.177	NA,NO	2,615.177		9,588.981
Gaseous Fossil		Natural Gas (Dry)	TJ	7,697.668	161,058.414	NO		306.680	168,449.402	1.000	NCV	168,449.402	15.509	2,612.504	NO	2,612.504	1.000	9,579.180
Other Gaseous Fossil												NO		NO	NO	NO		NO
	Other non-specified			NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Gaseous Fossil Totals												168,449.402		2,612.504	NO	2,612.504		9,579.180
Total												500,083.587		9,907.143	224.911	9,682.232		35,501.517
Biomass total												12,592.408		304.111	NO	304.111		1,115.073
		Solid Biomass	TJ	6,000.000	636.258	0.128		-45.910	6,682.039	1.000	NCV	6,682.039	30.000	200.461	NO	200.461	1.000	735.024
		Liquid Biomass	TJ	1,025.464	2,685.925	NO		142.015	3,569.374	1.000	NCV	3,569.374	19.226	68.625	NO	68.625	1.000	251.625
		Gas Biomass	TJ	2,340.994	NO	NO		NO	2,340.994	1.000	NCV	2,340.994	14.961	35.025	NO	35.025	1.000	128.423

Table D.5 Comparison of Results from Sectoral Approach and Reference Approach for 2012 (CRF 2012 Table 1.A(c)]

FUEL TYPES	REFERENCE APPROACH			SECTORAL APPROACH [1]		DIFFERENCE [2]	
	Apparent energy consumption [3] (PJ)	Apparent energy consumption (excluding non-energy use and feedstocks) [4] (PJ)	CO_2 emissions (Gg)	Energy consumption (PJ)	CO_2 emissions (Gg)	Energy consumption (%)	CO_2 emissions (%)
Liquid Fuels (excluding international bunkers)	235.328	224.429	16,333.357	238.331	17,229.024	-5.833	-5.199
Solid Fuels (excluding international bunkers) [5]	96.307	96.307	9,588.981	95.023	9,546.083	1.351	0.449
Gaseous Fuels	168.449	168.449	9,579.180	168.301	9,581.824	0.088	-0.028
Other [5]	1.822	1.822	149.813	1.835	150.507	-0.709	-0.461
Total [5]	***501.906***	***491.007***	***35,651.330***	***503.491***	***36,507.438***	***-2.479***	***-2.345***

Table D.6 (a) Implied emission factors (IEFs) for CO_2 – Liquid Fuels in Sector 1.A.1.a

Energy (TJ)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Heavy Fuel Oil	13978.93	23298.22	23793.05	23504.40	26473.38	25318.78	25772.37	33483.46	45689.26	57070.34	41771.86	50019.02
Gasoil	303.16	259.85	346.47	216.54	779.55	649.62	389.77	476.39	606.32	1082.71	1212.63	1082.71
total	**14282.09**	**23558.07**	**24139.52**	**23720.94**	**27252.93**	**25968.40**	**26162.15**	**33959.85**	**46295.57**	**58153.04**	**42984.49**	**51101.72**
Emission Factors (t CO_2/TJ)												
Heavy Fuel Oil	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00
Gasoil	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30
CO_2 Emissions National Approach Tier 1)												
Heavy Fuel Oil	1062.40	1770.66	1808.27	1786.33	2011.98	1924.23	1958.70	2544.74	3472.38	4337.35	3174.66	3801.45
Gasoil	22.22	19.05	25.40	15.87	57.14	47.62	28.57	34.92	44.44	79.36	88.89	79.36
total	**1084.62**	**1789.71**	**1833.67**	**1802.21**	**2069.12**	**1971.84**	**1987.27**	**2579.66**	**3516.83**	**4416.71**	**3263.55**	**3880.81**
IEF calculated	**75.94**	**75.97**	**75.96**	**75.98**	**75.92**	**75.93**	**75.96**	**75.96**	**75.96**	**75.95**	**75.92**	**75.94**
CO_2 emissions from ETS (Tier 3 bottom up)	1086.52	1788.62	1834.97	1803.59	2067.85	1985.81	1986.13	2617.23	3519.32	4533.60	3484.39	3925.34
difference	**0.17%**	**-0.06%**	**0.07%**	**0.08%**	**-0.06%**	**0.70%**	**-0.06%**	**1.44%**	**0.07%**	**2.58%**	**6.34%**	**1.13%**
IEF reported	**76.08**	**75.92**	**76.02**	**76.03**	**75.88**	**76.47**	**75.92**	**77.07**	**76.02**	**77.96**	**81.06**	**76.81**

Energy (TJ)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Heavy Fuel Oil	36436.44	23912.76	30201.29	30040.79	26180.99	15749.12	14187.59	8382.58	4308.13	1695.56	1648.98	**Energy balance data**
Gasoil	822.86	1169.32	1645.71	2841.39	2259.13	580.00	457.38	355.46	1095.69	325.16	304.27	**Energy balance data**
total	**37259.30**	**25082.08**	**31847.00**	**32882.18**	**28440.12**	**16329.13**	**14644.96**	**8738.04**	**5403.82**	**2020.72**	**1953.25**	**Liquid Fuels CRFReporter**
Emission Factors (t CO_2/TJ)												
Heavy Fuel Oil	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	
Gasoil	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	
CO_2 Emissions National Approach Tier 1)												
Heavy Fuel Oil	2769.17	1817.37	2295.30	2283.10	1989.76	1196.93	1078.26	637.08	327.42	128.86	125.32	
Gasoil	60.32	85.71	120.63	208.27	165.59	42.51	33.53	26.06	80.31	23.83	22.30	
total	**2829.48**	**1903.08**	**2415.93**	**2491.37**	**2155.35**	**1239.45**	**1111.78**	**663.13**	**407.73**	**152.70**	**147.63**	
IEF calculated	**75.94**	**75.87**	**75.86**	**75.77**	**75.79**	**75.90**	**75.92**	**75.89**	**75.45**	**75.57**	**75.58**	**IEF National Approach**
CO_2 emissions from ETS (Tier 3 bottom up)	2905.74	1992.62	2539.76	2562.77	2222.00	1284.23	1143.44	680.41	423.79	158.24	152.61	**Gg CO_2 CRFReporter**
difference	**2.62%**	**4.49%**	**4.88%**	**2.79%**	**3.00%**	**3.49%**	**2.77%**	**2.54%**	**3.79%**	**3.50%**	**3.27%**	
IEF reported	**77.99**	**79.44**	**79.75**	**77.94**	**78.13**	**78.65**	**78.08**	**77.87**	**78.42**	**78.31**	**78.13**	**IEF CRFReporter**

Table D.6 (b) Implied emission factors (IEFs) for CO_2 – Liquid Fuels in Sector 1.A.1.a

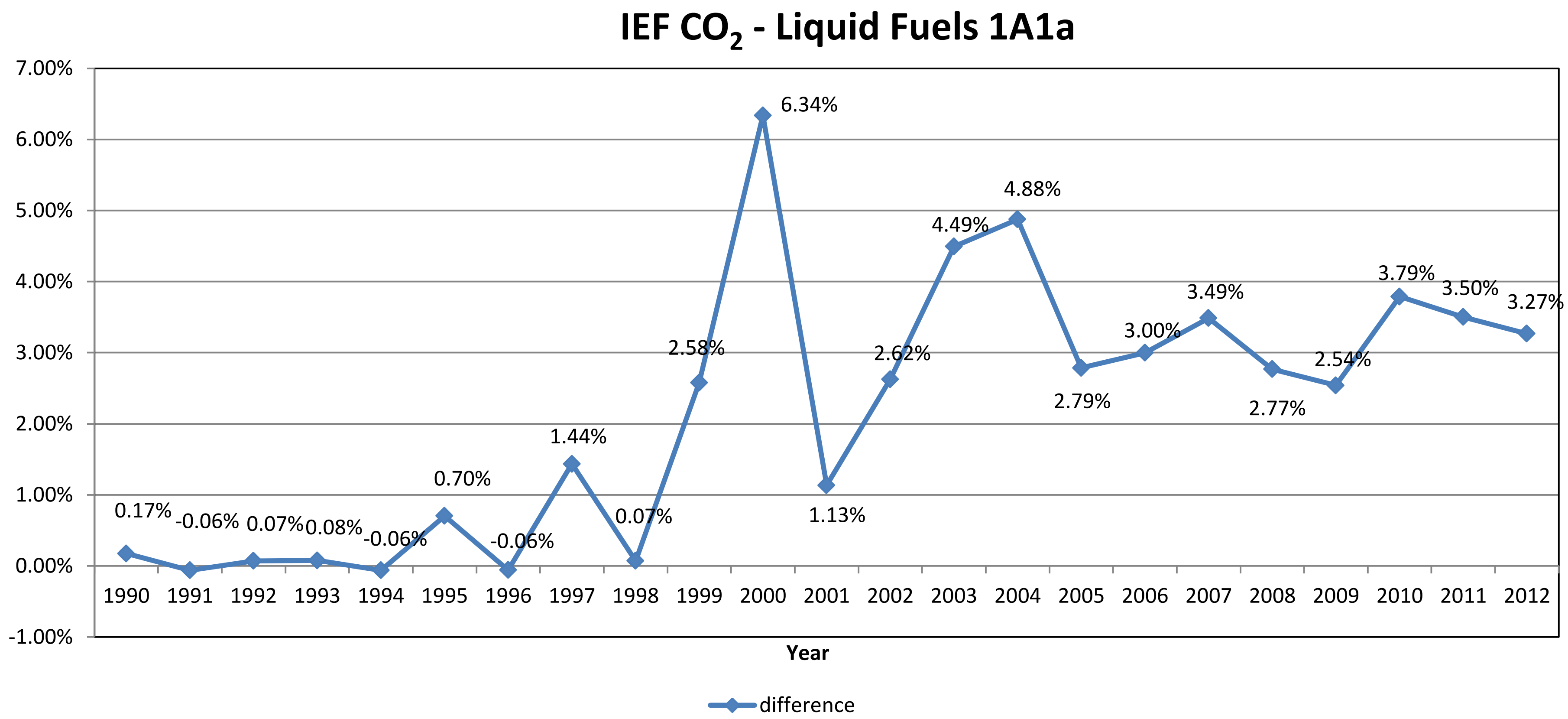


Table D.7 (a) Implied emission factors (IEFs) for CO_2 – Solid Fuels in Sector 1.A.1.a

Energy (TJ)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Coal	51972.08	51137.65	58287.50	56810.07	58544.91	62584.78	62177.52	60202.93	61174.75	52951.80	59728.50	63375.92	61343.32	55395.13	57003.60	59307.55	50953.01	49049.52	41505.71	32444.13	36320.56	38228.46	48571.51	**Energy balance data**
Milled Peat	23463.58	24374.71	25363.72	23222.17	23821.80	23385.71	22832.80	22871.73	21516.72	21516.72	20021.53	22466.79	22529.09	21010.53	13816.83	20488.09	18970.00	18806.62	23856.88	23314.27	20144.16	19799.83	23027.37	**Energy balance data**
Sod Peat	1323.57	1218.74	904.22	445.56	314.51	314.51	982.85	353.83	183.47	183.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**Energy balance data**
total	**76759.23**	**76731.10**	**84555.44**	**80477.79**	**82681.22**	**86285.00**	**85993.17**	**83428.49**	**82874.94**	**74651.99**	**79750.03**	**85842.71**	**83872.41**	**76405.67**	**70820.42**	**79795.64**	**69923.01**	**67856.14**	**65362.59**	**55758.40**	**56464.72**	**58028.29**	**71598.87**	**Solid Fuels CRFReporter**
Emission Factors (t CO_2/TJ)																								
Coal	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	94.60	
Milled Peat	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	115.00	
Sod Peat	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	104.00	
CO_2 Emissions National Approach (Tier 1)																								
Coal	4916.56	4837.62	5514.00	5374.23	5538.35	5920.52	5881.99	5695.20	5787.13	5009.24	5650.32	5995.36	5803.08	5240.38	5392.54	5610.49	4820.15	4640.08	3926.44	3069.21	3435.93	3616.41	4594.86	
Milled Peat	2698.31	2803.09	2916.83	2670.55	2739.51	2689.36	2625.77	2630.25	2474.42	2474.42	2302.48	2583.68	2590.85	2416.21	1588.93	2356.13	2181.55	2162.76	2743.54	2681.14	2316.58	2276.98	2648.15	
Sod Peat	137.65	126.75	94.04	46.34	32.71	32.71	102.22	36.80	19.08	19.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
total	**7752.52**	**7767.46**	**8524.86**	**8091.12**	**8310.56**	**8642.59**	**8609.98**	**8362.24**	**8280.63**	**7502.74**	**7952.79**	**8579.04**	**8393.92**	**7656.59**	**6981.48**	**7966.62**	**7001.71**	**6802.85**	**6669.98**	**5750.36**	**5752.50**	**5893.39**	**7243.01**	
IEF calculated	**101.00**	**101.23**	**100.82**	**100.54**	**100.51**	**100.16**	**100.12**	**100.23**	**99.92**	**100.50**	**99.72**	**99.94**	**100.08**	**100.21**	**98.58**	**99.84**	**100.13**	**100.25**	**102.05**	**103.13**	**101.88**	**101.56**	**101.16**	**IEF National Approach**
CO_2 emissions from ETS (Tier 3 bottom up)	7909.31	7795.76	8477.38	7955.29	8205.33	8645.06	8857.12	8606.14	8145.16	7454.31	8084.48	8688.84	8397.65	7731.52	7078.28	7909.68	6966.22	6703.73	6630.99	5765.58	5688.15	5857.32	7228.47	**Gg CO_2 CRFReporter**
difference	**1.98%**	**0.36%**	**-0.56%**	**-1.71%**	**-1.28%**	**0.03%**	**2.79%**	**2.83%**	**-1.66%**	**-0.65%**	**1.63%**	**1.26%**	**0.04%**	**0.97%**	**1.37%**	**-0.72%**	**-0.51%**	**-1.48%**	**-0.59%**	**0.26%**	**-1.13%**	**-0.62%**	**-0.20%**	
IEF reported	**103.04**	**101.60**	**100.26**	**98.85**	**99.24**	**100.19**	**103.00**	**103.16**	**98.28**	**99.85**	**101.37**	**101.22**	**100.12**	**101.19**	**99.95**	**99.12**	**99.63**	**98.79**	**101.45**	**103.40**	**100.74**	**100.94**	**100.96**	**IEF CRFReporter**

Table D.7 (b) Implied emission factors (IEFs) for CO_2 – Solid Fuels in Sector 1.A.1.a

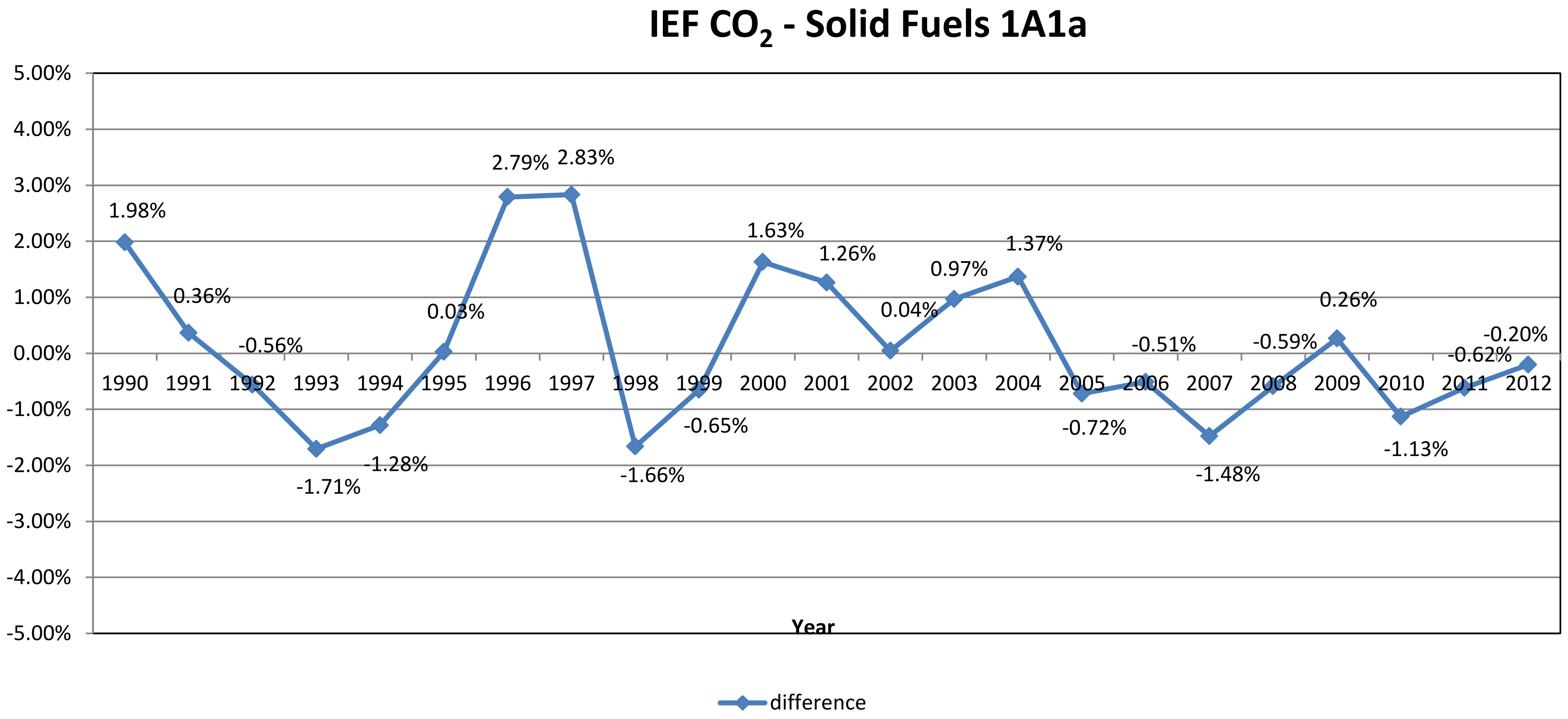


Table D.8 Implied emission factors (IEFs) for CO_2 – Liquid Fuels in Sector 1.A.2.f

Energy (TJ)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Kerosene	144.70	90.47	85.15	95.80	164.98	212.88	287.39	313.99	372.54	473.65	452.37	474.04	456.99	493.83	452.85	2326.07	1695.03	1390.03	1574.29	1573.05	1232.17	973.91	832.34	**Energy balance data**
Fuel Oil	3611.38	2007.31	2415.72	2466.61	3153.10	2935.85	2748.41	3012.82	2979.30	3180.05	3390.73	2668.90	2255.59	1951.78	1818.20	2367.06	1689.75	1534.88	1362.43	1347.66	1048.21	300.58	246.50	**Energy balance data**
LPG	1918.60	1467.29	1423.87	1498.04	1601.82	1578.86	1537.29	1551.88	1705.02	1799.71	1978.32	1862.06	2206.72	2839.82	3369.70	2960.05	3022.38	3401.18	3642.11	2143.33	2748.68	2658.72	2564.18	**Energy balance data**
Gasoil	3119.23	4295.10	4379.59	4295.10	4970.99	5675.05	4435.91	4633.05	4689.37	4999.16	5139.97	5419.73	5321.05	5288.70	4858.54	5767.26	5522.14	5414.65	5004.48	4711.97	4532.44	4266.90	4067.05	**Energy balance data**
Petroleum Coke	1971.87	1994.03	1462.29	1329.35	1971.87	2193.43	1019.17	2747.33	2414.99	2614.39	4608.42	5277.33	5951.78	7586.37	9018.88	9924.14	9829.63	10015.55	9196.13	4818.39	3053.84	2832.63	3799.72	**Energy balance data**
Naphta	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	0.00	0.00	**Energy balance data**
total	**10809.78**	**9898.20**	**9810.62**	**9728.91**	**11906.77**	**12640.08**	**10072.17**	**12303.07**	**12205.22**	**13110.97**	**15613.80**	**15746.06**	**16236.14**	**18204.52**	**19562.16**	**23388.58**	**21802.93**	**21800.29**	**20823.44**	**14638.41**	**12659.34**	**11032.74**	**11509.80**	**Energy balance data**
Emission Factors ($t CO_2/TJ$)																								
Kerosene	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	71.40	
Fuel Oil	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	
LPG	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	63.70	
Gasoil	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	
Petroleum Coke	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	93.65	95.13	93.43	93.21	92.93	93.55	93.60	93.24	92.87	
Naphta	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	73.33	
CO_2 Emissions National Approach (Tier 1)																								
Kerosene	10.33	6.46	6.08	6.84	11.78	15.20	20.52	22.42	26.60	33.82	32.30	33.85	32.63	35.26	32.33	166.08	121.03	99.25	112.40	112.32	87.98	69.54	59.43	
Fuel Oil	274.46	152.56	183.59	187.46	239.64	223.12	208.88	228.97	226.43	241.68	257.70	202.84	171.42	148.34	138.18	179.90	128.42	116.65	103.54	102.42	79.66	22.84	18.73	
LPG	122.21	93.47	90.70	95.43	102.04	100.57	97.93	98.85	108.61	114.64	126.02	118.61	140.57	180.90	214.65	188.56	192.53	216.66	232.00	136.53	175.09	169.36	163.34	
Gasoil	228.64	314.83	321.02	314.83	364.37	415.98	325.15	339.60	343.73	366.44	376.76	397.27	390.03	387.66	356.13	422.74	404.77	396.89	366.83	345.39	332.23	312.76	298.12	
Petroleum Coke	184.67	186.74	136.95	124.50	184.67	205.42	95.45	257.29	226.17	244.84	431.59	494.23	557.40	710.48	844.64	944.12	918.42	933.51	854.62	450.78	285.83	264.12	352.88	
Naphta	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	0.00	0.00	
total	**823.55**	**757.28**	**741.57**	**732.28**	**905.72**	**963.53**	**751.15**	**950.37**	**934.76**	**1004.65**	**1227.59**	**1250.02**	**1295.28**	**1465.86**	**1589.16**	**1904.62**	**1768.39**	**1766.19**	**1672.62**	**1150.66**	**964.02**	**838.63**	**892.50**	
IEF calculated	**76.19**	**76.51**	**75.59**	**75.27**	**76.07**	**76.23**	**74.58**	**77.25**	**76.59**	**76.63**	**78.62**	**79.39**	**79.78**	**80.52**	**81.24**	**81.43**	**81.11**	**81.02**	**80.32**	**78.61**	**76.15**	**76.01**	**77.54**	**IEF National Approach**
CO_2 emissions	823.55	757.28	741.57	732.28	905.72	963.53	751.15	950.37	934.76	1004.65	1227.59	1250.02	1295.28	1465.86	1589.16	1904.62	1768.39	1766.19	1672.62	1150.66	964.02	838.63	892.50	**Gg CO_2 CRFReporter**
difference	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	
IEF reported	**76.19**	**76.51**	**75.59**	**75.27**	**76.07**	**76.23**	**74.58**	**77.25**	**76.59**	**76.63**	**78.62**	**79.39**	**79.78**	**80.52**	**81.24**	**81.43**	**81.11**	**81.02**	**80.32**	**78.61**	**76.15**	**76.01**	**77.54**	**IEF CRFReporter**
% Share of Fuels	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
Kerosene	1.34%	0.91%	0.87%	0.98%	1.39%	1.68%	2.85%	2.55%	3.05%	3.61%	2.90%	3.01%	2.81%	2.71%	2.31%	9.95%	7.77%	6.38%	7.56%	10.75%	9.73%	8.83%	7.23%	
Fuel Oil	33.41%	20.28%	24.62%	25.35%	26.48%	23.23%	27.29%	24.49%	24.41%	24.25%	21.72%	16.95%	13.89%	10.72%	9.29%	10.12%	7.75%	7.04%	6.54%	9.21%	8.28%	2.72%	2.14%	
LPG	17.75%	14.82%	14.51%	15.40%	13.45%	12.49%	15.26%	12.61%	13.97%	13.73%	12.67%	11.83%	13.59%	15.60%	17.23%	12.66%	13.86%	15.60%	17.49%	14.64%	21.71%	24.10%	22.28%	
Gasoil	28.86%	43.39%	44.64%	44.15%	41.75%	44.90%	44.04%	37.66%	38.42%	38.13%	32.92%	34.42%	32.77%	29.05%	24.84%	24.66%	25.33%	24.84%	24.03%	32.19%	35.80%	38.67%	35.34%	
Petroleum Coke	**18.24%**	**20.15%**	**14.91%**	**13.66%**	**16.56%**	**17.35%**	**10.12%**	**22.33%**	**19.79%**	**19.94%**	**29.52%**	**33.52%**	**36.66%**	**41.67%**	**46.10%**	**42.43%**	**45.08%**	**45.94%**	**44.16%**	**32.92%**	**24.12%**	**25.67%**	**33.01%**	
Naphta	0.41%	0.44%	0.45%	0.45%	0.37%	0.35%	0.44%	0.36%	0.36%	0.34%	0.28%	0.28%	0.27%	0.24%	0.22%	0.19%	0.20%	0.20%	0.21%	0.30%	0.35%	0.00%	0.00%	
	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	

Annex E

Energy - Transport (IPCC Sector 1.A.3)

E.1 – E.4 Civil aviation data 1990-2012

E.5 Vehicle population and kilometre data 1990-2012

Table E.1 Number of Domestic LTOs by departure airport 1990-2012

Domestic LTOs No.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ex Dublin	7657	6944	6885	5921	6153	7235	7742	8134	8991	10183	11018	10947	10849	11261	12143	9976	10392	10803	9611	7844	6074	3331	2190
ex Cork	2872	2604	2582	2221	2307	2713	2903	3050	3372	3819	4132	4106	4069	4223	4438	3649	3721	4608	3919	2872	1861	809	445
ex Shannon	1737	1576	1562	1343	1396	1641	1757	1845	2040	2310	2500	2484	2462	2555	2865	2809	2892	2277	1897	1349	1077	834	764
ex Galway	1425	1293	1282	1102	1145	1347	1441	1514	1674	1895	2051	2038	2019	2096	2224	1631	1615	1815	1848	1563	1746	1252	51
ex Sligo	620	562	557	479	498	586	627	658	728	824	892	886	878	912	946	759	748	754	785	741	678	381	35
ex Donegal	581	527	523	449	467	549	588	617	682	773	836	831	824	855	717	684	747	736	754	739	697	721	733
ex Knock	445	404	400	344	358	421	450	473	523	592	641	637	631	655	753	565	557	568	481	510	454	253	79
ex Kerry	1133	1027	1019	876	910	1070	1145	1203	1330	1506	1630	1620	1605	1666	1755	1477	1515	1506	1418	1170	1048	460	781
ex Waterford	236	214	213	183	190	223	239	251	278	314	340	338	335	348	254	181	191	279	456	231	472	707	175
ex Other	347	314	312	268	279	328	350	368	407	461	499	496	491	510	539	495	518	411	476	305	282	277	241
Total	**17053**	**15465**	**15334**	**13187**	**13703**	**16113**	**17242**	**18115**	**20024**	**22679**	**24538**	**24381**	**24164**	**25080**	**26634**	**22226**	**22896**	**23757**	**21645**	**17324**	**14389**	**9025**	**5494**

Domestic LTOs (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ex Dublin	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	46%	45%	45%	45%	44%	45%	42%	37%	40%
ex Cork	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	16%	16%	19%	18%	17%	13%	9%	8%
ex Shannon	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	11%	13%	13%	10%	9%	8%	7%	9%	14%
ex Galway	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	7%	7%	8%	9%	9%	12%	14%	1%
ex Sligo	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	4%	4%	5%	4%	1%
ex Donegal	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%	5%	8%	13%
ex Knock	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	3%	3%	3%	1%
ex Kerry	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	7%	7%	7%	5%	14%
ex Waterford	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%	3%	8%	3%
ex Other	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table E.2 Distances between airport pairs used to estimate fuel consumption for cruise phase

Nautical Miles		Cork	Galway	Donegal	Dublin	Knock	Kerry	Shannon	Sligo	Waterford	Other
		EICK	**EICM**	**EIDL**	**EIDW**	**EIKN**	**EIKY**	**EINN**	**EISG**	**EIWF**	
EICK	**Cork**		89.18	192.52	124.89	124.88	43.37	54.12	146.58	56.04	89.18
EICM	**Galway**	89.18		106.92	96.28	36.93	70.51	35.94	60.13	95.09	89.18
EIDL	**Donegal**	192.52	106.92		121.75	70.16	177.15	142.26	46.80	177.42	89.18
EIDW	**Dublin**	124.89	96.28	121.75		95.56	139.93	105.34	97.52	79.89	89.18
EIKN	**Knock**	124.88	36.93	70.16	95.56		106.99	72.70	23.53	121.02	89.18
EIKY	**Kerry**	43.37	70.51	177.15	139.93	106.99		38.25	130.45	89.97	89.18
EINN	**Shannon**	54.12	35.94	142.26	105.34	72.70	38.25		95.53	74.21	89.18
EISG	**Sligo**	146.58	60.13	46.80	97.52	23.53	130.45	95.53		137.05	89.18
EIWF	**Waterford**	56.04	95.09	177.42	79.89	121.02	89.97	74.21	137.05		89.18
	Other	89.18	89.18	89.18	89.18	89.18	89.18	89.18	89.18	89.18	

Table E.3 LTO emissions factors by aircraft type

Aircraft Type	kg of fuel per LTO	CH_4 kg/ LTO	N_2O kg/ LTO
A30B	1540.55	0.12	0.20
A310	1540.55	0.63	0.20
A320	802.33	0.06	0.10
A321	802.33	0.14	0.10
A332	2231.52	0.13	0.20
A333	2231.52	0.13	0.20
A343	2231.52	0.39	0.20
AT43	115.20	0.02	0.02
AT72	137.00	0.03	0.02
ATP	569.51	0.10	0.10
B462	569.51	0.14	0.10
B463	569.51	0.14	0.10
B733	825.39	0.08	0.10
B734	825.39	0.08	0.10
B737	784.12	0.09	0.10
B738	763.48	0.07	0.10
B752	1253.00	0.02	0.10
B762	1617.09	0.33	0.10
B763	1617.09	0.12	0.20
B764	1617.09	0.10	0.20
BE20	51.80	0.06	0.01
BE40	58.30	0.06	0.01
CL30	569.51	0.10	0.10
CL60	569.51	0.10	0.10
DC10	2381.18	0.24	0.20
GLF2	569.51	0.14	0.10
GLF4	569.51	0.14	0.10
GLF5	569.51	0.03	0.10
H25B	569.51	0.14	0.10
LJ31	569.51	0.14	0.10
LJ45	569.51	0.14	0.10
LJ60	569.51	0.14	0.10
MD11	1003.06	0.24	0.20
MD82	1003.06	0.19	0.10
MD83	1003.06	0.19	0.10
T154	2190.00	7.59	0.20
Other	49.57	0.02	0.10

Table E.4 Weighted Cruise fuel use per flight (IEF) by departure airport 1990-2012

kg Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ex Dublin	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	494.8	442.3	459.8	537.6	496.4	510.5	526.2	490.8	409.1	390.2
ex Cork	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	394.2	245.3	266.9	399.9	410.7	439.8	494.8	501.9	394.4	173.2
ex Shannon	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	979.8	1010.3	1055.9	1059.3	978.1	990.0	938.6	826.5	625.6	655.3
ex Galway	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	167.3	159.4	160.3	158.5	176.9	196.1	160.5	159.2	147.9	124.7
ex Sligo	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	164.2	164.1	166.9	165.6	163.6	167.6	168.0	143.7	108.2
ex Donegal	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	213.7	212.1	210.6	213.8	215.2	212.4	216.0	215.6	191.0	126.4
ex Knock	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	214.5	192.6	202.7	242.8	244.8	230.1	201.6	186.8	176.0	240.2
ex Kerry	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	421.1	246.7	247.8	247.0	242.4	452.1	757.9	753.8	533.6	242.7
ex Waterford	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	104.8	109.8	105.5	210.1	287.0	130.4	164.8	151.2	101.9
ex Other	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	150.6	160.2	157.6	148.5	165.4	139.9	140.7	141.8	159.7	138.0
Total	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**454.5**	**402.0**	**433.5**	**492.9**	**451.1**	**467.0**	**485.6**	**440.6**	**334.9**	**326.7**

Table E.5 Vehicle numbers, by technology class 1990, 2000-2012

Sector	Subsector	Technology	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Passenger Cars	Gasoline 0,8 - 1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 0,8 - 1,4 l	ECE 15/00-01	31830	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 0,8 - 1,4 l	ECE 15/02	235783	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 0,8 - 1,4 l	ECE 15/03	35249	4285	2063	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 0,8 - 1,4 l	ECE 15/04	220458	192288	157760	115198	87750	60785	44162	30208	21293	14731	7424	5200	2942	1480
Passenger Cars	Gasoline 0,8 - 1,4 l	Open Loop	4683	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 1 - 91/441/EEC	0	291726	277565	271198	252511	234058	201949	175166	139275	113592	133343	113480	90518	70197
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 2 - 94/12/EEC	0	305296	387716	380373	375274	368217	354676	340548	320459	312717	308269	306322	279747	253530
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	81521	157601	236126	233047	230927	228512	213481	214849	197364	195914	193589
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	86208	173076	258324	276615	214128	235867	237561	238937
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	21291	38408
Passenger Cars	Gasoline 0,8 - 1,4 l	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	4901	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	77578	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	11370	1809	883	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	80153	81171	67563	51553	39906	28597	21643	15689	11320	8970	4757	3368	1721	780
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	7024	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	0	123147	118872	121366	114834	110113	98971	90979	74046	69163	85441	49813	37955	27322
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	128876	166046	170224	170663	173229	173820	176876	170373	190406	197526	154230	138133	118532
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	36482	71672	111086	114211	119940	121490	129983	137606	146920	143828	138376
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	42249	89894	137339	168424	137204	149920	148935	147394
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	2893	4731
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	1787	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/02	6841	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/03	1057	122	85	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Gasoline >2,0 l	ECE 15/04	4069	5493	6505	4895	4302	3304	2667	2114	1642	770	418	438	223	102
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	0	8333	11445	11525	12378	12723	12195	12259	10743	5940	7504	4973	3756	2785
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	0	8722	15987	16164	18396	20016	21417	23834	24719	16354	17347	11832	9949	7133
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	3465	7726	12835	14072	16162	17627	11164	12090	12058	11302	8968
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	5206	12113	19927	14466	12050	11176	10699	8609
Passenger Cars	Gasoline >2,0 l	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	417	323
Passenger Cars	Gasoline >2,0 l	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Passenger Cars	Diesel 1,4 - 2,0 l	Conventional	71928	39587	31809	23614	18276	13201	10384	8432	6832	3105	1043	1184	671	323
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	0	58749	55242	55591	52592	50833	47487	48898	44687	23104	26595	19091	15465	11451
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	0	61483	77165	77970	78161	79970	83399	95064	102819	58346	70583	71530	68272	59962
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	16711	32825	51284	54799	64463	73318	79799	97469	100005	104282	101081
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	20271	48314	82883	155636	157793	221345	243017	258345
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	57010	110841
Passenger Cars	Diesel 1,4 - 2,0 l	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Diesel >2,0 l	Conventional	3785	5398	4753	3844	3225	2515	1978	1210	922	771	3257	321	197	78
Passenger Cars	Diesel >2,0 l	PC Euro 1 - 91/441/EEC	0	8011	8255	9050	9281	9683	9045	7015	6030	5738	6550	4598	3697	2619
Passenger Cars	Diesel >2,0 l	PC Euro 2 - 94/12/EEC	0	8385	11530	12693	13793	15233	15886	13638	13875	14490	17384	11947	10745	7378
Passenger Cars	Diesel >2,0 l	PC Euro 3 - 98/69/EC Stage2000	0	0	0	2720	5793	9767	10438	9248	9894	19818	24006	24124	24216	19571
Passenger Cars	Diesel >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	3861	6932	11185	38652	38864	42171	42839	40494
Passenger Cars	Diesel >2,0 l	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	4520	8962
Passenger Cars	Diesel >2,0 l	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	LPG	Conventional	2830	220	220	150	153	153	0	0	0	0	0	0	0	0
Passenger Cars	LPG	PC Euro 1 - 91/441/EEC	0	280	280	169	153	153	70	75	75	70	70	70	30	30
Passenger Cars	LPG	PC Euro 2 - 94/12/EEC	0	216	216	169	153	153	85	80	80	85	85	85	85	85
Passenger Cars	LPG	PC Euro 3 - 98/69/EC Stage2000	0	0	0	0	0	0	90	90	90	85	85	85	85	85
Passenger Cars	LPG	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	90	90	90	90	90	85	85	85
Passenger Cars	LPG	PC Euro 5 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	40	40
Passenger Cars	LPG	PC Euro 6 - EC 715/2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Light Commercial Vehicles	Gasoline <3,5t	Conventional	33306	1821	1271	850	588	394	224	122	69	48	37	27	14	6
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	0	3097	917	727	585	453	299	185	116	84	67	49	42	40
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	0	0	2123	1668	1374	1125	802	554	384	308	263	206	159	140
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	408	692	874	637	468	354	312	295	256	311	219
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	284	421	485	535	548	528	355	301
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	30	53
Light Commercial Vehicles	Gasoline <3,5t	LD Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Light Commercial Vehicles	Diesel <3,5 t	Conventional	89223	62672	53848	53361	38845	31914	24683	19306	14838	11634	9485	7417	4474	2274
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 1 - 93/59/EEC	0	106574	38870	45653	38652	36684	33059	29333	24912	20424	17205	13765	13482	16033
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 2 - 96/69/EEC	0	0	89942	104772	90837	91112	88497	87861	82717	74707	67526	57316	51148	56599
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 3 - 98/69/EC Stage2000	0	0	0	25626	45804	70719	70282	74250	76253	75757	75665	71230	99840	88101
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 4 - 98/69/EC Stage2005	0	0	0	0	0	0	31300	67027	104716	129528	140423	146941	114024	121487
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 5 - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	9475	21343
Light Commercial Vehicles	Diesel <3,5 t	LD Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Heavy Duty Trucks	Gasoline >3,5 t	Conventional	294	167	140	119	102	87	71	54	44	42	38	30	25	23
Heavy Duty Trucks	Rigid <=7,5 t	Conventional	9628	2608	2024	1503	1130	841	580	412	301	216	115	75	45	13
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro I - 91/542/EEC Stage I	0	3467	3222	2955	2671	2353	1913	1579	1274	984	817	629	534	515
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro II - 91/542/EEC Stage II	0	4034	5080	4717	4455	4243	3821	3597	3277	2795	2357	1906	1666	1633
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro III - 2000 Standards	0	0	0	1154	2247	3293	3034	3039	3021	2834	2641	2368	3251	2541
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	1351	2744	4148	4845	4902	4885	3713	3504
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	314	616
Heavy Duty Trucks	Rigid <=7,5 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 7,5 - 12 t	Conventional	9219	3946	3048	2258	1687	1234	870	608	424	280	133	85	50	15
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro I - 91/542/EEC Stage I	0	5247	4852	4423	3968	3465	2884	2333	1796	1278	942	718	602	582
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro II - 91/542/EEC Stage II	0	6103	7651	7067	6471	6249	5753	5314	4619	3632	2719	2173	1877	1845
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro III - 2000 Standards	0	0	0	1716	3266	4873	4560	4490	4258	3683	3047	2700	3664	2871
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	2046	4054	5847	6298	5654	5571	4184	3959
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	355	696
Heavy Duty Trucks	Rigid 7,5 - 12 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 12 - 14 t	Conventional	1555	1405	1178	920	726	564	453	348	205	132	60	38	23	7
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro I - 91/542/EEC Stage I	0	1868	1876	1803	1708	1585	1501	1337	867	603	429	317	279	277
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro II - 91/542/EEC Stage II	0	2174	2958	2880	2851	2859	2994	3044	2230	1713	1237	961	860	878
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro III - 2000 Standards	0	0	0	700	1439	2229	2374	2572	2056	1737	1386	1194	1679	1366
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	1065	2323	2824	2970	2573	2464	1917	1884
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	160	331
Heavy Duty Trucks	Rigid 12 - 14 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 14 - 20 t	Conventional	132	143	126	100	90	74	64	52	94	70	34	24	15	5
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro I - 91/542/EEC Stage I	0	190	201	196	214	208	211	200	397	320	244	200	181	181
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro II - 91/542/EEC Stage II	0	220	316	313	356	374	422	456	1020	910	705	604	554	573
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro III - 2000 Standards	0	0	0	77	180	291	335	385	940	923	790	751	1087	891
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	149	346	1291	1578	1466	1549	1241	1229
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	106	216
Heavy Duty Trucks	Rigid 14 - 20 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 20 - 26 t	Conventional	0	0	0	5	5	4	4	3	3	2	1	1	0	1
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro I - 91/542/EEC Stage I	0	0	0	11	12	12	14	13	11	11	9	6	6	5
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro II - 91/542/EEC Stage II	0	0	0	17	20	21	29	29	29	30	26	19	17	18
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro III - 2000 Standards	0	0	0	4	10	16	23	25	27	31	29	23	34	28
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	10	22	37	53	53	48	39	38
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	4	7
Heavy Duty Trucks	Rigid 20 - 26 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 26 - 28 t	Conventional	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro I - 91/542/EEC Stage I	0	0	0	1	2	1	2	1	2	2	1	1	1	1

Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro II - 91/542/EEC Stage II	0	0	0	2	2	2	2	3	4	4	3	2	2	2
Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro III - 2000 Standards	0	0	0	1	1	2	2	2	4	4	3	3	4	3
Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	0	2	5	8	6	5	5	4
Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Heavy Duty Trucks	Rigid 26 - 28 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 28 - 32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro I - 91/542/EEC Stage I	0	0	0	1	1	1	1	0	1	1	1	0	1	0
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro II - 91/542/EEC Stage II	0	0	0	1	1	1	1	1	2	4	3	1	1	1
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro III - 2000 Standards	0	0	0	0	0	1	0	1	2	4	3	1	2	2
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	0	0	0	6	6	3	3	2
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid 28 - 32 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid >32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Rigid >32 t	HD Euro I - 91/542/EEC Stage I	0	0	0	1	1	1	2	0	0	0	0	0	1	0
Heavy Duty Trucks	Rigid >32 t	HD Euro II - 91/542/EEC Stage II	0	0	0	2	2	2	2	0	2	1	1	1	1	1
Heavy Duty Trucks	Rigid >32 t	HD Euro III - 2000 Standards	0	0	0	1	2	2	2	2	2	1	1	2	2	2
Heavy Duty Trucks	Rigid >32 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	0	2	2	2	2	3	3	3
Heavy Duty Trucks	Rigid >32 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Heavy Duty Trucks	Rigid >32 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 40 - 50 t	Conventional	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro I - 91/542/EEC Stage I	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro III - 2000 Standards	0	0	0	0	0	0	0	0	1	0	0	1	1	0
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 40 - 50 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 50 - 60 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro I - 91/542/EEC Stage I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro III - 2000 Standards	0	0	0	0	0	0	1	0	0	0	1	0	1	0
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Trucks	Articulated 50 - 60 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buses	Urban Buses Standard 15 - 18 t	Conventional	3011	1034	812	611	468	348	247	173	126	98	55	38	23	7
Buses	Urban Buses Standard 15 - 18 t	HD Euro I - 91/542/EEC Stage I	0	1373	1294	1202	1106	974	814	663	533	445	388	316	277	289
Buses	Urban Buses Standard 15 - 18 t	HD Euro II - 91/542/EEC Stage II	0	1593	2044	1918	1845	1756	1625	1511	1371	1264	1121	957	863	916
Buses	Urban Buses Standard 15 - 18 t	HD Euro III - 2000 Standards	0	0	0	469	931	1364	1290	1277	1264	1282	1256	1189	1684	1427
Buses	Urban Buses Standard 15 - 18 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	575	1152	1736	2192	2331	2452	1923	1967

Buses	Urban Buses Standard 15 - 18 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	162	346
Buses	Urban Buses Standard 15 - 18 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buses	Coaches Standard <=18 t	Conventional	753	1050	813	605	467	348	247	173	126	98	55	38	23	7
Buses	Coaches Standard <=18 t	HD Euro I - 91/542/EEC Stage I	0	1395	1296	1189	1103	974	814	663	533	445	388	316	277	289
Buses	Coaches Standard <=18 t	HD Euro II - 91/542/EEC Stage II	0	1620	2047	1898	1841	1756	1625	1511	1371	1264	1121	957	863	916
Buses	Coaches Standard <=18 t	HD Euro III - 2000 Standards	0	0	0	463	930	1364	1290	1277	1264	1282	1256	1189	1684	1427
Buses	Coaches Standard <=18 t	HD Euro IV - 2005 Standards	0	0	0	0	0	0	576	1152	1737	2192	2331	2452	1923	1967
Buses	Coaches Standard <=18 t	HD Euro V - 2008 Standards	0	0	0	0	0	0	0	0	0	0	0	0	163	346
Buses	Coaches Standard <=18 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mopeds	2-stroke <50 cm³	Conventional	2274	4358	4651	4265	4222	3697	2225	1721	1263	993	842	715	501	460
Mopeds	2-stroke <50 cm³	Mop - Euro I	0	0	0	0	0	0	1050	1033	1179	1392	1179	1001	701	460
Mopeds	2-stroke <50 cm³	Mop - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	251	230
Mopeds	2-stroke <50 cm³	Mop - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mopeds	4-stroke <50 cm³	Conventional	2274	4358	4650	4265	4222	3698	2226	1722	1264	994	842	714	501	460
Mopeds	4-stroke <50 cm³	Mop - Euro I	0	0	0	0	0	0	450	442	505	596	505	429	301	460
Mopeds	4-stroke <50 cm³	Mop - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	250	230
Mopeds	4-stroke <50 cm³	Mop - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	2-stroke >50 cm³	Conventional	2274	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	4-stroke <250 cm³	Conventional	0	10036	10292	9638	9535	8817	6605	5885	5561	4937	4397	3738	2771	2562
Motorcycles	4-stroke <250 cm³	Mot - Euro I	0	0	0	0	0	0	1500	1962	2383	3291	3598	3737	2770	2562
Motorcycles	4-stroke <250 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	1386	1281
Motorcycles	4-stroke <250 cm³	Mot - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	4-stroke 250 - 750 cm³	Conventional	15922	10736	11988	13481	15404	16778	14220	14959	15765	14691	13954	12515	9774	9482
Motorcycles	4-stroke 250 - 750 cm³	Mot - Euro I	0	0	0	0	0	0	3000	4986	6756	9794	11416	12515	9774	9482
Motorcycles	4-stroke 250 - 750 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	4887	4741
Motorcycles	4-stroke 250 - 750 cm³	Mot - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles	4-stroke >750 cm³	Conventional	0	1150	1332	1498	1711	1864	1274	1662	1751	1633	1550	1391	1086	1054
Motorcycles	4-stroke >750 cm³	Mot - Euro I	0	0	0	0	0	0	750	554	751	1088	1269	1390	1086	1054
Motorcycles	4-stroke >750 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	543	527
Motorcycles	4-stroke >750 cm³	Mot - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annex F

Industrial Processes (IPCC Sector 2)

F.1 Cement production (IPCC sector 2.A.1)

F.2 Lime production (IPCC sector 2.A.2)

F.3 Limestone and Dolomite Use (IPCC sector 2.A.3)

F.4 Soda Ash Use (IPCC sector 2.A.4)

F.5 Glass Production (IPCC sector 2.A.7)

F.6 Bricks and Tiles (IPCC sector 2.A.7)

Table F.1 Cement production 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A1 Cement	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Clinker production (kilotonnes)																							
Cement Plant 1	913	811	764	744	905	921	1,125	1,317	1,154	1,326	1,399	1,462	1,496	1,566	1,691	1,669	1,665	1,685	1,424	706	579	564	853
Cement Plant 2	685	613	608	584	660	680	667	770	776	799	908	915	902	905	977	957	900	934	902	501	362	283	254
Cement Plant 3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	802	1,010	1,015	1,115	1,204	1,228	1,227	1,214	1,010	790	745	545	615
Cement Plant 4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	381	411	547	608	609	557	441	367	413	466
Total	**1,599**	**1,424**	**1,371**	**1,328**	**1,565**	**1,601**	**1,792**	**2,087**	**1,930**	**2,125**	**3,109**	**3,386**	**3,413**	**3,967**	**4,283**	**4,400**	**4,400**	**4,441**	**3,893**	**2,438**	**2,053**	**1,805**	**2,189**
Emission Factor t CO_2/t Clinker Produced																							
Cement Plant 1	0.553	0.546	0.546	0.546	0.546	0.546	0.546	0.546	0.546	0.546	0.546	0.546	0.542	0.534	0.504	0.536	0.537	0.534	0.536	0.537	0.533	0.534	0.537
Cement Plant 2	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.553	0.538	0.518	0.533	0.535	0.536	0.544	0.542	0.534	0.536	0.533
Cement Plant 3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.542	0.542	0.542	0.542	0.544	0.536	0.531	0.537	0.550	0.558	0.552	0.546	0.546
Cement Plant 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.525	0.686	0.540	0.528	0.529	0.535	0.533	0.523	0.523	0.530
IEF t CO_2/t Clinker	**0.553**	**0.549**	**0.549**	**0.549**	**0.549**	**0.549**	**0.549**	**0.549**	**0.549**	**0.549**	**0.547**	**0.547**	**0.545**	**0.536**	**0.536**	**0.536**	**0.534**	**0.535**	**0.541**	**0.544**	**0.538**	**0.535**	**0.538**
Emissions CO_2 (kilotonnes)																							
Cement Plant 1	505	443	417	406	494	503	614	719	630	724	764	798	810	836	853	894	894	900	763	379	309	301	458
Cement Plant 2	379	339	336	323	365	376	369	426	429	442	502	506	499	487	506	510	481	500	491	272	193	152	136
Cement Plant 3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	435	547	550	604	654	658	651	652	555	441	411	297	336
Cement Plant 4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	200	282	295	321	322	298	235	192	216	247
Total	**884**	**782**	**753**	**729**	**859**	**879**	**983**	**1,145**	**1,059**	**1,166**	**1,701**	**1,851**	**1,860**	**2,127**	**2,295**	**2,357**	**2,348**	**2,374**	**2,107**	**1,327**	**1,105**	**966**	**1,177**

Table F.2 Lime Production 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A2 Lime	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Lime production (kilotonnes)																							
Lime Plant 1	84.4	87.1	89.8	92.5	95.2	97.9	100.6	103.3	106.0	108.0	90.5	97.5	102.8	112.8	116.0	100.5	101.7	115.4	124.3	93.9	113.2	118.2	131.4
Lime Plant 2	170.8	144.4	125.9	150.5	151.8	125.6	139.6	149.8	150.1	98.6	157.8	146.0	139.6	126.9	130.1	135.7	129.0	136.5	121.3	111.0	138.5	143.0	149.5
Total	**255.2**	**231.5**	**215.7**	**243.0**	**247.0**	**223.5**	**240.1**	**253.0**	**256.1**	**206.6**	**248.3**	**243.5**	**242.4**	**239.7**	**246.1**	**236.2**	**230.8**	**251.9**	**245.6**	**204.9**	**251.7**	**261.2**	**280.9**
Emission Factor t CO_2/t Lime Produced																							
Lime Plant 1	0.757	0.800	0.730	0.834	0.805	0.827	0.794	0.918	0.795	0.800	0.801	0.826	0.808	0.813	0.808	0.795	0.794	0.806	0.770	0.762	0.759	0.765	0.759
Lime Plant 2	0.879	0.849	0.769	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.747	0.746	0.769	0.903	0.829	0.764	0.771	0.760	0.759	0.764	0.769	0.760	0.767
IEF t CO_2/t Lime	**0.839**	**0.830**	**0.753**	**0.843**	**0.832**	**0.839**	**0.826**	**0.877**	**0.826**	**0.823**	**0.767**	**0.778**	**0.785**	**0.861**	**0.819**	**0.777**	**0.781**	**0.781**	**0.765**	**0.763**	**0.765**	**0.762**	**0.763**
Emissions CO_2 (kilotonnes)																							
Lime Plant 1	63.9	69.7	65.5	77.2	76.6	80.9	79.8	94.8	84.3	86.4	72.5	80.5	83.0	91.7	93.7	79.8	80.8	93.0	95.7	71.6	85.9	90.4	99.7
Lime Plant 2	150.2	122.5	96.9	127.7	128.8	106.6	118.4	127.1	127.4	83.7	117.9	108.9	107.3	114.6	107.8	103.6	99.5	103.7	92.1	84.9	106.5	108.7	114.7
Total	**214.1**	**192.2**	**162.4**	**204.9**	**205.4**	**187.5**	**198.2**	**221.9**	**211.7**	**170.1**	**190.4**	**189.4**	**190.3**	**206.3**	**201.5**	**183.5**	**180.3**	**196.7**	**187.8**	**156.4**	**192.4**	**199.1**	**214.4**

Table F.3 Limestone and Dolomite Use 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A3 Limestone and Dolomite use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Limestone use (kilotonnes)																							
Power plant 1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	9.929	4.673	5.133	7.749	8.323	5.281	4.755	4.810	2.197	2.318	1.883	0.825
Power plant 2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.090	0.960	1.353	0.080	0.527	0.186
Brick Manufacturer	0.343	0.309	0.292	0.240	0.292	0.412	0.377	0.549	0.523	0.575	0.406	0.390	0.303	0.317	0.293	0.289	0.552	0.442	0.394	NO	NO	NO	NO
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.035	0.031	0.031	NO	NO	NO	NO
Sugar processing	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	1.216	0.178	NO	NO	NO	NO	NO	NO
Total	**0.343**	**0.309**	**0.292**	**0.240**	**0.292**	**0.412**	**0.377**	**0.549**	**0.523**	**0.575**	**0.406**	**10.319**	**4.976**	**5.449**	**8.042**	**9.828**	**6.046**	**5.318**	**6.196**	**3.550**	**2.398**	**2.409**	**1.011**
Emission Factor t CO_2/t Limestone Use																							
Power plant 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.436	0.436	0.436	0.441	0.436	0.436	0.436	0.436	0.430	0.430	0.431	0.431
Power plant 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.440	0.440	0.440	0.440	0.440	0.440
Brick Manufacturer	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.440	0.439	0.440	0.440	0.440	NA	NA	NA	NA
Tile manufacturer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.442	0.429	0.435	NA	NA	NA	NA
Sugar processing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.440	0.438	NA	NA	NA	NA	NA	NA
IEF t CO_2/t Limestone Use	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.440**	**0.436**	**0.436**	**0.436**	**0.441**	**0.437**	**0.437**	**0.436**	**0.437**	**0.434**	**0.430**	**0.433**	**0.432**
Emissions CO_2 (kilotonnes)																							
Power plant 1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	4.331	2.038	2.239	3.420	3.630	2.303	2.074	2.098	0.945	0.997	0.811	0.355
Power plant 2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.039	0.422	0.595	0.035	0.232	0.082
Brick Manufacturer	0.151	0.136	0.128	0.106	0.128	0.181	0.166	0.242	0.230	0.253	0.179	0.171	0.133	0.139	0.129	0.127	0.243	0.194	0.174	NO	NO	NO	NO
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.015	0.013	0.014	NO	NO	NO	NO
Sugar processing	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	0.535	0.078	NO	NO	NO	NO	NO	NO
Total	**0.151**	**0.136**	**0.128**	**0.106**	**0.128**	**0.181**	**0.166**	**0.242**	**0.230**	**0.253**	**0.179**	**4.502**	**2.171**	**2.378**	**3.549**	**4.292**	**2.640**	**2.321**	**2.707**	**1.540**	**1.032**	**1.042**	**0.437**

Table F.4 Soda ash use 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A4 Soda ash use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	Soda ash used (kilotonnes)																						
Lime Plant 2	0.237	0.212	0.173	0.266	0.127	0.168	0.224	0.243	0.258	0.132	0.171	0.216	0.132	0.154	0.198	0.202	0.150	0.136	0.106	0.132	0.177	0.166	0.211
	Emission Factor t CO_2/t Soda ash used																						
IEF t CO_2/t Soda ash use	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.413	0.411	0.411	0.411	0.411	0.411	0.415
	Emissions CO_2 (kilotonnes)																						
Lime Plant 2	0.097	0.087	0.071	0.109	0.052	0.069	0.092	0.100	0.106	0.054	0.070	0.089	0.054	0.063	0.081	0.083	0.062	0.056	0.044	0.054	0.073	0.068	0.087

Table F.5 Glass production 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A7 Glass production	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Carbonate use (kilotonnes)																							
Glass plant 1	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.412	0.363	0.438	0.438	0.328	NO	NO	NO	NO	NO	NO	NO
Glass plant 2	1.720	1.695	1.364	1.655	1.837	1.549	1.266	1.637	1.408	1.498	1.273	0.537	0.440	0.440	0.581	0.472	0.701	0.600	0.422	0.063	NO	NO	NO
Glass bottle	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	60.000	30.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Glass wool	1.746	1.746	1.485	1.746	1.746	1.746	1.746	1.746	1.541	1.870	2.057	1.809	1.161	0.734	0.709	0.628	0.708	0.699	0.461	NO	NO	NO	NO
Total	**63.878**	**63.852**	**63.260**	**63.812**	**63.994**	**63.707**	**63.423**	**63.794**	**63.360**	**63.781**	**63.742**	**62.758**	**31.964**	**1.612**	**1.727**	**1.428**	**1.409**	**1.299**	**0.882**	**0.063**	**NO**	**NO**	**NO**
Emission Factor t CO_2/t Carbonate Use																							
Glass plant 1	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	NA	NA	NA	NA	NA	NA	NA
Glass plant 2	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	0.275	NA	NA	NA
Glass bottle	0.200	0.195	0.191	0.186	0.182	0.178	0.173	0.169	0.165	0.160	0.156	0.151	0.147	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Glass wool	0.441	0.441	0.441	0.441	0.441	0.441	0.441	0.441	0.441	0.441	0.441	0.438	0.431	0.425	0.423	0.415	0.415	0.415	0.415	NA	NA	NA	NA
IEF t CO_2/t Carbonate Use	**0.209**	**0.204**	**0.199**	**0.196**	**0.192**	**0.188**	**0.183**	**0.180**	**0.174**	**0.172**	**0.168**	**0.162**	**0.161**	**0.343**	**0.336**	**0.337**	**0.345**	**0.350**	**0.348**	**0.275**	**NA**	**NA**	**NA**
Emissions CO_2 (kilotonnes)																							
Glass plant 1	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.113	0.100	0.120	0.120	0.090	NO	NO	NO	NO	NO	NO	NO
Glass plant 2	0.473	0.466	0.375	0.455	0.505	0.426	0.348	0.450	0.387	0.412	0.350	0.148	0.121	0.121	0.160	0.130	0.193	0.165	0.116	0.017	NO	NO	NO
Glass bottle	11.970	11.708	11.445	11.183	10.920	10.658	10.395	10.133	9.870	9.608	9.345	9.083	4.410	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Glass wool	0.769	0.769	0.654	0.769	0.769	0.769	0.769	0.769	0.679	0.824	0.906	0.793	0.500	0.312	0.300	0.261	0.294	0.290	0.191	NO	NO	NO	NO
Total	**13.325**	**13.056**	**12.587**	**12.520**	**12.307**	**11.966**	**11.625**	**11.465**	**11.049**	**10.957**	**10.714**	**10.136**	**5.131**	**0.553**	**0.580**	**0.481**	**0.487**	**0.455**	**0.307**	**0.017**	**NO**	**NO**	**NO**

Table F.6 Bricks and tiles 1990-2012

Activity data, emission factors and emissions

IPCC Sector 2A7 Bricks and tiles	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Raw material use (clays, shale, bricks and flues) (kilotonnes)																							
Fireclay plant 1	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	30.75	32.64	35.59	37.17	41.21	34.32	33.81	16.52	2.73	0.17	0.57	0.75
Brick Manufacturer 1	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	43.14	44.54	45.90	46.12	47.58	46.06	47.71	45.06	26.22	13.62	15.66	21.96	-
Brick Manufacturer 2	39.64	35.68	33.69	27.75	33.69	47.57	43.60	63.42	60.45	66.40	65.90	63.16	49.23	51.35	48.46	52.22	48.30	38.39	20.88	NO	NO	NO	NO
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	18.83	21.22	19.71	19.16	NO	NO	NO	NO
Total	**110.39**	**106.43**	**104.44**	**98.50**	**104.44**	**118.32**	**114.35**	**134.17**	**131.20**	**137.15**	**139.79**	**138.45**	**127.77**	**133.07**	**133.21**	**158.31**	**151.55**	**136.97**	**82.78**	**16.35**	**15.83**	**22.54**	**0.75**
Emission Factor t CO_2/t Raw Material Use																							
Fireclay plant 1	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.036	0.046	0.045	0.048	0.046	0.048	0.048	0.048	0.055	0.056	0.054	0.041
Brick Manufacturer 1	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.034	0.028	0.026	0.036	NA
Brick Manufacturer 2	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.049	NA	NA	NA	NA
Tile manufacturer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.051	0.061	0.069	0.067	NA	NA	NA	NA
IEF t CO_2/t Raw Material Use	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.046**	**0.044**	**0.046**	**0.046**	**0.047**	**0.047**	**0.049**	**0.050**	**0.048**	**0.033**	**0.027**	**0.037**	**0.041**
Emissions CO_2 (kilotonnes)																							
Fireclay plant 1	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.10	1.51	1.60	1.79	1.88	1.65	1.63	0.80	0.15	0.01	0.03	0.03
Brick Manufacturer 1	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.90	1.96	2.02	2.03	2.09	2.03	2.10	1.98	0.89	0.38	0.41	0.80	-
Brick Manufacturer 2	1.92	1.73	1.63	1.35	1.63	2.31	2.11	3.07	2.93	3.22	3.19	3.06	2.39	2.49	2.35	2.53	2.34	1.86	1.01	NO	NO	NO	NO
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.97	1.30	1.36	1.29	NO	NO	NO	NO
Total	**5.07**	**4.88**	**4.79**	**4.50**	**4.79**	**5.46**	**5.27**	**6.23**	**6.08**	**6.37**	**6.49**	**6.12**	**5.91**	**6.12**	**6.23**	**7.41**	**7.40**	**6.83**	**4.00**	**0.53**	**0.42**	**0.83**	**0.03**

Annex G

Agriculture (IPCC Sector 4)

G.1 Animal Populations

G.2 Methane Emission Factors for Enteric Fermentation

G.3 Methane Emission Factors for Manure Management

G.4.1 Allocation of animal wastes to AWMS-Cattle

G.4.2 Allocation of animal wastes to AWMS-Other Livestock

G.5 Nitrogen excretion values for Livestock 1990-2012

G.6 Input Parameters for the calculation of N_2O Emissions from Agricultural Soils

G.7 Nitrogen application to agricultural soils from sewage sludge (4.D.1.6) 1990-2012

G.8 Activity data, parameters and emission factors for N-Fixing Crops (4.D.1.3) 1990-2012

G.9 Activity data, parameters and emission factors for Crop Residue (4.D.1.4) 1990-2012

Table G.1 Animal Populations 1990-2012

1000 head	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total Cattle	6822	6921	6973	6959	6965	7009	7282	7491	7592	7348	7012	7022	6961	6971	6973	6951	6925	6827	6828	6813	6543	6428	6709
Dairy Cows	1341	1309	1262	1256	1247	1239	1241	1227	1216	1187	1165	1165	1146	1146	1139	1025	1054	1054	1060	1060	1039	1076	1101
All Other Cattle	5481	5612	5711	5703	5718	5770	6041	6264	6376	6160	5847	5857	5814	5826	5834	5926	5872	5773	5768	5753	5504	5352	5609
Other Cows	730	801	903	958	990	1022	1098	1183	1222	1192	1171	1178	1153	1166	1179	1121	1171	1185	1198	1169	1125	1103	1138
Dairy Heifers	172	156	187	191	207	230	238	244	226	212	205	202	223	221	234	214	204	197	195	196	234	252	266
Other Heifers	80	71	106	116	104	123	134	149	128	121	133	140	142	139	142	191	193	212	180	156	170	202	201
Cattle < 1 yrs	1716	1765	1695	1738	1736	1746	1852	1938	1965	1821	1752	1824	1799	1761	1771	1962	1953	1941	1959	1889	1761	1845	2036
Cattle < 1 yrs - male	903	919	889	914	904	915	974	1023	1055	965	919	955	953	922	930	958	951	947	969	918	827	892	1023
Cattle < 1 yrs - female	813	846	806	824	832	831	878	915	910	856	833	869	846	839	842	1005	1002	994	990	971	935	954	1013
Cattle 1 - 2 yrs	1663	1692	1638	1587	1586	1586	1639	1717	1783	1706	1517	1515	1593	1577	1535	1642	1506	1466	1496	1542	1407	1270	1376
Cattle 1 - 2 yrs - male	986	981	982	958	952	964	996	1055	1086	1039	912	913	992	983	950	972	845	818	832	851	760	673	770
Cattle 1 - 2 yrs - female	677	711	656	630	634	622	643	662	697	667	605	602	601	594	585	670	661	648	664	690	647	597	606
Cattle > 2 yrs	1093	1099	1152	1078	1058	1023	1036	986	1002	1058	1016	941	845	902	911	734	782	715	687	750	760	640	554
Cattle > 2 yrs - male	826	798	830	773	740	712	732	690	708	737	722	642	560	599	605	537	565	510	476	501	506	426	361
Cattle > 2 yrs - female	266	301	322	305	318	311	304	296	294	321	295	299	284	303	305	197	217	206	211	249	254	214	193
Bulls	27	29	32	36	38	40	44	48	50	51	53	56	59	60	63	61	63	57	54	52	47	38	37
Total Sheep	8021	8484	8736	8977	8559	8364	8329	8051	8572	8547	7957	7455	6682	6481	6703	6431	6187	5656	5105	4727	4328	4428	4843
Ewes Lowland	2397	2543	2622	2576	2511	2427	2369	2390	3056	2936	2814	2704	2637	2552	2464	2627	2414	2207	2057	1928	1920	1954	2036
Ewes Upland	1961	2080	2145	2108	2055	1986	1938	1955	1310	1258	1206	1159	1130	1094	1056	657	604	552	514	482	480	489	509
Rams lowland	64	67	70	69	67	66	62	64	81	79	77	75	73	72	70	77	74	69	63	58	59	59	61
Rams upland	53	55	57	56	55	54	51	52	35	34	33	32	31	31	30	19	19	17	16	14	15	15	15
Other Sheep>1 - lowland	164	96	89	99	107	113	106	118	172	153	143	128	129	144	140	124	122	109	112	103	96	101	116
Other Sheep>1 - upland	134	79	73	81	88	92	86	97	74	66	61	55	55	62	60	31	31	27	28	26	24	25	29
Lambs - lowland	1787	1960	2024	2194	2022	1994	2044	1856	2692	2815	2535	2312	1838	1768	2019	2317	2339	2140	1853	1693	1387	1428	1661
Lambs - upland	1462	1604	1656	1795	1654	1632	1672	1519	1154	1206	1086	991	788	758	865	579	585	535	463	423	347	357	415
Total Pigs	1222	1325	1404	1504	1514	1546	1643	1708	1810	1775	1727	1760	1791	1729	1704	1679	1632	1544	1486	1444	1509	1551	1532
Gilts in Pig	21	22	25	23	22	24	25	27	26	25	21	23	20	20	22	20	22	21	21	20	19	19	20
Gilts not yet Served	12	14	15	14	15	18	17	18	19	16	18	19	20	18	19	20	19	16	16	17	15	15	15
Sows in Pig	83	90	96	101	99	100	103	108	109	109	110	107	110	104	102	100	96	96	91	89	92	90	84
Other Sows for Breeding	31	31	33	33	30	31	36	37	38	38	32	37	33	32	30	34	31	28	25	27	29	27	25
Boars	6	7	7	6	6	5	5	5	5	4	4	4	3	3	3	2	2	2	2	2	2	1	1
Pigs 20 Kg +	749	803	837	905	918	952	1016	1064	1144	1094	1038	1036	1062	1043	1028	1010	1034	939	932	911	953	965	960
Pigs Under 20 Kg	319	358	392	422	425	417	442	450	469	489	504	535	543	508	500	494	429	443	400	378	400	434	426
Total Poultry	11413	12338	12913	12712	13675	14078	15016	15189	15327	15130	15321	15663	15183	15788	16743	16042	15426	12839	12839	14923	14923	14658	15342
Layer	1868	1800	2231	1832	1730	1371	1701	1580	1559	1537	1572	1676	1613	1907	1906	1950	1970	1813	1813	2145	2145	2060	2600
Broiler	8035	8905	9067	9522	10393	11092	11730	12096	12287	12200	12426	12629	12322	12672	13375	12818	12360	9696	9696	11904	11904	11520	11520
Turkey	1509	1633	1615	1358	1552	1616	1585	1513	1482	1393	1322	1358	1248	1209	1461	1274	1097	1330	1330	874	874	1078	1222
Horses	62	63	65	66	67	68	70	72	73	76	70	71	73	70	73	80	87	89	99	98	106	106	111
Mules	8	7	8	9	8	7	8	7	8	7	5	5	5	6	6	6	7	7	9	9	8	9	10
Goats	17	17	18	18	16	16	15	15	15	14	8	8	8	8	8	7	7	7	9	10	11	11	10
Fertiliser (1000's tonnes/N)	379.3	370.1	358.3	378.0	404.8	428.8	416.9	380.4	432.0	442.9	407.6	368.7	363.5	388.1	362.5	352.2	342.1	321.6	309.0	306.8	362.4	295.8	296.5

Table G.2 CH_4 Emission Factors for Enteric Fermentation (kg/head/year)

Animal Category	Animal Liveweight (kg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cattle																								
Dairy cows	535.0	101.4	101.9	102.5	103.0	103.6	104.1	104.6	105.2	105.7	106.3	106.8	107.4	107.9	108.5	108.4	107.8	109.4	109.8	110.0	108.5	113.1	113.2	112.8
Beef cows(Suckler Cows)	500.0	74.0	74.0	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.2	74.2	74.2	74.2	74.5	74.1	74.3	73.9	74.9	72.8	72.9	74.1	75.5
Dairy heifers	388.0	51.8	51.7	51.6	51.4	51.3	51.2	51.1	50.9	50.8	50.7	50.5	50.4	50.3	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2
Beef heifers	450.0	55.4	55.3	55.2	55.0	54.9	54.8	54.6	54.5	54.4	54.2	54.1	53.9	53.8	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7
Bulls for breeding	500.0	86.4	86.0	85.6	85.3	84.9	84.5	84.2	83.8	83.4	83.0	82.7	82.3	81.9	81.5	81.5	81.5	81.5	81.5	81.5	81.5	81.5	81.5	81.5
Male cattle																								
< 1 year	140.0	30.5	30.4	30.3	30.2	30.2	30.1	30.0	29.9	29.9	29.8	29.7	29.7	29.6	29.5	29.7	29.7	29.6	29.7	29.7	29.8	29.1	29.8	30.1
1 - 2 years	388.0	62.2	62.1	62.0	61.8	61.7	61.6	61.4	61.3	61.2	61.0	60.9	60.8	60.6	60.5	59.3	58.9	59.9	59.2	59.1	58.6	60.0	58.0	56.6
> 2 years*	500.0	55.1	53.5	51.9	50.2	48.6	47.0	45.4	43.8	42.2	40.6	38.9	37.3	35.7	34.1	35.2	37.7	37.8	38.6	37.0	38.8	39.8	38.3	37.2
Female cattle																								
< 1 year	140.0	27.0	27.1	27.2	27.2	27.3	27.3	27.4	27.5	27.5	27.6	27.6	27.7	27.7	27.8	27.9	27.9	27.8	27.8	27.6	27.6	27.0	27.6	27.7
1 - 2 years	388.0	53.5	52.9	52.2	51.5	50.8	50.1	49.4	48.7	48.0	47.4	46.7	46.0	45.3	44.6	44.5	45.6	46.4	46.6	47.0	47.7	48.6	47.9	48.0
> 2 years*	500.0	21.7	21.7	21.8	21.8	21.9	22.0	22.0	22.1	22.1	22.2	22.3	22.3	22.4	22.5	22.5	22.4	22.4	22.4	22.5	22.6	22.6	22.7	22.7
Sheep																								
Lowland Ewes		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Upland Ewes		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Rams		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Sheep > 1 yrs		8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Lambs		3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
Horses		18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Mules		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Goats		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pigs																								
Gilts in Pig	160.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Gilts not yet Served	120.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Sows in Pig	200.0	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Other Sows for Breeding	210.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Boars	225.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Pigs > 20 Kg	58.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Pigs < 20 Kg	13.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Poultry	2.4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

* Note: This value is low because this category of animal only live part of their third year

Table G.3 CH_4 Emission Factors for Manure Management (kg/head/year)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Cattle																							
Dairy cows	21.6	21.5	21.4	21.3	21.3	21.2	21.1	21.0	20.9	20.8	20.8	20.7	20.6	20.5	20.5	20.4	20.6	20.6	20.6	20.4	20.8	20.9	20.8
Beef cows(Suckler Cows)	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.3	13.8	13.9	14.1	14.4
Dairy heifers	13.4	13.2	13.0	12.8	12.6	12.5	12.3	12.1	11.9	11.7	11.5	11.3	11.1	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Beef heifers	15.6	15.4	15.2	15.0	14.8	14.6	14.3	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Bulls for breeding	23.8	23.4	23.0	22.7	22.3	21.9	21.6	21.2	20.8	20.4	20.1	19.7	19.3	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Male cattle																							
< 1 year	9.3	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.2	8.2	8.6	8.2	8.3	8.3	8.5	8.4	8.5
1 - 2 years	16.9	16.7	16.5	16.3	16.1	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	14.3	13.9	14.0	14.1	14.0	14.0	13.9	14.3	13.5	12.9
> 2 years*	5.2	4.9	4.6	4.3	4.1	3.8	3.5	3.2	3.0	2.7	2.4	2.2	1.9	1.6	1.8	2.1	1.9	2.3	2.0	2.3	2.4	2.2	2.0
Female cattle																							
< 1 year	8.4	8.4	8.3	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
1 - 2 years	14.9	14.5	14.1	13.7	13.2	12.8	12.4	12.0	11.6	11.1	10.7	10.3	9.9	9.5	9.2	9.7	9.9	9.9	10.1	10.4	10.8	10.4	10.4
> 2 years*	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sheep																							
Lowland Sheep	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Upland Sheep	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Rams	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sheep >1 yrs	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lambs	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Horses	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Mules	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Goats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pigs																							
Gilts in Pig	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Gilts not yet Served	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Sows in Pig	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Other Sows for Breeding	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9	31.9
Boars	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Pigs > 20 Kg	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Pigs < 20 Kg	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Poultry																							
Layers	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Broilers	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Turkeys	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

* Note: This value is low because this category of animal only live part of their third year.

Table G.4.1 Allocation of Animal Wastes to Animal Waste Management Systems – Cattle

Cattle	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Number of days housed																							
Dairy Cows	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	117	117	117	117	117	117
Suckler Cows	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	142
Dairy Heifer	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Other Heifer	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139	139
Under1yr	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	222	223	223	230	224	224
Oneto2yrs	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	155	157	157	154	153
Over2yrs	23	23	23	23	23	23	23	23	23	23	23	23	23	23	25	29	28	31	29	31	32	28	28
Bulls	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	155	157	157	154	153
Number of days grazing																							
Dairy Cows	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	248	248	248	248	248	248
Suckler Cows	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	223
Dairy Heifer	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
Other Heifer	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226	226
Under1yr	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	143	142	142	135	141	141
Oneto2yrs	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	210	208	208	211	212
Over2yrs	342	342	342	342	342	342	342	342	342	342	342	342	342	342	340	336	337	334	336	334	333	337	337
Bulls	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	210	208	208	211	212
Proportion to each AWMS																							
Liquid																							
Dairy Cows	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Suckler Cows	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Dairy Heifer	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Other Heifer	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Under1yr	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.42	0.41	0.42	0.42	0.43	0.42	0.42
Oneto2yrs	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.33
Over2yrs	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Bulls	0.42	0.42	0.42	0.41	0.41	0.41	0.40	0.40	0.40	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Solid																							
Dairy Cows	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Suckler Cows	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Dairy Heifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Heifer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Under1yr	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.19	0.20	0.20	0.20	0.20	0.20
Oneto2yrs	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Over2yrs	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.03
Bulls	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Pasture																							
Dairy Cows	0.66	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.70	0.70
Suckler Cows	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Dairy Heifer	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Other Heifer	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Under1yr	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.37	0.39	0.39
Oneto2yrs	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.58
Over2yrs	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.93	0.92	0.92	0.92	0.92	0.91	0.91	0.92	0.92
Bulls	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49

Table G.4.2 Allocation of Animal Wastes to Animal Waste Management Systems – Other Livestock

Animal Category	Days housed	% housed	% outwintered	Housing Type		Proportion to each AWMS		
				% Slurry based	% Straw based	Liquid	Solid	Pasture
Sheep								
Lowland Ewes	61.00	47.07	52.93	0.00	100.00	0.00	0.08	0.92
Upland Ewes	85.00	44.34	55.66	0.00	100.00	NA	0.10	0.90
Rams	85.00	22.34	77.66	0.00	100.00	NA	0.05	0.95
Lambs	58.00	16.88	83.12	0.00	100.00	NA	0.03	0.97
Other sheep	61.00	47.07	52.93	0.00	100.00	NA	0.08	0.92
Pigs								
Gilts in pig	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Gilts not yet served	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Sows in pig	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Other sows for breeding	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Boars	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Pigs < 20 kg	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Pigs > 20 kg	365.00	100.00	0.00	100.00	0.00	1.00	0.00	0.00
Poultry								
Layers	365.00	88.00	12.00	84.20	15.80	0.74	0.14	0.12
Broilers	365.00	100.00	0.00	0.00	100.00	0.00	1.00	0.00
Turkeys	365.00	100.00	0.00	0.00	100.00	0.00	1.00	0.00
Horses	143.00	100.00	0.00	0.00	100.00	0.00	0.39	0.61
Mules and Asses	143.00	100.00	0.00	0.00	100.00	0.00	0.39	0.61
Goats	0.00	0.00	100.00	0.00	0.00	0.00	0.00	1.00

Table G.5 Nitrogen excretion values for Livestock 1990-2012

N excretion (kg/head/year)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	N excretion values																						
Dairy Cows	95.5	95.9	96.3	96.6	97.0	97.3	97.7	98.0	98.4	98.7	99.1	99.5	99.8	100.2	100.0	97.8	100.0	100.4	100.7	99.7	102.5	102.6	99.7
Suckler Cows	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8
Dairy Heifer	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4
Other Heifer	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4
Under1yr	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6	27.6
One to 2yrs	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4	63.4
Over 2yrs	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2	37.2
Bulls	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8	73.8
Ewes Lowland	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
Ewes Upland	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Rams - lowland	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Rams - upland	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Other Sheep>1 - lowland	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Other Sheep>1 - upland	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Lambs - lowland	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Lambs - upland	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Gilts in pig	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Gilts not yet served	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Sows in pig	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Other breeding sows	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Boars	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
Fatteners > 20 kg	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Fatteners < 20 kg	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Laying hen per bird place	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Broiler per bird place	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Turkey per bird place	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Horses	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
Mules	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Goats	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9

Table G.6 Input Parameters for the calculation of N_2O Emissions from Agricultural Soils

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
$Frac_{GASF}$	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02
$Frac_{GRAZ}$	0.64	0.63	0.64	0.64	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.63	0.63	0.62	0.62	0.62	0.61	0.61	0.61	0.62	0.61
$Frac_{GASM1}$	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37	0.37	0.36	0.37	0.37	0.36	0.36	0.36	0.36	0.36
$Frac_{GASM2}$	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06
$Frac_{GASM}$	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18
F_{BN} (tonnes/year)	511.6	443.4	443.4	886.7	852.6	648.0	733.2	661.6	1105.0	627.5	262.6	303.5	255.8	467.2	491.1	644.6	682.1	436.5	378.6	757.1	852.6	562.7	545.7
$Frac_{LEACH}$	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
F_{SN} (ktonnes/year)	368.7	359.3	346.2	367.1	393.8	418.6	406.7	370.8	421.0	431.2	397.1	359.1	354.2	378.8	354.3	344.5	334.3	314.9	301.2	297.4	351.8	287.9	290.4
F_{AM} (ktonnes/year)	107.4	109.3	110.0	110.6	111.1	112.3	116.7	121.0	122.8	118.2	113.0	114.2	114.6	114.0	114.3	115.4	114.1	112.6	113.0	112.5	110.0	108.3	113.1
F_S (tonnes/year)	105.5	106.1	107.0	107.6	107.9	97.1	92.2	255.1	365.0	568.7	741.4	932.7	1103.6	1228.7	1687.6	1839.7	1913.1	1952.0	1990.4	2027.8	2064.5	2103.4	2140.1
F_{CR} (ktonnes/year)	19.7	19.0	19.3	16.2	17.9	19.4	20.8	20.0	19.9	21.1	21.7	19.7	17.8	20.0	23.6	18.0	10.6	10.2	11.7	10.5	10.8	12.2	9.4

Table G.7 Nitrogen application to agricultural soils from sewage sludge (4.D.1.6) 1990-2012

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
N applied (t/year)	105.5	106.1	107.0	107.6	107.9	97.1	92.2	255.1	365.0	568.7	741.4	932.7	1103.6	1228.7	1687.6	1839.7	1913.1	1952.0	1990.4	2027.8	2064.5	2101.3	2140.1

Table G.8 Activity data, parameters and emission factors for N-Fixing Crops (4.D.1.3) 1990-2011

	Pulses yield $Crop_{BF}$	Residue/ Crop Product mass ratio (Res_{BF})	Residue/ Crop Product mass ratio (Res_{BF})	Fraction Dry matter ($Frac_{DM}$)	Fraction of crop biomass that is nitrogen ($Frac_{NCRBF}$)	Nitrogen Fixed by Crops F_{BN}	EF_1	Emissions
	tonnes		(1 + Res_{BF})			kg N_2O-N/yr		Gg N_2O
	A	B	C	D	E	F = A * C * D * E * 1000	G	= F * G * 44/28000000
1990	15,000	1.80	2.80	0.87	0.014	511,560	0.0125	0.0100
1991	13,000	1.80	2.80	0.87	0.014	443,352	0.0125	0.0087
1992	13,000	1.80	2.80	0.87	0.014	443,352	0.0125	0.0087
1993	26,000	1.80	2.80	0.87	0.014	886,704	0.0125	0.0174
1994	25,000	1.80	2.80	0.87	0.014	852,600	0.0125	0.0167
1995	19,000	1.80	2.80	0.87	0.014	647,976	0.0125	0.0127
1996	21,500	1.80	2.80	0.87	0.014	733,236	0.0125	0.0144
1997	19,400	1.80	2.80	0.87	0.014	661,618	0.0125	0.0130
1998	32,400	1.80	2.80	0.87	0.014	1,104,970	0.0125	0.0217
1999	18,400	1.80	2.80	0.87	0.014	627,514	0.0125	0.0123
2000	7,700	1.80	2.80	0.87	0.014	262,601	0.0125	0.0052
2001	8,900	1.80	2.80	0.87	0.014	303,526	0.0125	0.0060
2002	7,500	1.80	2.80	0.87	0.014	255,780	0.0125	0.0050
2003	13,700	1.80	2.80	0.87	0.014	467,225	0.0125	0.0092
2004	14,400	1.80	2.80	0.87	0.014	491,098	0.0125	0.0096
2005	18,900	1.80	2.80	0.87	0.014	644,566	0.0125	0.0127
2006	20,000	1.80	2.80	0.87	0.014	682,080	0.0125	0.0134
2007	12,800	1.80	2.80	0.87	0.014	436,531	0.0125	0.0086
2008	11,100	1.80	2.80	0.87	0.014	378,554	0.0125	0.0074
2009	22,200	1.80	2.80	0.87	0.014	757,109	0.0125	0.0149
2010	25,000	1.80	2.80	0.87	0.014	852,600	0.0125	0.0167
2011	16,500	1.80	2.80	0.87	0.014	562,716	0.0125	0.0111

IPCC Equation 4.26 Tier 1b $\mathrm{FBN} = \sum i\, [CropBFi * \left(1 + \frac{ResBFi}{CropBFi}\right) * FracDMi * FracNCRBFi]$

Table G.9 Activity data, parameters and emission factors for Crop Residue (4.D.1.4) 1990-2012

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Crop j												**ktonnes**											
Pulses	15	13	13	26	25	19	22	19	32	18	8	9	8	14	14	19	20	13	11	22	25	17	16
Potatoes	605	571	638	569	642	618	733	472	482	559	455	478	519	488	552	409	383	399	345	336	420	356	232
Sugarbeet	1,480	1,409	1,397	1,117	1,390	1,547	1,476	1,648	1,640	1,712	1,829	1,498	1,301	1,505	1,851	1,380	-	-	-	-	-	-	-
Barley	1,223	1,148	1,168	958	910	1,084	1,225	1,087	1,073	1,278	1,310	1,277	963	1,198	1,327	1,024	1,137	1,125	1,294	1,227	1,223	1,412	1,152
Oats	144	143	136	129	128	129	146	132	119	136	127	119	134	155	155	113	145	159	174	146	148	168	145
Wheat	598	674	714	539	572	583	771	725	673	597	737	769	867	794	1,019	803	801	713	993	690	669	929	618
Residue/ Crop Product mass ratio (Res j)																							
Pulses	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Potatoes	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sugarbeet	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Barley	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Oats	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Wheat	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Fraction Dry matter ($Frac_{DM}$)																							
Pulses	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Potatoes	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Sugarbeet	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Barley	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Oats	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Wheat	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Fraction of crop biomass that is nitrogen ($Frac_{NCRBF}$)																							
Pulses	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
Potatoes	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Sugarbeet	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Barley	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Oats	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Wheat	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Crop Residues (F_{CR})												**tonnes N_2O-N/yr**											
Pulses	329	285	285	570	548	417	471	425	710	403	169	195	164	300	316	414	438	281	243	487	548	362	351
Potatoes	2,263	2,136	2,386	2,128	2,401	2,311	2,743	1,765	1,803	2,089	1,701	1,786	1,940	1,826	2,065	1,530	1,432	1,492	1,290	1,257	1,569	1,332	868
Sugarbeet	8,680	8,264	8,193	6,551	8,152	9,073	8,654	9,667	9,619	10,041	10,727	8,786	7,629	8,828	10,917	8,094	NO	NO	NO	NO	NO	NO	NO
Barley	5,364	5,035	5,123	4,202	3,991	4,754	5,371	4,768	4,706	5,603	5,745	5,602	4,223	5,253	5,818	4,493	4,986	4,932	5,676	5,383	5,364	6,193	5,053
Oats	1,206	1,197	1,139	1,080	1,072	1,080	1,223	1,102	997	1,142	1,080	994	1,118	1,298	1,299	944	1,216	1,332	1,459	1,220	1,240	1,407	1,217
Wheat	1,850	2,084	2,209	1,668	1,770	1,804	2,386	2,242	2,082	1,848	2,282	2,380	2,683	2,457	3,153	2,484	2,478	2,207	3,072	2,135	2,071	2,875	1,912
EF_1	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	1.0125
Emissions												**Gg N_2O**											
Pulses	0.006	0.006	0.006	0.011	0.011	0.008	0.009	0.008	0.014	0.008	0.003	0.004	0.003	0.006	0.006	0.008	0.009	0.006	0.005	0.010	0.011	0.007	0.007
Potatoes	0.044	0.042	0.047	0.042	0.047	0.045	0.054	0.035	0.035	0.041	0.033	0.035	0.038	0.036	0.041	0.030	0.028	0.029	0.025	0.025	0.031	0.026	0.017
Sugarbeet	0.171	0.162	0.161	0.129	0.160	0.178	0.170	0.190	0.189	0.197	0.211	0.173	0.150	0.173	0.214	0.159	NO	NO	NO	NO	NO	NO	NO
Barley	0.105	0.099	0.101	0.083	0.078	0.093	0.106	0.094	0.092	0.110	0.113	0.110	0.083	0.103	0.114	0.088	0.098	0.097	0.111	0.106	0.105	0.122	0.099
Oats	0.024	0.024	0.022	0.021	0.021	0.021	0.024	0.022	0.020	0.022	0.021	0.020	0.022	0.026	0.026	0.019	0.024	0.026	0.029	0.024	0.024	0.028	0.024
Wheat	0.036	0.041	0.043	0.033	0.035	0.035	0.047	0.044	0.041	0.036	0.045	0.047	0.053	0.048	0.062	0.049	0.049	0.043	0.060	0.042	0.041	0.056	0.038
Total	**0.387**	**0.373**	**0.380**	**0.318**	**0.352**	**0.382**	**0.410**	**0.392**	**0.391**	**0.415**	**0.426**	**0.388**	**0.349**	**0.392**	**0.463**	**0.353**	**0.207**	**0.201**	**0.231**	**0.206**	**0.212**	**0.239**	**0.185**

IPCC Equation 4.29 Tier 1b $\mathrm{FCR} = \sum j\ [Crop\ j * \left(\frac{Res\ j}{Crop\ j}\right) * FracDMj * FracNCROj] + \sum j\ [CropBF\ j * \left(\frac{ResBF\ j}{CropBF\ j}\right) * FracDMj * FracNCRBFj]$

Annex H

Activity Data for LULUCF Category 5.A Forest Land

H.1 Derivation of Historic Deforestation Areas for LULUCF and KP LULUCF

H.1.1 Tracking Deforestation using CORINE Land Cover Datasets (GPG approach 3)

H.1.2 Sampling approach: NFI grid points and aerial photography (modified GPG approach 3)

H.1.3 Modification to deforestation records from 2006 onwards

H.2 Detailed Non-Forest Land Use Change Matrices

H.1 Derivation of Historic Deforestation Areas for LULUCF and KP LULUCF

Lack of a method to record historic land use change is a significant gap in the LULUCF inventory. Ireland has attempted to improve the methodology to track deforestation, in particular, but this has only been implemented since 2006.

There are currently two data sources available to transparently report historic deforestation. However, both methods are limited and are not fully in accordance with IPCC good practice guidance for LULUCF because they do not accurately represent forest area changes, which are consistent with the forest definition (minimum area of 0.1 ha).

H.1.1 Tracking Deforestation using CORINE Land Cover Datasets (GPG approach 3)

The reporting of LUC matrices in Table 7.4 of chapter 7 show deforestation areas since 1990 (KP_CRF, Chapter 11) and have been estimated using CLC 1990-2000 and CLC 2000-2006.

H.1.1.1 Background Information

Coordination of Information on the Environment, CORINE, is an EU initiative established in 1985. The CORINE methodology for indicating *Change in Land Cover* (CLC) between 1990 and 2006 is complex (CEC 1993). Computer aided visual interpretation of satellite images (Büttner et al. 2004) was applied in the process of updating the 1990 European Land Cover to 2000 (±1 year) and the Land Cover change detection for the interval of 1990–2000, and 2000-2006 using Landsat MSS and TM satellite images. The smallest unit identified in CLC 2000 is 25 ha, and the minimum width of a linear feature is 100 m. Changes detected in the CORINE CLC were incorporated in CORINE 2000/6 only if the final CORINE polygon met the minimum mapping unit criterion of 25 ha. This means that a newly afforested area can only be detected by CORINE if it is larger than 25 ha. Clearly this is unlikely to accurately represent afforestation or deforestation since 1990, because the average size of newly established private forest parcels is 8 ha, and they are highly disperse and fragmented (Black et al, 2009 previously supplied to ERT).

The forest definition used by CORINE Land over (Bossard et al. 2000) is: “Areas occupied by forest and woodlands with a vegetation pattern composed of native or exotic coniferous and/or deciduous trees and which can be used for the production of timber or other forest products. The forest trees are under normal climatic conditions higher than 5 m with a canopy closure of 30 per cent at least”. Codes 311 representing deciduous forests, 312 for coniferous forests and 313 for mixed forests were used to interpret the change in forest area. The class, CLC 324, was excluded from the analysis, based on the assumption that this would represent recently felled/replanted and afforested areas, which are less than 10 years old. CLC 324 areas also include some semi-natural woodlands and scrub colonisation (not defined as forest land in the NFI), including: a) birch scrub on cutaway peatland; b) hazel encroachment in the Burren landscape and gorse colonisation on rough grassing land. This reclassification of land areas without ground truthing is one of our main concerns with the CLC 1990 to 2006 analysis.

Comparison of more recent high resolution datasets and CORINE clearly show that there is a mismatch in land cover classification in Ireland (Black et al., 2009). Therefore, we suggest that the misrepresentation of the CORINE afforested and deforestation area between 1990 and 2006 in Ireland may be associated with:

a) statistical misrepresentation of Irish forest land parcels in CORINE (i.e. low resolution of CORINE);
b) aggregation of classified categories, which may not reflect forest area change. This may be particularly relevant for CLC 324 (transitional woodland and scrub land,

which may also include areas subjected to encroachment by hazel on the Burren, birch colonisation of cutaway midland peat and gorse on grazed upland, all of which may not be defined as forest land according the national definition (chapter 11).

CORINE classification and resolution problems have been highlighted in other comparative studies across northern Europe (Hazeu and de Wit 2004, Cruickshank and Tomlinson 1996).

H.1.1.2 Methodology

Despite the above mentioned inappropriateness of CLC for reporting areas under LULUCF in a consistent, representative and accurate manner, this methodology uses the only data currently available to track historic land use change (see chapter 7).

For this exercise, the following codes were extracted; CLC 311, 312 and 313 to represent forest land area that were present in 1990, but were converted to land cover other that forest in the 2000 and 2006 time series. The resulting polygons were then intersected with a national soils map using ARCGIS to derive a land use change and soil type matrix to the periods 1990 to 2000 and 2000-2006. The resulting forest and soils GIS layers were then sampled using the NFi sample grid as discussed in H1.2 below.

H.1.2 Sampling approach: NFI grid points and aerial photography (modified GPG approach 3)

This sampling approach is a modification of approach 3, where the grids or centroids are sampled using a systematic sampling procedure adopted in the NFI. Note:

- The NFI was not designed to track land use change because the systematic grid (2 x 2 km) sample weighting factor used to derive total areas statistics in 400 ha (i.e. 1 sample point represents 400 ha). For small changes in forest areas, such as deforestation the sampling error is very large. For example if 10 PSP grid point are identified to be deforested than the total area represented in 4,000 ha with a lower and upper confidence limit of 945 and 7,055 ha, respectively. This represents a sampling error of 76 per cent;

- Another problem with this method is that it does not represent forest area change in a manner that is consistent with the forest area definition (0.1 ha), so is in conflict with IPCC GPG for LULUCF. This is why the NFI afforested areas are statistically adjusted using the IFORIS spatial data to consistently represent afforestation areas (see Chapter 11). However, there is at present no data available to adjust the NFI estimates of deforested land.

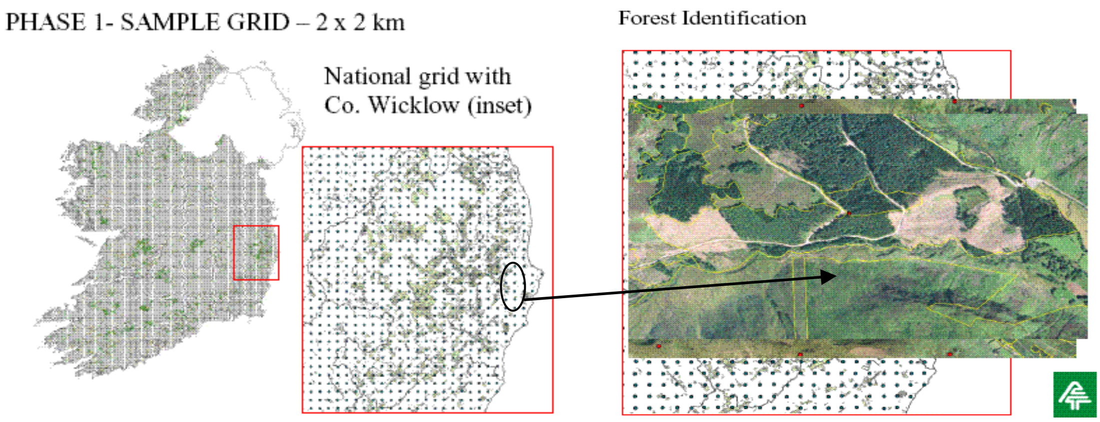


Figure H.1: The NFI systematic sample approach used to classify land use for each permanent sample plot (PSP)

The use of the NFI stratified sample 2x2 km grid of PSP described in chapter 11. Assessment of ca.18,000 point intersects with aerial photographs from 2000 and 2006 provides the opportunity to assess deforestation for this period. This method identified 15 NFI PSP grid samples which were deemed to be deforested between 2000 and 2006. The current land uses of these previously deforested lands were determined from photo interpretation using the 2006 images. Figure H.1 shows 2 examples of the GIS analysis and photo interpretation.

Figure H.2: Examples of NFI PSP (as indicated by the red cross) which were classified forests in 2000 but have since been converted to other land uses in 2006

Assessments of deforestation from 1995 to 2000 were based on a GIS intersection of the 18,000 NFI plots with the FIP95 forest parcel polygon layer. This exercise produced 105 forest parcels which were classified as forest in the FIPS 95 dataset but where classified as non-forest land in the NFI aerial photography interpretation. These 105 polygons were cross-checked with 1995 black and white aerial photographs to verify that they were forests in 1995. However, most of the sampled forest polygons were deemed to not be deforested or were originally other land uses in 1995. This was due to interpretation inconsistencies of photographs and mapping errors in the FIPS95 layer. Only 5 NFI sample points were identified to be deforested between 1995 and 2000.

The final deforestation-land use change-soils matrices for 1995-2000 and 2000-2006 were obtained by intersecting identified deforested PSP points with the national soils map database (Table 2, Figure H.3), see database for detailed information.

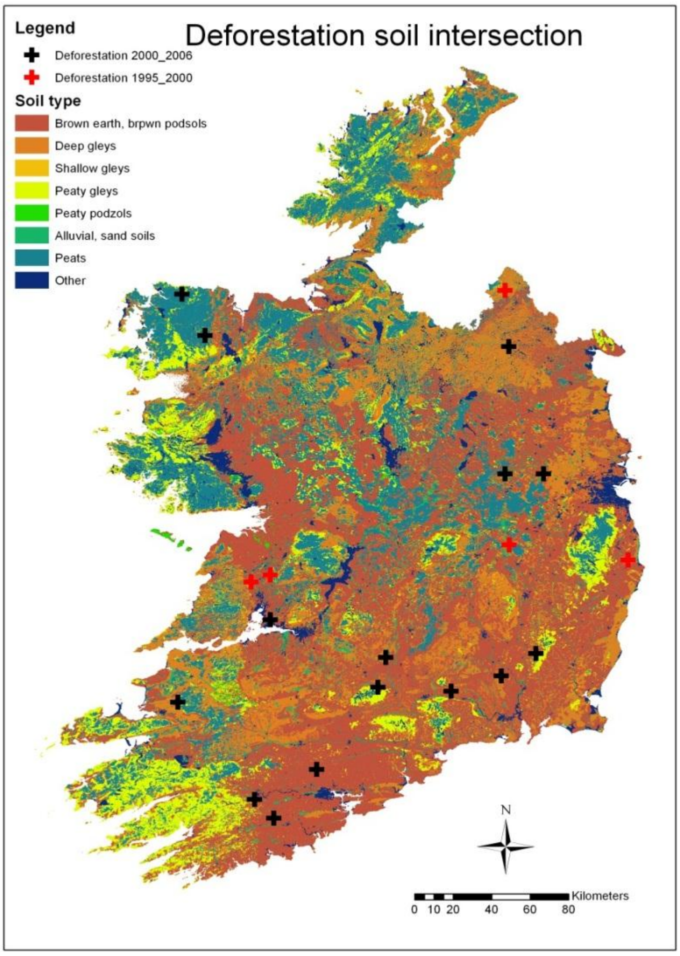


Figure H.3 The Irish soils map showing intersection with NFI PSP plots determined to be deforested between 1995 and 2006

H.1.3 Modification to deforestation records from 2006 onwards

The current methods for recording deforestation from 2006 onwards included the use of felling licence records. However, a QA exercise conducted in 2010 highlighted that 134 to 268 ha per year of land deforested since 2006 was not included in the felling licence records, if forests were less than 10 years old. These areas are not subject to the forestry act felling licence application. However, records were kept because these areas were previously subject to premium payments under the afforestation scheme. Owners in receipt of these payments are obliged to notify the Forest service if these areas are taken out (‘**lands taken out’**) of the premiums payment due to deforestation. A data base of these records is being compiled to capture the land use change and soil categories if the information is available.

However, until this information does become available, the land use and soil type matrices from the felling record data for corresponding years will be used. The biomass, litter and DOM losses associated with deforestation will be based on the NFI, PSP average of all 10 year old forest areas.

Combination of the three different approaches was used to produce deforestation data for the entire time series (Table H.2).

Table H.2 The new deforestation, land use change and soil type matrix

Period	Source	Land use	Soil category	Area (ha) per year	% for period
1990-1994	**CLC1990-2000**			**20.6**[11]	**100**
		Grassland	Mineral	2.5	12.2
		Grassland	Peat		
		Grassland	Peaty mineral	5.7	27.9
		Settlement	Mineral	10.2	49.4
		Settlement	Peat		
		Settlement	Peaty mineral		
		Wetland	Mineral		
		Wetland	Peat		
		Wetland	Peaty mineral		
		Other	Mineral	2.2	10.5
		Other	Peat		
		Other	Peaty mineral		
1995-1999	**NFI-FIPs 95**			**333.3**[12]	**100**
		Grassland	Mineral	266.7	80
		Grassland	Peat		
		Grassland	Peaty mineral		
		Settlement	Mineral		
		Settlement	Peat		
		Settlement	Peaty mineral		
		Wetland	Mineral		
		Wetland	Peat		
		Wetland	Peaty mineral		
		Other	Mineral	66.6	20
2000-2005	**NFI-2000-2006**			**857.1**[13]	**100**

[11] The CLC 1990-1994 area was calculated using the values show in table 1a to be, where annual deforestation area 1990-1994 = $\frac{area1990 \rightarrow 2000}{10 \times 5} \times 5$

[12] NFI 1995-1999 area was calculated using the values show in table 2a to be, where the annual deforested area 1995-1999 = $\frac{area1995 \rightarrow 2000}{6 \times 5} \times 5$

[13] NFI 2000-2005 area was calculated using the values show in table 2b to be, where the annual deforested area 2000-2005 = $\frac{area2000 \rightarrow 2006}{7 \times 6} \times 6$

		Grassland	Mineral	342.8	40
		Grassland	Peat		0
		Grassland	Peaty mineral	57.4	6.7
		Settlement	Mineral	171.4	20
		Settlement	Peat		0
		Settlement	Peaty mineral		0
		Wetland	Mineral	56.6	6.6
		Wetland	Peat	114.0	13.3
		Wetland	Peaty mineral		0
		Other	Mineral	57.4	6.7
		Other	Peat	57.4	6.7
		Other	Peaty mineral		0
2006	**Felling licence and land taken out**			**376.44**	**100**
	242.34+134.1	Grassland	Mineral	5.3	1.4
	(LFL+LTO)[14]	Grassland	Peat		0
		Grassland	Peaty mineral	19.7	5.2
		Settlement	Mineral	17.1	4.5
		Settlement	Peat		0
		Settlement	Peaty mineral	0.6	0.2
		Wetland	Mineral		0
		Wetland	Peat	299.9	79.7
		Wetland	Peaty mineral	30.8	8.2
		Other	Mineral	3.1	0.8
		Other	Peat		0
		Other	Peaty mineral		0
2007	**Felling licence and land taken out**			**338.7**	**100**
	174.83+163.9	Grassland	Mineral	0.6	0.2
	(LFL+LTO)[4]	Grassland	Peat	14.5	4.3
		Grassland	Peaty mineral		0
		Settlement	Mineral	4.7	1.4
		Settlement	Peat	0.8	0.3
		Settlement	Peaty mineral		0
		Wetland	Mineral		0
		Wetland	Peat	297.2	87.7
		Wetland	Peaty mineral		0
		Other	Mineral	8.6	2.5
		Other	Peat	12.4	3.6
		Other	Peaty mineral		
2008	**Felling licence and land taken out**			**294.5**	**100**
	26.42+268	Grassland	Mineral	80.2	27.2
	(LFL+LTO)[4]	Grassland	Peat	0.04	0.01
		Grassland	Peaty mineral		0
		Settlement	Mineral	66.4	22.6
		Settlement	Peat		0
		Settlement	Peaty mineral		0
		Wetland	Mineral		0
		Wetland	Peat	24.5	8.3

[14] LFL is areas from limited felling licence records and LTO is the areas from lands taken out

		Wetland	Peaty mineral	21.2	7.2
		Other	Mineral	100.9	34.3
		Other	Peat		0
		Other	Peaty mineral	1.1	0.4
2009	**Felling licence and land taken out**			**196.9**	**100**
	49.9+147	Grassland	Mineral	5.1	2.6
	(LFL+LTO)[4]	Grassland	Peat		
		Grassland	Peaty mineral		
		Settlement	Mineral	15.4	7.8
		Settlement	Peat	1.5	0.7
		Settlement	Peaty mineral	1.5	0.8
		Wetland	Mineral		0
		Wetland	Peat		0
		Wetland	Peaty mineral		0
		Other	Mineral	121.1	61.5
		Other	Peat	19.9	10.1
		Other	Peaty mineral	32.4	16.4
2010	**Felling licence and land taken out**			**124**	**100**
	26+98	Grassland	Mineral	39.7	39.1
	(LFL+LTO)[4]	Grassland	Peat		
		Grassland	Peaty mineral		
		Settlement	Mineral	7.9	6.3
		Settlement	Peat		0.7
		Settlement	Peaty mineral	47.2	37.9
		Wetland	Mineral		0
		Wetland	Peat	0.5	0.4
		Wetland	Peaty mineral		0
		Other	Mineral	18.5	14.8
		Other	Peat	4.5	3.6
		Other	Peaty mineral	6.1	6.9

H.2 Detailed Non-Forest Land Use Change Matrices

This annex supplements the material in Table 7.4 Summary Land Use Matrices 1990-2012. It provides detailed tables for annual estimates of area for the non-Forest Land, land use categories. Shown are estimates of gains and losses related to each land use type on an annual basis, the subsequent annual net change in area and the resultant cumulative total area under each category.

Also shown in the tables are the summary values for Remaining Land and In Transition which appear in the Common Reporting Format submission.

The tables in the annex demonstrate the consistency between Table 7.4 and the CRF figures. These tables are an important tool for QA/QC.

Table H.2.1 Cropland Matrix

	Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF	Cropland Remaining Cropland	424.65	404.56	401.69	400.00	398.37	394.89	392.48	390.34	387.89	381.79	374.69
CRF	Cropland in Transition Cummulative	0.00	0.00	0.00	2.62	15.41	15.41	16.80	26.21	26.21	26.21	26.21
CRF	Total Cropland	424.65	404.56	401.69	402.62	413.79	410.30	409.28	416.55	414.10	408.00	400.90
	Forest to Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Grassland to Cropland	0.00	0.00	2.62	12.80	0.00	1.38	9.42	0.00	0.00	0.00	0.82
	Settlement to Cropland											
	Total Gain in Cropland	0.00	0.00	2.62	12.80	0.00	1.38	9.42	0.00	0.00	0.00	0.82
	Cropland to Forest	1.58	1.91	1.67	1.60	1.95	2.37	2.10	1.14	1.29	1.27	1.57
	Cropland to Grassland	18.48	0.93	0.00	0.00	1.50	0.00	0.00	1.26	4.75	5.78	0.00
	Cropland to Wetland											
	Cropland to Settlement	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.05
	Cropland to Other land											
	Total Loss from Cropland	20.08	2.87	1.70	1.63	3.48	2.41	2.14	2.45	6.10	7.10	1.62
	Net Change Forest/Cropland	-1.58	-1.91	-1.67	-1.60	-1.95	-2.37	-2.10	-1.14	-1.29	-1.27	-1.57
	Net Change Grassland/Cropland	-18.48	-0.93	2.62	12.80	-1.50	1.38	9.42	-1.26	-4.75	-5.78	0.82
	Net Change Wetland/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Settlement/Cropland	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05	-0.06	-0.05
	Net Change Other Land/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Matrix Increment	Annual net Change	-20.08	-2.87	0.92	11.17	-3.48	-1.02	7.28	-2.45	-6.10	-7.10	-0.80
Annual Matrix	Cumulative Cropland	424.65	404.56	401.69	402.62	413.79	410.30	409.28	416.55	414.10	408.00	400.90
Total Matrix	Total Cropland	424.65	404.56	401.69	402.62	413.79	410.30	409.28	416.55	414.10	408.00	400.90

Table H.2.1 Cropland Matrix (continued)

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CRF	**Cropland Remaining Cropland**	373.07	371.55	370.16	369.33	356.43	317.43	312.43	310.93	310.71	293.21	236.71	236.49	236.28
CRF	**Cropland in Transition Cumulative**	27.03	43.05	52.74	66.37	66.37	66.37	66.37	66.37	115.49	115.49	115.49	127.61	144.22
CRF	**Total Cropland**	400.10	414.60	422.90	435.70	422.80	383.80	378.80	377.30	426.20	408.70	352.20	364.10	380.50
	Forest to Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Grassland to Cropland	16.02	9.69	13.63	0.00	0.00	0.00	0.00	49.12	0.00	0.00	12.12	16.62	0.00
	Settlement to Cropland													
	Total Gain in Cropland	16.02	9.69	13.63	0.00	0.00	0.00	0.00	49.12	0.00	0.00	12.12	16.62	0.00
	Cropland to Forest	1.46	1.33	0.75	0.75	0.72	0.24	0.22	0.19	0.20	0.25	0.20	0.20	0.00
	Cropland to Grassland	0.00	0.00	0.00	12.07	38.19	4.68	1.23	0.00	17.23	56.17	0.00	0.00	0.00
	Cropland to Wetland													
	Cropland to Settlement	0.07	0.06	0.08	0.08	0.09	0.08	0.05	0.03	0.07	0.09	0.02	0.02	0.00
	Cropland to Other land													
	Total Loss from Cropland	1.52	1.39	0.83	12.90	39.00	5.00	1.50	0.22	17.50	56.50	0.22	0.22	0.00
	Net Change Forest/Cropland	-1.46	-1.33	-0.75	-0.75	-0.72	-0.24	-0.22	-0.19	-0.20	-0.25	-0.20	-0.20	0.00
	Net Change Grassland/Cropland	16.02	9.69	13.63	-12.07	-38.19	-4.68	-1.23	49.12	-17.23	-56.17	12.12	16.62	0.00
	Net Change Wetland/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Settlement/Cropland	-0.07	-0.06	-0.08	-0.08	-0.09	-0.08	-0.05	-0.03	-0.07	-0.09	-0.02	-0.02	0.00
	Net Change Otherland/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Matrix Increment	**Annual net Change**	14.50	8.30	12.80	-12.90	-39.00	-5.00	-1.50	48.90	-17.50	-56.50	11.90	16.40	0.00
Annual Matrix	**Cummulative Cropland**	400.10	414.60	422.90	435.70	422.80	383.80	378.80	377.30	426.20	408.70	352.20	364.10	380.50
Total Matrix	**Total Cropland**	400.10	414.60	422.90	435.70	422.80	383.80	378.80	377.30	426.20	408.70	352.20	364.10	380.50

Table H.2.2 Grassland Matrix

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF	Grassland Remaining Grassland	4414.2	4408.2	4400.3	4382.4	4376.2	4367.3	4351.1	4347.1	4342.6	4338.2
CRF	Grassland in Transition	18.5	19.5	19.6	19.7	21.3	21.6	21.8	23.4	28.5	34.5
CRF	Total Grassland	4432.8	4427.7	4419.9	4402.1	4397.4	4388.8	4372.9	4370.5	4371.1	4372.7
	Forest to Grassland	8	8	8	8	8	267	267	267	267	267
	Cropland to Grassland	18475	929	0	0	1504	0	0	1260	4754	5777
	Wetland to Grassland	61	61	61	61	61	30	30	30	30	30
	Settlement to Grassland	0	0	0	0	0	0	0	0	0	0
	Other land to Grassland	0	0	0	0	0	0	0	0	0	0
	Total Gain in Grassland	18544	998	69	69	1573	297	297	1557	5051	6073
	Grassland to Forest	4745	5744	5010	4799	5838	7113	6294	3430	3878	3800
	Grassland to Cropland	0	0	2618	12797	0	1381	9418	0	0	0
	Grassland to Wetland	0	0	0	0	0	0	0	0	0	0
	Grassland to Settlement	310	282	286	306	380	392	497	544	587	629
	Grassland to Other land	0	0	0	0	0	0	0	0	0	0
	Total Loss from Grassland	5055	6026	7914	17903	6217	8886	16209	3974	4466	4429
	Net Change Forest/Grassland	-4737	-5736	-5002	-4791	-5830	-6846	-6028	-3164	-3612	-3534
	Net Change Grassland/Cropland	18475	929	-2618	-12797	1504	-1381	-9418	1260	4754	5777
	Net Change Wetland/Grassland	61	61	61	61	61	30	30	30	30	30
	Net Change Settlement/Grassland	-310	-282	-286	-306	-380	-392	-497	-544	-587	-629
	Net Change Otherland/Grassland	0	0	0	0	0	0	0	0	0	0
Matrix Increment	Total Annual net Change	13489	-5028	-7845	-17834	-4644	-8589	-15912	-2418	585	1644
Annual Matrix	Matrix Total Grassland Annual	4432.8	4427.7	4419.9	4402.1	4397.4	4388.8	4372.9	4370.5	4371.1	4372.7

Table H.2.2 Grassland Matrix (continued)

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CRF	Grassland Remaining Grassland	4332.2	4310.6	4295.3	4277.8	4273.5	4268.8	4264.3	4260.4	4208.2	4204.4	4199.7	4184.4	4164.6
CRF	Grassland in Transition	35.0	35.5	36.0	36.4	49.0	87.7	92.4	93.7	94.2	112.0	169.0	170.3	170.3
CRF	Total Grassland	4367.2	4346.0	4331.3	4314.2	4322.5	4356.4	4356.7	4354.2	4302.4	4316.4	4368.7	4354.7	4334.9
	Forest to Grassland	400	400	400	400	400	400	0	0	400	400	800	1200	0
	Cropland to Grassland	0	0	0	0	12074	38190	4678	1233	0	17234	56165	0	0
	Wetland to Grassland	75	75	75	75	75	88	88	88	88	88	88	88	0
	Settlement to Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other land to Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Gain in Grassland	475	475	475	475	12549	38679	4766	1321	488	17722	57054	1288	0
	Grassland to Forest	4709	4833	4893	3070	3409	3660	3617	3229	2812	2992	3741	2994	2993
	Grassland to Cropland	816	16023	9689	13626	0	0	0	0	49120	0	0	12118	16616
	Grassland to Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grassland to Settlement	517	738	661	837	886	1055	900	580	357	743	949	202	187
	Grassland to Other land	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Loss from Grassland	6041	21593	15243	17533	4295	4715	4517	3809	52289	3734	4691	15313	19796
	Net Change Forest/Grassland	-4308	-4433	-4492	-2670	-3008	-3260	-3617	-3229	-2412	-2592	-2941	-1794	-2993
	Net Change Grassland/Cropland	-816	-16023	-9689	-13626	12074	38190	4678	1233	-49120	17234	56165	-12118	-16616
	Net Change Wetland/Grassland	75	75	75	75	75	88	88	88	88	88	88	88	0
	Net Change Settlement/Grassland	-517	-738	-661	-837	-886	-1055	-900	-580	-357	-743	-949	-202	-187
	Net Change Otherland/Grassland	0	0	0	0	0	0	0	0	0	0	0	0	0
Matrix Increment	Total Annual net Change	-5566	-21118	-14768	-17058	8254	33964	250	-2488	-51801	13988	52363	-14025	-19796
Annual Matrix	Total Grassland	4367.2	4346.0	4331.3	4314.2	4322.5	4356.4	4356.7	4354.2	4302.4	4316.4	4368.7	4354.7	4334.9

Table H.2.3 Wetland Matrix

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF	Wetland Remaining Wetland	1,299.35	1,288.38	1,278.80	1,269.62	1,258.46	1,244.92	1,232.93	1,226.38	1,218.98	1,211.73
CRF	Wetland in Transition	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRF	Total Wetland	1,299.35	1,288.38	1,278.80	1,269.62	1,258.46	1,244.92	1,232.93	1,226.38	1,218.98	1,211.73
	Forest to Wetland	0	0	0	0	0	0	0	0	0	0
	Cropland to Wetland										
	Grassland to Wetland										
	Settlement to Wetland										
	Other land to Wetland										
	Total Gain in Wetland	0	0	0	0	0	0	0	0	0	0
	Wetland to Forest	9016	10914	9518	9119	11092	13515	11959	6517	7369	7221
	Wetland to Cropland										
	Wetland to Grassland	61	61	61	61	61	30	30	30	30	30
	Wetland to Settlement										
	Wetland to Other land										
	Total Loss from Wetland	9076	10975	9579	9180	11152	13545	11989	6547	7399	7251
	Net Change Forest/Wetland	-9016	-10914	-9518	-9119	-11092	-13515	-11959	-6517	-7369	-7221
	Net Change Wetland/Cropland	0	0	0	0	0	0	0	0	0	0
	Net Change Wetland/Grassland	-61	-61	-61	-61	-61	-30	-30	-30	-30	-30
	Net Change Settlement/Wetland	0	0	0	0	0	0	0	0	0	0
	Net Change Otherland/Wetland	0	0	0	0	0	0	0	0	0	0
Matrix Increment	Annual net Change	-9076	-10975	-9579	-9180	-11152	-13545	-11989	-6547	-7399	-7251
Annual Matrix	Wetland Annual	1299350	1288375	1278796	1269616	1258464	1244919	1232930	1226383	1218984	1211733

Table H.2.3 Wetland Matrix (continued)

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CRF	Wetland Remaining Wetland	1,202.71	1,193.98	1,185.62	1,180.64	1,175.40	1,170.06	1,166.36	1,163.04	1,160.14	1,157.06	1,153.23	1,150.15	1,147.15
CRF	Wetland in Transition	0.17	0.34	0.51	0.68	0.85	1.02	1.02	1.42	1.42	1.82	1.82	2.22	2.22
CRF	Total Wetland	1,202.88	1,194.32	1,186.13	1,181.32	1,176.25	1,171.08	1,167.38	1,164.46	1,161.56	1,158.88	1,155.05	1,152.37	1,149.38
	Forest to Wetland	170.6	170.6	170.6	170.6	170.6	170.6	0	400	0	400	0	400	0
	Cropland to Wetland													
	Grassland to Wetland													
	Settlement to Wetland													
	Other land to Wetland													
	Total Gain in Wetland	170.6	170.6	170.6	170.6	170.6	170.6	0	400	0	400	0	400	0
	Wetland to Forest	8946	8660	8280	4912	5162	5250	3617	3229	2812	2992	3741	2994	2993
	Wetland to Cropland													
	Wetland to Grassland	75	75	75	75	75	88	88	88	88	88	88	88	0
	Wetland to Settlement													
	Wetland to Other land													
	Total Loss from Wetland	9021	8735	8355	4987	5236	5338	3705	3317	2900	3080	3830	3082	2993
	Net Change Forest/Wetland	-8776	-8490	-8109	-4742	-4991	-5079	-3617	-2829	-2812	-2592	-3741	-2594	-2993
	Net Change Wetland/Cropland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Net Change Wetland/Grassland	-75	-75	-75	-75	-75	-88	-88	-88	-88	-88	-88	-88	0
	Net Change Settlement/Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Net Change Otherland/Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0
Matrix Increment	Annual net Change	-8850	-8565	-8184	-4817	-5066	-5168	-3705	-2917	-2900	-2680	-3830	-2682	-2993
Annual Matrix	Total Wetland Annual	1202883	1194318	1186134	1181318	1176252	1171084	1167379	1164462	1161562	1158882	1155052	1152370	1149376

Table H.2.4 Settlement Matrix

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF	Settlement Remaining Settlement	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78
CRF	Settlement in Transition	0.37	0.70	1.04	1.41	1.86	2.31	2.88	3.51	4.19	4.92
CRF	Total Settlement	98.14	98.48	98.82	99.19	99.63	100.09	100.66	101.29	101.97	102.69
	Forest to Settlement	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	Cropland to Settlement	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06
	Grassland to Settlement	0.31	0.28	0.29	0.31	0.38	0.39	0.50	0.54	0.59	0.63
	Wetland to Settlement										
	Other land to Settlement	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04
	Total Gain in Settlement	0.37	0.34	0.34	0.36	0.45	0.45	0.57	0.63	0.68	0.73
	Settlement to Forest										
	Settlement to Cropland										
	Settlement to Grassland										
	Settlement to Wetland										
	Settlement to Other land										
	Total Loss from Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Forest/Settlement	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
	Net Change Settlement/Cropland	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06
	Net Change Settlement/Grassland	0.31	0.28	0.29	0.31	0.38	0.39	0.50	0.54	0.59	0.63
	Net Change Settlement/Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Otherland/Settlement	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04
Matrix Increment	Total Annual net Change	0.37	0.34	0.34	0.36	0.45	0.45	0.57	0.63	0.68	0.73
Annual Matrix	Total Settlement	98.14	98.48	98.82	99.19	99.63	100.09	100.66	101.29	101.97	102.69

Table H.2.4 Settlement Matrix (continued)

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CRF	**Settlement Remaining Settlement**	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78	97.78
CRF	**Settlement in Transition**	5.69	6.71	7.64	8.78	9.98	11.37	12.81	14.68	16.29	17.15	18.24	18.48	19.49
CRF	**Total Settlement**	103.46	104.49	105.42	106.56	107.75	109.14	110.58	112.45	114.07	114.92	116.02	116.25	117.27
	Forest to Settlement	0.17	0.17	0.17	0.17	0.17	0.17	0.40	1.20	1.20	0.00	0.00	0.00	0.80
	Cropland to Settlement	0.05	0.07	0.06	0.08	0.08	0.09	0.08	0.05	0.03	0.07	0.09	0.02	0.02
	Grassland to Settlement	0.52	0.74	0.66	0.84	0.89	1.05	0.90	0.58	0.36	0.74	0.95	0.20	0.19
	Wetland to Settlement													
	Other land to Settlement	0.03	0.05	0.04	0.05	0.06	0.07	0.06	0.04	0.02	0.05	0.06	0.01	0.01
	Total Gain in Settlement	0.77	1.02	0.94	1.14	1.19	1.39	1.44	1.87	1.61	0.86	1.10	0.23	1.02
	Settlement to Forest													
	Settlement to Cropland													
	Settlement to Grassland													
	Settlement to Wetland													
	Settlement to Other land													
	Total Loss from Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Forest/Settlement	0.17	0.17	0.17	0.17	0.17	0.17	0.40	1.20	1.20	0.00	0.00	0.00	0.80
	Net Change Settlement/Cropland	0.05	0.07	0.06	0.08	0.08	0.09	0.08	0.05	0.03	0.07	0.09	0.02	0.02
	Net Change Settlement/Grassland	0.52	0.74	0.66	0.84	0.89	1.05	0.90	0.58	0.36	0.74	0.95	0.20	0.19
	Net Change Settlement/Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Otherland/Settlement	0.03	0.05	0.04	0.05	0.06	0.07	0.06	0.04	0.02	0.05	0.06	0.01	0.01
Matrix Increment	**Total Annual net Change**	0.77	1.02	0.94	1.14	1.19	1.39	1.44	1.87	1.61	0.86	1.10	0.23	1.02
Annual Matrix	**Total Settlement**	103.46	104.49	105.42	106.56	107.75	109.14	110.58	112.45	114.07	114.92	116.02	116.25	117.27

Table H.2.5 Other Land Matrix

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF	Other Land Remaining Other Land	395891.7324	395298.9	394779.3	394279.4	393670.8	392934	392272.1	391893.6	391467.4	391046.3
CRF	Other Land in Transition	2.2	4.4	6.6	8.8	11	77.6	144.2	210.8	277.4	344
CRF	Total Other Land	395,894	395,303	394,786	394,288	393,682	393,012	392,416	392,104	391,745	391,390
	Forest to Other Land	2.2	2.2	2.2	2.2	2.2	66.6	66.6	66.6	66.6	66.6
	Cropland to Other Land										
	Grassland to Other Land										
	Wetland to Other Land										
	Settlement to Other Land										
	Total Gain in Other Land	2.2	2.2	2.2	2.2	2.2	66.6	66.6	66.6	66.6	66.6
	Other Land to Forest	474.51	574.41	500.97	479.94	583.77	711.30	629.43	343.02	387.84	380.04
	Other Land to Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Settlement	20.22	18.39	18.67	20.00	24.77	25.56	32.40	35.51	38.34	41.05
	Total Loss from Other Land	494.73	592.80	519.64	499.94	608.54	736.86	661.83	378.53	426.18	421.09
	Net Change Forest/Other Land	-472.31	-572.21	-498.77	-477.74	-581.57	-644.70	-562.83	-276.42	-321.24	-313.44
	Net Change Other Land/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other Land/Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other land/Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other land/Settlement	-20.22	-18.39	-18.67	-20.00	-24.77	-25.56	-32.40	-35.51	-38.34	-41.05
Matrix Increment	Annual net Change	-492.53	-590.60	-517.44	-497.74	-606.34	-670.26	-595.23	-311.93	-359.58	-354.49
Annual Matrix	Other Land	395894	395303	394786	394288	393682	393012	392416	392104	391745	391390

Table H.2.5 Other Land Matrix (continued)

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CRF	Other Land Remaining Other Land	390541.9	389978.3	389383.3	388964.9	388485.2	387945.3	387324	386783.9	386323.3	385808.9	385167.16	384690.53	384215.28
CRF	Other Land in Transition	458.8	573.6	688.4	803.2	918	1032.8	2632.8	2632.8	3032.8	3032.8	3030.6	3028.4	3026.2
CRF	Total Other Land	391,001	390,552	390,072	389,768	389,403	388,978	389,957	389,417	389,356	388,842	388,198	387,719	387,241
	Forest to Other Land	114.8	114.8	114.8	114.8	114.8	114.8	1600	0	400	0	0	0	0
	Cropland to Other Land													
	Grassland to Other Land													
	Wetland to Other Land													
	Settlement to Other Land													
	Total Gain in Other Land	114.8	114.8	114.8	114.8	114.8	114.8	1600	0	400	0	0	0	0
	Other Land to Forest	470.85	515.50	551.98	363.88	422.02	471.15	562.59	502.25	437.23	465.96	581.99	465.67	465.65
	Other Land to Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other Land to Settlement	33.71	48.15	43.15	54.61	57.81	68.83	58.73	37.86	23.32	48.46	61.96	13.16	12.18
	Total Loss from Other Land	504.56	563.65	595.13	418.49	479.84	539.98	621.32	540.11	460.55	514.41	643.94	478.82	477.83
	Net Change Forest/Other Land	-356.05	-400.70	-437.18	-249.08	-307.22	-356.35	1037.41	-502.25	-37.23	-465.96	-581.99	-465.67	-465.65
	Net Change Other Land/Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other Land/Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other land/Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Net Change Other land/Settlement	-33.71	-48.15	-43.15	-54.61	-57.81	-68.83	-58.73	-37.86	-23.32	-48.46	-61.96	-13.16	-12.18
Matrix Increment	Total Annual net Change	-389.76	-448.85	-480.33	-303.69	-365.04	-425.18	978.68	-540.11	-60.55	-514.41	-643.94	-478.82	-477.83
Annual Matrix	Total Other Land	391001	390552	390071	389768	389403	388977	389956	389416	389356	388841	388197	387718	387240.5

Annex I

Waste (IPCC Sector 6)

I.1 Summary of Parameter Input Values to Estimate Methane Generation using 2006 IPCC Guidelines Model

I.2 Time Series of Solid Waste Disposal and Composition 1990-2012

I.3 Parameters, EFs for Clinical Waste Incineration 1990-2012

I.4 Parameters, EFs for Solvent (Liquid/Vapour destruction) Waste Incineration 1990-2012

Table I.1 Summary of Parameter Input Values to Estimate Methane Generation using 2006 IPCC Guidelines Model

Model Run	Grouping or IPCC licence number	Number of Sites	Active Period	Status in 2012	MSW Total (t)	MSW 2012 (t)	[a]DOC Fraction	DOC_f	[b]Decay Rate k	[c]MCF
1	From 1969	13	1956-2012	Open	7,469,630	164,253	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
2	From 1979	10	1972-2012	Open	7,137,471	160,403	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
3	1985-2002	5	1983-2002	Closed	2,190,371	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
4	Small Closed	9	1957-2003	Closed	2,602,723	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
5	Recent Closed	16	1975-2008	Closed	7,486,891	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
6	W0004	1	1997-2010	Closed	4,790,944	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.75	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	1.0
7	W0127	1	1976-2001	Closed	4,812,569	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.8,1.0
8	W0009	1	1971-2012	Open	3,596,042	12,182	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.8,1.0
9	W0012	1	1965-2009	Closed	2,675,434	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.8,1.0
10	W0081	1	1999-2011	Closed	2,015,205	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.75	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	1.0
12	W0047	1	1996-2010	Closed	2,123,265	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.6
12	W0201	1	2008-2012	Open	1,271,599	302,818	0.20, 0.22, 0.45, 0.46, 0.40, 0.32	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	1.0
13	New Sites	10	1995-2012	Open	4,884,751	439,256	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	1.0
14	Town Dumps	~250	1956-1998	Closed	15,372,064	NO	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.4
15	Sewage Sludge	1	1990-2012	Open	314,302	2,159	0.05	0.60	0.20	0.8,1.0
16	Street Cleanings	1	1990-2012	Open	1,633,714	22,291	0.15, 0.20, 0.40, 0.43, 0.24, 0.24	0.60	0.20, 0.10, 0.07, 0.04, 0.07, 0.10	0.8,1.0

a The six values are for food, garden, paper, wood and straw, textiles and disposable nappies
b The six values are for food, garden, paper, wood and straw, textiles, disposable nappies
c Where two values are given, the first is for years up to 1998 (pre landfill licensing) and the second is for subsequent years

Table I.2 Time Series of Solid Waste Disposal and Composition 1990-2012

Year	Pop	MSW Prod Rate kg/cap/day	MSW Managed tonnes	MSW to SWDS %	MSW to SWDS tonnes	Street Cleansing tonnes	Sewage Sludge tonnes	MSW Food %	MSW Garden %	MSW Paper %	MSW Wood %	MSW Textiles %	MSW Nappies %	MSW Other %	MSW Organic tonnes	MSW Garden tonnes	MSW Paper tonnes	MSW Wood tonnes	MSW Textiles tonnes	MSW Nappies[a] tonnes	MSW Other tonnes
1990	3,505,800	1.4	1,506,652	0.92	1,388,648	46,959	16,365	39.1%	0.0%	29.3%	5.2%	9.7%	0.0%	16.7%	560,920		420,980	74,950	138,865		239,891
1991	3,525,700	1.4	1,543,676	0.92	1,422,772	46,554	16,458	37.5%	0.0%	29.5%	5.2%	7.9%	0.0%	19.8%	551,539		433,180	76,609	116,669		291,329
1992	3,554,500	1.4	1,517,306	0.92	1,398,467	46,100	16,592	36.0%	0.0%	29.6%	5.2%	6.2%	0.0%	23.0%	519,565		427,779	75,340	89,505		332,377
1993	3,574,100	1.4	1,554,155	0.92	1,432,430	46,704	16,684	34.4%	0.0%	29.8%	5.2%	4.5%	0.0%	26.2%	508,983		440,134	77,109	65,896		387,010
1994	3,585,900	1.4	1,667,414	0.92	1,536,818	49,234	16,739	32.9%	0.0%	29.9%	5.2%	2.7%	0.0%	29.3%	521,148		474,288	82,626	43,038		464,952
1995	3,601,300	1.4	1,614,731	0.92	1,488,262	46,791	16,489	31.3%	0.0%	30.1%	4.6%	1.0%	1.0%	32.1%	480,537		461,313	70,067	14,891	14,891	493,354
1996	3,626,100	1.4	2,285,235	0.92	2,097,369	58,194	16,798	28.7%	0.0%	27.6%	3.9%	0.9%	0.9%	38.0%	618,630		595,608	84,692	19,801	18,530	818,302
1997	3,664,300	1.5	2,408,192	0.91	2,200,861	69,596	23,529	27.3%	0.0%	28.2%	3.4%	1.0%	0.9%	39.3%	618,915		640,884	76,778	22,036	19,355	892,489
1998	3,703,100	1.5	2,212,398	0.91	2,013,326	80,999	24,213	25.7%	0.0%	28.3%	2.9%	1.0%	0.8%	41.3%	537,220		592,819	60,643	20,975	17,335	865,332
1999	3,741,600	1.7	2,291,958	0.90	2,052,870	80,156	28,400	25.9%	0.0%	28.3%	2.3%	1.1%	0.9%	41.5%	553,258		602,804	49,395	24,317	18,908	884,344
2000	3,789,500	1.8	2,652,431	0.88	2,337,715	79,312	31,588	24.5%	0.0%	30.5%	1.7%	1.3%	1.0%	41.1%	591,233		737,643	40,153	31,436	23,231	993,331
2001	3,847,200	1.9	2,819,847	0.87	2,444,842	78,469	27,043	25.1%	0.0%	30.2%	1.0%	1.4%	1.0%	41.2%	632,855		763,143	26,486	36,527	25,853	1,038,447
2002	3,917,200	1.9	2,969,861	0.79	2,354,654	65,573	21,706	25.9%	0.0%	29.1%	0.8%	1.5%	1.1%	41.6%	626,094		704,055	19,424	35,626	27,064	1,007,964
2003	3,979,900	2.0	2,876,099	0.72	2,059,403	71,779	15,445	26.0%	0.0%	30.7%	0.7%	1.5%	1.1%	39.9%	554,187		653,847	15,811	32,473	24,430	850,435
2004	4,045,200	2.0	2,908,811	0.66	1,932,317	26,344	10,696	29.4%	3.6%	26.9%	2.2%	4.2%	3.5%	30.3%	575,857	69,790	526,192	42,402	82,845	68,759	592,816
2005	4,133,800	2.0	2,962,364	0.65	1,937,844	23,875	3,192	29.3%	3.5%	26.8%	4.8%	3.8%	3.5%	28.3%	575,185	68,810	525,176	93,524	74,207	69,420	555,396
2006	4,232,900	2.2	3,304,329	0.64	2,110,955	30,366	1,962	29.6%	3.8%	25.5%	1.3%	4.0%	3.3%	32.3%	634,310	82,075	547,100	27,246	86,544	71,733	692,313
2007	4,339,000	2.1	3,458,182	0.63	2,194,800	70,334	2,002	35.6%	3.3%	20.6%	1.8%	6.2%	4.1%	28.6%	805,735	73,626	466,316	40,198	139,349	92,433	647,477
2008	4,422,100	2.0	3,314,128	0.62	2,070,075	24,969	2,041	29.8%	3.3%	23.2%	1.8%	5.7%	4.4%	31.7%	624,339	69,816	486,831	38,602	118,837	92,817	663,802
2009	4,459,300	1.8	3,010,663	0.61	1,837,004	26,701	2,081	30.9%	3.8%	20.8%	1.5%	6.2%	4.9%	31.9%	575,148	71,218	388,011	27,512	115,771	92,164	593,881
2010	4,470,700	1.7	2,554,463	0.58	1,480,512	18,713	2,120	31.8%	3.7%	21.7%	0.9%	6.2%	4.7%	31.0%	476,398	54,786	325,051	14,048	92,693	70,838	465,412
2011	4,574,900	1.7	2,498,884	0.53	1,318,837	22,291	2,159	30.9%	3.4%	23.0%	1.1%	5.8%	4.5%	31.2%	414,217	45,743	308,594	15,236	78,373	60,124	418,840
2012	4,585,400	1.7	2,044,285	0.53	1,078,913	22,291	2,199	31.8%	3.6%	21.6%	0.9%	6.1%	4.7%	31.2%	350,024	39,885	238,023	10,067	67,593	51,548	344,063

[a] Nappies are assumed to be included in the textiles proportion during the period 1990-1995 inclusive.

Table I.3 Parameters, EFs for Clinical Waste Incineration 1990-2012

	Quantity of Clinical Waste (SW_{CW})	Dry Matter content of Clinical Waste (dm_{CW})	Fraction of Carbon in the dry matter as % (CF_{CW})	Fraction of fossil carbon in total carbon as % (FCF_{CW})	Oxidation Factor (OF_{CW})	Emissions CO_2 (Fossil)
	Gg					Gg CO_2
	A	B	C	D	E	= A * B * C * D * E * 44/12
1990	4.0	NA	60.00	40.00	1.000	3.52
1991	4.0	NA	60.00	40.00	1.000	3.52
1992	4.0	NA	60.00	40.00	1.000	3.52
1993	4.0	NA	60.00	40.00	1.000	3.52
1994	4.0	NA	60.00	40.00	1.000	3.52
1995	4.0	NA	60.00	40.00	1.000	3.52
1996	4.0	NA	60.00	40.00	1.000	3.52
1997	4.0	NA	60.00	40.00	1.000	3.52
1998	NO	NA	60.00	40.00	1.000	NO
1999	NO	NA	60.00	40.00	1.000	NO
2000	NO	NA	60.00	40.00	1.000	NO
2001	NO	NA	60.00	40.00	1.000	NO
2002	NO	NA	60.00	40.00	1.000	NO
2003	NO	NA	60.00	40.00	1.000	NO
2004	NO	NA	60.00	40.00	1.000	NO
2005	NO	NA	60.00	40.00	1.000	NO
2006	NO	NA	60.00	40.00	1.000	NO
2007	NO	NA	60.00	40.00	1.000	NO
2008	NO	NA	60.00	40.00	1.000	NO
2009	NO	NA	60.00	40.00	1.000	NO
2010	NO	NA	60.00	40.00	1.000	NO
2011	NO	NA	60.00	40.00	1.000	NO
2012	NO	NA	60.00	40.00	1.000	NO

Equation 5.1, 2006 IPCC Guidelines: CO_2 emissions = $\sum i\ (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$

i, type of waste incinerated (CW: Clinical Waste)

Table I.4 Parameters, EFs for Solvent (Liquid/Vapour destruction) Waste Incineration 1990-2012

	Quantity of Fossil Liquid Waste (SW_i)	Dry Matter content of Fossil Liquid Waste (dm_i)	Fraction of Carbon in the dry matter as % (CF_i)	Fraction of fossil carbon in total carbon as % (FCF_i)	Oxidation Factor (OF_i)	Emissions CO_2
	Gg					Gg CO_2
	A	B	C	D	E	= A * B * C * D * E * 44/12
1990	27.084	NA	80.00	100.00	1.000	79.446
1991	27.084	NA	80.00	100.00	1.000	79.446
1992	27.084	NA	80.00	100.00	1.000	79.446
1993	27.084	NA	80.00	100.00	1.000	79.446
1994	27.084	NA	80.00	100.00	1.000	79.446
1995	27.084	NA	80.00	100.00	1.000	79.446
1996	27.084	NA	80.00	100.00	1.000	79.446
1997	22.482	NA	80.00	100.00	1.000	65.947
1998	17.880	NA	80.00	100.00	1.000	52.448
1999	18.940	NA	80.00	100.00	1.000	55.557
2000	20.000	NA	80.00	100.00	1.000	58.667
2001	21.491	NA	80.00	100.00	1.000	63.040
2002	21.830	NA	80.00	100.00	1.000	64.035
2003	32.821	NA	80.00	100.00	1.000	96.275
2004	37.415	NA	80.00	100.00	1.000	109.751
2005	36.229	NA	80.00	100.00	1.000	106.270
2006	35.042	NA	80.00	100.00	1.000	102.790
2007	27.970	NA	80.00	100.00	1.000	82.045
2008	20.898	NA	80.00	100.00	1.000	61.301
2009	21.298	NA	80.00	100.00	1.000	62.474
2010	18.177	NA	80.00	100.00	1.000	53.319
2011	12.615	NA	80.00	100.00	1.000	37.004
2012	13.385	NA	80.00	100.00	1.000	39.263

Equation 5.1, 2006 IPCC Guidelines: CO_2 emissions = $\sum i \, (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$

Annex J

Ireland's Response to the Recommendations in the UNFCCC Annual Review Reports

J.1 for Submission 2011

J.2 for Submission 2012

Table J.1 Ireland's Response to the recommendations in the UNFCCC Annual Review Report for Submission 2011

Sector	Issue	ARR Paragraph	Recommendation	Party response	NIR Section
General	Completeness	10	The ERT noted that Ireland had reported the emissions for some categories as not estimated ("NE"), in particular for some categories in the LULUCF sector (land converted to wetlands, land converted to settlements). Generally, the ERT recommends that the Party provide these missing estimates in its future annual submissions or, alternatively, considers replace "NE" with the notation key for not occurring ("NO") if the relevant emissions/removals are not occurring.	Emissions from "land converted to wetlands" and "land converted to settlements" are now reported in this submission 2013 if occurring in any given year or "NO" is reported otherwise.	See CRF Table 5
General	Completeness	11	The ERT encourages the Party to continue its efforts to include in its inventory emission estimates for other categories for which there are no methodologies or emission factors for estimating emissions available in the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance) or in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines), such as estimates of CO2 emissions from asphalt roofing, road paving with asphalt, and food and drink, potential emissions of SF6 from consumption in sporting goods, N2O emissions from the use of N2O for anaesthesia.	The inventory agency will consider the ERT's encouragement and continue to prioritise inventory improvements based KCs and review findings within current resources.	
General	Inventory preparation: Key Categories	17	Although the inventory agency has not performed a tier 2 key category analysis, owing to resource constraints, some elements of the qualitative approaches mentioned in the IPCC good practice guidance section 7.2.2 (namely mitigation techniques and technologies, high expected emission growth, high uncertainty, unexpectedly low or high emissions) are already being carried out. The results of the key category analysis are discussed in the NIR and are used as a driving factor for the prioritization of improvements to the national inventory. Ireland is considering implementing a tier 2 key category analysis on an annual basis, if resources allow. The ERT encourages Ireland to implement a tier 2 key category analysis in future submissions where resources allow.	The inventory agency carried out some work on a tier 2 KCA during this submission. The work was not finalised in time for this submission (2013) as the current KCA and uncertainty assessment are not performed at the same level of disaggregation.	Chapter 1, section 1.5
LULUCF	Inventory preparation: Uncertainties	20	With regard to uncertainty assessment for LULUCF activities, the ERT noted inconsistencies between different elements of the Party's submission. In particular, according to chapter 1.7 of the NIR, on uncertainty assessment, uncertainty has been estimated for LULUCF under both the Convention inventory and Article 3, paragraph 3, activities, whereas according to chapter 7.9 of the NIR, on uncertainties for LULUCF, full evaluation of uncertainties in quantitative terms has not been possible for LULUCF for the current submission (but an estimate for Article 3, paragraph 3, activities under the Kyoto Protocol is provided in chapter 11). In table 1.9 of the NIR, the only available disaggregation for LULUCF is between "liming" and "non-liming". The ERT recommends that the Party provide consistent information on uncertainty assessment for LULUCF in the different parts of its submission, and, for LULUCF uncertainty assessment, to use the same categories used to estimate emissions and removals.	The uncertainty analysis has been significantly improved in this submission 2013, in particular, for LULUCF. Additional information on uncertainty for LULUCF and KP-LULUCF is also provided in Chapters 7 and 11 of NIR 2013.	Chapter 1, section 1.7 and Table 1.13 Chapter 7 and 11 Sections 7.3.4.7, 7.3.5.7 and 7.9 Section 11.6.

General	Inventory preparation: Recalculations and time-series consistency	24, 25	(24) The ERT noted that for 2008 the major impact on the estimate of total GHG emissions was due to the recalculation of the estimates of CO2 emissions from fuel combustion activities and from manufacturing industries and construction, and to the recalculation of estimates of CH4 emissions from solid waste disposal on land. The effect of the recalculations for the base year (as reported in the CRF tables) was an increase by 0.06 per cent in CO2 eq emissions excluding LULUCF. The effect of the recalculations for 2008 (as reported in the CRF tables) was an increase by 0.52 per cent in CO2 eq excluding LULUCF. The rationale for these recalculations is provided in the NIR and in CRF table 8(b). (25) The ERT noted that the Party provides different figures for the overall impact of recalculations in different parts of its submission. The ERT recommends that the Party provide the correct values in all the elements of its submission.	Every effort is made to report recalculations consistently between the National Inventory Report and the CRF Submission.	Chapter 10, section 10.3 and Tables 10.2 and 10.3 See also CRF Tables 8(a)s1 and 8 s(a)s2
IP and LULUCF, Art 7.1 KP	Inventory preparation: Verification and quality assurance/quality control approaches	27	With regard to industrial processes, the Party only provides information on QA/QC checks regarding information made available through the EU ETS. Given the diversity of categories within this sector, the Party is recommended to provide specific information for each category; in particular, the Party is encouraged to specify which tier of the monitoring and reporting guidelines under the EU ETS applies to that category and to explain how this is in line with the IPCC good practice guidance. The Party is also recommended to provide information on QA/QC for LULUCF.	The EU ETS sector covers all emissions from CRF 2.A mineral products or 66 per cent of total IP emissions. Additional information on QA\QC for industrial gas emissions will be provided in future submissions. Additional extensive information on QA\QC for LULUCF has been provided in this submission 2013.	Chapter 7, section 7.10
General	Inventory preparation: Transparency	28	The degree of transparency of the information included in the NIR and in the CRF is, in general, quite good. The ERT did not identify any restrictions relating to the provision of information in the CRF tables and the NIR for confidentiality reasons. In particular, the ERT commends the Party for improving the use of notation keys since previous submissions. However, incorrect notation keys are still used in the CRF tables. For example, emissions from national navigation are reported as not occurring (“NO”), but should actually be included elsewhere (“IE”).	Emissions from national navigation are reported in this and the previous submission.	Chapter 3, section 3.2.1.3.3 See also CRF Table 1.A(a)s3
General	Follow-up to previous reviews: Notation keys	30	The ERT recommends that Ireland continue the efforts already in place to improve its submission, particularly in relation to providing sector-specific QA/QC information also for the other sectors. The ERT also notes that recommendations by previous review reports concerning the use of notation keys were only partially implemented by the Party, and inconsistencies still exist between the different parts of the submission. The ERT, therefore, recommends the Party to further improve the use of notation keys in the CRF.	The Inventory agency notes the ERT’s recommendation. Additional information on QA\QC has been provided in this submission 2013. Every effort is made to report consistently between the National Inventory Report and the CRF Submission.	

Energy	Sector overview: Recalculations descriptions in transport (COPERT)	38	Ireland reported substantial recalculations of N2O and CH4 emissions from road transportation. In 2008, these recalculations represented a downward revision of 23.0 per cent in N2O emissions (38.15 Gg CO2 eq) and of 15.1 per cent in CH4 emissions (4.07 Gg CO2 eq). During the review, Ireland provided very transparent and detailed comparisons of emissions from the "Computer programme to calculate emissions from road transport" (COPERT) version 4.6.1, used in Ireland's previous submission, and COPERT version 4.8.0, used in Ireland's latest submission. This latest version of the COPERT model includes all vehicle technologies up to Euro VI for passenger cars, Euro VI for heavy duty vehicles and Euro III for motorcycles. In addition, the ERT found that significant recalculations in CH4 and N2O emissions were caused by a software bug in COPERT version 4.6.1, which misallocated the hot and cold emissions of these GHGs (and ammonia), as well as a correction in the N2O hot EF of urban buses standard Euro III. The ERT recommends that Ireland ensure its future NIR submissions include a clear description of the main reasons (i.e. improvements) behind the recalculations when changing from one version of COPERT to another.	This inventory submission also used a revised COPERT version from COPERT 4 version 8.0 to COPERT 4 version 9.1	Chapter 3, sections 3.2.1.3.2 and 3.7. See also Tables 3.7 and 3.8 of chapter 3.
Energy	Reference and sectoral approaches: Solid fuels & CRF vs Eurostat energy stats difference	39, 40	(39) The difference between the reference approach and the sectoral approach was 0.60 per cent in 2009. However, the ERT noted the overall difference for fossil fuels is small because of the netting of positive (solid fuels) and negative (liquid and gaseous fuels) differences. There is a significant discrepancy between CO2 emissions from the sectoral and the reference approach for solid fuels (4.2 per cent). The categories residential and public heat and electricity production are the largest consumers of solid fuels in the energy sector in Ireland. During the review the ERT asked the Party to clarify whether the difference could be explained by lower CO2 emissions from EU ETS combustion installations using coal compared with CO2 emissions calculated from the AD in the energy balance. The Party provided the ERT with a comparison of emissions from solid fuels from EU ETS and the energy balances at a more disaggregated level for all years between 1990 and 2009. The comparison suggests that the difference could be explained by the application of a constant net calorific value (NCV) for all years using the energy balance data, whereas the CO2 estimates reported in the CRF tables correspond to verified EU ETS emissions. Ireland informed the ERT that the issue would be solved with the harmonization of the energy balance and EU ETS AD. The ERT recommends that the Party ensure as much consistency as possible between the AD reported in the CRF tables and in its energy balance. (40) During the review, the Party stated that its inventory agency will request the compiler of Ireland's energy statistics to investigate the differences between apparent consumption reported to UNFCCC and that reported to the International Energy Agency. The ERT welcomes Ireland's proactive approach. The ERT also recommends that the Party investigate the differences between the AD submitted in its CRF tables with the energy balances reported to Eurostat under the EU regulation on energy statistics, which has legal provisions aimed at ensuring the consistency of energy data in the energy balances with AD in the CRF tables.	Differences between the Reference and Sectoral approaches in this submission for the year 2011 are <1.0 %	CRF 2011 Table 1.Ac

Energy	Reference and sectoral approaches: International bunker fuels	41	The ERT noted that CH4 and N2O emissions from marine bunkers have not been estimated because of the lack of national EFs. The Revised 1996 IPCC Guidelines provide EFs for the EU as well as factors developed by Lloyd's Register (see IPCC good practice guidance page section 2.4.1.2). It is good practice to use the factors developed by Lloyd's Register to estimate CH4 and N2O emissions from large marine diesel engines consuming distillate or residual fuel oils. The ERT recommends that the Party assess the use and applicability of these EFs for CH4 and N2O for reporting emissions from international shipping in its future annual submissions.	Emissions of CH4 and N2O have been estimated for all years from 1990-2011 in this submissio0n 2013.	Chapter 3, section 3.5 See also CRF Table 1.C
Energy	Reference and sectoral approaches: Feedstocks and non-energy use of fuels: lubricants	42	Ireland's reporting of feedstocks and non-energy use is generally transparent and consistent with the Revised 1996 IPCC Guidelines. During the review, a minor issue was the reporting of white spirit in CRF table 1.A(d) on feedstocks and non-energy use. There is no fraction reported for carbon stored and thus 100 per cent is assumed to be emitted as CO2. However, the same table shows that only 15.33 Gg of carbon from lubricants was emitted in 2009, implying that 100 per cent of white spirit consumption had been stored. Ireland informed the ERT that all white spirit is reported as part of the total non-energy consumption (feedstocks) and that the inventory agency would include this minor liquid fuel use as being stored in CRF table 1.A(b) in its future submissions. The ERT recommends that the Party ensure full consistency between tables 1.A(b) and 1.A(d) in future annual submissions.	Every effort is made to report feedstocks in a consistent manner in the CRF Submission.	CRF Table 1.A(b) and 1.A(d)
Energy	Key categories: Stationary combustion: all fuels – CO2	46	The previous review report concluded that the implied EFs to derive CO2 emissions from energy industries are not comparable with those of other Parties. CO2 emissions reported by Ireland are from the EU ETS, whereas the underpinning AD in the CRF tables are from the energy balances. The current ERT believes that CO2 emissions from energy industries are accurate and complete, and that the time series is consistent because of the use of identical AD from the EU Directive from large combustion plants. However, the implied emission factors (IEFs) in the CRF tables are calculated on the basis of AD not used in the estimation of CO2 emissions. During the review, the Party informed the ERT that the issue regarding the energy data in the national energy balance and the corresponding energy data reported through the EU ETS are being harmonized to ensure that both are fully consistent. This would mean that the energy data reported in the next energy balance will be the same as the EU ETS data. The ERT looks forward to this improvement and recommends that Ireland use consistent AD, EFs and emissions in its 2012 annual submission.	Improvements were made in the consistency of data reported under EU ETS and the national energy balance in Submission 2012 (1990-2010 data) and continued in this submission 2013.	

Energy	Non-key categories: Stationary combustion: all fuels N2O, CH4	47	Ireland uses the energy balances to estimate CH4 and N2O emissions in energy industries. The previous review report “strongly recommended” that the Party use consistent data for estimating emissions of GHGs in its future annual submissions. The current ERT believes that the Party is making significant efforts to improve the consistency of the AD reported in the energy balance and in the EU ETS regarding CO2 emissions. The ERT also argues that the accuracy of the reporting of Ireland’s second most important category energy industries and gas (CO2) should not be at the expense of ensuring full consistency in the estimation of non-CO2 gases. The harmonization of the energy balances and EU ETS AD may lead to improvements in the estimation of CH4 and N2O emissions. The ERT recommends that the Party include transparent information, including on how to ensure time-series consistency, about the potential recalculations of emissions of non-CO2 gases in its future annual submissions.	See above. Energy data reported from EU ETS and the national energy balance are fully harmonised for Energy Industries, CRF 1.A.1.a.	
IP and Solvent and other product use	Sector overview: F-gases consumption drivers for different sub-categories	53	Emissions from the industrial processes sector decreased by 29.2 per cent from 2008 to 2009, mainly as a consequence of the decrease in CO2 emissions from cement and HFCs in refrigeration and air-conditioning equipment. CO2 emissions from lime production also declined contributing to the sector’s overall emissions reductions, despite the increase in F-gases consumption such as: HFC consumption for subcategories foam blowing, fire extinguishers, aerosols/metered dose inhalers, and SF6 consumed for electrical equipment and in semiconductor manufacturing. The ERT encourages Ireland to provide a more detailed description in its future annual submissions of F-gases consumption trends at each specific subcategory, as the ERT observed that different drivers explain the trends of emissions for different sub-categories.	Additional information on F-gas trends is provided in this submission 2013.	Chapter 4, sections 4.4.2.1 to 4.4.2.7
IP and Solvent and other product use	Sector overview	54	Ireland has reported the following categories as “NE”: CO2 emissions from asphalt roofing, road paving with asphalt, and food and drink; potential emissions of SF6 from consumption in sporting goods and N2O emissions from the use of N2O for anaesthesia. The ERT commends the Party for having tried to estimate and clarify the potential SF6 emissions from sporting goods (consumption of halocarbons and SF6), following the recommendation in the previous review report. However, potential emissions from sporting goods were not estimated due to the lack of methodologies in the Revised 1996 IPCC Guidelines or in the IPCC good practice guidance. The ERT encourages the Party to investigate ways to estimate emissions for these categories wherever possible. In addition, the Party is also recommended to correct some uses of notation keys, such as the substitution of “NO” to “IE” for aerosols disposal emissions and the insertion of “IE” in industrial refrigeration for the identified HFCs, in order to bring consistency to the NIR and CRF tables.	The inventory agency has not been able to estimate potential emissions of SF6 from sporting goods in this submission due to a lack of an appropriate methodology. This issue will be revisited in future submissions if resources allow. The notation key for disposal emissions has been changed from “NO” to “IE” in this submission 2013. The notation key for industrial refrigeration is now “IE” in this and the previous submission.	See CRF Table 2(II).Fs1 and Table 2(II).Fs2

IP and Solvent and other product use	Sector overview: Tier reference at each category level	55	The ERT considers that data availability and the relevant documentation have, in general, been reported in a transparent manner for the industrial processes sector. However, regarding the estimation approaches, the ERT recommends that the Party make reference to which tier from the Revised 1996 IPCC Guidelines was applied at each category level. The ERT commends Ireland for having addressed a recommendation of the previous review report regarding the provision of AD analysis in annex E for cement production, limestone and dolomite use, glass production, bricks and tiles, and for having provided more information on technologies and processes in the NIR. An analysis of the observed changes in the emission level and/or trend for cement production and semiconductor manufacture was also made. However, the ERT still considers that Ireland could considerably enhance the transparency and completeness of its inventory by providing an analysis of the observed changes in emissions from the consumption of halocarbons and SF6, limestone and dolomite use, and soda ash use.	Additional information has been provided in this submission 2013 for lime production and soda ash use. Additional information on F-gas trends is provided in this submission 2013.	See Annex F, tables F.2 and F.4 of NIR 2013.
IP and Solvent and other product use	Sector overview: AD and EF transparency at each category level	56	As raised in previous review reports, the ERT noted that Ireland is still not presenting transparent information on the time series of AD and EFs for each category separately, as appropriate, and for the variations of emissions from year to year. The ERT considers that the approach adopted by Ireland impairs transparency, and reiterates the recommendation in the previous review report of increasing the level of disaggregation of the above-mentioned issues in its future annual submissions by providing additional information for the following categories: lime production, soda ash use, aerosols and metered dose inhalers.	Additional information is provided in this submission 2013. The inventory agency is considering adding additional information in NIR 2014 and its Annexes for F gas emissions.	Annex F, tables F.2 and F.4
IP and Solvent and other product use	Sector overview: Uncertainty analysis and F-gases	57	The NIR still includes only a very short section on the uncertainty analysis and QA/QC procedures for the industrial processes sector in general. The ERT reiterates once more the recommendation made in the past two reviews reports for the Party to provide more detailed information for all categories under mineral production, except for cement production, at each category level or under the sectoral uncertainty section in its future annual submissions. The ERT also recommends that the Party fill the CRF tables with the percentage of manufacture, in life and disposal factors regarding F-gases consumption categories, instead of the proportions currently reported.	Additional information on uncertainty and QA\QC will be provided in submission 2014.	
IP and Solvent and other product use	Key categories: Cement production CO2: CaO and MgO content of clinker	58	CO_2 emissions from cement production is the largest source of GHG emissions in the Party's industrial processes sector, accounting for 62.7 per cent of total sectoral emissions. Ireland uses plant-specific data and EFs reported under the EU ETS to estimate emissions from cement production. Estimates include the consideration of the cement kiln dust factor. However, the Party still does not report information on the CaO and MgO content of the clinker, which is used to derive the country-specific estimates. The ERT, therefore, reiterates the recommendation in the previous review report, in accordance with the IPCC good practice guidance, that Ireland include information on the CaO and MgO content of the clinker in its future annual submissions.	The inventory agency has obtained information on CaO and MgO content of clinker from all four cement operators in 2013 for all years from 2008 to 2012. The data is available to ERTs upon request.	Chapter 4, section 4.2.1

IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6: HFCs, PFCs and SF6	59	The ERT noted once more that in CRF table 2(II).F Ireland still used the notation keys "IE" and "NA" to report AD and the corresponding estimates of emissions of HFCs from refrigeration and air-conditioning equipment. Estimated emissions from manufacturing and from disposal for commercial refrigeration are reported as "IE" and included under stock, and AD are reported as "NA", thus not allowing the application of the bottom-up approach. The ERT notes that Ireland still has not implemented the recommendation from previous years' review reports to investigate this matter further in order to improve the transparency of its reporting by reviewing its use of the notation keys for this category.	The top down methodology used does not allow reporting of emissions from manufacturing and disposal separately from emissions from stocks. The notation key "IE" is therefore used, as emissions from manufacturing and disposal are included elsewhere, i.e. with stocks.	
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6: HFCs, PFCs and SF6	60	The ERT also noted that the recommendation in the previous review report for the provision of more information on the share of new vehicles was not addressed in the 2011 annual submission. The ERT reiterates this recommendation for the future annual submissions. In addition, the ERT reiterates the recommendation in the previous review report for the correction of mobile air-conditioning IEFs for product manufacturing, lifetime and disposal losses in the future annual submission.	Additional information provided in this submission 2013.	Chapter 4, sections 4.4.2.1 and 4.8 Annex E, table E.5 See CRF Table 2(II).Fs1
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6: HFCs, PFCs and SF6	61	Ireland reports emissions of HFC-23 and HFC-227ea from fire extinguishers in the 2011 submission. However, the ERT notes that only sectoral background data is provided for HFC 227ea in CRF table 2(II).F. The ERT reiterates the recommendation from the previous review that Ireland provides background data on HFC-23 from fire extinguishers in the future annual submissions	Sectoral background data is now provided for both HFC 23 and HFC 227ea in this submission 2013 and the previous submission in 2012.	See CRF Table 2(II).Fs2
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6: HFCs, PFCs and SF6	62	With regard to aerosols, the ERT notes that the notation key "NA" is used to report HFC-134a and HFC-152a emissions for the major sub-categories (personal-care products, household products, industrial products and other general products) and encourages Ireland to undertake national surveys in order to obtain actual AD, instead of using UK market based estimates, and report these data in its future annual submissions. The ERT also notes that the NIR includes only the product life factor for dose inhalers and encourages Ireland to provide more details regarding the manufacturing product leak factor and EFs for HFC emissions.	Additional information provided in this submission 2013.	Chapter 4, sections 4.4.2.4 and 4.8
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6: HFCs, PFCs and SF6	63	With regard to semiconductor manufacture, the ERT notes that the NIR includes the same explanation on F-gases use in semiconductor manufacturing as in the previous annual submission. The ERT encourages Ireland to provide more explanation on the use of HFCs, PFCs and SF6, which would enhance transparency and better present the efforts made by the plants to reduce emissions of these GHGs.	Additional information on semiconductor manufacture is provided in this submission 2013. http://www.eeca.eu/data/File/ESIA%20Perfluoro%20Brochure%20LR%20Final.pdf	Chapter 4, section 4.4.2.5

IP and Solvent and other product use	Non-key categories: Limestone and dolomite use CO2	65	During the review, Ireland did not provide an explanation regarding the sharp fall of CO2 emissions from 2008 to 2009, but referred to the AD contained in annex E of the NIR. The ERT recommends that the Party include an explanation of the emissions variation from year to year either in the introduction part of the industrial processes sector or under the category-level section in order to improve the transparency of the NIR. The ERT also recommends a more detailed explanation regarding the IEF used (it currently represents the average of the two consumers) in order to improve transparency.	Additional information on lime production is provided in Annex F, NIR 2013. The trend in emissions correlates directly with production data.	Annex F, table F.2
IP and Solvent and other product use	Non-key categories: Limestone and dolomite use CO2	66	The ERT welcomes the Party's answer during the review over the correction in the notation key for brick manufacture and recommends the inclusion of this information in the future annual submissions.	The information is correct in this submission 2013.	Annex F, table F.6
Agriculture	Sector overview: Uncertainty literature reference	70	The NIR is generally transparent in relation to the methodologies, AD and EFs used. However, there is lack of information regarding background data and references to well recognized literature used to calculate uncertainties. During the review, Ireland provided the ERT with the data and references requested. The ERT recommends that the Party include all the information provided regarding uncertainties in the future annual submissions.	Additional information on uncertainties is provided in NIR 2013.	Chapter 6, section 6.6
Agriculture	Key categories: Enteric fermentation CH4	73	Milk yields for beef cows reported in CRF table 4.A (7.808 kg/day) do not change from year to year and are rather high compared with the estimates of yields for non-dairy cows given in the Revised 1996 IPCC Guidelines (table A-2). CRF table 4.A contains data on the working hours per day (three hours) for dairy cattle. However, common practice in the world shows that bulls are used as drafting animals. During the review, Ireland clarified that average milk yields are reported as the average daily production along with the days of lactation per year, which is in line with the IPCC good practice guidance. The Party further responded that livestock is not used for draft purposes in the country. The ERT recommends that Ireland remove data about working hours per day for draft animals in CRF table 4.A of its future annual submissions.	Information on “hours worked” by animals as been removed from the CRF Submission 2013.	See CRF Table 4.A
Agriculture	Key categories: Enteric fermentation CH4	74	The ERT noted that the data on the fraction of gross energy that is converted to CH4 for cattle reported in the NIR (0.065) and the CRF tables (0.06) are inconsistent. During the review, the Party explained that the correct value is the value presented in the NIR. The ERT recommends that Ireland revise the data about the CH4 conversion rate in the CRF tables of its future annual submissions.	This inconsistency was corrected in Submission 2012 (1990-2010 data) and is correct in this submission 2013.	See CRF Table 4.A

Agriculture	Key categories: Enteric fermentation CH4	76	The Party applied a tier 1 approach to estimate CH4 emissions from sheep. For lowland ewes, upland ewes and rams, the default EF for enteric fermentation of 8 kg CH4/head/year is used as per table 4-3 of the Revised 1996 IPCC Guidelines for developed countries. The EF for lambs is estimated with correction to the number of months that young animals are alive and the values of the gross energy fraction that is converted to CH4. To improve the comparability of estimates, the ERT recommends that the Party apply the same method as for swine to calculate the corrected EFs per sheep subcategories, which is in line with the IPCC good practice guidance. The ERT further reiterates the recommendation from the previous review report for Ireland to investigate the possibility of the development and implementation of a tier 2 approach for the calculation of CH4 emissions from sheep.	The data necessary to apply a Tier 2 method for sheep is not available at this time. Additional information is provided in this submission 2013.	Chapter 6, section 6.9
Agriculture	Key categories: Manure management CH4	77	According to CRF table 4.B(a), the CH4 producing potential for non-dairy cattle amounts to 0.24 m3 CH4/kg organic matter excretion as volatile solids (VS), while according to table B-1 of the Revised 1996 IPCC Guidelines, the maximum CH4 producing capacity of manure (Bo) for non-dairy cattle for all regions (except for Latin America) is 0.17 m3 CH4/kg VS. Ireland explained that the Bo value for non-dairy cattle is based on a publication from O'Mara (2006). The ERT recommends that Ireland further investigate whether the value of 0.24 m3/kg VS was obtained using standardized methods, including a sampling methodology as prescribed in the IPCC good practice guidance.	Additional information is provided in this submission 2013.	Chapter 6, section 6.3.1
Agriculture	Key categories: Manure management CH4	78	The VS values for dairy (2.81 kg/head/day) and non-dairy cattle (1.33 kg/head/day) from CRF table 4.B(a) are almost two times lower than the default VS values from the 1996 Revised IPCC Guidelines (5.08 kg/head/day and 2.65 kg/head/day, respectively, as per table B-1, data for Western Europe). During the review, Ireland responded, to a question raised by the ERT, that the VS values for dairy cows and non-dairy cattle are estimated using the information provided in the model developed by O'Mara (2006). The main reason for the discrepancy is that the default digestibility value of 60 per cent is very low in comparison to the digestibility of feeds in Ireland (60 per cent would be equivalent to poor quality hay). In Ireland, the digestibility of silage is approximately 70 per cent, while that of grass and concentrates is approximately 80 per cent. The explanation provided is considered to be reasonable and the ERT recommends that Ireland include it in future NIRs to increase transparency.	This information has been provided in this submission 2013.	Chapter 6, section 6.3.1
Agriculture	Key categories: Manure management CH4	79	The VS value reported in CRF table 4.B(a) for mules and asses is 1.72 kg/head/day and differs from the default value presented in the Revised 1996 IPCC Guidelines table B-7 (0.94 kg/head/day). The Party explained that the VS value for horses was erroneously used for mules and asses. The ERT recommends that Ireland recalculates CH4 emissions from manure management of mules and asses in the future annual submissions.	This value was corrected in Submission 2012 (1990-2010 data) and is correct in this submission 2013.	See CRF Table 4.B(a)s1

Agriculture	Key categories: Direct soil emissions N2O	80	The tier 1b method from the IPCC good practice guidance was used to estimate the nitrogen contribution from nitrogen-fixing crops and crop residues returned to the soil. However, the data used (such as the annual crop production of nitrogen-fixing crops and other crops and the fraction of crop residues used for fodder) to estimate the N2O emissions from the above-mentioned categories are not transparently described in the NIR. The ERT recommends that Ireland improve the transparency of reporting by including summary tables with data used to estimate N2O emissions from N-fixing crops and crop residues returned to soils in future NIRs.	Additional information has been provided in this submission 2013.	Chapter 6, section 6.5.1 and Annex G tables G.8 and G.9
Agriculture	Key categories: Direct soil emissions N2O	81	In CRF table 4.D, for FracNCRBF and FracNCRO, the notation key "NO" is used without corresponding explanations, while according to the NIR data (page 96) for these fractions the default values from the IPCC good practice guidance were used. The ERT recommends that the Party remove this inconsistency by including the same information on these fractions in both the NIR and CRF table 4.D in its future annual submissions.	These values were provided in Submission 2012 (1990-2010 data) and are also provided in this submission 2013.	See CRF Table 4.Ds2 See Annex G, tables G.8 and G.9 of NIR 2013.
Agriculture	Key categories: Direct soil emissions N2O	82	The ERT reiterates the recommendations of the previous review reports that Ireland report the amount of nitrogen in sewage sludge applied to soils separately from nitrogen input with manure and that it estimate the volatilization of ammonia and nitrogen oxide after sludge spreading.	Sewage sludge is reported separately in this submission 2013 in CRF category 4.D.1.6. Volatilised Ammonia emissions have not yet been estimated for sewage sludge.	Chapter 6, sections 6.8 and 6.9 CRF Table 4.Ds1 Annex G table G.7 of NIR 2013
Agriculture	Non-key categories: Field burning of agricultural residues CH4 and N2O	83	According to CRF table 4.F, field burning of agricultural residues does not occur in Ireland and no further explanations are provided. During the review, the Party explained that the burning of agricultural residues is prohibited in Ireland as a result of the requirements imposed on farmers/agricultural enterprises that are in receipt of payment/subsidies (e.g. under Area Aid, the Rural Environmental Protection Scheme and subsequently Cross Compliance Measures under the Single Farm Payment). The ERT recommends that Ireland provide this information in the NIR and CRF documentation boxes with reference to official documents in its future annual submissions.	Additional information and a relevant reference have been provided in this submission 2013. http://www.agriculture.gov.ie/farmerschemespayments/crosscompliance/	Chapter 6, section 6.1
LULUCF	Sector overview	86	The Party uses different methods for reporting emissions and removals from LULUCF sinks and sources under the Convention and its Kyoto Protocol. Considering that a number of errors have been found in reported data in the CRF tables and inconsistencies between data reported in the CRF tables and the NIR tables, the ERT recommends that Ireland harmonize the methods used for estimating emissions and removals reported under the Convention and its Kyoto Protocol. The ERT also notes that the Party did not provide the uncertainty analysis for the LULUCF sector and, therefore, recommends that the Party provide it in its future annual submissions.	The methodologies used for estimating emissions/removals from LULUCF for Convention and Kyoto Protocol reporting have been harmonised in this submission 2013. Uncertainty analysis for LULUCF has also been significantly improved in this submission.	Chapter 7 and 11. See response to ARR finding para. 20 above.

LULUCF	Sector overview	87	Although Ireland reported in its NIR (table 7.4) a consistent time series of land use and land-use change matrices, the data time series reported in the CRF tables does not represent a consistent representation of land and is not consistent with that provided in the NIR. For forest land the area reported in NIR table 7.4 is 745,324 ha, while in CRF table 5.A it is 718,674 ha; for grassland it is 3,787,800 ha versus 3,893,840 ha; for cropland there is correspondence between the two sources of data (399,500 ha for both); for wetlands it is 53,415 ha versus 53,432 ha; for settlements it is 114,600 ha versus 114,319 ha; for other land it is 879,572 ha versus 890,803 ha. Moreover, a number of inconsistencies have been detected for AD of subcategories. Furthermore, the total area reported in the CRF tables changes annually, for example 5,224,860 ha in 1990 and 6,070,568 ha in 2009. The ERT recommends that the Party provide a consistent and accurate time series of land use and land-use change matrices and that it ensure full correspondence among data reported in the NIR and in the CRF tables. The ERT also recommends that the Party revise and strengthen the sector-specific QA/QC procedures.		
LULUCF	Sector overview	88	The ERT notes that Ireland applied a country-specific stock change method to calculate the carbon stock gains in biomass, which consists of comparing the total carbon stocks at two points in time but not in the same area (i.e., the area used to calculate the stock at time 1 may be different from the area used to calculate the stock at time 2). This method is not consistent with the IPCC good practice guidance for LULUCF (see, for example, equation 3.2.3 of the IPCC good practice guidance for LULUCF method 2 relating to “a given forest area at two points in time”). Thus, the method applied by the Party can result in the reporting of emissions and removals that never occur in reality, since the accounted fluxes may simply be the result of the transfer of carbon stocks from one stratum to another. The ERT recommends that, when the Party applies the stock change method, it calculate the carbon stock values at two consecutive points in time in the same area. The ERT also recommends that the Party revise all its estimates of biomass carbon stock changes and associated emissions and removals and that it report in its future annual submissions the revised estimates.	This issue is resolved in this submission 2013.	Chapter 7, section 7.3
LULUCF	Sector overview	89	The ERT notes that some pools have not been estimated, such as dead organic matter for categories of conversion from forest land to any other land use and soil organic matter of each reported conversion category to settlement and other land and for conversion from forest land to wetlands. To ensure completeness in the report the ERT recommends that the Party provide these missing estimates in its future annual submissions.	This issue of carbon stock change within soils converted to settlement has not been resolved in this submission. However, the 2006 IPCC guidelines, and other relevant literature will be examined to try to address this in future submissions	Chapter 7, section 7.9.4
LULUCF	Sector overview	90	The ERT noted several instances of incorrect use of the notation keys in the sectoral background data tables: when an activity is assumed not to have any impact on the carbon stored in a pool, Ireland tends to use the notation key “NO” instead of “NA”. The ERT recommends that Ireland revise its use of the notation keys in its future annual submissions, in order to increase the transparency of its reporting.	The use of notation keys has been reviewed with the aim of assuring consistent and correct usage throughout the NIR in this submission 2013	

LULUCF	Key categories: Land converted to forest land CO2	91	Ireland divides its forest land into three subcategories: young (7 to 25 years) mature (older than 25 years) and unclassified clearfelled areas (containing afforested and reforested areas younger than 7 years and areas without tree cover). The ERT notes that although the annual recruitment of area of the young subdivision (i.e. the transfer of area from the afforested/reforested class (0 to 7 years old) to the young class) is done on the basis of annual records of the afforested and reforested (replanted) areas, the annual recruitment of area of the mature subdivision (i.e. the transfer of area from the young class to the mature class) is done on a constant basis (i.e. 5.6 per cent each year). Considering the availability of annual data on afforested and reforested areas, the ERT recommends the Party to use as the annual accretion of the mature forest category the area that was afforested and reforested 26 years before the year in which the accretion area is added.		
LULUCF	Key categories: Grassland N2O	92	The ERT notes that Ireland in its CRF table 5.C for the category grassland remaining grassland does not report stock changes from mineral soils (the notation key NO is used) while it reports stock changes (i.e. emissions) from organic soils. The ERT also notes that Ireland in its CRF table 5.C for the category land converted to grassland does report stock changes (i.e. emissions) from organic soils. This means that some management activity occurs in organic soils under grassland that causes the oxidation of organic matter. However, the Party is not reporting in table 4.D under the category cultivation of histosols the corresponding N2O emissions caused by the oxidation of organic matter in managed grassland. The ERT sees that intensive and extensive management practices in pastureland are part of the agricultural practices of a country. The ERT, therefore, recommends the Party to report information to demonstrate that N2O emissions due to oxidation of organic matter in organic soils in managed grassland have been reported in table 4.D under the category cultivation of histosols.	The Inventory Agency considered this comment, however it is not clear what is at issue. The grasslands areas for which carbon losses are reported are drained organic soils. They are not cultivated in a conventional cropland sense. The emission are reported under LULUCF as they are due to the land use activity (i.e. drainage) and would occur regardless of whether the grassland is used for agricultural production or not.	
LULUCF	Non-key categories: Wetlands	93	The ERT notes that, inconsistent with the IPCC good practice guidance for LULUCF, areas of natural wetlands are not reported in CRF table 5.D, wetlands. The ERT encourages the Party to report in its future submissions the total area of natural wetlands as a subdivision of the category wetlands remaining wetlands.	This is issue has been addressed in this submission 2013.	Chapter 7, section 7.6
LULUCF	Non-key categories: Other land	94	The ERT notes that, inconsistent with the IPCC good practice guidance for LULUCF, areas of natural grassland that are an available reserve for rough grazing but that are not grazed in the inventory year are reported under the land use category other land. The ERT recommends that Ireland report in its future annual submissions such areas as a subdivision of the land use category grassland.	There is not sufficient activity data available to follow the review recommendation at this time. Research on long term monitoring of land use change will be considered in order to address this issue in future submissions.	

LULUCF	Non-key categories: Biomass burning CO2	95	As reported on page 118 of the NIR, the Party, in calculating emissions from biomass burning on forest land and in incorporating the effect of forest fires into the model CARBWARE, assumes that 40 per cent of biomass (IPCC default EF taken from the IPCC good practice guidance for LULUCF table 3A 1.12) is consumed by forest fires and, consequently, 60 per cent stands on the forest land, mainly as dead organic matter. However, the model CARBWARE does not incorporate in its equations, which estimate carbon stock changes in dead mass and litter, the transfer of carbon stock from the biomass pool due to forest fires. The ERT recommends that the Party amend the CARBWARE equations in order to remove the bias and submit recalculated estimates in its future annual submissions.		
Waste	Non-key categories: Waste incineration CO2 and N2O	104	In its 2011 submission, Ireland reported emissions from waste incineration for the period 1990–2009 as “NO”. It was noted in the previous review report that there was indeed a small amount of clinical waste incinerated up to 1997. In its response to the recommendation in the previous review report Ireland will consider providing estimates for clinical waste incineration in its submission for the 2012 annual submission. The ERT welcomes this effort.	Information on Incineration of clinical wastes and waste solvents has been provided in this submission.	Chapter 8, sections 8.4, 8.4.1 and 8.4.2
Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Overview (106), Afforestation and reforestation – CO2 (108) and Deforestation – CO2 (109)	106, 108, 109	(106) The ERT found inconsistencies in AD reported in CRF table NIR-2 for the years 2008 and 2009. The total area reported for 2009 (7,111,786 ha) does not match the area reported for 2008 (7,111,777 ha); the area reported in cell J8 of the 2009 table (previous year total afforestation), 264,930 ha, does not match the total area reported as afforested in the 2008 table, 264,880 ha. The area deforested in 2009 is reported as previously subject to afforestation/reforestation. The ERT recommends that Ireland improve the accuracy in the time series of AD for afforestation/reforestation and deforestation activities and that it report consistent land representation of areas subject to afforestation/reforestation and deforestation in its future annual submissions. (108) Ireland, in calculating emissions from biomass burning on land subject to afforestation/reforestation and in incorporating the effect of forest fires into the model CARBWARE assumes that 40 per cent of biomass (IPCC’s EF taken from the IPCC good practice guidance for LULUCF table 3A 1.12) is consumed by forest fires and, consequently, 60 per cent stands on the forest land, mainly as dead organic matter. However, the model CARBWARE does not incorporate in its equations that estimate carbon stock changes in dead mass and litter the transfer of carbon stock from the biomass pool due to forest fires. The ERT recommends that the Party amend the CARBWARE equations in order to remove the bias and submit revised unbiased estimates in its future submissions. (109) The ERT notes that Ireland does not report carbon stock changes from SOM for deforestation to settlement and other land and does not provide information that demonstrates that SOM is not a source of emissions. The ERT recommends that the Party provide in its future annual submissions estimates of SOM carbon stock changes for both mineral soils and organic soils of forest land converted either to settlement or to other land or demonstrate that this pool is not a source. Furthermore, due to the high uncertainty of data the ERT encourages the Party to improve its analysis on stock changes in the SOM pool for conversion from forest land to grassland as new information becomes available.		

Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Deforestation – CO2	110	The ERT notes that equations 11.10 and 11.11, reported on page 176 of the NIR, calculate the aboveground and below ground biomass multiplying the total biomass by (1–R) and R, respectively, where R is the root/shoot ratio, and the total biomass is calculated by applying to the standing mass a BEF that includes the root/shoot ratio. Further the ERT notes that the total biomass equals the aboveground biomass multiplied by (1+R) or the belowground biomass multiplied by (1/R + 1). Therefore, the ERT recommends the Party to correct the equation 11.10 by substituting the term (1-R) with 1/(1+R) and equation 11.11 by substituting the term R with 1/(1/R + 1); furthermore the ERT recommend the Party to provide transparent information on how the biomass expansion factor has been calculated and to report all elements (e.g. the root/shoot ratio) applied in the calculation of the BEF.		
Conclusions and recommendations		134, 135	(134) The ERT identifies the following cross-cutting issues for improvement: (a) The strengthening of QA/QC procedures for specific sectors, in particular for LULUCF, and the provision of more detailed information on QA/QC arrangement for industrial processes and for LULUCF; (b) The implementation of a tier 2 key category analysis; (c) The improvement of the uncertainty assessment for LULUCF, and the provision of consistent information on this subject in the different parts of its submission; (d) The further improvement of the use of notation keys in the CRF; (e) The provision of estimates for categories and gases for which no methodologies and emission factors exist in the Revised 1996 IPCC Guidelines and in the IPCC good practice guidance. (135) During the review, the ERT formulated a number of recommendations relating to the information presented in Ireland's annual submission. The key recommendations are that Ireland: (a) Provide more detailed information on QA/QC procedures for categories in the energy and industrial processes sectors that include installations under the EU ETS, in particular by specifying which tier of the monitoring and reporting guidelines under the EU ETS applies to that category and provide information on how these estimates are in line with the IPCC good practice guidance; (b) Provide a clear indication about the methodological tiers used in the estimation of emissions in the industrial processes sector; (c) Improve the use of notation keys in the CRF for categories in the industrial processes sector, in particular for subcategories under the consumption of halocarbons and SF6; (d) Improves transparency in the agriculture chapter of the NIR by providing references to background data and to the well-recognized literature used to calculate uncertainties; (e) Further harmonize the methods used for estimating emissions and removals for the LULUCF sector reported under the Convention and its Kyoto Protocol.	See above.	

Table J.2 Ireland's Response to the recommendations in the UNFCCC Annual Review Report for Submission 2012

Sector	Issue	ARR Paragraph	Recommendation	Party response	NIR Section
General	Completeness	10	The inventory covers all mandatory source and sink categories for the period 1990–2010 and is complete in terms of years and geographical coverage. However, the ERT noted that some emission sources have been reported as not estimated ("NE"), including: CH_4 emissions from land converted to wetlands; CH_4 emissions from land converted to settlements; N_2O emissions from solvents; CO_2 emissions from asphalt roofing, road paving with asphalt, and food and drink production; and CH_4 emissions from poultry. The ERT encourages Ireland to provide estimates for these categories in its next annual submission and to continue its efforts to include, in its inventory, emission estimates for categories for which there are no methodologies or emission factors (EFs) available to estimate emissions in the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance) or in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines).	The inventory agency will consider the ERT's encouragement and continue to prioritise inventory improvements based on KCs and review findings within current resources.	
General	Key category analysis	16	In response to a question raised by the ERT during the review, Ireland explained that a tier 2 key category analysis was not performed due to resource constraints. However, some elements of the qualitative approaches mentioned in section 7.2.2 of the IPCC good practice guidance (namely, mitigation techniques and technologies, high expected emissions growth, high uncertainty, unexpectedly low or high emissions) are already being carried out by the Party, and, therefore, Ireland does not expect the performance of a tier 2 key category analysis to result in significant improvements to the inventory. The results of the key category analysis are discussed in the NIR and are used as a driving factor for the prioritization of inventory improvements. The ERT encourages Ireland to implement a tier 2 key category analysis in future annual submissions.	The inventory agency carried out some work on a Tier 2 KCA during this and the previous submission. The work was not finalised in time for this submission (2014) as the current KCA and uncertainty assessment are not performed at the same level of disaggregation.	Chapter 1, Section 1.5
General	KCA	17	Ireland has identified CO_2 emissions from afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol as a key category for 2010. The results of the key category analysis for the KP-LULUCF activities are presented in KP-LULUCF CRF table NIR-3. The ERT encourages Ireland to include, in the NIR, a paragraph explaining the data sources and the analysis performed.		Chapter 1, Section 1.5.2
General	Transparency	23	The degree of transparency of the information included in the NIR and in the CRF tables is, in general, relatively good. The ERT did not identify any restrictions relating to the provision of information in the CRF tables or in the NIR for confidentiality reasons. In particular, the ERT commends the Party for improving the use of the notation keys in the energy sector (transport and fugitive emissions). However, some incorrect notation keys are still used in the CRF tables. For example, emissions from domestic navigation (residual oil) are reported as not occurring ("NO"), but should actually be reported as included elsewhere ("IE"), based on the information provided in response to questions raised by the ERT during the review (see para. 43 below).		Chapter 3, Section 3.2.1.3.3

Energy	Completeness	31	The reporting in the energy sector is complete in terms of gases and generally complete in terms of categories. The ERT noted that Ireland does not report CH4 and N2O emissions associated with charcoal use, as described in paragraph 40 below.	CH4 and N2O emissions from charcoal used for cooking are now reported in sub-category 1.A.4.b for all years	Chapter 3, Section 3.2.1.4
Energy	QA/QC	33	The ERT noted that Ireland has improved the description of its QA/QC procedures for the energy sector in relation to the use of EU ETS data in the estimation of emissions from public electricity and heat production under energy industries. However, the ERT further noted that the Party does not provide information on the category-specific QA/QC measures in the NIR. The ERT considers that this reduces the transparency of the Party's reporting. The ERT therefore recommends that Ireland provide information on the category-specific QA/QC measures in its next annual submission.		Chapter 3, Section 3.6
Energy	Sectoral and reference approach	34	Ireland has reported the reference and sectoral approaches. The difference between the reference approach and the sectoral approach was –0.41 per cent in 2010. The ERT noted that the Sustainable Energy Authority of Ireland (SEAI) is continuing to develop its own procedures to ensure that the national energy balances are fully harmonized with the requirements of the Statistical Office of the European Union and the International Energy Agency (IEA) and are made available in a timely manner to facilitate the annual reporting of the GHG emission estimates. Ireland further explained that arrangements have been established whereby the bottom-up energy data reported to EPA for individual enterprises for all relevant energy-use categories covered by the EU ETS will be reconciled at an early stage with the corresponding top-down information collected by SEAI. This procedure aims to progressively minimize the differences between the energy data reported by SEAI and those supplied by individual enterprises for particular subcategories and fuels. The ERT commends Ireland for developing these data harmonization procedures and encourages the Party to report on the progress made with respect to the implementation of these procedures in its next annual submission.		Chapter 3, Section 3.6
Energy	Sectoral and reference approach, International bunker fuels	35	The ERT noted a discrepancy in the comparison of jet kerosene consumption in civil aviation between the CRF tables (527.75 TJ) and the IEA data (1,075.00 TJ). Similarly, residual fuel oil used in navigation was reported as "NO" in the CRF tables, whereas IEA reports residual fuel consumption of 800 TJ. In response to a question raised by the ERT during the review, the Party explained that the fuel consumption data reflected in the IEA data for Ireland are reported by the Department of Communications, Energy and Natural Resources (DCENR), while the data reflected in the CRF tables are taken from the energy balances prepared by SEAI. Ireland further confirmed that the correct AD are those from the national energy balances and that SEAI is currently in discussion with DCENR to provide all statistical information to IEA in the future on all types of fuels consumed in the country, including any revisions to historical data, in an effort to improve the consistency of all energy data sets. The ERT welcomes this initiative by Ireland and recommends that the Party report on the progress made in the implementation of this initiative in its next annual submission.		Chapter 3, Section 3.6

Energy	Sectoral and refernce approach, International bunker fuels	36	The ERT noted that CH4 and N2O emissions from marine bunkers were reported as "NE". In CRF table 9(a), the Party states that there are no IPCC default CH4 and N2O EFs. However, consistent with the recommendations in the previous review report, the ERT notes that CH4 and N2O EFs are available in Volume 3 of the Revised 1996 IPCC Guidelines. In response to a question raised by the ERT during the review, Ireland explained that, by applying the IPCC default EFs, it has prepared a provisional GHG inventory for the years 1990–2011, which includes CH4 and N2O emissions from marine bunker fuel use. These new emission estimates will be reported in the 2013 annual submission. The ERT welcomes this effort by Ireland to estimate CH4 and N2O emissions from marine bunker fuel use and recommends that the Party report these emissions in its next annual submission.	CH4 and N2O emissions from marine bunkers have been estimated by applying the IPCC Default EFs.	Chapter 3, Section 3.5
Energy	Non-key categories, Stationary combustion: biomass - CO2, CH4 and N2O	40	The ERT noted that Ireland does not report the emissions associated with charcoal use. In response to a question raised by the ERT during the review, the Party indicated that the national energy balances do not indicate any production or use of charcoal in Ireland. The ERT further noted that the statistical database of the Food and Agriculture Organization of the United Nations (FAOSTAT) provides information on charcoal import quantities for Ireland. For example, according to the FAOSTAT data, Ireland had charcoal imports amounting to 1,157 t in 2010.	CH4 and N2O emissions from charcoal used for cooking are now reported in sub-category 1.A.4.b for all years	Chapter 3, Section 3.2.1.4
Energy	Non-key categories, Other transportation: liquid fuels – CO2, CH4 and N2O	43	In response to a question raised by the ERT during the review on the allocation of emissions from ground activities at airports and harbours, Ireland reported that the national energy balance does not provide a breakdown of the fuel used by mobile or stationary plants at airports or harbours. The ERT considered that this implies that the fuel consumption for these activities is included elsewhere. However, the ERT noted that Ireland used the notation key "NO" to report liquid fuels in the subcategory other transportation. The ERT therefore recommends that the Party review the notation key used to report liquid fuels and, as appropriate, change the notation key from "NO" to "IE", in its next annual submission.		
Energy	Non-key categories, Other sectors: biomass – CH4 and N2O	44	The ERT noted that the Party has reported biomass use in the subcategory agriculture/forestry/fisheries as "NO". The ERT further noted that other reporting countries with national circumstances similar to those of Ireland report biomass consumption in this subcategory. In response to a question raised by the ERT during the review, Ireland explained that, according to the energy statistics published in 2009 for the years 1990– 2008, a small amount of woody biomass was used in agricultural activities in the years 2007 and 2008. SEAI investigated this issue and found that the woodchips were used in animal bedding and standoff pads (woodchip corrals) and not for combustion purposes. Based on this analysis, the woodchip use was removed from the national energy balance for 2007 onwards. The ERT welcomes this explanation and recommends that Ireland include this information in the NIR of its next annual submission. The ERT further encourages the Party to conduct periodic surveys or similar studies as the one conducted in 2009 to assess the use of biomass for combustion purposes in the subcategory agriculture/forestry/fisheries.		Chapter 3, Section 3.2.1.4

IP and Solvent and other product use	Transparency	51	The ERT noted that the NIR does not follow the recommended structure of the national inventory report with regard to the sector chapters7 (e.g. the structure outlined for chapters 3–9). With respect to clinker production, the description of the methods, AD and EFs would be more transparent if the Party followed the recommended reporting structure. The ERT therefore reiterates the encouragement in the previous review report that Ireland use the recommended reporting structure in its next annual submission in order to increase transparency		Chapter 4, Section 4.2.1
IP and Solvent and other product use	Key categories, Cement production – CO2	52	CO2 emissions from cement production are the largest source of GHG emissions in the industrial processes sector (amounting to 1,299.05 Gg CO2 eq in 2010). The emission estimates for the period 1990–2010 are based on emissions reported by the plants. For the years 1990–2003, the plants reported their own emission estimates, which were calculated using a method based on the same assumptions used for the development of Ireland's first national allocation plan. This method is in line with the IPCC tier 2 methodology. Emissions for the years 2004–2010 are from each plant's reporting under the EU ETS. The estimates include the consideration of the cement kiln dust factor. However, the Party does not yet report information on the calcium oxide (CaO) and magnesium oxide (MgO) content of the clinker. The ERT therefore reiterates the recommendation in the previous review report that Ireland include information on the CaO and MgO content of the clinker in its next annual submission, in accordance with the IPCC good practice guidance.	Information on calcium oxide (CaO) and magnesium oxide (MgO) content of clinker has been provided to the inventory agency by the plant operators, however, this information is not published in this inventory report as the cement producers deem it to be confidential. The data are available to the expert review teams for annual GHG inventory reviews upon request.	Chapter 4, Section 4.2.1
IP and Solvent and other product use	Key categories, Consumption of halocarbons and SF6 – HFCs	53	Consumption of halocarbons and SF6 is a key category, both for the level and for the trend, according to CRF table 7. However, this is not consistent with the information provided in tables 1.2 and 1.3 of the NIR. The ERT recommends that Ireland cross-check the information in the CRF tables and in the NIR and make appropriate corrections in its next annual submission.		
IP and Solvent and other product use	Key categories, Consumption of halocarbons and SF6 – HFCs	54	Ireland has followed up on several of the recommendations made in previous review reports. The recalculations made as a result of the recommendations and their impact on the emission estimates are explained in section 4.6 of the NIR. The ERT commends the Party for this improvement and encourages Ireland to include additional information from section 4.6 of the NIR (e.g. the updated disposal factor for vehicles at 'end of life', the revised product lifetime factor from 0.01 per cent to 0.049 per cent for fire extinguishers) in the relevant sections of the NIR where the methodological issues are described.		
IP and Solvent and other product use	Key categories, Consumption of halocarbons and SF6 – HFCs	55	The ERT noted that Ireland still uses the notation keys "IE" and "NA" in CRF table 2(II).F to report the AD and corresponding estimates of HFC emissions from refrigeration and air-conditioning equipment, except mobile air conditioning. The emission estimates for manufacturing and for the disposal of commercial refrigeration equipment are reported as "IE" and included under "stock", and the AD are reported as "NA", thereby preventing the ERT from replicating the bottom-up approach. The ERT strongly reiterates the recommendation in previous review reports that Ireland investigate this matter further by reviewing the use of the notation keys for this category, in order to improve the transparency of its reporting in its next annual submission.		

IP and Solvent and other product use	Non-key categories, Limestone and dolomite use – CO_2	56	In the previous review report, the ERT noted that Ireland had not provided an explanation regarding the sharp fall in CO_2 emissions from 2008 (2.71 Gg CO_2 eq) to 2009 (1.54 Gg CO_2 eq) (a 43.1 per cent decrease) in the NIR. The Party has not included an explanation in the 2012 NIR either. The ERT therefore reiterates the recommendation in the previous review report that Ireland include an explanation for the inter-annual fluctuation in CO_2 emissions, either in the introductory part of the chapter on the industrial processes sector or at the category level, in order to improve the transparency of the NIR in its next annual submission.		Chapter 4, Section 4.2.3
Agriculture	Transparency	62	The ERT noted that, in the 2012 NIR, Ireland only briefly described the methodologies used to estimate CH_4 emissions from enteric fermentation and manure management and did not provide the emission calculation results, although these results were reported in the CRF tables. To improve transparency, the ERT encourages Ireland to provide all necessary input parameters, together with the calculation results, in the NIR of its next annual submission.		
Agriculture	Key categories, Enteric fermentation – CH_4	63	The ERT noted that Ireland has applied a country-specific method to calculate CH_4 emissions from cattle. The model used to estimate CH_4 emissions from dairy cattle covers 12 production systems. Separate model calculations are undertaken for each production system and a weighted average EF is then calculated using population data for each region. Each production system is defined in terms of calving date, dates of winter housing and spring turnout to grass, and milk yield and composition. With respect to milk yield and composition, monthly time steps, or parts thereof, are developed for each production system; different fat and protein contents are therefore used for each time step in each region based on the known lactation structure. The ERT found that not all of the necessary input data are provided in the 2012 annual submission and that the calculations are not replicable. In response to questions raised by the ERT during the review with regard to this issue, Ireland provided the necessary data and supporting documentation. The information provided sufficiently clarifies the method used to estimate the emissions. The ERT commends Ireland for providing this information and recommends that the Party incorporate this information in the NIR of its next annual submission, in order to improve transparency.		
Agriculture	Key categories, Enteric fermentation – CH_4	64	Ireland has applied a tier 1 approach to estimate CH_4 emissions from sheep. For lowland ewes, upland ewes, rams and sheep older than one year, the Party has used the IPCC default EF for enteric fermentation of 8 kg CH_4/head/year for developed countries as per table 4-3 of the Revised 1996 IPCC Guidelines. The EF for sheep is estimated using a correction for the number of months that young animals are alive and the value of the gross energy fraction converted to CH_4, as per table 4.9 of the IPCC good practice guidance. The ERT notes that it is good practice to use tier 2 methods for the key categories, and therefore reiterates the recommendation in the previous review report that Ireland investigate the possibility of developing and implementing a tier 2 approach for the calculation of CH_4 emissions from sheep in its next annual submission.	The inventory agency is currently investigating the applicability of developing Tier 2 estimates of CH_4 from enteric fermentation and manure management from sheep. Discussions are on-going with agricultural research institutions in relation to sourcing appropriate country specific data with respect to feed intake and management regimes for sheep in Ireland.	Chapter 6, Section 6.9

Agriculture	Key categories, Manure management – CH_4 and N_2O	65	The ERT noted that, for animal categories other than dairy cattle, the Party uses fixed N excretion rates throughout the time series (1990–2010). In response to a question raised by the ERT during the review, Ireland explained that, owing to the lack of information available to estimate dynamic, year-specific N excretion rates for all other animal categories, it uses available national statistics on these animal categories. The ERT considers that for animal categories other than dairy cattle there is no convincing evidence to substantiate the use of fixed N excretion rates throughout the whole time series. The ERT strongly recommends that Ireland either substantiate the use of fixed N excretion rates in the NIR of its next annual submission, or increase its efforts to obtain the relevant AD, including the necessary input data on N excretion rates, for all animal categories other than dairy cattle, and recalculate the CH_4 and N_2O emission estimates accordingly in its next annual submission, in order to ensure the accuracy of the emissions estimates.		Chapter 6, Section 6.4
Agriculture	Key categories, Manure management – CH_4	66	The ERT reiterates the recommendation in the previous review report regarding the issue of the CH_4 production potential of non-dairy cattle (0.24 m^3 CH_4/kg organic matter excretion as volatile solids (VS)), namely that Ireland investigate whether the value of 0.24 m^3/kg VS was obtained using standardized methods, including a sampling methodology, as prescribed in the IPCC good practice guidance.		Chapter 6, Section 6.3.1
Agriculture	Key categories, Direct soil emissions – N_2O	67	The ERT found an inconsistency in the values for the amount of N fixed in N-fixing crops (FBN) provided in CRF table 4.D and in table F.6 of the NIR. In response to a question raised by the ERT during the review, Ireland provided the correct values for FBN, which should have been provided in the NIR for the full time series. Ireland also explained that the value provided in table F.6 of the NIR for FBN is in fact the emission value and not the FBN value. The ERT recommends that Ireland correct this error in its next annual submission.	Table G.8 (N-Fixing Crops) of the NIR has been updated.	Annex G, Table G.8

Agriculture	Non-key categories, Field burning of agricultural residues – CH4 and N2O	68	The burning of agricultural residues does not occur in Ireland as a result of the requirements imposed on farmers/agricultural enterprises, which receive subsidies. These requirements include, for example, Area Aid, the Rural Environment Protection Scheme and the Cross Compliance Measures under the Single Farm Payment.[1] During the review, the ERT accessed the web resources provided by the Party and found that under the Rural Environment Protection Scheme the ban on the burning of straw, stubble and vegetation was indeed explicitly mentioned. However, these measures are applied on a voluntary basis and data on farmer participation indicated a rate of approximately 50 per cent (information available for 2005 only). Spot and planned burnings for management purposes are still allowed. Based on this information, the ERT concludes that, to some extent, field burning of agricultural residues is still being practised in Ireland, and strongly recommends that the Party further clarify, in its next annual submission, whether all farmers have participated in the implementation of these measures. If it is found that field burning of agricultural residues takes place in the country, the ERT strongly recommends that Ireland estimate the associated emissions and report them in its next annual submission.	The inventory agency has undertaken a review of crop residue burning (CRF 4.F) using the MODIS fire detection archive for Ireland which utilizes NASA earth data (https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data). The review examined 602 active fire points for the years 2001 to 2011 (years for which information is available). There is limited evidence to suggest that burning of crop residues is common practice in Ireland with only eight active fires (of the 602 identified) being within a 500m radius of cropland over the timeseries as shown through GIS analysis. The study is part of a larger body of work aimed at tracking land use change for inclusion in LULUCF estimates. Thus a published report is not available for this submission but can be provided to expert review teams if required.	Chapter 6, Section 6.9

LULUCF	Consistency	73	The ERT notes that the Party uses different versions of the CARBWARE model to estimate emissions and removals from LULUCF sinks and sources under the Convention and its Kyoto Protocol. In response to questions raised by the ERT during the review, Ireland indicated that the Kyoto Protocol version provides more accurate estimates of the carbon stock changes for all pools based on NFI data, completed for the first time in 2006. This version could not be applied to reporting areas under the Convention because there is no historic NFI information prior to 2006. Therefore, a volume-based assessment of biomass is conducted for the reporting under the Convention. The carbon stock changes in forest biomass estimated for the reporting under the Convention are lower than those reported for forests under the Kyoto Protocol because of the underestimation of the volume in young crops less than seven years old. The Party conservatively assumes that there are zero carbon stock changes in these crops because there is no detectable volume increment. The same assumption is applied to the carbon stock changes in dead organic matter (DOM) for the reporting under the Convention to ensure consistency with the methodologies used for the estimation of biomass. The method used to report the soil carbon stock changes is the same both under the Convention and under the Kyoto Protocol. It is envisaged that the model versions used for the reporting under the Convention and its Kyoto Protocol will be harmonized once the second NFI is completed in 2013. The ERT recommends that, in the next annual submission and until the next NFI is completed, the Party use the Kyoto Protocol version of the CARBWARE model for the reporting under the Convention, using backcasting techniques, as necessary, for the years prior to 2006. The ERT further recommends that Ireland continue its work to harmonize the methods used for estimating the emissions and removals reported under the Convention and its Kyoto Protocol.		Chapter 7, Section 7.3.1
LULUCF	Key categories, Land converted to forest land – CO2	75	Ireland divides its forest land into three subcategories: young (seven to 25 years), mature (older than 25 years) and unclassified clear felled areas (containing afforested and forested areas younger than seven years and areas without tree cover). The ERT noted that the previous review report recommended that Ireland use the area that was afforested and reforested 26 years before the year in which the accretion area is added as the annual accretion to the mature forest category. In response to a question raised by the ERT during the review regarding the timing of the addition of the accretion area, Ireland clarified that the assumption used to assign forest areas for the 2012 annual submission is that 5 per cent of the young crop category moves into the mature category each year. This means that there is a full turnover of these forest plantations every 20 years. In this way, the time series of forest strata by area and age for the years 1990–2010 was constructed using information from the Forest Information Planning System base year of 1995. For the years 1996–2010, data were obtained by accounting for annual changes in area per species, while for the years 1990–1994, the process was reversed using a backward extrapolation to obtain consistent time-series data. The ERT welcomes this clarification and recommends that the Party clearly explain this issue in its next annual submission.		

LULUCF	Key categories, Grassland remaining grassland – N2O	76	The ERT noted that the areas reported in NIR table 7.4 for 2010 for grassland remaining grassland (3,787.80 kha) are inconsistent with those reported in CRF table 5.C (3,733.45 kha). The ERT recommends that Ireland ensure the consistency of this information in the CRF tables and in the NIR for all years in its next annual submission.		Chapter 7, Section 7.2.3
LULUCF	Key categories, Grassland remaining grassland – N2O	77	The ERT noted that N2O emissions from grassland have been reported in NIR table 7.1, while in CRF tables 5 and 5.C they have been reported as "NO". However, no additional explanation has been provided regarding the subcategory under which these emissions are reported or justification for the use of the notation key "NO". The ERT recommends that Ireland provide clear explanations of where these emissions have been reported in its next annual submission.		CRF: Table 5 NIRI: Chapter 7, Section 7.2.1, Table 7.1
LULUCF	Non-key categories, Other land – CO2	78	The impact of the recalculations made by Ireland for this category is a continuous increase in net removals across the time series since 2002 (e.g. an increase of 132.94 Gg CO2 eq, or 818.1 per cent, for 2009). Although this increase could be largely explained by the conversion of 313.15 kha of grassland to other land in 2010, the ERT noted that the area of grassland converted to other land reported in NIR table 7.4 (74.58 kha) and in the CRF tables is inconsistent. The ERT recommends that Ireland cross-check the information in the NIR and in the CRF tables and, as appropriate, revise the calculations for the time series in its next annual submission.		Chapter 7, Section 7.2.3
LULUCF	Non-key categories, Other land – CO2	79	In the previous review report, the ERT noted that, inconsistent with the IPCC good practice guidance for LULUCF, the areas of natural grassland that are an available reserve for rough grazing but that are not grazed in the inventory year were reported under the land-use category other land. The ERT reiterates the recommendation in the previous review report that Ireland introduce natural grassland areas as a subdivision of the land-use category grassland, in its next annual submission.	In the 2014 submission, natural grassland areas are included as a subdivision of the Grassland land use category.	Chapter 7, Section 7.5.1
Waste	Key categories, Solid waste disposal on land – CH4	82	Ireland used a tier 2 method to estimate CH4 emissions from solid waste disposal on land, which is in line with the IPCC good practice guidance. A combination of IPCC default and country-specific EFs were used in this category and default degradable organic carbon (DOC) values from the 2006 IPCC Guidelines were used for the different waste types (wood and straw, and textiles). However, the ERT noted that the Party did not provide documentation justifying the appropriateness of the default values from the 2006 IPCC Guidelines for the national circumstances of Ireland. The ERT recommends that the Party provide such documentation in its next annual submission, in order to improve transparency.	Information has been provided in this submission.	Chapter 8, Section 8.2.2

Waste	Key categories, Solid waste disposal on land – CH_4	83	Ireland used a combination of decay constants (k) for different waste types, which required historical data for three to five half-lives for each waste type. In the NIR, the Party did not provide information on the historical time series for each of the model runs, as raised in the recommendations in previous review reports. However, in response to questions raised by the ERT during the review, the Party provided additional information on the generation of the time series for each model run. The ERT recommends that the Party incorporate this additional information in its next annual submission.		Chapter 8, Section 8.2.2
Waste	Key categories, Solid waste disposal on land – CH_4	84	Ireland uses waste composition data from national statistics to quantify the fractional distribution of waste between food waste, paper, wood and straw, textiles and disposable nappies in order to assign different DOC and methane conversion factor values for each waste type. The Party did not provide any information in the NIR on the source of the AD for garden waste. In response to a question raised by the ERT during the review, the Party provided additional information showing that the organic waste reported in national statistics is biodegradable food, garden and landscaping waste, and, where the context permits, also includes industrial organic sludges. For the purposes of emission estimates, organic waste is classified as food, as that is the largest proportion of organic material, and no further information on the composition of organic waste is available. The ERT recommends that Ireland provide information on the composition of organic waste (in terms of food, straw, wood, etc.), for the purpose of assigning input parameters for the first-order decay method, in its next annual submission, in order to improve the accuracy of its inventory.		Chapter 8, Section 8.2.2

Annex K

KP-LULUCF

Allometric Equations for Biomass

Growth Models and Pre-processing Functions for CARBWARE v5

Allometric Equations for Biomass

Table K.1: Allometric equations used to calculate biomass component for individual trees (kg d.wt tree^{-1})

Similar species are grouped into 6 different cohorts based on available research information (Spruces, Pines, Larches, Other conifers, fast growing broadleaves and slow growing broadleaves). Abbreviations: AB-above ground, TB-total biomass, BB-below ground, FB-foliage, SB-stem (i.e. timber >7cm diameter), L_{HR}= lop and top from harvest residues, DBH diameter at breast height (1.3 m) in cm, H –height in m.

Eq	Function	Range	Equation	Coefficients				r^2	RMSE	Slope	Source
				a	b	c	d				
Spruce											
1	AB	H>4.5m	$a \times DBH^b + c \times H^d$	0.23	2.12	5 x 10^{-7}	4.99	0.91	0.29	1.01	i, ii
2	AB	H<4.5m	$a \times H^b \times c$	1.32	1.7	1.38		0.86	0.2	1.1	i, ii
3	TB		$\exp[Ln(a) + b \times Ln(AG)]$	1.02	1.033			0.91	0.08	1.03	ii, iii
4	BB		TB-AB								
5	FB		$AB \times a + b \times \exp[-c \times AB]$	0.025	0.089	0.003		0.68	3.4	0.98	i, ii
6	SB		$\exp[Ln(a) + b \times Ln(AG)]$	0.405	1.09			0.99	2.99	1.03	ii, iii
7	L_{HR}		AB-SB								
Pines											
8	AB	H>3.8m	$a \times DBH^b + c \times H^d$	0.07	2.42	0.039	2.51	0.93	0.13	0.94	ii, iii
9	AB	H<3.8m	$a \times H^b$	0.12	3.91			0.95	0.74	0.95	i, ii
10	TB		$\exp[Ln(a) + b \times Ln(AG)]$	1.15	1.01			0.96	0.4	1.01	ii, iii
4	BB		TB-AB								
5	FB		$AB \times a + b \times \exp[-c \times AB]$	0.025	0.089	0.003		0.68	3.4	0.98	i, ii
11	SB		$\exp[Ln(a) + b \times Ln(AG)]$	0.71	1.005			0.97	0.27	0.96	ii, iii
7	L_{HR}		AB-SB								
Larch											
12	AB	H>2m	$a \times DBH^b + c \times H^d$	0.11	2.31	0.001	3.29	0.94	0.27	0.94	ii, iii
13	AB	H<2m	$a \times H^b$	0.03	1.91			0.67	0.44	1.2	i, ii
14	TB		$\exp[Ln(a) + b \times Ln(AG)]$	1.43	0.98			0.99	0.25	0.99	ii, iii
4	BB		TB-AB								

Eq	Function	Range	Equation	Coefficients				r^2	RMSE	Slope	Source
				a	b	c	d				
5	FB		$AB \times a + b \times \exp[-c \times AB]$	0.025	0.089	0.003		0.68	3.4	0.98	i, ii
15	SB		$\exp[Ln(a) + b \times Ln(AG)]$	0.903	0.972			0.98	0.28	0.96	ii, iii
7	L_{HR}		AB-SB								
Other conifers											
16	AB	H>3.8m	$a \times DBH^b + c \times H^d$	0.022	2.73	0.19	2.06	0.96	0.46	1.008	ii, iii
17	AB	H<3.8m	$a \times H^b \times c$	0.005	1.58	1.12		0.86	0.28	1.02	i, ii
18	TB		$\exp[Ln(a) + b \times Ln(AG)]$	1.59	0.96			0.99	0.28	1.005	ii, iii
4	BB		TB-AB								
5	FB		$AB \times a + b \times \exp[-c \times AB]$	0.025	0.089	0.003		0.68	3.4	0.98	i, ii
19	SB		$\exp[Ln(a) + b \times Ln(AG)]$	0.89	0.96			0.98	0.57	1.055	ii, iii
7	L_{HR}		AB-SB								
Slow growing broadleaves											
20	AB	H>3.0m	$a + \left[\frac{b \times DBH^c}{DBH^c + 246872}\right]$	0.08	25000	2.5	246872				iv
21	AB	H<3.0m	$a \times H^b$	0.031	1.72			0.84	0.88	0.91	i, ii
22	BB		$\exp(-a + Ln(DBH) + b)$	1.509	0.284						iv
23	FB	DBH>10cm	$a \times (DBH \times 10)^b$	0.009	1.47			0.96			v
24	FB	DBH<10cm	$AB \times 0.3$					0.78	1.2	0.79	i, ii
25	SB	DBH>19cm	$a \times (DBH \times 10)^b$	0.0002	2.5			0.97			v
26	SB	DBH<9cm	$\frac{AB + BB}{1.4}$								BEF
7	L_{HR}		AB-SB								
Slow growing broadleaves											
20	AB	H>3.0m	$a + \left[\frac{b \times DBH^c}{DBH^c + 246872}\right]$	0.06	25000	2.5	246872				iv

Eq	Function	Range	Equation	Coefficients				r^2	RMSE	Slope	Source
				a	b	c	d				
21	AB	H<3.0m	$a \times H^b$	0.031	1.72			0.84	0.88	0.91	i, ii
22	BB		$\exp(-a + Ln(DBH) + b)$	1.509	0.284						iv
27	FB	DBH>3cm	$a + b \times DBH^c$	0.375	0.0024	2.517		0.90			vi
28	FB	DBH<3cm	$AB \times 0.3$					0.78	1.2	0.79	i, ii
29	SB	DBH>35cm	$a \times DBH^b$	0.0001	2.535			0.97			v
30	SB	DBH<9cm	$\frac{AB + BB}{1.4}$								BEF, vii
7	L_{HR}		AB-SB								

i National research harvested tree database (COFORD funded project CARBiFOR)
ii Black et al., Biomass equations for modelling C dynamics in Irish forests (in prep)
iii Forest Research pulled tree database (Brice Nicholl, NRS, Forest Research, UK)
iv Brown S (2002) . Measuring carbon in forests: current status and future challenges. Environmental Pollution 116: 363-372.
v Johansson, T. Dry matter amounts and increment in 21-to 91-year-old common alder and grey alder some practical implicatons. Canadian Journal of Forest Research 29 1679-1690.
vi Bartelink, H.H., Allometric relationship for biomass and leaf area of beech (Fagus sylvatica L). Annals of Forest Science, 1997. 54: p. 39-50.
vii Black K., Tobin B., Saiz G., Byrne K. & Osborne B. (2004). Improved estimates of biomass expansion factors for Sitka spruce. Irish Forestry 61:50-65.

Growth Models and Pre-processing Functions for CARBWARE v5

K.1: CARBWARE pre-processing functions and growth models

The NFI permanent plot sampling procedure does not sample all trees in a plot (see Figure 11.4). Therefore, it is not possible to derive productivity index information, such as Height index or Yield class, which can be used to drive conventional stand based productivity models. The alternative and most statistically valid procedure adopted was the use of single tree models, to simulate tree growth between NFI cycles. These models can be cross-validated and re-parameterised once a repeat NFI cycle is completed. This section discussed the development of the CARBWARE growth model from draft versions for submission to International, peer reviewed Scientific Journals.

K.1-A: Pre-processing functions

Height-Diameter And Crown Ratio Modelling For Six Species Cohorts.

It is common among forestry datasets that tree height (H) or crown ratio (CR) is not measured on every tree. This creates interest in estimating the height of such trees.

A common forest inventory approach used to derive missing H and CR values involves the use of single parameter (DBH) models based on species and plot specific predictions (NFI, 2007; Wykoff et al., 1982). However, is has been suggested that these Chapman-Richards functions, or derivations thereof, are problematic because the function approaches the asymptote too rapidly, particularly when there is a weak relationship between DBH and H in larger trees. In addition, individual plot DBH-H data is sometimes too sparse to parameterise plot specific functions. Generalised DBH-H functions avoid the need to parameterise relationship for every stand. Since the relationship between DBH and H is influenced by the relative competitive position of trees within a stand and management interventions, site-level stand-density information is often incorporated (Temesgen and Gadow, 2004). Taking their results as a starting point, we address here several issues that arise in the context of our modelling dataset. These include the application of nonlinear mixed effects models which successfully borrow strength across all permanent plots, thereby facilitating imputation in plots where data is sparse or unevenly distributed. The permanent sample plot data, taken from a range of spacing and thinning experiments, used in this study is well suited, albeit not arising by design, to evaluate these stand-density parameters to describe variations in H and CR across different silvicultural conditions.

Materials and methods

Data

Data used were obtained from Coillte Teoranta's (the Irish Forestry Board state commercial forestry company) permanent sample plot record system. The dataset contains records from many silvicultural and thinning trials established during the period 1963 to 2001. The trials were initially established as replicated experimental designs with repeated measurements typically undertaken every five years. The dataset is described in Broad and Lynch (2007).

Incorporating competition covariates

The modelling here follows Temesgen and Gadow (2004) who based their work on Yang et al. (1978) and incorporated competition covariates into the Yang/Weibull function (Table 1, Model 2).We evaluate that model and also use test for differences between management regimes conditional on the DBH-H model by incorporating dummy indicator variables in the linear regression models of the model parameters. Our aim in this section was to test if the inclusion of certain covariates, typically relating to the competition in a forest stand/plot, improved the baseline DBH-H model (Table G.2.1, Model 1). We also investigated whether the model was improved by including random effects on the level of the plot (Table G.2.1, Model 3).

The competition covariates are plot basal area (BA, m^2 ha^{-1}), basal area in larger trees (BAL, m^2 ha^{-1}) which is the integral of the empirical frequency distribution of the BA variable from the subject tree to the largest diameter tree in the plot and plot density (DENS, trees ha^{-1}). Models were fitted in NLMixed procedure in SAS using the Trust-Region algorithm. Grids were specified as starting values for parameters where sensible.

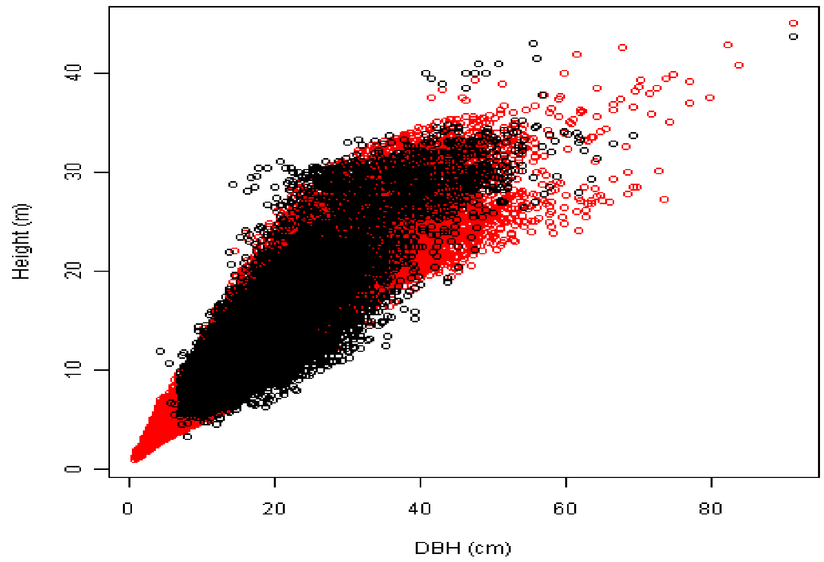


Figure K.1-A.1. Model 2 Height estimates (red) and actual heights (black)

The estimates presented here depict a "cloud" because they are conditioned on covariates that vary between trees (BAL) and plots (Density, Basal Area) and over time (BAL, Density, BA).

Table K.1-A.1

	Model	-2l	BIC
1	$H = a(1-\exp(b.DBH^{c}))$	65185	65223
2	$H = (a_1 + a_2 BAL + a_3 BA)(1-\exp(b.DBH^{(c_1 - c_2 BAL)}))$	58341	58417
3	$H = (Ui + a_1 + a_2 BAL + a_3 DENS + a_4 BA)(1-\exp(b.DBH^{(c_1 - c_2 BAL)}))$	44980	45034

Table K.1-A.2 Likelihood statistics for different forms of the DBH-H model

Model 2 is the model used in CARBWARE for the 6 different cohorts. If dependent variables had no significant influence on the H model prediction, these variables were excluded from the model.

Cohort	Model (2 variation)	a1	a2	a3	b	c1	c2
Spruce	$H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(b.DBH^{(c_1 - c_2 BAL)}))$	33.69	-0.274	0.1603	0.024	0.8846	0.0064
Pine	$H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.BAL))$	16.905	0.083	0.0803	0.042		
Larch	$H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.BAL))$	32.59	0.1052	0.1229	0.023		
Conifers	$H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.DBH^{c_1}))$	23.226	0.1381	0.0703	0.027	1.1021	
FGB	$H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.DBH))$	14.661	0.1167	0.0187	0.076		
SGB	$H = (a_1 + a_2 BAL)(1 - \exp(-b.DBH^{c}))$	29.677	0.1034		0.044	0.7813	

BAL is the sum of the basal area of all individual trees larger than the subject tree (m^2 per ha)
BA is the basal area of all trees in the plot (normalised to a ha)
DBH is the diameter at breast height (cm)

Table K.1-A.3. CR models used in CARBWARE for the 6 different cohorts

If dependent variables had no significant influence on the H model prediction, these variables were excluded from the model.

The CR model takes the form of:

$$CR = \frac{\exp(lCR)}{1 + \exp(lCR)}$$

where *lCR* is derived from the non-linear equations, which may vary for different cohorts.

Cohort	Model (*lCR* variations)	a1	a2	a3	a4	a5	b	c
Spruce	$lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + a_5 \left[\frac{H}{BAL}\right] + bDBH^{c}$	4.8705	-0.017	-0.397	-0.119	-0.296	0.0003	2
Pine	$lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + bDBH^{c}$	3.8478	-0.024	-0.213	-0.137		0.0002	2
Larch	$lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H$	5.8306	-0.018	-0.794	-0.039			

Conifers	$lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + bDBH^c$	4.1759	-0.019	-0.394	-0.965		0.0004	2
FGB	$lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + a_5 \left[\frac{H}{DBH} \right] + bDBH^c$	2.4539	-0.009	-0.145	-0.045	-0.591	0.0001	2
SGB	$lCR = (a_1 + a_2 BAL + a_3 H + a_5 \left[\frac{H}{BAL} \right]$	1.477	-0.005	-0.017	-0.578			

BAL is the sum of the basal area of all individual trees larger than the subject tree (m^2 per ha)
CCF is the crown competition factor, which is a measure of the crown areas of the subject tree relative to a open grown tree that would not be subjected to crown competition (taken from Hassenhaur, see section B of this appendix)
DBH is the diameter at breast height (cm)
H is height (m) form actual or predicted H estimates (Table K.1-A.2)

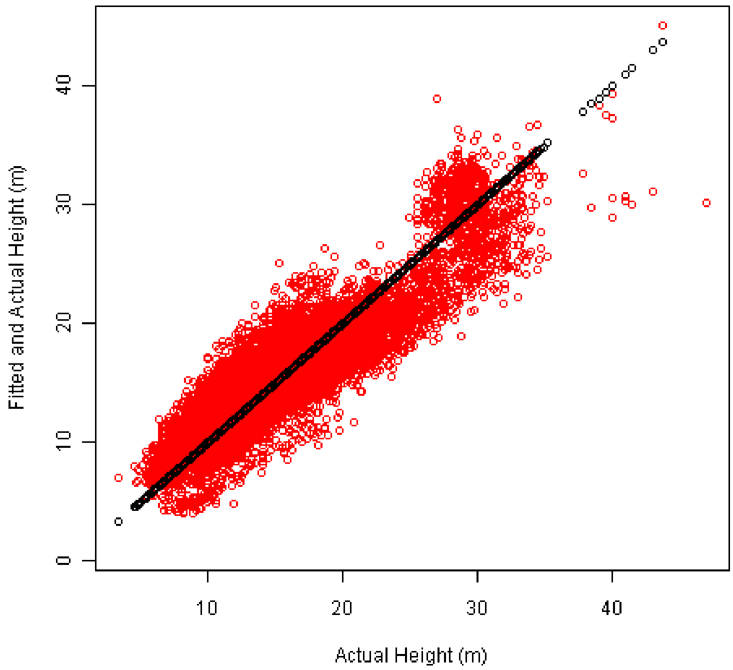


Figure K.1-A.2. Fitted and actual height plotted (all cohorts model 2) against actual height

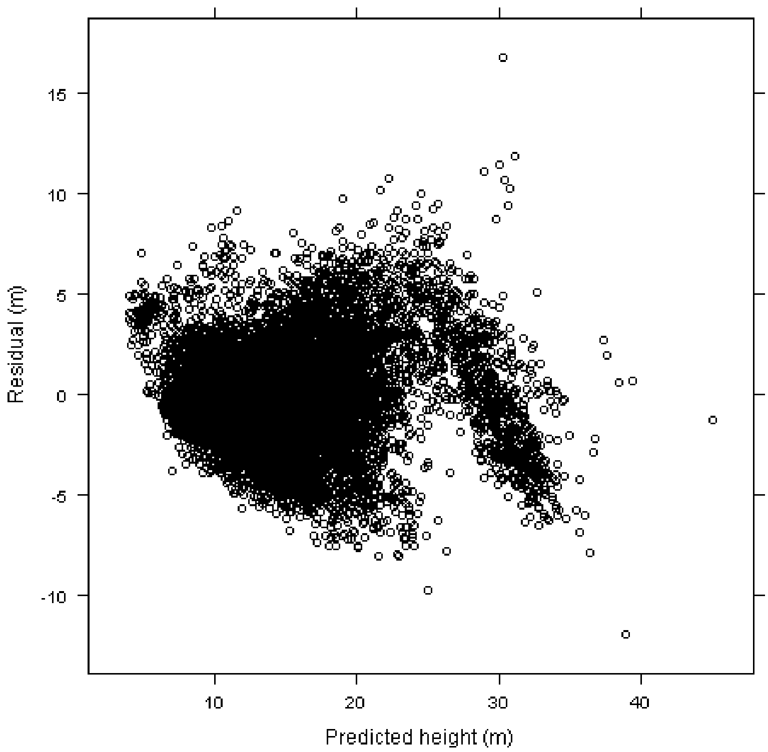


Figure K.1-A.3. Raw residuals from the fitted model plotted against the fitted height value

External validation

Based on the data presented above, model 2 was selected for validation against external data sets. In this section we compare model predictions against data from PSP non-research plots.

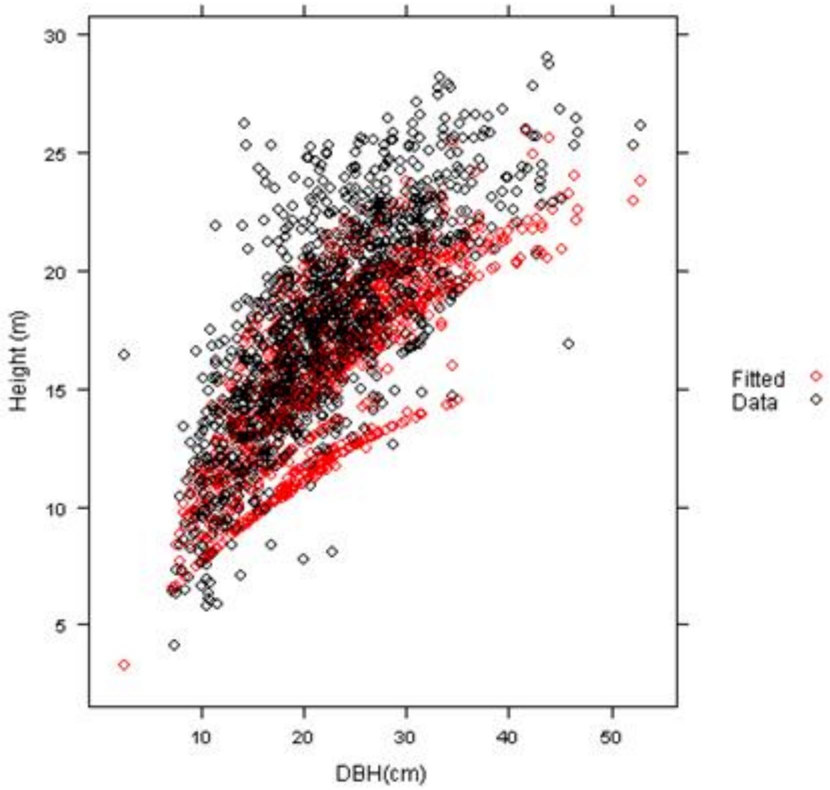


Figure K.1-A.4. Estimated and observed validation heights versus DBH

Generalised and plot-specific models

In this section we discuss the implications of using a generalised DBH-H model (i.e. one whose parameters are fitted to the entire dataset) with a plot-specific model (i.e. one whose parameters are estimated for each plot separately). We compare a mixed effects model and a plot-specific model. The former is plot-specific by the inclusion of a random residual plot effect. In what follows, by *mixed model* we mean the random asymptote model (Table K.1-A.1, Model 3). To get an idea of the difference between plot-specific and mixed-model results, we extract a plot from the dataset that exhibits a wide range of DBH and H values and then compare the models for that plot. This makes sense because the context of the comparison is how well a given model will perform for a given plot, primarily. In particular we will compare the standard error of prediction for a new tree height for both models. In the case of the mixed model, this standard error of prediction is derived as conditional on the estimated random plot effect.

A plot-specific Yang/Weibull model gives a smaller standard error of prediction than the same model estimated from the entire dataset, because residual variability for any given model will always increase from a subset of the data (plot specific) to the entire dataset (generalised). In other words, the generalised model predictions are less precise than the plot-specific predictions for any given plot, and the model mean estimate tends *towards* the overall mean and *away* from the plot-specific mean.

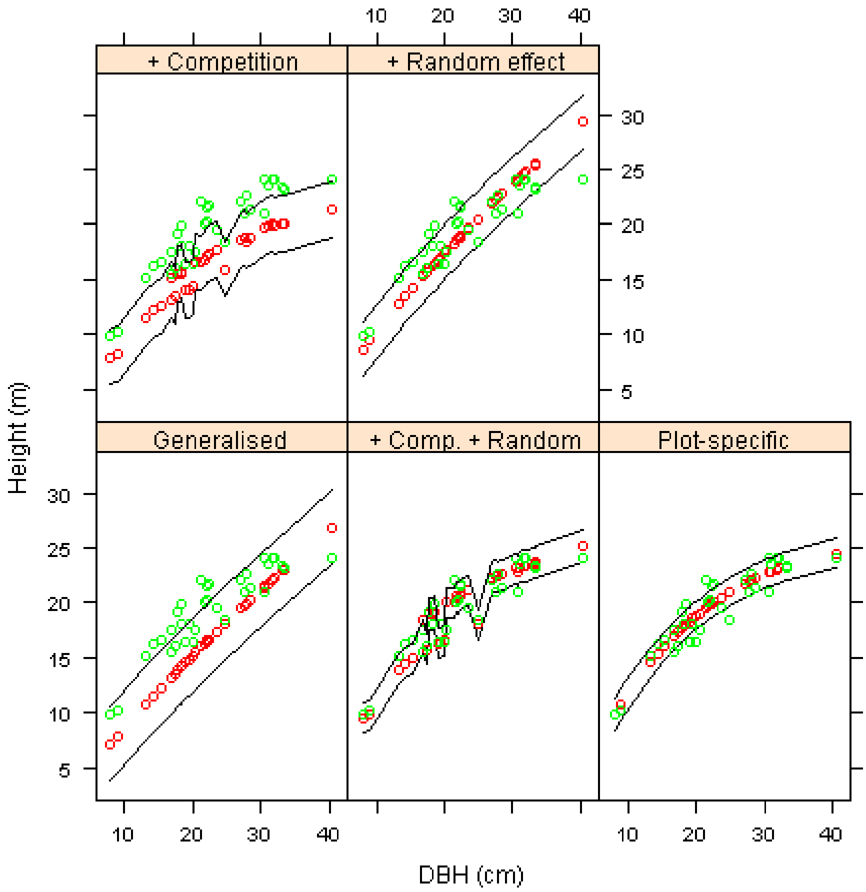


Figure K.1-A.5. Model predictions for a single plot with various models, all based on the Yang/Weibull funtion (cf. Table K.1-A.1

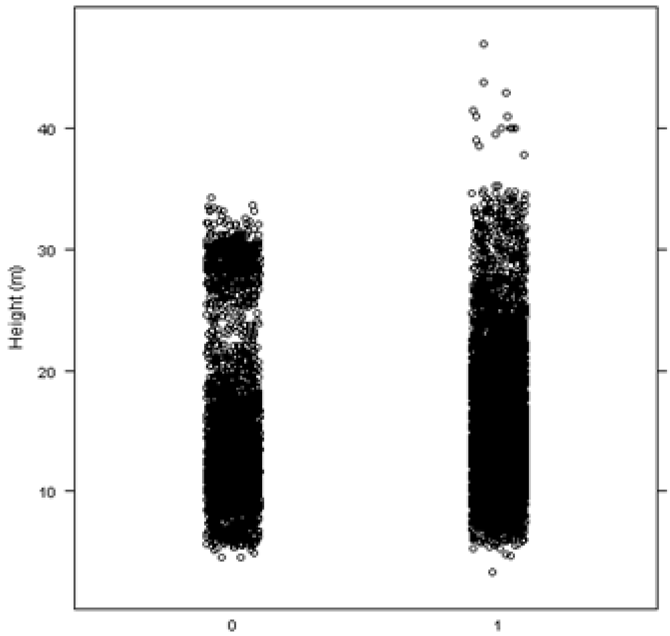
Green, red and black are data, estimates, and single standard error of prediction, respectively. Competition denotes a generalised model with competition covariates (cf. Model 2, Table K.1-A.1), Random denotes a plot-specific random asymptote (cf. Model 3, Table K.1-A.1), Generalised denotes parameters are estimated from the entire dataset. The smallest standard error of prediction is associated with the Plot-specific model, followed by the + Comp. + Random model. Average s.e.p. for these models are 1.39 and 1.25 respectively.

Thinning effects

All observations in the dataset were categorised by us as “thinned” or “non-thinned” depending on the general management regime for the plot. We estimated the following model to test for a residual thinning effect, having conditioned on other effects. :

$$H = (U_i + a + a_1 BAL + a_2 DENS + a_3 BA + a_4 I(Thinned))(1 - \exp(b.DBH^{(c_1 - c_2 BAL)}))$$

where I(*Thinned*) is an indicator function valued 1 if the plot was thinned and 0 otherwise. The BIC of this model was 45037, and the Wald test for the a_4 parameter ($p = 0.08$) indicated that the thinning effect was not statistically significant at the 5% level. The a_4 estimate was greater than zero, perhaps reflecting the longer tail in the height distribution for trees in thinned plots (Figure K.1-A.6).



0 = Unthinned *1 = Thinned*

Figure K.1-A.6. Strip-plot of Heights in the calibration dataset

Discussion

We have shown that it is possible to derive a generalised model that performs well and which by its nature deals with the data sparseness issue by estimating the "typical" parameter value and modifying this value as a function of the plot- and tree-level characteristics. The BIC results and the graphical results suggest that the inclusion of covariates in the model improves the DBH-H model (i.e Model 2), as was shown by Temesgen and von Gadow.

The inclusion of covariates in the model is a move away from the baseline model, which is a generalised approach that presumes that competition (as measured on the scale of the plot by DENS, and BA, and on the scale of the tree by BAL) does not affect the allometric relationship between DBH and H over the tree's lifetime, when subjected to different competition pressure introduced by spacing or thinning. In the next section we address the issue of generalised vs plot specific modelling. However, our results at this point suggest that the Temesgen and von Gadow model that models plot differences through competition variables is a unified single-step approach. By contrast, the plot-specific approach can be seen as a multi-step approach, whereby the DBH-H relationship for each subject is modelled individually, and competition effects are at best implicitly described by the plot-specific fitted parameters. We might suspect that datasets that are heterogeneous across plots might be more accurately modelled using plot-specific approaches. Similarly, a generalised model might perform well on plots that are nearer the centre of the sample space than plots where management conditions are more atypical for a given dataset.

In conclusion, we adopt the use of generalised competition based models in the CARBWARE software because this performs better across all data (See Table K.2.2).

K.1-B: Growth Modelling

(a) Modelling diameter increments in Irish Forests

Introduction

The modelling approach adapted in this version of CARBWARE v5 is the use of diameter increment models for all trees with a DBH greater that 5cm. This model in a distance independent individual tree growth model parameterised on Coillte permanent plot data recorded every 4 to 6 year since 1954 to 2003. These include pure and mixed species stands at establishment planting densities of 5000 to 1000 trees per ha and with different thinning treatments. The advantage of using a single tree growth model and the nature of the parameterisation data set is that different silvicultural regimes and species mixtures can be handled by one generalised modelling framework. In addition, the application data set, i.e. the data from which models will be run, does not contain explicit complete longitudinal data representing stand variable, which are used in conventional growth models.

Data operations

Two datasets are referred to, Coillte permanent sample plot (PSP) and NFI. Some of the data operations referred to below differ between these because the former has complete enumeration on a plot and is longitudinal, the latter samples from the plot and is cross-sectional.

In general, the modelling framework that we base our work on, PrognAus (see various references below), informed the types of data operations required. The framework involves, using their terminology, site, competition and size variables. Our focus was on the latter variables, and site or plot effects were accounted for using mixed model methods, whereby plot or site effects are random, blocking, effects, rather than effects whose levels have physical dimension. In any case, site or plot effects are not a feature of the growth simulator. Furthermore, incomplete enumeration of certain independent variables meant that random effects were difficult to estimate because of the sparse data. We can illustrate that elsewhere but such detail is not relevant to the CARBWARE software manual.

The variables described here are those that feature in the diameter increment model that we aim towards calibrating:

$$Dinc(cm) = \exp(a_0 + a_1 \ln DBH + a_2 DBH^2 + a_{3.} \ln CR + a_{4.} \ln CCF + a_5 .BAL)$$

See Table K.1-B.1 below and the text for explanation of symbols.

Data operations were concerned with assembling datasets of the variables used in the growth model, insofar as was feasible. Below, we describe any substantive data operations that were performed on the variables of interest. We exclude from this description any operations related to “data cleaning”. The main data cleaning result was to omit negative diameter increments from the dataset. Such omissions were made after such derived variables as BAL, BA and plot density were calculated. That decision was based on the fact that the omission did not have a significant impact on the results, which suggested that no further modelling was necessary to compensate for the omission. Also, if the trees involved were omitted prior to the calculation of derived variables, those variables would have been subject to an even greater bias.

Table K.1-B.1. Explanation of some symbols used in the text

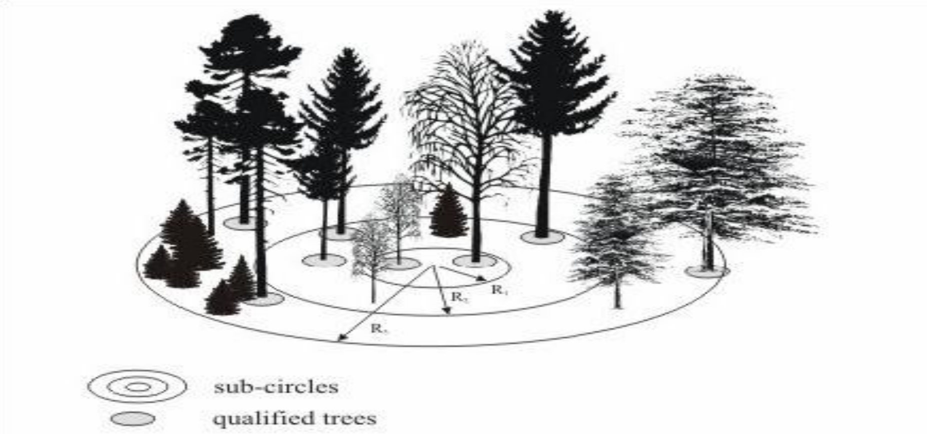
Variable	Formula	Scale of measurement
CR	Crown length/height	Range (0,1)
DBH	Diameter at 1.3 m	Cm
Crown competition factor (CCF)	The "open-grown" (e.g. if every tree had zero competitors) crown area of all trees in a plot expressed as a percentage of plot area.	Percent
BAL	A function for each plot that takes as its argument any tree's rank in the diameter distribution ordered from smallest to largest and returns the combined basal area of all trees with higher rank.	$M^2\ ha^{-1}$
BA	Plot basal area	$M^2\ ha^{-1}$
Annualised diameter increment (Dinc)	(DBH(t+1)-DBH(t))/([t+1] – [t]). DBH(t) stands for "DBH on the occasion of the t^{th} measurement". Since measurment intervals vary, this implies that [t +1] – [t] = 1 is not necessarily true, hence the use of the term "annualised".	cm

Open-grown crown width (cw), is an intermediary variable in the calculation CCF. We estimated *cw* using equations derived by Hasenauer (1997). These equations return open-grown crown width in *metres*. Hasenauer (1997) derived species-specific equations that we apply in approximation to cohorts,

Spruce : $cw = \exp(-\mathbf{0.3232})*((DBH)^{0.6441})$
Other conifers : $cw = \exp(\ \mathbf{0.092})\ *((DBH)^{0.538})$
Pine : $cw = \exp(-\mathbf{0.1797})*((DBH)^{0.6267})$
Larch : $cw = \exp(-\mathbf{0.3396})*((DBH)^{0.6823})$
Slow-growing broadleaves : $cw = \exp(-\mathbf{0.3973})*((DBH)^{0.7328})$
Fast-growing broadleaves : $cw = \exp(\ \mathbf{0.1366})*((DBH)^{0.6183})$
(where a circumflex denotes exponentiation.)

Open grown crown area (m^2) = $(\mathbf{0.25})*(\mathbf{3.141593}*cw^2)$

NFI and PSP datasets differed primarily in the fact that PSP plots were fully enumerated, whereas NFI plots were sampled. The sampling method, in conjunction with an assumption of homogeneous spatial diameter distribution, informs the calculation of a sampling weight or *expansion factor* which is used to allow for the possibility that some trees on a given plot were not sampled. The expansion factor is inversely proportional to the prior probability of a given tree's inclusion in the sample, based on the trees diameter class. Each tree in the sample is thus duplicated by a number of times equal to its expansion factor. This duplication is allowed for when calculating plot-level derived variables, e.g. Density, by incorporating the expansion factor into the equations. For example, the estimated number of trees on a plot with a single sampled tree of 8cm is $(12.62/3)^2$. See Figure K.1-B.1 for an explanation.



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12,62
Sub-circle area (m^2)	28,3	153,9	500
Treshold diameter (mm)	70	120	200

Figure K.1-B.1. The NFI sampling scheme at the plot-level

The *expansion factor* for a tree in the *i*th diameter class is $(R_3/R_i)^2$

Diameter increment

The diameter increment model for each cohort was calibrated by fitting to data from the PSP dataset.

$Dinc = \exp(a_0 + a_1 \ln DBH + a_2 DBH^{\wedge 2} + a_3 . \ln CR + a_4 . \ln CCF + a_5 . BAL) + e$

Where a_i, i = 1…5 are coefficients and *e* is a residual that was autocorrelated between measurements on the same tree and independent otherwise. The fitting was done in the Glimmix procedure in SAS, and the model is a GLM with Gaussian variance function and a log link. This is slightly different from Monserud and Sterba (1997), who log-transformed the response, where we log-transform the expected value of *Dinc*, and didn't model autocorrelation.

Where fitting was unsatisfactory, i.e. because of parameter instability or data sparseness, a submodel was selected. A criterion of model selection was that the parameters should be qualitatively similar to those estimated by Monserud and Sterba (1997). In this respect, the fitting of the increment models is better described as model calibration than model selection.

The parameters for the fitted models were:

FGB

$E(Dinc) = EXP(-2.8528 + LN(DBH)*1.1729 - 0.00012*DBH^2 + LN(CR)*0.8241 - 0.000015*CCF)$

Larch

$E(Dinc) = EXP(-2.2969 + LN(DBH)*0.6338 - 0.00096*CCF)$

OC

$E(Dinc) = EXP(-1.4191 + LN(DBH)*0.554 - 0.00025*DBH^2 + LN(CR)*0.5549 - 0.00052*CCF - 0.00646*BAL)$

Pine

$E(Dinc) = EXP(-1.3466 + LN(DBH)*0.741 - 0.001*DBH^2 + LN(CR)*0.998 - 0.00066*CCF - 0.00417*BAL)$

SGB

$E(Dinc) = EXP(-2.5897 + LN(DBH)*0.7534 - 0.00068*DBH\hat{}^2 - 0.0006*CCF - 0.00979*BAL)$

Spruce

$E(Dinc) = EXP(-1.8628 + LN(DBH)*0.9456 - 0.0005*DBH^2 + LN(CR)*1.1639 - 0.000638*CCF-0.00273*BAL)$

Uncertainty:

In this section we look at various measures of the performance for the different models discussed above. The performance measures quoted give rough ideas about how the models perform. It should be noted that performance can be improved somewhat by including plot and site effects but since these are problematic for extrapolation from PSP to NFI, they were omitted from the Dinc model. They were also omitted from within NFI imputation models, by which we mean imputation models calibrated on NFI data, for similar considerations. They were not omitted from PSP-specific models.

We looked at the performance of the various models – DBH-H, CR, Dinc – for the two datasets. Some measures we could have used, that are used by Thurig et al (2005), for example, are *accuracy, precision,* and *excess error,* calculated as follows.

Accuracy : ((Σ(**pred**icted-**obs**erved)/n)*100)/m. Where *m* is E(obs), and *n* is the number of observations.
Precision : SD(pred-obs)
Empirical Excess error (%): ((1-Sec)/Sei)*100. Where *Sec* is the *precision* of the calibration data, and *Sei* the *precision* of the independent data.
Theoretical Excess error : $(1/n)[\Sigma(pred_{(-1)}-obs)^2- \Sigma(pred-obs)^2]$. Where pred(-1) is the leave one out prediction error

Note that *empirical excess error* is only viable when doing external validation.

Temesgen and von Gadow (2004), for example, use *root mean squared error* (RMSE) and Bias to evaluate their models.

Bias : (Σ(pred-obs)/n)
RMSE : $\sqrt{(\Sigma(pred-obs)^2/n-p)}$. Where *p* is the number of parameters in the model.

Another measure is *mean absolute error* (MAE).
MAE : Σ |pred-obs|/n
A certain amount of model selection was done, as noted above, when fitting the models to the data in the first place. This ensures that the fitted models are the most parsimonious to minimise residual error. However, model performance is best evaluated by external validation or, failing that, some cross-validation. We conduct leave-k-out cross validation on the Dinc calibration data. *MAE* and *RMSE* are calculated for each cross-validation dataset replicate. External validation data was only available for the PSP DBH-H model, and that is discussed in another document.

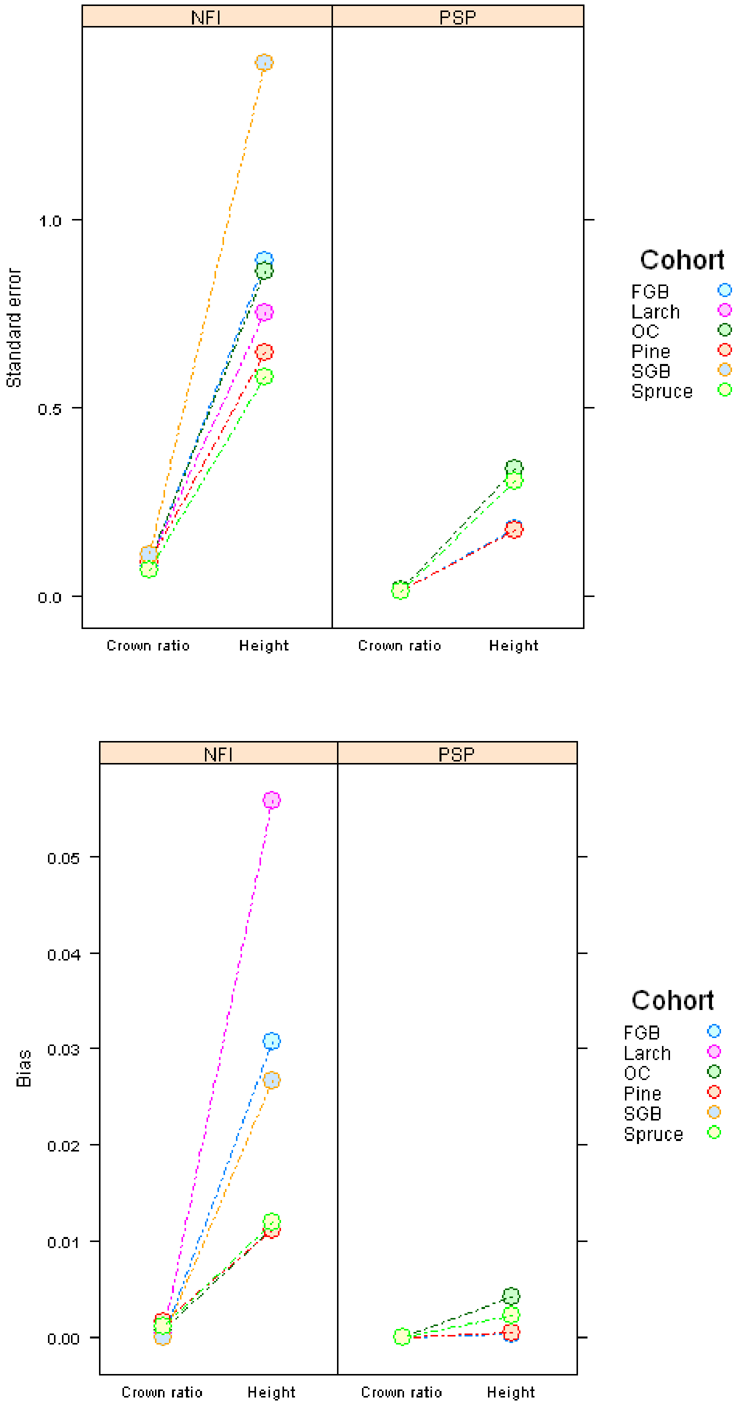
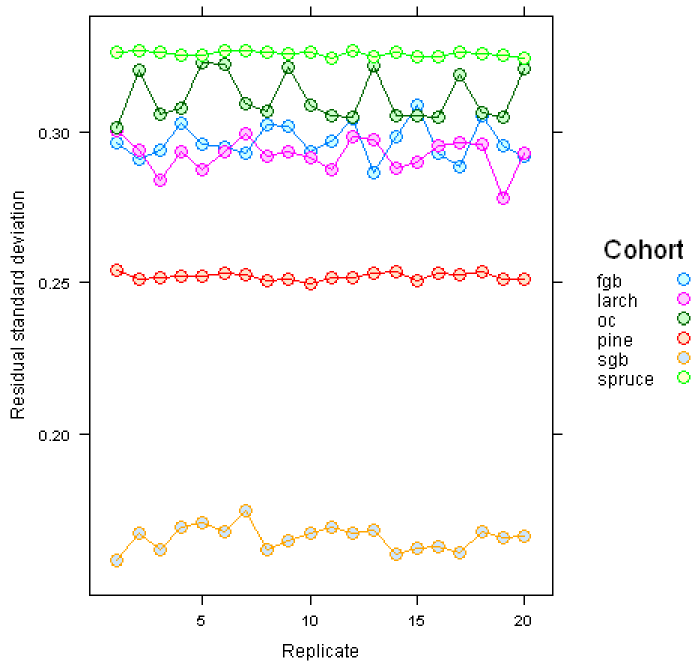


Figure K.1-B.2. Within-sample Precision (upper panel) and Bias (lower panel) for imputation
Values are plotted for each dataset, for cohorts, and for models of Height and Crown ratio.



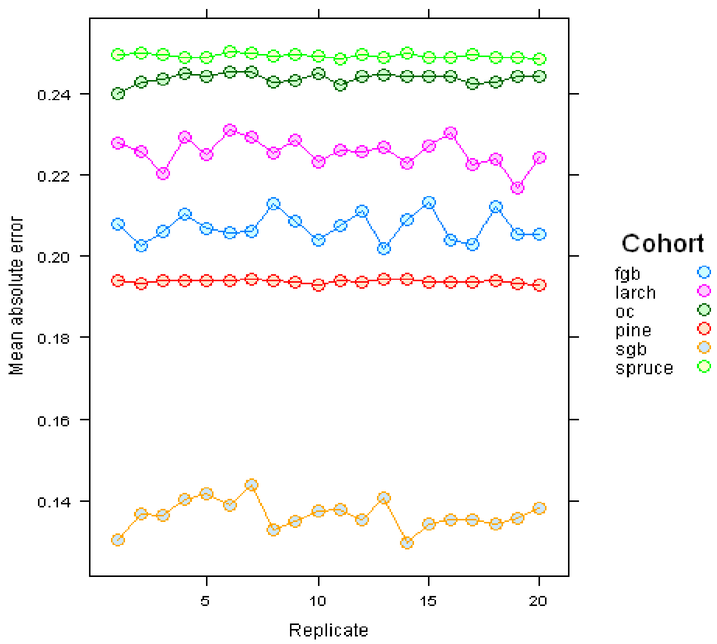


Figure K.1-B.3. Leave k-out cross validation results, precision (top) and mean absolute error (bottom) for the Dinc model

The probability of inclusion in the validation dataset is 0.33. 20 cross-validation replicates are displayed.

Discussion and conclusions

The lines joining the points in Figure K.1-B.2 are only included to facilitate a comparison between panels. The interpolating lines in Figure K.1-B.3 are indicative of variability between the different cross-validation runs. This variability is partly a function of data resources, i.e. the number of cases, and the size of the validation sample as a proportion of the number of cases. The low variability of Pine and Spruce, the cohorts with by far the most number of cases, reflects this.

In Figure K.1-B.2, the better performance of PSP versus NFI is partly a result of including such blocking effects as site and plot. This idea is also illustrated with more detail in the document on DBH-H modelling.

From Figure K.1-B.2, bias levels are low for both NFI and PSP. Pine and Spruce, the most important cohorts, are among the top performers. This partly reflects the better data resources for those cohorts.

Taken together, these results can inform uncertainty/sensitivity analyses) to be completed in 2011).

(b) Modelling height increments for small trees

Introduction

Height growth for small trees is a driving developmental force as trees compete for light and vertical growing space. Because of this, the small-tree portion of CARBWARE is a height-growth driven model; height growth is estimated first, and then diameter growth is predicted from height growth (see section B of this Annex G). Equations used to predict small-tree height increment vary by species, variant, silvicultural practice and site type. Most single tree based models for young growth, generally use the same the same predictors as described for DBH increment models. However, the NFI data set provides little or no information on predictors for young tree height. The development of a H growth model for trees less than 1.3 m to a maximum H of 2.3 to 5.1 m (i.e. the diameter at breast H, DBH) is described here. The model uses a empirical Chapman-Richards approach for different species with sub models for different height index ratios (i.e. mean H over age as proxy's for young stand productivity and site factors).

Methodology

Modelling framework

The model uses a empirical Chapman-Richards approach for different species with sub models for different height index ratios (i.e. mean H over age as proxy's for young stand productivity and site factors).

$$xHinc_{i,j}^{n+1} = \frac{a_1}{1+\exp(-1\times\left[\dfrac{age^n - a_2}{a_3}\right])} \quad \ldots\ldots(1)$$

where, *xH* is mean height of all trees in the NFI plot for the $_i$th species and $_j$th H index ratio at the determined age (n+1). The age of the forest (n) is obtained from the NFI stand attribute data. The partial coefficients (*a*) for each species and productivity class and goodness of f
Once the new mean tree H ($xH_n+xHinc_{n+1}$) is computed, the individual tree H is recalculated based on a scaling function:

$$H_{n+1} = \frac{H_n}{xH_n}\times H_n \quad \ldots\ldots(2)$$

where, H_{n+1} is the individual H of the tree in the plot in the year following the NFI , H_n is the individual H in the year the last NFI was completed (2005), and xH_n is the mean H of trees in the plot in the year the last NFI was completed.

The Productivity class (H over age) categories were defined to match conventional yield class productivity indices (YC*eq*) as described by (Christy and Edwards, 1981). This was derived by comparison of Chapman Richard outputs from each H index ratio (HI) with static age-H tables at ca. 10 to 20 year old crops.

$$YCeq = HI = \min,\{YCH_{ij} - xH_{ij}\}^2$$

where, YC *eq* is the *HI* equivalent to YC at the lowest least-squares different between the yield table H values (*YCH*) and the predicted mean height (*x*H see equation 1) for the *i*th cohort and *j*th HI.

Selection of tree for H increment model

All trees with no measurable DBH are selected for growth increment using the H model. The CARBWARE model also selects eligible trees to be grown using the H growth model based on cohort-specific threshold DBH values (Table K.1-B.2). These are derived from analysis of the minimum DBH ranges suitable for the DBH increment model. The transition from the H to DBH increment model is based on the threshold H value which corresponds to the minimum allowable DBH value to be used in the DBH increment model (Table K.1-B.2). If a tree has a larger corresponding DBH than the threshold value, it is grown using the DBH increment model.

Table K.1-B.2. Threshold minimum DBH values suitable for use din DBH increment model and corresponding cut-off H values used for H growth in small trees

Cohort	DBH threshold (cm)	Corresponding H (m)
Spruce	4	2.7
Pine	4	5.1
Larch	2	3.6
Other conifers	4	3.1
Slow growing Broadleaves (SGB)	2	4.2
Fast growing Broadleaves (FGB)	2	3.2

Datasets and measure of goodness of fit

We used both the Coillte PSP and NFI individual tree data base to develop H-age curves (range 0.1 to 12 m). Data operations were concerned with assembling datasets of the variables used in the H model, insofar as was feasible.

We looked at the performance of the various models –H-Age for different cohort for the combined datasets. Some measures we could have used, that are used by Thurig et al (2005), for example, are *accuracy, precision,* and *excess error,* calculated as follows.

Accuracy : ((Σ(**pred**icted-**obs**erved)/n)*100)/m. Where *m* is E(obs), and *n* is the number of observations.

Precision : SD(pred-obs)

Empirical Excess error measures could not be performed because there was no external validation data set (Thirig et al., 2005).

Bias : (Σ(pred-obs)/n)

RMSE : $\sqrt{(\Sigma(\text{pred-obs})^2/\text{n-p})}$. Where *p* is the number of parameters in the model.

Results

Fitted model parameters

Table K.1-B.3 shows the partial coefficients for each species and productivity class for the Chapman-Richards H-Age functions.

Table K.1-B3 Spruce cohort

HI range	YC*eq*				Precision	RMSE	Bias
		a_1	a_2	a_3			
>1.2	>24	1.02	5.59	2.04	1.8	4.69	0.32
1-1.2	24	1.05	7.05	2.32	1.42	4.23	-0.23
0.8-1	22	0.76	5.98	1.63	1.33	3.21	0.11
0.6-0.8	20	0.66	5.51	1.33	0.66	2.55	0.56
0.5-0.6	18	0.57	5.26	1.12	0.89	1.69	0.45
0.4-0.5	16	0.53	5.35	1.47	1.11	3.66	0.32
0.3-0.4	14	0.48	5.32	0.54	0.74	3.54	0.62
0.2-0.3	12	0.44	6.59	2.20	1.53	4.53	0.24
0.1-0.2	10	0.35	6.93	2.27	0.69	1.77	-0.43
<0.1	<10	0.28	8.02	0.35	1.9	4.23	-0.7

Annex K.2: CARBWARE stand modification functions

The NFI permanent plots structure is modified at each growth cycle iteration to simulate the losses associated with natural mortality and harvest. This section discusses the development of the CARBWARE modification functions from draft versions for submission to International, peer reviewed Scientific Journals.

K.2-A: Mortality models

Introduction

In the general context of forest growth models, and at the most basic level, the tree mortality module's role at each iteration is to classify a particular tree in the dataset as being either dead or alive. This paper approaches this problem in the context of an individual-tree model of mortality that is both age- and distance-independent. The specific modelling framework within which the mortality module will be applied, is a framework similar to the PrognAus framework, with the goal of estimating annual forest dynamics for Ireland.

Literature review

There are two areas of interest for the literature context of this paper: *tree-mortality* modelling, and *threshold-based* classification. (Note that this paper is not focussed on a survival analysis, as one might perhaps expect, because such models are time-dependent.)

1. *Mortality modelling* in Forest Succession.
Wunder et al. [2006a] compared the use of classical stress-thresholds in mortality modules of forest succession (\gap") models. They conclude that logistica1 regression-based models are superior to stress-threshold models with regard to predicting time of tree death.

Baesens et al. [2003] review threshold-based classifiers in the context of credit-scoring. They examine logistic regression, discriminant analysis, k-nearest neighbour, neural networks and decision trees, advanced kernel-based classification algorithms such as support vector machines and least-squares support vector machines (LS-SVM). They assess performance using the classification accuracy and the area under the receiver operating characteristic curve. They found that both the LS-SVM and neural network classifiers yield a very good performance, but also simple classifiers such as logistic regression and linear discriminant analysis perform very well for credit scoring.

Bigler and Bugmann [2004] introduced a new approach to modelling tree mortality based on different growth patterns of entire tree-ring series. They were interested in predicting time of tree death. In their study, dendrochronological data from *Picea abies* (Norway spruce) in the Swiss Alps were used to calibrate mortality models using logistic regression. They introduced a mortality threshold and classified a tree as dead if its modelled mortality probability curve plotted over time went above that threshold. They ignored autocorrelation at the modelling stage, and applied a jackknife method to correct for the resulting biased variance estimates. They found that the most reliable models were those that included relative growth rate and a short-term growth trend as explanatory variables.

Focussing on the role played by life-history strategies in determining tree mortality Wunder et al. [2008] investigated whether the relationship between growth and mortality divers among tree species and site conditions. This carries on from Monserud [1976] who showed that reduced growth generally accompanies a higher mortality risk. For each of nine species, they modelled mortality probablity as a function of relative basal area increment, tree size and site. They selected the species-specific model with the highest goodness-of-fit and calculated the area under the receiver operating characteristic curve and calibration measures. The discriminatory power as measured by AUC ranged from 0.62 to 0.87. They found that most growth-mortality relationships differed among species and sites, i.e. there is no universal growth-mortality relationship.

It has been noted that a lack of long-term growth/mortality data has made it difficult to evaluate the performance of mortality models. Wunder et al. [2006b] adopt a “virtual ecology" approach to this problem, simulating forests with either of two a priori specified growth-mortality relationships. They simulate different sampling regimes in these virtual forests, thereby generating virtual tree-ring data, forest inventory data, or a combination of both. They compare eight existing or newly developed models of different structural flexibility by their ability to model the growth-mortality relationship in the simulated data, and quantify the deviation from the *a priori* specified growth-mortality relationships with the Kullback-Leibler distance. Of the models they evaluated, the highest accuracies were obtained with tree-ring based models, which required only small (approx. 60) numbers of dead trees. For larger sample sizes (approx 500 dead trees) forest inventory based models were also seen to be accurate. They also showed that exible statistical approaches were superior to less flexible models only for large sample sizes (totally 2000 trees) and that the additional use of Bayesian statistics, model accuracies only when model flexibility was constrained. They also provided guidelines for sufficient sampling schemes in real forests.

In the PrognAus framework, Monserud and Sterba [1999] modelled mortality in Austrian forests for six major species based on 5-year re-measurements of the permanent plot network of the Austrian National Forest Inventory. Their general results, varying slightly between species, was that inverse of tree diameter, crown ratio and BAL were respectively the three most closely correlated factors in their model with 5-year mortality rates. They compared mortality rates across tree diameter class, thereby identifying a classic U-shape in mortality rates as diameter class increased. They modelled mortality rates rather than individual tree mortality probability, and validated the model with the chi-square statistic calculated between observed and estimated. Because the explanatory variables in their model were measured on the scale of the individual tree, they were able to calculate the classification success rate using the complement of the overall proportion
of mortality (i.e., approximately 93%, although it is not clear from the text) as the threshold. On this basis, their model correctly classified between 81 and 92%, of live trees, and between 25 and 44%, of dead trees. However, their treatment of the threshold is very brief, and may not be a typical interpretation, e.g. in their interpretation, a tree is classified as dead if the threshold exceeds the modelled probability. Also, they derive a total correct classification accuracy of 86%.

Materials and Methods

We fitted logistic regression models to the growth dataset. We investigated model performance in the case of separate models for each cohort. (Principal issue here was the lack of data for some cohorts). The response variable was a binary indicator of mortality (arbitrarily, 1 = tree dead at time of DBH measurement, 0 = tree alive). We only included trees whose cause of death was natural mortality, e.g. such causes as windblown, diseased, were excluded. Explanatory variables were as such that were selected by Monserud and Sterba [1999] {DBH and transformations thereof, CR, BAL, CCF}, but we also investigated relative growth indicators that Bigler and Bugmann [2004] noted as being useful correlates. Site and plot effects were modelled as random, and consecutive observations on the same tree were modelled as being correlated. Conditional on this correlation structure the fixed effects parameters were selected by backward selection starting with the candidate set of covariates just listed.

Models were fitted by maximum likelihood and individual fixed effects were identified as non-significant on the basis of asymptotic Wald-tests. This was done for each cohort separately. Performance of candidate models was then evaluated by cross-validation and external validation (comparing fitted to observed mortality in NFI dataset) and with threshold-based classification tools like the ROC and ROL curves and related measures and hypothesis tests. Cross-validation was done on a leave-k out basis, where the data \left-out" was selected at random. Up to twenty independent cross-validation runs were performed, and up to 33% of the data was left-out as cross-validation data for each run.

Other performance measures were consulted, and the ROC convex hull played a role in our chosen classifier. We used threshold-averaging to investigate the performance of the classifier in cross-validation and bootstrap scenarios. We derived confidence bands for the ROC curve of the chosen classifier following the approach of Macskassy et al. [2005]. (Note, the authors have also developed techniques for point interval estimation also, the reference appearing in that paper.)

Performance measures in ROC space and their role in uncertainty analysis

The AUC of the ROC curve is the estimated probability that the classifier will give a higher score to positive cases than negative cases. (In our application, the estimated probability of mortality is higher for dead trees than live trees.) We envisage that an uncertainty analysis of the forest growth model of which the mortality classifier is a component part could utilise this probability and its standard error in monte-carlo simulation assessments of overall uncertainty and sensitivity.

The AUC is equivalent to the Mann-Whitney U-statistic, and methods for comparing AUCs have been developed as a result, e.g. Heagerty et al. [2000]. The principal complicating factor here is the underlying correlation structure of the comparison, which can be influenced by details pertaining to the derivation of the classification forecasts, the setup of the calibration datasets, or whether the forecasts are clustered in some way, e.g. DeLong et al. [1988], Obuchowski [1997], Heagerty et al. [2000], Mason and Graham [2002].

The convex hull of a classifier, or group of classifiers, in ROC space, can be seen as the optimal attainable classification performance. Fawcett [2006] notes that candidate classifiers that do not attain the convex hull can be discarded, on the grounds that a better classifier in ROC space exists. He suggests a method for interpolating between candidate classifiers to better approach the limit of performance estimated by the convex hull based on mis-classification costs and the prior class distribution.

When comparing ROC curves, per se, a complicating factor when it is of interest to compare different classifiers crops up if the classifiers in question are of a different \class", e.g. a probabilistic classifier versus a discrete classifier, or, more generally, comparisons across model classes, whose scoring systems are incommensurate Fawcett [2006].

Datasets

Permanent Sample Plot

The mortality model is calibrated on data extracted from the permanent sample plot record system of Coillte Teoranta (the Irish Forestry Board state commercial forestry company). Broad and Lynch [2006b] provide details of the dataset in the context of modelling plot volume. The database consists of records of many silvicultural and thinning trials. These longitudinal trials were established from the 1950s onwards, and were initially established as replicated and blocked experimental designs Broad and Lynch [2006a].

Although there are several categories of disease or mortality causes in the PSP database {including, Windblown, Uprooted, Diseased, Broken and Dead}, we modelled only the binary response Dead/Alive for the initial model. In this way, after derived variables { basal area, plot density, etc. {were calculated, only data points that could be classified as Dead/Alive, were kept in the calibration dataset

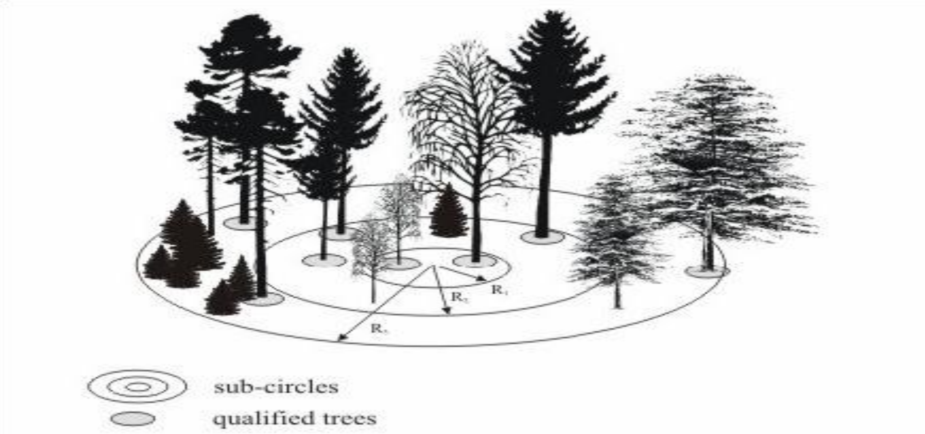
National Forest Inventory Plot data

We validated the ROC curve for the chosen model on the NFI data. In the NFI sample, the probability that a tree's status as dead or alive will be recorded { more generally, the probability that any feature of the tree is measured { is a function of its diameter class at the time of survey, and its distance from the centre of the plot. The expansion factor concept is a weight that varies between each tree in the dataset that estimates the prior probability of the tree's inclusion in the dataset. Figure K.2-A.1 shows that trees of three diameter classes are only recorded if they are observed within a certain distance from the plot centre. The expansion factor we use, and that used by the NFI, assumes a random distribution for tree diameter in the plot. Because of that assumption, the weight assigned to a tree in the ith diameter class is:

$$\frac{R_3^2}{R_i^2} \quad \text{.......(1)}$$

where Ri denotes the radius of the concentric circle associated with the ith diameter class.

In practice, the expansion factor, or weight, is used to estimate plot-level features, e.g. basal area. In such calculations, we estimate the number of trees of the ith diameter class that were not included in the sample by $\frac{R_3^2}{R_i^2}$ * ni, where ni is the number of trees of the ith class



	R_1	R_2	R_3
Sub-circle radius (m)	3	7	12,62
Sub-circle area (m^2)	28,3	153,9	500
Treshold diameter (mm)	70	120	200

Figure K.2-A.1. The NFI concentric-plot sampling schema

that are included in the sample. The expansion factor therefore defines the relationship between each included tree and the estimated number of trees of the same class that were not included (Equation 2).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

where n_{ij} _ EF_{ij} is the product of the expansion factor for the *j* th tree in the *I* th class, and $\check{N}_{ij}$ is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 2 is the representative tree number. With minor and obvious changes to the equation, we can calculate other tree-level estimates, including representative basal area, and individual-tree estimates can be aggregated for the entire plot to give plot-level estimates, including representative density.

The question to address in the current paper is whether we can arrive at a sensible definition of representative mortality. At issue is how to derive a binary individual-tree-level mortality rule based on information in the NFI dataset, given the fact that there is missing information due to the sampling scheme. With this in mind, Figure K.2-A.2 classifies all dead trees in the PSP database by cohort, and describes the empirical distribution of diameter classes conditional on mortality status. (We have included the diameter class (0,7] for completeness, even though there is no equivalent in the NFI dataset.) Note that the left-hand column is very similar to the unconditional distribution of diameter classes, so it does not need to be displayed. On those grounds, a comparison of the columns of Figure K.2-A.2 shows the dramatic extent to which the chance of mortality declines if a tree does not die while in the lowest diameter class. For example, the global fraction of trees in the Spruce cohort in the lowest diameter class is very small, but this class represents 50% of dead trees in the cohort. Similarly for Pine, OC and FGB.

The right-hand column of Figure K.2-A.2, at least for the cohorts with enough observations, suggests a way to make the operation of a binary mortality rule more accurate in the context of the NFI sampling scheme. The basic idea would be to use the column heights as weights in a finite mixture function whose components would be the outcome of the mortality rule. Rather than reducing the expansion factor by one unit when death is predicted (which, we can show, can lead to an unrealistically height global mortality rate), the actual reduction would be a function of the weight for the given diameter class. This method could be stochastic or deterministic. Other information might be used to inform the values of the weights, including a forester's rule of thumb about global mortality (i.e., _ 6%), or information from the NFI or a meta-analysis.

A similar approach would be to mix the outcome of the mortality rule with the diameter class mortality weights. It might be possible to iteratively tune the weights and/or the rule's cut-off parameter.

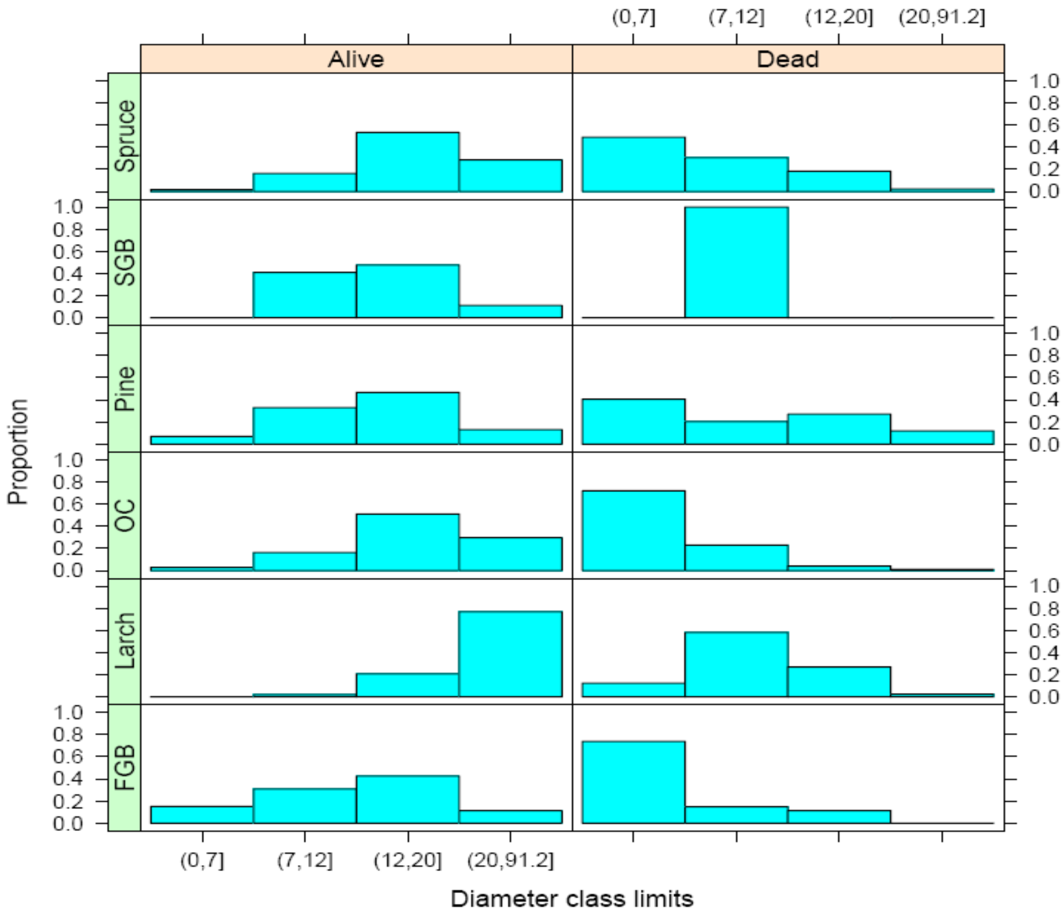


Figure K.2-A.2 The empirical distribution in the PSP dataset of diameter classes of dead/alive trees classified by cohorts

Results

*Candidate model Number 1*Candidate model 1 was a fixed effects model. A logistic GLM was fitted in Glimmix. The _fixed effects were DBH, BAL, and

$$\text{RelDiamInc}\left(\frac{growth(t-t-1)}{DBH(t)}\right)$$

Part of the reason for looking at this model was that it was not subject to additional uncertainty due to imputation of missing X data, as would have been the case with the model put forward by Monserud and Sterba [1999], which also conditioned mortality on CR, a variable that was not measured on every tree in our dataset.
There are several points of interest to the results of this model fitting:

1. The characteristics of the parameters.
2. The cross-validation exercise.

3. The out-of-sample/deployment performance. E.g. how well the model described NFI mortality.

Estimated parameters Candidate Model 1 (Used in CARBWARE models)

The fitted parameters and their standard errors are presented in Table K.2-A.1. We supply parameter estimates for cohort-wise fits and the fit to the entire dataset, with no cohort-effect parameter.

Table K.2-A.1. Candidate model 1 parameters

Fast-growing broadleaves cohort

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	-2.9295	0.1510	11784	-19.41	0.0001
DBH	-0.4307	0.02508	11784	-17.17	0.0001
BAL	0.06816	0.004384	11784	15.55	0.0001
RelDiamInc	-1.6783	1.2147	11784	-1.38	0.1671

Larch cohort

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	3.0526	0.1691	6544	18.06	0.0001
DBH	-0.4373	0.01276	6544	-34.27	0.0001
BAL	0.05688	0.003066	6544	18.56	0.0001
RelDiamInc	-14.7793	2.5794	6544	-5.73	0.0001

Other conifers

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	4.3636	0.1090	21239	40.02	0.0001
DBH	-0.8384	0.01447	21239	-57.95	0.0001
BAL	0.05970	0.002078	21239	28.72	0.0001
RelDiamInc	-29.2957	1.0322	21239	-28.38	0.0001

Pine cohort

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	2.3952	0.04531	187E3	52.86	0.0001
DBH	-0.8127	0.007225	187E3	-112.49	0.0001
BAL	0.08083	0.000999	187E3	80.91	0.0001
RelDiamInc	-23.0015	0.3995	187E3	-57.57	0.0001

Slow growing broadleaves

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	29.6029	7.1305	1027	4.15	0.0001
DBH	-2.1970	0.4873	1027	-4.51	0.0001
BAL	-0.1225	0.01754	1027	-6.98	0.0001
RelDiamInc	-2199.90	521.36	1027	-4.22	0.0001

Spruce cohort

Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	1.2286	0.02747	298E3	44.72	0.0001
DBH	-0.6640	0.003840	298E3	-172.93	0.0001
BAL	0.05051	0.000529	298E3	95.57	0.0001
RelDiamInc	-13.0524	0.2544	298E3	-51.30	0.0001

Candidate Model 2

The fixed effects in Candidate model 2 were those in Monserud and Sterba [1999], and diameter increment as a proportion of diameter (RelDiamInc).

Cross-validation and deployment performance

We performed plot-wise and case-wise leave k-out cross-validation of the chosen models. The case-wise deletion algorithm was very slow for the Pine and Spruce cohorts, in which case we opted to use only plot-wise deletion. The algorithm selected plots for deletion from the fitting dataset using a Bernoulli mechanism with parameter p, which we sometimes changed depending on the number of plots in the cohort dataset. Details are provided with each graphical representation of the results in Figures below. Twenty \leave-outs"were performed and the variability in these twenty runs is represented by the dotted curves.

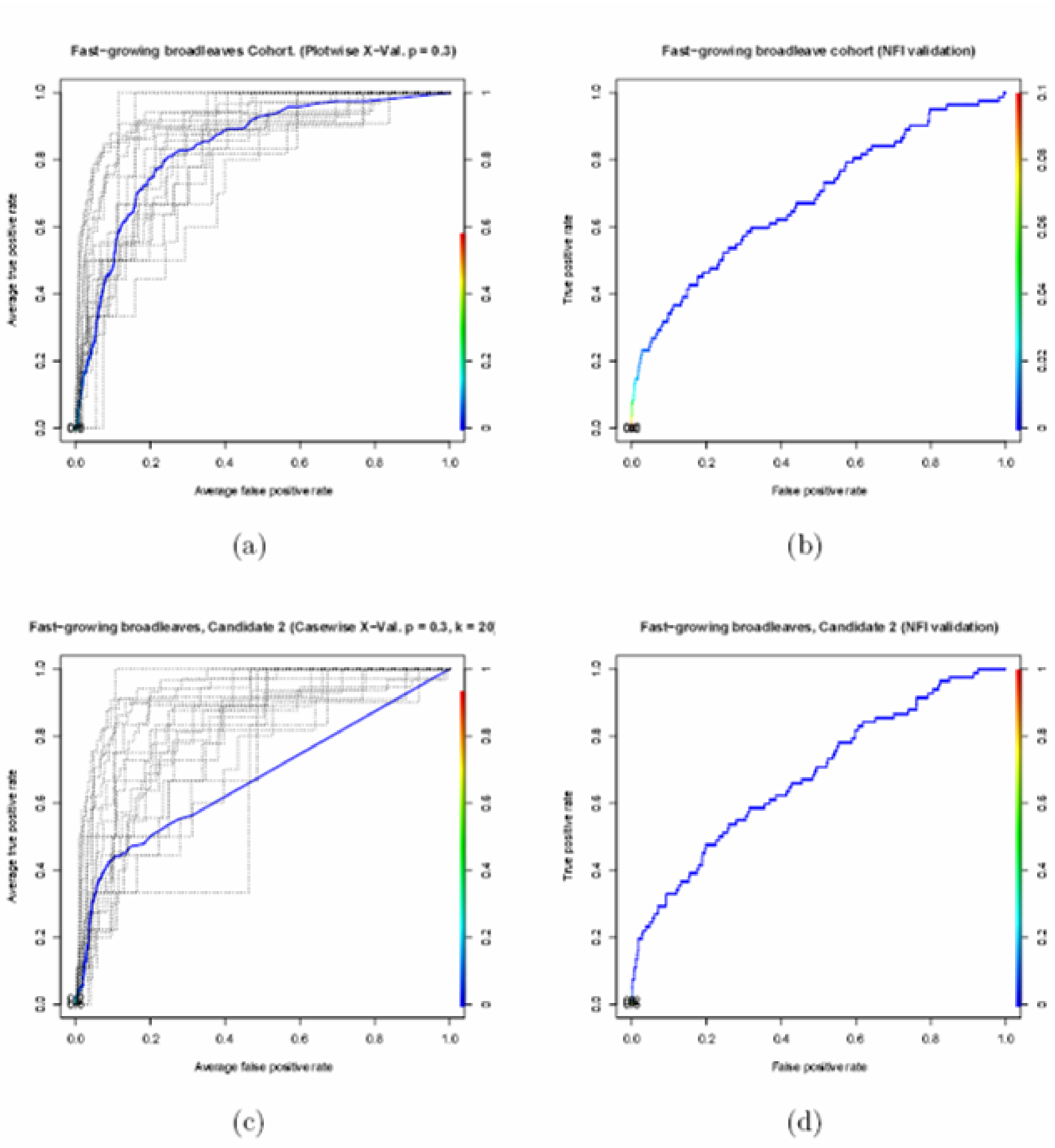


Figure K.2-A.3. The Receiver operating characteristic curve for Candidate model 1 (panels (a),(b)) and model 2 (panel (c),(d)) in the Fast-growing broadleaves cohort

20-fold cross-validation plotwise with average leave-out probability p = 0.3. Curves for each cross-validation run and a threshold-averaged curve are shown.

We estimated the ROC curve for each cohort model's out-of-sample performance by comparing model predictions with the actual NFI mortality data (Figures K.2-A.3). The cross-validation and deployment performance plots are presented pair-wise in the Figures below. In all cased model candidate outperformed candidate based on false positives and fit. For example we show the results for Fast growing cohorts in Figure K.2-A.3. Note that Slow-growing broadleaves cohort did not have enough data for the cross-validation to be feasible, the ROC curve for that cohort depicts in-sample performance.

Models fitted to NFI data

When fitting models to the NFI data we used backward elimination, starting with the parameters in the Monserud and Sterba [1999] model. Relative diameter was not used, because the dataset is cross-sectional. In Figure K.2-A.4 we present an example of the out-of-sample performance (i.e. their performance in predicting NFI data) of the two PSP-calibrated models, and the in-sample performance of the NFI-calibrated model.

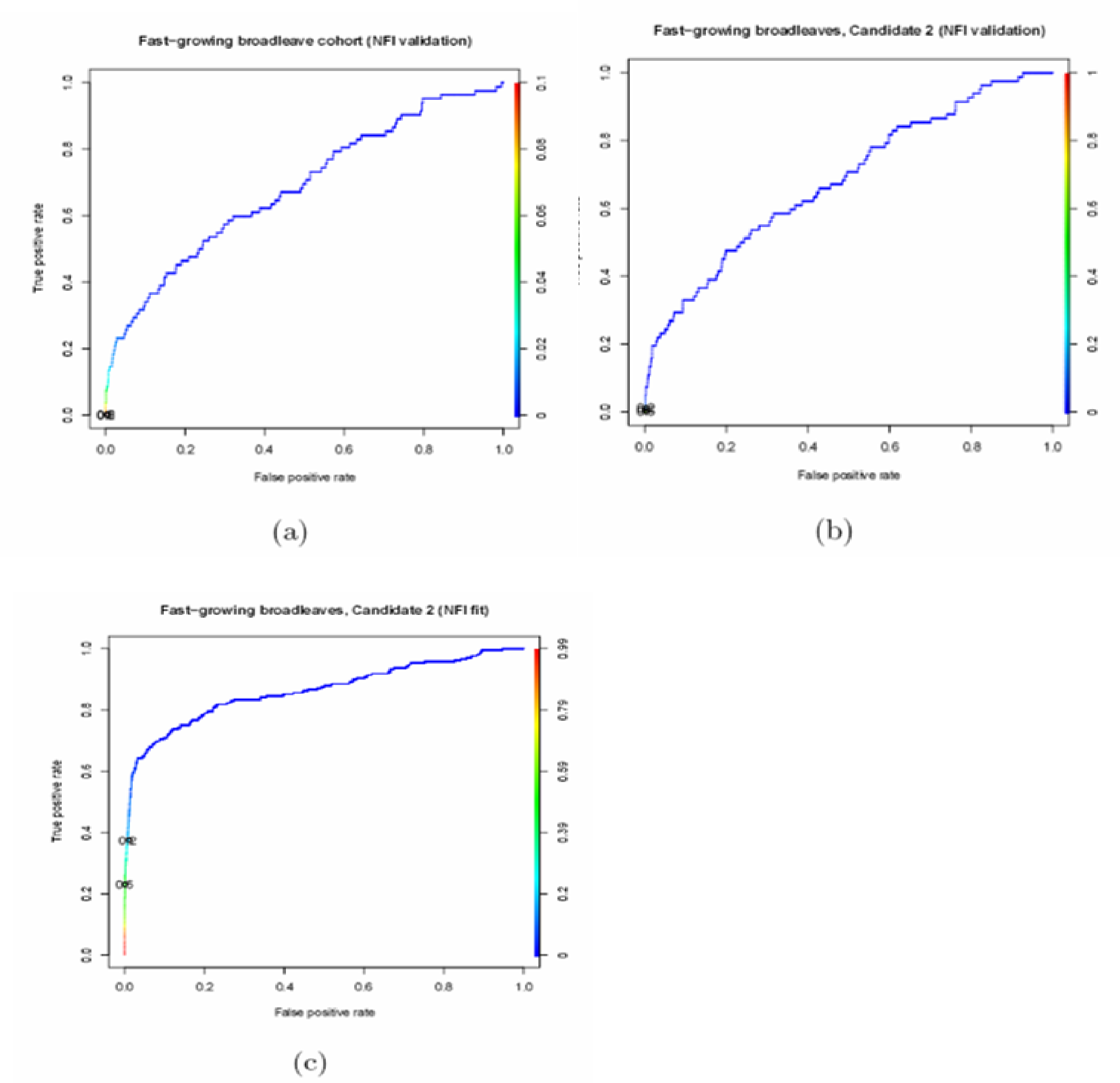


Figure K.2-A.4. The Receiver operating characteristic curve for Fast-growing broadleaves cohort Candidate models 1 and 2 fitted on PSP, and for the NFI-fitted model.

The selected CARBWARE models based on NFI data fits

Fast-growing broadleaves cohort

$$Pmort = IL(12.93 + 0.068 \times BAL - 2.868 \times CR - 0.962 \times DBH - 72.28 \times \frac{1}{DBH} + 0.009 \times DBH^2$$

Larch cohort

$$Pmort = IL(-4.9266 + 0.04273 \times DBH)$$

Other conifers

$$Pmort = IL(-4.5226 + 0.067\times BAL - 6.05\times CR + 0.066\times DBH)$$ **Pine cohort**

$$Pmort = IL(2.395 + 0.0408\times BAL - 3.0036\times CR - 0.2263\times DBH - 24.21\times \frac{1}{DBH})$$

Slow growing broadleaves

$$Pmort = IL(15.78 + 0.0109\times BAL - 2.2807\times CR - 0.771\times DBH - 94.002\times \frac{1}{DBH} + 0.00449\times DBH^2$$

Spruce cohort

$$Pmort = IL(6.8976 + 0.0912\times BAL - 21.3795\times CR - 0.8287\times DBH - 49.15\times \frac{1}{DBH} + 0.008\times DBH^2$$

Where ($0 < Pmort < 1$) is the probability the tree is dead. We map then this estimated probabiilty onto the binary (Dead, Alive) outcome using a cutoff, which may differ between cohorts. More details on this is give elsewhere. IL(.) is the inverse logit, e.g. IL(x) = exp(x)/(1+exp(x)).

Choosing the operational cut-off

To identify a cut-off level to use for the mortality probability estimate, we plotted the True positive rate (TPR) and (FPR) on the same axis versus the cut-off (e.g. Figure K.2-A.5). In forest mortality, the number of positive cases (dead trees) is usually greatly outnumbered by the number of negative cases. This suggests that, all mis-classification costs being equal, the cut-off should be chosen with a view to keeping as small as feasible the rate of false positives predicted by the resulting rule, even though the rate of true positives is reduced as an unavoidable consequence. When combining individual cohort results to make an aggregate prediction the issue of false positive rate is of particular importance for large cohorts, because they have a greater weight in the aggregate estimate. In Figure K.2-A.5 we represent an FPR of not greater than 0.001 with a blue vertical line, and an FPR of not greater than 0.01 with a green vertical line, to illustrate the trade-off involved in each particular case.

Table K.2-A.2 Formulae for some standard performance measures used in the text

Performance Measure	Formula
Accuracy	$\frac{TP+TN}{TP+FP+TN+FN}$
Rate of positive predictions	$\frac{TP+FP}{TP+FP+TN+FN}$
Correlation Coefficient	$\frac{(TP.TN)-(FP.FN)}{\sqrt{(TP+FN).(TN+FP).(TP+FP).(TN+FN)}}$

Note TP, TN, FP, and FN are the numbers of true positives, true negatives, false positives and false negatives, which are tallied by comparing the predictions with the data.

Figures K.2-A.6 illustrate some other considerations for choosing cut-off points, accuracy, rate of positive predictions and a correlation coefficient are plotted for a range of cut-offs (cf. Table K.1-B.2 for definitions of terms).

The graphs illustrate why the accuracy measure should not be used in isolation when choosing a cut-off. For example, in Figure K.2-A.6 a high accuracy is obtained despite the correlation coefficient indicating that the correlation between correct predictions and the data is worse than random, i.e. a negative correlation coefficient. Some performance measure formulae are given in Table K.2-A.2. These measures and others are described in Sing et al. [2005].

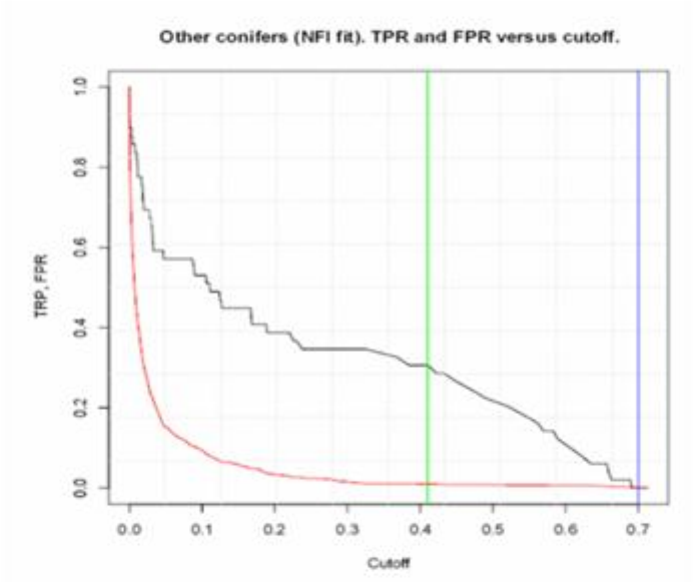


Figure K.2-A.5 TPR (Black) and FPR (Red) versus cut-off for Fast-growing broadleaves

The vertical green line shows the cut-of where FPR < 0.01, the blue vertical line shows the cut-off where FPR< 0.001

Discussion

In binary classification, a common approach is to visualise the parameterised curve described by plotting two performance measures as a parametric curve parameterised by the threshold value. Comparing models based on classification and mis-classification rate (precision, recall, etc.) make more sense when there is some hierarchy of misclassification errors. That is, that we can quantify the relative importance of gains from correct classification and losses from incorrect classification. Such a loss function is particularly useful when the number of objects to be classified is not equal, because then the trade-off curves are much more likely to be nonlinear and the concept of trade-off between competing performance measures is not easy to understand. The problem is how to specify losses/gains, in other words, how to quantify Trade-off, how to measure gains and losses in the same units so a net trade-off can be calculated. Otherwise, it is not always clear, even for commonly presented parameterised curves, in what sense the trade-off is occurring, particularly when a “good" classifier, e.g. one that exhibits desirable tendencies in threshold-space, can *a priori* exhibit a number of different “shapes" when presented as a “trade-off" curve.

For example, the class ROC trade-off curve has *a priori* a sense in which a classifier is good or bad. This is when the majority of the ROC curve lies below the line of equality. However, the precision-recall curve is not so easily understood. We know that the best classifier from a group is the one with the largest area between the curve and the line of equality. However, because the value of the precision at zero threshold is a function of the number of objects in each class to be classified, it is possible to have a “good" classifier for which that area is zero. However, such a classifier is probably not statistically better than the naive, 50:50 classifier. We propose that for a classifier to be demonstrably better than the naive classifier, it should at the minimum describe a positive region between the curve and the line of equality. We conclude that the precision-recall curve does not describe a trade-off, and that in fact, a trade-off should have a point of equilibrium and the gains and losses should be incurred when the threshold moves from that point in either direction. In other words, the gains and losses as quantified by the two performance measures should be negatively correlated, for the parameterised graph to truly describe a trade-off. The precision-recall performance measures, for example, are positively correlated (both have TP in the numerator), and so their parameterised curve representation does not describe a true trade-off situation in every region of threshold space. If we overlay the two graphs with precision and recall on the y and y' axes, and threshold on the x axis, we can see more clearly where a true trade-off may occur. It is likely that should a true trade-off occur, that the region between the parameterised curve and the line of equality will have to be positive. As external corroboration, DeLong et al. [1988] note that the cost or loss function is essential to deciding the optimal cutpoint/threshold for a ROC curve. In summary, there are therefore two issues: comparing classifiers and, given a classifier, choosing a cut-off point.

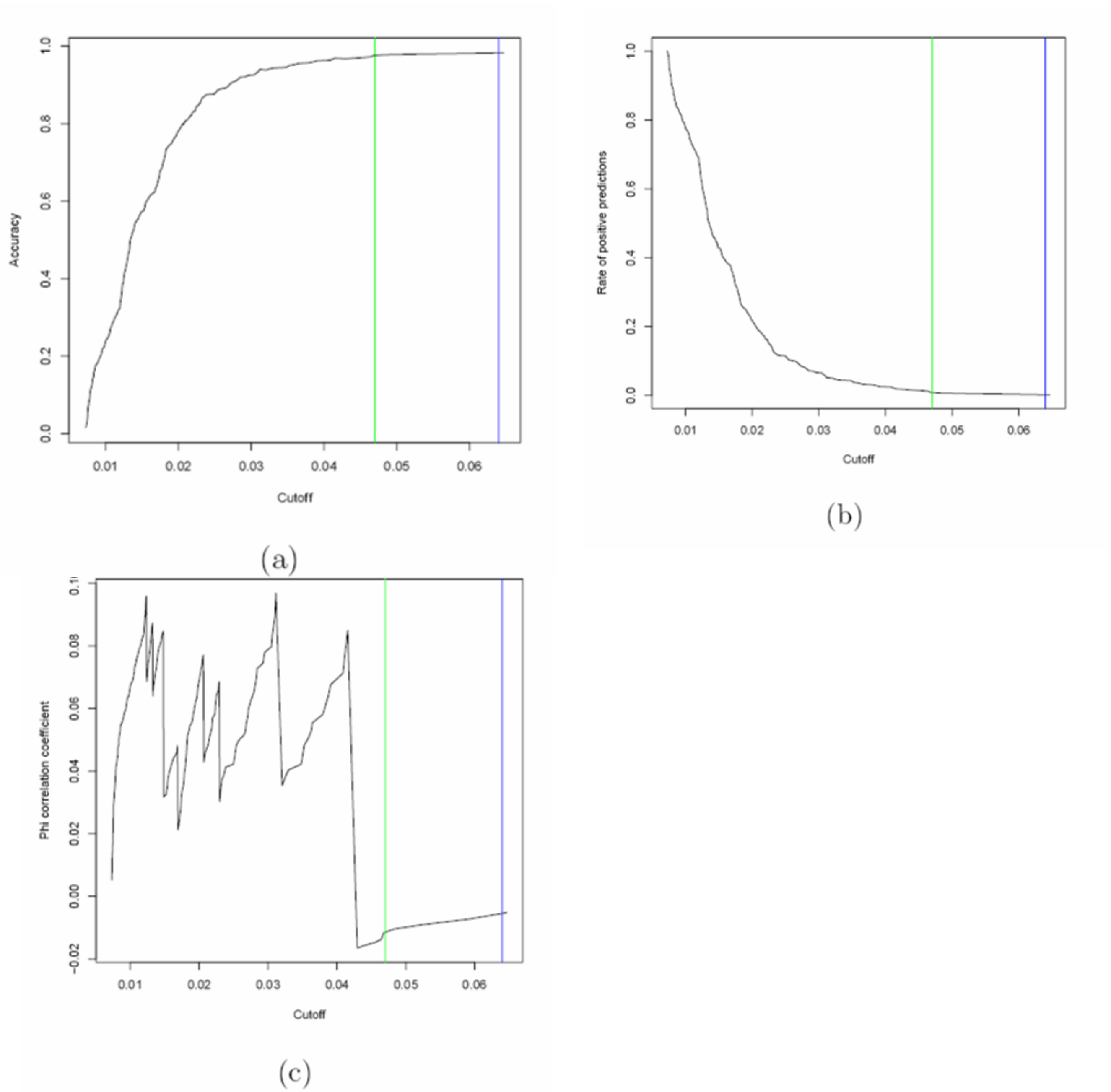


Figure K.2-A.6 Illustrating some other performance measures of the NFI-calibrated model for the Larch cohort across the cut-off range and in particular the 0.01 (green vertical) and 0.001(blue vertical) cut-off points

This latter can only be done in conjunction with some kind of loss function describing costs of the different types of classification error. The kind of classifier we are using, based on multiple correlation/regression, and therefore wholly empirical, is easier to select than other types of classifier. We can use model selection criteria based on correlation/regression, or minimization of errors, or some other abstract modelling concepts. Then, the classifier selected, we can choose the cut-off. In what we call mechanistic classifiers, such as described in Martin-Davila et al. [2005], where the classifier is predicated first and foremost on an understood pathway, not naive correlation, the threshold has a physical dimension, and the choice of cut-off has a defined purpose in a physical system. Note that a logistic regression with a single explanatory variable can be made to fit such a schema. In fact, it might be possible to define a convex hull of the multiple explanatory variables to take the place of single-variable classifier in that schema. Also, some variables might be better at defining the threshold than others and this can also be examined. A convex hull defined by cut-off points in each explanatory variable might be envisaged to play the role of a kind of “syncretized" cut-off point. In such an instance, it would be relevant to assess the cross-correlations among the explanatory variables.

Conclusions

We set out to determine a logistic regression model of mortality that could be used to describe mortality in the NFI data. This was the ultimate goal of the model. We investigated the possibility of calibrating this model on the permanent sample plot longitudinal data but found that we could improve the result be simply calibrating the parameters on the NFI data alone. In the absence of a mis-classification cost function we chose the cut-off for transforming predictions on the logit scale to the binary (dead, alive) scale based on the false positive rate (the rate at which the model predicted mortality incorrectly). Specifically, we chose the cut-off to keep this as small as reasonably possible.

K.2-B: Other modifications in the growth simulator

Thinning/Harvest

We assume that all thinning occur randomly. Random thinning can be implemented on an individual plot level. The CARBWARE user sets a basal area (BA) to be removes as stipulated in the harvest activity data (in the ‘**Eventstable**’) so thinning of trees are selected at random from the plot until this target BA is achieved. The thinned or harvested trees in a given plot are removed from the growth database and populated in a modifier table within the CarwKP_08 database. These data are then called up in the allocation module (Annex H2 and NIR section 11.2.3).

Although it is common practice that clear felled stands are replanted within 2 years, the CARBWARE model does no re-populate clear felled plots due to uncertainty of re-establishment success and species choice. This is a conservative approach and is consistent with the rules applied, which differentiate between deforestation and clear fell with re-establishment (NIR section 11.4.2)

Annex L

Standard Electronic Format (SEF) 2013

UNFCCC SEF application

Version 1.2

Workflow

Unlock file

Completeness Check

Consistency Check

Lock file

Functions

Mandatory data

Import XML

Reset SEF

Export XML

Export XML (Imported)

Settings

Party:	Ireland
ISO:	IE
Submission year:	2014
Reported year:	2013
Commitment period:	1
Completeness check:	YES
Consistency check:	YES
File locked:	YES
Lock timestamp:	10/01/2014 16:13
Submission version number:	1
Submission type:	Official

Party	Ireland
Submission year	2014
Reported year	2013
Commitment period	1

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	227556711	NO	NO	NO	NO	NO
Entity holding accounts	1810375	576178	NO	5471684	503489	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	735	NO	NO	2059	NO	NO
Retirement account	66719736	1238883	NO	2780994	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	296087557	1815061	NO	8254737	503489	NO

Commitment period 1

Table 2 (a). Annual internal transactions

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Article 6 issuance and conversion												
Party-verified projects		NO					NO		NO			
Independently verifed projects		NO					NO		NO			
Article 3.3 and 3.4 issuance or cancellation												
3.3 Afforestation and reforestation			NO				NO	NO	NO	NO		
3.3 Deforestation			NO				NO	NO	NO	NO		
3.4 Forest management			NO				NO	NO	NO	NO		
3.4 Cropland management			NO				NO	NO	NO	NO		
3.4 Grazing land management			NO				NO	NO	NO	NO		
3.4 Revegetation			NO				NO	NO	NO	NO		
Article 12 afforestation and reforestation												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired lCERs							NO	NO	NO	NO		
Replacement for reversal of storage							NO	NO	NO	NO		NO
Replacement for non-submission of certification report							NO	NO	NO	NO		NO
Other cancellation							NO	NO	NO	NO	NO	NO
Sub-total		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	NO	NO	NO	NO	NO	NO

Party	Ireland
Submission year	2014
Reported year	2013
Commitment period	1

Add registry | Delete registry | No external transactions

Table 2 (b). Annual external transactions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Transfers and acquisitions												
GB	NO	NO	NO	110352	NO	NO	NO	NO	NO	NO	NO	NO
EU	NO	1635668	NO	942579	NO	NO	3854805	554972	NO	561807	NO	NO
CH	NO	NO	NO	256927	NO	NO	NO	NO	NO	38771	NO	NO
CDM	NO	NO	NO	NO	547940	NO	NO	NO	NO	NO	NO	NO
NL	NO	13359	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
RU	NO	44169	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	NO	1693196	NO	1309858	547940	NO	3854805	554972	NO	600578	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	NO	1693196	NO	1309858	547940	NO	3854805	554972	NO	600578	NO	NO

Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Temporary CERs (tCERS)								
Expired in retirement and replacement accounts	NO							
Replacement of expired tCERs			NO	NO	NO	NO	NO	
Expired in holding accounts	NO							
Cancellation of tCERs expired in holding accounts	NO							
Long-term CERs (lCERs)								
Expired in retirement and replacement accounts		NO						
Replacement of expired lCERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of lCERs expired in holding accounts		NO						
Subject to replacement for reversal of storage		NO						
Replacement for reversal of storage			NO	NO	NO	NO		NO
Subject to replacement for non-submission of certification report		NO						
Replacement for non-submission of certification report			NO	NO	NO	NO		NO
Total			NO	NO	NO	NO	NO	NO

Party	Ireland
Submission year	2014
Reported year	2013
Commitment period	1

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

Account type	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Party holding accounts	223701906	1635668	NO	903808	NO	NO
Entity holding accounts	1810375	78734	NO	5277156	1051429	NO
Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
Non-compliance cancellation accounts	NO	NO	NO	NO		
Other cancellation accounts	735	NO	NO	2059	NO	NO
Retirement account	66719736	1238883	NO	2780994	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
lCER replacement account for expiry	NO	NO	NO	NO		
lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
Total	292232752	2953285	NO	8964017	1051429	NO

Party	Ireland
Submission year	2014
Reported year	2013
Commitment period	1

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Issuance pursuant to Article 3.7 and 3.8	314184272											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	314184272	NO		NO			NO	NO	NO	NO		
Annual transactions												
Year 0 (2007)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 1 (2008)	2029090	NO	NO	3778980	NO	NO	1245569	NO	NO	108000	NO	NO
Year 2 (2009)	3237702	NO	NO	9285054	NO	NO	3269878	NO	NO	5762220	NO	NO
Year 3 (2010)	5439324	722440	NO	9241948	NO	NO	9339288	NO	NO	9111174	NO	NO
Year 4 (2011)	5560581	237295	NO	13946988	NO	NO	18004498	435000	NO	10465530	NO	NO
Year 5 (2012)	2175913	1290326	NO	6237051	503489	NO	4680827	NO	NO	8790419	NO	NO
Year 6 (2013)	NO	1693196	NO	1309858	547940	NO	3854805	554972	NO	600578	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sub-total	18442610	3943257	NO	43799879	1051429	NO	40394865	989972	NO	34837921	NO	NO
Total	332626882	3943257	NO	43799879	1051429	NO	40394865	989972	NO	34837921	NO	NO

Table 5 (b). Summary information on replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Previous CPs			NO	NO	NO	NO	NO	NO
Year 1 (2008)		NO	NO	NO	NO	NO	NO	NO
Year 2 (2009)		NO	NO	NO	NO	NO	NO	NO
Year 3 (2010)		NO	NO	NO	NO	NO	NO	NO
Year 4 (2011)		NO	NO	NO	NO	NO	NO	NO
Year 5 (2012)	NO	NO	NO	NO	NO	NO	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO	NO	NO
Total	NO	NO	NO	NO	NO	NO	NO	NO

Table 5 (c). Summary information on retirement

	Retirement					
	Unit type					
Year	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Year 1 (2008)	NO	NO	NO	NO	NO	NO
Year 2 (2009)	19668515	NO	NO	713192	NO	NO
Year 3 (2010)	16991714	NO	NO	223643	NO	NO
Year 4 (2011)	16230638	394883	NO	730497	NO	NO
Year 5 (2012)	13828869	844000	NO	1113662	NO	NO
Year 6 (2013)	NO	NO	NO	NO	NO	NO
Year 7 (2014)	NO	NO	NO	NO	NO	NO
Year 8 (2015)	NO	NO	NO	NO	NO	NO
Total	66719736	1238883	NO	2780994	NO	NO

Party	Ireland
Submission year	2014
Reported year	2013
Commitment period	1

Add transaction | Delete transaction | No corrective transaction

Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Add transaction | Delete transaction | No corrective transaction

Table 6 (b). Memo item: Corrective transactions relating to replacement

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Add transaction | Delete transaction | No corrective transaction

Table 6 (c). Memo item: Corrective transactions relating to retirement

	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Appendix 1
Standard Independent Assessment Report
(Electronic Appendix)