



## **IRELAND**

# **NATIONAL INVENTORY REPORT 2013**

### **GREENHOUSE GAS EMISSIONS 1990 - 2011 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 NIR for 2013 and refers to the inventory time-series for the years 1990-2011.

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 2013 is also its submission under the Kyoto Protocol, with 2011 being the fourth 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 2013 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in 1990 and the contribution from fluorinated gases in 1995. The baseline value was established at 55.607 Mt CO<sub>2</sub>eq and results in total allowable emissions of 314.184272 Mt CO<sub>2</sub>eq in the commitment period, which equates to the average of 62.837 Mt CO<sub>2</sub>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<sub>2</sub>eq at the end of the five-year period.

## ES.2 Emissions Trends and Key Categories

In 2011, total emissions of greenhouse gases (excluding the *LULUCF* sector) in Ireland were 57,512.48 Gigagrams (Gg) CO<sub>2</sub> equivalent, which is 4.1 per cent higher than emissions in 1990. The total for 2011 is 18.0 per cent lower than the peak of 70,170.49 Gg CO<sub>2</sub> equivalent in 2001 when emissions reached a maximum following a period of unprecedented economic growth. The *Energy* sector accounted for 64.2 per cent of total emissions in 2011, *Agriculture* contributed 30.8 per cent while a further 3.1 per cent emanated from *Industrial Processes*, 1.8 per cent was due to *Waste* and 0.1 per cent was due to *Solvents*. Emissions of CO<sub>2</sub> accounted for 65.5 per cent of the national total in 2011, with CH<sub>4</sub> and N<sub>2</sub>O contributing 20.2 per cent and 13.2 per cent, respectively. The combined emissions of HFC, PFC and SF<sub>6</sub> accounted for 1.0 per cent of total emissions in 2011.

Tier 1 level assessment of emission source categories (ranking on the basis of their contribution to total emissions) identified 24 key categories in 2011 (excluding the *LULUCF* sector). There were 13 key categories of CO<sub>2</sub>, accounting for 63.4 per cent of total emissions. There were seven key categories of CH<sub>4</sub>, three key categories of N<sub>2</sub>O and 1 key category of HFC in level assessment, which accounted for 19.4 per cent, 11.6 per cent and 1.0 per cent of total emissions, respectively. The results of the Tier 1 key category analysis clearly show the impact of CO<sub>2</sub> emissions from energy consumption on total emissions in Ireland. These combustion sources of CO<sub>2</sub> emissions accounted for 12 out of 24 key categories identified by level assessment in 2011 and for two-thirds (61.7) per cent of total emissions. The top ten key categories contributed 73.6 per cent of total emissions in 2011 with emissions of CO<sub>2</sub> from the combustion of liquid fuels (petrol and diesel) by road traffic being the single largest source, accounting for 18.6 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 7.09 per cent in the 2011 inventory (excluding the *LULUCF* sector) and a trend uncertainty of 2.3 per cent for the period 1990 to 2011. These values are determined largely by the low uncertainty in the estimates of CO<sub>2</sub> 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 65.5 per cent of emissions contributed by CO<sub>2</sub> are estimated to have an uncertainty of 1.16 per cent. Emissions of N<sub>2</sub>O from the agriculture sector account for over 95 per cent of the level uncertainty in the 2011 inventory. The impact of HFC, PFC and SF<sub>6</sub> on inventory uncertainty in the year 2011 is negligible (0.2 per cent) because they account for only 1 per cent of total emissions.

Ireland has reported net greenhouse gas removals amounting to 13,691.08 Gg CO<sub>2</sub> eq. for 2008 to 2011 under Article 3.3 of the Kyoto Protocol in respect of 279.63 kha of lands subject to afforestation since 1990 while there were net emissions of 110.41 Gg CO<sub>2</sub> for a

deforested area of 8.24 kha for the same 4 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 2011. 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 2013 submission and the latest inventories for the years 1990-2011 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 2011. The largest increase took place in transport with an increase of 126.8 per cent on 1990 levels, while there were increases of 17.8 per cent and 14.8 per cent in the emissions from electricity production and the industrial sectors, respectively. The emissions from agriculture, the other main source category, increased during the 1990s but have decreased to 8.8 per cent below 1990 levels in 2011. As the emissions from energy increased, the contribution of agriculture to total national emissions decreased from 35.6 per cent in 1990 to 30.8 per cent in 2011. 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<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO) and volatile organic compounds (VOC). Emissions of SO<sub>2</sub> contribute to the formation of aerosols, which may offset the effects of greenhouse gases, while CO, NO<sub>x</sub> and VOC are precursors of ozone, another naturally occurring greenhouse gas. This NIR does not describe the methods used to estimate emissions of SO<sub>2</sub>, NO<sub>x</sub>, CO and VOC but the annual emissions estimates over the period 1990-2011 are included in the submission.

The emissions of most of the indirect gases have decreased substantially in the period 1990-2011 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 2011 in Ireland are of the order of 85.8 per cent in the case of SO<sub>2</sub>, 66.9 per cent for CO and 51.9 per cent for NMVOC and 37.6 per cent for NO<sub>x</sub>.



# **PART I**

## **ANNUAL INVENTORY SUBMISSION 2013**

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# Chapter One

## Introduction

### 1.1 Background and Context

This report constitutes Ireland's National Inventory Report (NIR), for the years 1990-2011, as required under the United Nations Framework Convention on Climate Change. Ireland's submission under the UNFCCC in 2013 is also its submission under the Kyoto Protocol, with 2011 being the fourth 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 2013 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in 1990 and the contribution from fluorinated gases in 1995. The baseline value was established at 55.607 Mt CO<sub>2</sub>eq and results in total allowable emissions of 314.184272 Mt CO<sub>2</sub>eq in the commitment period, which equates to the average of 62.837 Mt CO<sub>2</sub>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<sub>2</sub>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<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), the most widely known and most ubiquitous of the anthropogenic greenhouse gases, along with 13 hydrofluorocarbons (HFC), seven perfluorocarbons (PFC) and sulphur hexafluoride (SF<sub>6</sub>). 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are important because they are normally emitted in large amounts, HFC, PFC and SF<sub>6</sub> 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<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO) and volatile organic compounds (VOC). Emissions of SO<sub>2</sub> contribute to the formation of aerosols, which may offset the effects of greenhouse gases, while CO, NO<sub>x</sub> 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<sub>2</sub>, NO<sub>x</sub>, 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.

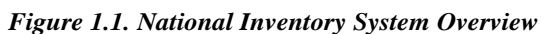
*Table 1.1. Key Data Providers and Information covered by MOU*

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	<b>Table 1.1-1.4</b> 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)	<b>Table 2.1</b> 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 Gais	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 <sub>2</sub> estimates and related fuel and production data for installations covered by the EU ETS <sup>1</sup>	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

<sup>1</sup>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



### 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O. 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<sub>2</sub> 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<sub>2</sub> emissions of 15,770 Gg in 2011, accounting for 27.4 per cent of total greenhouse gas emissions (57,512.48 Gg CO<sub>2</sub> 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<sub>2</sub> 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 1990-2011. 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<sub>2</sub>)

Tier 2 or Tier 3 methods are used for the majority of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> in other LULUCF categories and for relevant CH<sub>4</sub> and N<sub>2</sub>O emissions in this sector are invariably Tier 1.

### Methane (CH<sub>4</sub>)

Ireland's national circumstances are well captured in the Tier 2 methods applied for the major sources of CH<sub>4</sub> in the inventory, which are enteric fermentation and manure management associated with cattle and the CH<sub>4</sub> emissions from solid waste disposal sites.

Tier 2 and Tier 3 methods are used for CH<sub>4</sub> 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<sub>4</sub> emissions.

### Nitrous oxide (N<sub>2</sub>O)

Ireland relies on the simplified IPCC Tier 1 methodologies and default emission factors to estimate all N<sub>2</sub>O emissions in agriculture, which is the main source of N<sub>2</sub>O in the inventory.

Tier 2 and Tier 3 methods are used for N<sub>2</sub>O 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<sub>2</sub>O 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 2011 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 2014 submission.

### 1.5.1 Key Categories at IPCC Level 2

As inventories of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O were developed in Ireland during the 1990s, it was quickly established that CO<sub>2</sub> 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<sub>4</sub> emissions produced by large cattle herds and the N<sub>2</sub>O 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<sub>2</sub>. 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<sub>2</sub> emissions from fuel combustion and CH<sub>4</sub> and N<sub>2</sub>O 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 2011 are shown in Table 1.2 and Table 1.3, respectively. It can be seen that there are six highly significant key categories of emissions in Ireland in the 1990-2011 trend.

They are the CO<sub>2</sub> combustion sources in *1.A.1 Energy Industries*, *1.A.3 Transport*, *1.A.4 Other Sectors* and *1.A.2 Manufacturing Industries and Construction*, along with the CH<sub>4</sub> emissions from category *4.A Enteric Fermentation* and N<sub>2</sub>O emissions from *4.D Agricultural Soils*. These six categories accounted for 85.1 per cent and 89.5 per cent of total emissions in 1990 and 2011, respectively. In the case of 2011 emissions, three additional Level 2 source categories are needed to reach the cumulative 95 per cent threshold that defines a key category: *4.B Manure Management* with CH<sub>4</sub> emissions, *2.A.1 Cement Production* with CO<sub>2</sub> emissions and *6.A Solid Waste Disposal on land* with CH<sub>4</sub> emissions. The increase in the contribution of CO<sub>2</sub> emissions from category *1.A.3 Transport* from 9.1 per cent in 1990 to 19.4 per cent in 2011 is notable, along with the corresponding reductions in the contributions from the two categories (*4.A* and *4.D*) in *Agriculture*. 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, CO<sub>2</sub> emissions in *2.A.1 Cement production* and *5.A Forest land* become a key category in 1990, and CO<sub>2</sub> emissions in *5.A Forest land* become a key category in 2011.

**Table 1.2. Key Categories at IPCC Level 2 in 1990**

IPCC Level 2 Source Category	GHG	Emissions in 1990 (Gg CO <sub>2</sub> eq)	1990 Level Assessment (%)	Cumulative Total of Level (%)
1.A.1. Energy Industries	CO <sub>2</sub>	11,158.61	20.20	20.20
1.A.4 Other Sectors(Comm/Resid/Agric)	CO <sub>2</sub>	10,031.09	18.16	38.35
4.A Enteric Fermentation	CH <sub>4</sub>	9,574.12	17.33	55.68
4.D. Agricultural Soils	N <sub>2</sub> O	7,271.12	13.16	68.85
1.A.3 Transport	CO <sub>2</sub>	5,021.69	9.09	77.93
1.A.2. Manufacturing Industries and Construction	CO <sub>2</sub>	3,942.64	7.14	85.07
4.B Manure Management	CH <sub>4</sub>	2,353.63	4.26	89.33
6.A Solid Waste Disposal on land	CH <sub>4</sub>	1,173.05	2.12	91.45
2.B.2 Nitric Acid Production *	N <sub>2</sub> O	1,035.40	1.87	93.33
2.B.1 Ammonia Production *	CO <sub>2</sub>	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 2011**

IPCC Level 2 Source Category	GHG	Emissions in 2011 (Gg CO <sub>2</sub> eq)	2011 Level Assessment (%)	Cumulative Total of Level (%)
1.A.1. Energy Industries	CO <sub>2</sub>	11,798.29	20.51	20.51
1.A.3 Transport	CO <sub>2</sub>	11,162.29	19.41	39.92
1.A.4 Other Sectors(Comm/Resid/Agric)	CO <sub>2</sub>	9,235.41	16.06	55.98
4.A Enteric Fermentation	CH <sub>4</sub>	8,438.93	14.67	70.65
4.D. Agricultural Soils	N <sub>2</sub> O	6,682.19	11.62	82.27
1.A.2. Manufacturing Industries and Construction	CO <sub>2</sub>	4,175.23	7.26	89.53
4.B Manure Management	CH <sub>4</sub>	2,132.51	3.71	93.24
2.A.1 Cement Production	CO <sub>2</sub>	966.27	1.68	94.92
6.A Solid Waste Disposal on land	CH <sub>4</sub>	830.85	1.44	96.37

*Table 1.4. Summary of Methods*

IPCC SOURCE AND SINK CATEGORIES	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC	PFC	SF <sub>6</sub>
<b>1. Energy</b>						
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
<b>2. Industrial Processes</b>						
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 <sub>6</sub>	NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF <sub>6</sub>	NA	NA	NA	T1, T2, T3	T1a	T1, T1a
G. Other	NA	NA	NA	NA	NA	NA
<b>3. Solvent and Other Product Use</b>	CR, CS	NA	NA	NA	NA	NA
<b>4. Agriculture</b>						
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
<b>5. Land-Use Land-Use Change Change and Forestry</b>						
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
<b>6. Waste</b>						
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
<b>7. Other</b>	NA	NA	NA	NA	NA	NA
<b>Article 3.3 Afforestation and Deforestation</b>	Tier 3	Tier 1	Tier 1	NA	NA	NA
<b>International Bunkers</b>						
Aviation	Tier 1	D	D	NA	NA	NA
Marine	Tier 1	D	D	NA	NA	NA
<b>Multilateral Operations</b>	NA	NA	NA	NA	NA	NA
<b>CO<sub>2</sub> Emissions from Biomass</b>	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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	HFC	PFC	SF <sub>6</sub>
<b>1. Energy</b>						
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
<b>2. Industrial Processes</b>						
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 <sub>6</sub>	NA	NA	NA	NA	NA	NA
F. Consumption of Halocarbons and SF <sub>6</sub>	NA	NA	NA	CS	CS	CS
G. Other	NA	NA	NA	NA	NA	NA
<b>3. Solvent and Other Product Use</b>	CR	NA	NA	NA	NA	NA
<b>4. Agriculture</b>						
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
<b>5. Land-Use Land-Use Change and Forestry</b>						
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
<b>6. Waste</b>						
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
<b>7. Other</b>	NA	NA	NA	NA	NA	NA
<b>Article 3.3 Afforestation and Deforestation</b>	CS	D	D	NA	NA	NA
<b>International Bunkers</b>						
Aviation	CS	CR	CR	NA	NA	NA
Marine	CS	D	D	NA	NA	NA
<b>Multilateral Operations</b>	NA	NA	NA	NA	NA	NA
<b>CO<sub>2</sub> Emissions from Biomass</b>	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 2011 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 1990-2011 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 2011 key category analysis is provided in Tables B.1-4 in Annex B.

The results of the level and trend assessments for 2011 excluding LULUCF categories may be summarised as follows:

- (i) level assessment identifies 24 key categories, all of which but five (CO<sub>2</sub> emissions in both 2.A.1. and 1.A.4.c. for liquid fuels, plus CH<sub>4</sub> emissions in 4.B.1. and 4.B.8. and N<sub>2</sub>O emissions in 4.D.3.) are also key categories by trend assessment;
- (ii) there are 13 key categories of CO<sub>2</sub> in level assessment, accounting for 63.4 per cent of total emissions;
- (iii) there are 7 key categories of CH<sub>4</sub>, three key categories of N<sub>2</sub>O and one category of HFC in level assessment, which account for 19.5 per cent, 11.6 per cent and 0.9 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) trend assessment identifies 21 key categories, all of which but two (solid fuels CH<sub>4</sub> emissions in 1.A.4.b. and solid fuels CO<sub>2</sub> emissions in 1.A.2.) are key categories for 2011 level assessment;
- (vi) there are 12 key categories of CO<sub>2</sub> in trend assessment, accounting for 82.5 per cent of the total trend;
- (vii) there are 6 key categories of CH<sub>4</sub>, two key categories of N<sub>2</sub>O and one key category of HFC in trend assessment, which account for 8.6 per cent, 2.7 per cent and 1.9 per cent, respectively, of the total trend.

The results of the level and trend assessment for 2011 including LULUCF categories may be summarised as follows:

- (i) the level assessment identifies 29 key categories, 17 of these are sources of CO<sub>2</sub> emissions, accounting for 65.8 per cent of total emissions;
- (ii) there are 5 additional categories that are not present in the assessment excluding LULUCF, of which 3 are *LULUCF* and the remaining 2 are CO<sub>2</sub> emissions from 1.A.2 (solid fuels) and N<sub>2</sub>O emissions from 4.B.13 (solid storage);
- (iii) the three additional *LULUCF* categories are CO<sub>2</sub> emissions from 5.A.2 – land converted to forest land (6.0 per cent of total emissions), 5.C.1 – grassland remaining grassland (0.9 per cent), and 5.A.1 – forest land remaining forest land (0.7 per cent).
- (iv) there are 7 key categories from sources of CH<sub>4</sub>, 4 key categories from N<sub>2</sub>O and 1 category of HFC, which account for 17.7 per cent, 11.2 per cent and 0.9 per cent, respectively, of total emissions;

- (v) *Energy* accounts for 13 key categories, *Agriculture* for 10, *LULUCF* for 3, while *Industrial Processes* contributes 2 and *Waste* contributes 1;
- (vi) the trend assessment identifies 26 key categories, three of which were not identified as key categories in the level assessment: CO<sub>2</sub> emissions from 5.E.2 – land converted to settlements, 5.C.2 – land converted to grassland and 5.B.2 – land converted to cropland;
- (vii) there are 18 key categories of CO<sub>2</sub> in the trend assessment, accounting for 84.1 per cent of the total trend;
- (viii) there are 5 key categories of CH<sub>4</sub>, 2 key categories of CH<sub>4</sub> and one key category of HFC in the trend assessment, which account for 7.4 per cent, 2.3 per cent and 1.4 per cent, respectively, of the total trend.

The list of key categories given by level assessment in 2011 is very similar to that for 1990. However, the higher ranking of the main CO<sub>2</sub> sources in *Energy*, at the expense of CH<sub>4</sub> and N<sub>2</sub>O sources in *Agriculture*, is notable in 2011. The top ten key categories (excluding LULUCF) were in a different order but identical apart from two (1.A.4.a and 1.A.2. with CO<sub>2</sub> emissions both from liquid fuels in 1990 were replaced by 1.A.4.b. with CO<sub>2</sub> emissions from liquid fuels and 1.A.2. CO<sub>2</sub> emissions from gaseous fuels) and contributed 70.1 and 73.6 per cent, of total emissions in 1990 and 2011, respectively. The emissions of CO<sub>2</sub> from the use of petrol and diesel by road traffic (1.A.3.b) and from fuel combustion in 1.A.1 *Energy Industries* were the largest source categories of greenhouse gas emissions in Ireland in 2011, accounting for 18.6 and 20.5 per cent of the total, respectively.

The CO<sub>2</sub> removals in category 5.A.2 *Land Converted to Forest Land*, CO<sub>2</sub> emissions in 5.C.1 *Grassland Remaining Grassland* and CO<sub>2</sub> removals in 5.A.1 *Forest Land Remaining Forest Land* are key categories in level assessment when the LULUCF sector is included in the detailed analysis. Similarly, CO<sub>2</sub> 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 in 2011 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 29 key categories in 2011 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<sub>2</sub> emissions from energy consumption on total emissions in Ireland. These emissions account for 13 of the key categories listed in Table 1.10 and for 56.7 per cent of total emissions in 2011. While key categories determined by CO<sub>2</sub> 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<sub>2</sub> 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<sub>4</sub> from enteric fermentation in cattle (dairy and non-dairy) and the use of verified estimates for CO<sub>2</sub> emissions from cement production means that the contributions from three additional key categories (ranked 4, 9 and 17 in Table 1.9), making up a further 13.9 per cent of the total, are also known with probably the highest certainty now achievable. The N<sub>2</sub>O emissions from *4.D Agricultural Soils* and CH<sub>4</sub> emissions from *4.B Manure Management* and *6.A Solid Waste Disposal on Land* account for most of the remaining important key categories in Table 1.7. 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 2011. This involved the allocation of responsibilities linked to the national system mentioned in section 1.3.2 and the use of a template spreadsheet 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 2013 submission.

Ireland's calculation spreadsheets 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<sub>2</sub> 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 most recent work in this forum focused on harmonising the reporting relating to sub-categories under 2.A (Mineral Products) across the EU Member States.

The inventory team contracted an external service provider, Aether, to assist in aspects of inventory compilation in 2012. 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 2011 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 2011 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 high 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 Construction) 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<sub>2</sub> 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O released from combustion sources are high and not well established quantitatively. For CH<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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 uncertainty estimates for F-gases are those developed by the consultants who produced the F-gas inventories for Ireland in 2005 as the data sources and methodologies remain unchanged.

The Tier 1 uncertainty analysis (excluding LULUCF) for Ireland's 2011 inventory under the Convention gives an overall uncertainty of 7.09 per cent in total emissions and a trend uncertainty of 2.3 per cent for the period 1990 to 2011 similar to the values reported in 2012 of 6.83 and 2.63 per cent respectively.

These relatively low estimates are determined largely by the low uncertainties in the estimate of CO<sub>2</sub> emissions, which accounts for 65.5 per cent of total Irish emissions in 2011 and which are estimated to have a level uncertainty of 1.16 per cent (excluding LULUCF). When CH<sub>4</sub> is included, bringing the proportion of total emissions up to 86 per cent, the total uncertainty estimate is 2.04 per cent (excluding LULUCF), even though there are large uncertainties assigned to the CH<sub>4</sub> emission factors in some source categories. However, it is the influence of N<sub>2</sub>O 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<sub>2</sub>O from 1990 to 2011 and the relatively small share of this gas in total emissions. The impact of HFC, PFC and SF<sub>6</sub> on inventory uncertainty remains negligible because these gases account for only 1 per cent of total emissions in Ireland.

The Tier 1 uncertainty analysis (including LULUCF) for Ireland's 2011 inventory under the Convention (Table 1.13) gives an overall uncertainty of 12.51 per cent in total emissions and a trend uncertainty of 6.62 per cent for the period 1990 to 2011.

The overall uncertainty (including LULUCF) of the inventory in 2011 is estimated at 12.51 per cent which is showing an increase since the last submission. The corresponding value in 2010 was 7.15 per cent. The reason for the increase from 2010 to 2011 is due to revised estimates from the LULUCF sector and the effect on national total emissions and the

revision to the activity data and emission factor uncertainty values used in this year's analysis. The overall trend uncertainty increased in 2011 when compared to 2010 to a value of 6.62 per cent compared to 2.72 per cent.

The overall uncertainty estimate for Article 3.3 activities in 2011 is 16.70 per cent, which is determined largely by an uncertainty of 16.79 per cent calculated for CO<sub>2</sub> 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 2013 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 work done for the current reporting cycle serves to maintain a complete and consistent emissions time-series by improving the inventories for the years 1990-2010 to bring them fully into line with that for 2011. The completeness of the inventory has been improved by including combustion emissions from charcoal use for cooking in the energy sector (1.A.4.b) and from waste incineration of clinical and solvent wastes (6.C.a-b). 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 <sub>2</sub> 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	3,021.86	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	1,380.91	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	77.19
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	81.44
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 2011(excluding LULUCF)**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	2011 Emissions exclud. LULUCF (Gg CO <sub>2</sub> eq)	2011 Level assessment exclud. LULUCF (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10,696.23	18.60	18.60
2	1.A.1	Energy Industries - Solid Fuels	CO2	5,950.18	10.35	28.94
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	5,403.02	9.39	38.34
4	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,221.02	9.08	47.42
5	1.A.4.b	Residential - Liquid Fuels	CO2	3,106.47	5.40	52.82
6	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2,762.22	4.80	57.62
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,611.47	4.54	62.16
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,572.06	4.47	66.63
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2,042.55	3.55	70.19
10	1.A.4.b	Residential - Solid Fuels	CO2	1,966.41	3.42	73.60
11	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1,725.04	3.00	76.60
12	1.A.4.b	Residential - Gaseous Fuels	CO2	1,359.20	2.36	78.97
13	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,308.50	2.28	81.24
14	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,183.33	2.06	83.30
15	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,106.56	1.92	85.22
16	2.A.1	Cement Production	CO2	966.27	1.68	86.90
17	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	906.22	1.58	88.48
18	6.A	Waste - Solid Waste Disposal on land	CH4	830.85	1.44	89.92
19	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	713.79	1.24	91.17
20	4.A.3	Enteric Fermentation - Sheep	CH4	571.08	0.99	92.16
21	2.F	Consumption of Halocarbons & SF6	HFC	538.61	0.94	93.09
22	4.B.1	Manure Management - Dairy Cattle	CH4	474.76	0.83	93.92
23	1.A.1	Energy Industries - Liquid Fuels	CO2	428.70	0.75	94.67
24	4.B.8	Manure Management - Pigs	CH4	414.29	0.72	95.39

**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 <sub>2</sub> eq)	1990 Emissions for LULUCF (Gg CO <sub>2</sub> eq)	Absolute Values (Gg CO <sub>2</sub> eq)	1990 Level assessment includ. LULUCF (%)	Cumulative Total (%)
1	1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	-3,287.59	8,009.44	13.49	13.49
2	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,630.17		5,630.17	9.48	22.97
3	1.A.4.b	Residential - Solid Fuels	CO2	5,606.94		5,606.94	9.44	32.41
4	1.A.3.b	Road Transport - Liquid Fuels	CO2	4,690.42		4,690.42	7.90	40.31
5	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2			3,287.59	5.54	45.85
6	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.86		3,021.86	5.09	50.94
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35		2,868.35	4.83	55.77
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99		2,854.99	4.81	60.58
9	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2,198.38		2,198.38	3.70	64.28
10	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00		1,957.00	3.30	67.57
11	1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66		1,880.66	3.17	70.74
12	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,380.91		1,380.91	2.33	73.07
13	4.B.1	Manure Management - Non-Dairy cattle	CH4	1,279.75		1,279.75	2.16	75.22
14	1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51		1,268.51	2.14	77.36
15	1.A.4.b	Residential - Liquid Fuels	CO2	1,175.35		1,175.35	1.98	79.34
16	6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05		1,173.05	1.98	81.31
17	2.B	Chemical Industry	N2O	1,035.40		1,035.40	1.74	83.06
18	4.A.3	Enteric Fermentation - Sheep	CH4	1,032.48		1,032.48	1.74	84.80
19	2.B	Chemical Industry	CO2	990.23	602.37	990.23	1.67	86.46
20	2.A.1	Cement Production	CO2	884.00		884.00	1.49	87.95
21	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02		873.02	1.47	89.42
22	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24		871.24	1.47	90.89
23	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30		660.30	1.11	92.00
24	4.B.1	Manure Management - Dairy Cattle	CH4	608.23		608.23	1.02	93.03
25	5.C.1	LULUCF - Grassland Remaining Grassland	CO2			602.37	1.01	94.04
26	4.B.13	Manure Management - Solid Storage	N2O	371.24		371.24	0.63	94.66
27	1.A.4.b	Residential - Solid Fuels	CH4	356.29		356.29	0.60	95.26

**Table 1.9. Key Category Analysis Level Assessment 2011 (including LULUCF)**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	2011 Emissions excl. LULUCF (Gg CO <sub>2</sub> eq)	2011 Emissions for LULUCF (Gg CO <sub>2</sub> eq)	Absolute Values (Gg CO <sub>2</sub> eq)	2011 Level assessment incl. LULUCF (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10,696.23	-3,821.95	10,696.23	16.91	16.91
2	1.A.1	Energy Industries - Solid Fuels	CO2	5,950.18		5,950.18	9.41	26.32
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	5,403.02		5,403.02	8.54	34.87
4	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,221.02		5,221.02	8.26	43.12
5	5.A.2	LULUCF - Land converted to Forest Land	CO2			3,821.95	6.04	49.16
6	1.A.4.b	Residential - Liquid Fuels	CO2	3,106.47		3,106.47	4.91	54.08
7	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2,762.22		2,762.22	4.37	58.44
8	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,611.47		2,611.47	4.13	62.57
9	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,572.06		2,572.06	4.07	66.64
10	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2,042.55		2,042.55	3.23	69.87
11	1.A.4.b	Residential - Solid Fuels	CO2	1,966.41		1,966.41	3.11	72.98
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1,725.04		1,725.04	2.73	75.71
13	1.A.4.b	Residential - Gaseous Fuels	CO2	1,359.20		1,359.20	2.15	77.86
14	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,308.50		1,308.50	2.07	79.93
15	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,183.33	542.95	1,183.33	1.87	81.80
16	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,106.56		1,106.56	1.75	83.55
17	2.A.1	Cement Production	CO2	966.27		966.27	1.53	85.08
18	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	906.22		906.22	1.43	86.51
19	6.A	Waste - Solid Waste Disposal on land	CH4	830.85		830.85	1.31	87.82
20	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	713.79		713.79	1.13	88.95
21	4.A.3	Enteric Fermentation - Sheep	CH4	571.08		571.08	0.90	89.85
22	5.C.1	LULUCF - Grassland Remaining Grassland	CO2			542.95	0.86	90.71
23	2.F	Consumption of Halocarbons & SF6	HFC	538.61		538.61	0.85	91.57
24	4.B.1	Manure Management - Dairy Cattle	CH4	474.76		474.76	0.75	92.32
25	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2		-430.99	430.99	0.68	93.00
26	1.A.1	Energy Industries - Liquid Fuels	CO2	428.70		428.70	0.68	93.68
27	4.B.8	Manure Management - Pigs	CH4	414.29		414.29	0.66	94.33
28	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	377.76		377.76	0.60	94.93
29	4.B.13	Manure Management - Solid Storage	N2O	374.69		374.69	0.59	95.52

**Table 1.10. Key Category Analysis Trend Assessment 1990-2011 (excluding LULUCF)**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions excl. LULUCF (Gg CO <sub>2</sub> eq)	2011 Emissions excl. LULUCF (Gg CO <sub>2</sub> eq)	2011 Level assessment excl. LULUCF (%)	2011 Trend assessment excl. LULUCF (%)	Contribution to Trend (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4,690.42	10,696.23	18.60	9.71	20.73	20.73
2	1.A.4.b	Residential - Solid Fuels	CO2	5,606.94	1,966.41	3.42	6.46	13.80	34.53
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	5,403.02	9.39	5.75	12.28	46.81
4	1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	5,950.18	10.35	3.99	8.51	55.33
5	1.A.4.b	Residential - Liquid Fuels	CO2	1,175.35	3,106.47	5.40	3.14	6.71	62.04
6	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2,042.55	3.55	1.89	4.04	66.08
7	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,359.20	2.36	1.80	3.85	69.93
8	1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	428.70	0.75	1.49	3.18	73.11
9	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00	1,183.33	2.06	1.43	3.04	76.15
10	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	906.22	1.58	1.13	2.40	78.55
11	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,630.17	5,221.02	9.08	1.07	2.28	80.84
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2,198.38	1,725.04	3.00	0.94	2.01	82.85
13	2.F	Consumption of Halocarbons & SF6	HFC	1.31	538.61	0.94	0.90	1.92	84.76
14	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	377.76	0.66	0.88	1.89	86.65
15	4.A.3	Enteric Fermentation - Sheep	CH4	1,032.48	571.08	0.99	0.84	1.80	88.44
16	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99	2,572.06	4.47	0.67	1.43	89.87
17	6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05	830.85	1.44	0.65	1.39	91.26
18	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.86	2,762.22	4.80	0.64	1.37	92.63
19	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35	2,611.47	4.54	0.63	1.34	93.97
20	1.A.4.b	Residential - Solid Fuels	CH4	356.29	124.88	0.22	0.41	0.88	94.84
21	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,279.75	1,106.56	1.92	0.38	0.80	95.65

**Table 1.11. Key Category Analysis Trend Assessment 2011(including LULUCF)**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions includ. LULUCF (Gg CO <sub>2</sub> eq)	2011 Emissions includ. LULUCF (Gg CO <sub>2</sub> eq)	2011 Level assessment includ. LULUCF (%)	2011 Trend assessment includ. LULUCF (%)	Contribution to Trend (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4,690.42	10,696.23	16.91	8.44	14.67	14.67
2	1.A.4.b	Residential - Solid Fuels	CO2	5,606.94	1,966.41	3.11	5.95	10.34	25.01
3	5.A.2	LULUCF - Land converted to Forest Land	CO2	17.90	3,821.95	6.04	5.64	9.80	34.81
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	5,403.02	8.54	5.04	8.75	43.57
5	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	3,287.59	430.99	0.68	4.56	7.92	51.49
6	1.A.1	Energy Industries - Solid Fuels	CO2	8,009.44	5,950.18	9.41	3.84	6.68	58.17
7	1.A.4.b	Residential - Liquid Fuels	CO2	1,175.35	3,106.47	4.91	2.75	4.77	62.95
8	5.E.2	LULUCF - Land converted to Settlements	CO2	1,173.05	9.56	0.02	1.84	3.20	66.15
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2,042.55	3.23	1.65	2.86	69.01
10	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,359.20	2.15	1.59	2.76	71.77
11	1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	428.70	0.68	1.37	2.38	74.15
12	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1,957.00	1,183.33	1.87	1.34	2.33	76.48
13	6.A	Waste - Solid Waste Disposal on land	CH4	14.73	830.85	1.31	1.21	2.10	78.58
14	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5,630.17	5,221.02	8.26	1.16	2.02	80.60
15	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	906.22	1.43	0.99	1.72	82.32
16	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2,198.38	1,725.04	2.73	0.92	1.60	83.92
17	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	377.76	0.60	0.82	1.42	85.34
18	2.F	Consumption of Halocarbons & SF6	HFC	1.31	538.61	0.85	0.80	1.38	86.72
19	4.A.3	Enteric Fermentation - Sheep	CH4	1,032.48	571.08	0.90	0.79	1.37	88.09
20	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	47.10	542.95	0.86	0.73	1.27	89.36
21	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2,854.99	2,572.06	4.07	0.70	1.22	90.58
22	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.86	2,762.22	4.37	0.68	1.19	91.77
23	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35	2,611.47	4.13	0.66	1.15	92.92
24	5.C.2	LULUCF - Land converted to Grassland	CO2	0.00	322.79	0.51	0.48	0.83	93.75
25	5.B.2	LULUCF - Land converted to Cropland	CO2	602.37	329.34	0.52	0.46	0.81	94.56
26	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1,279.75	1,106.56	1.75	0.38	0.67	95.22

Table 1.12. Tier 1 Uncertainty Estimates 2011 excluding LULUCF (continued on following pages)

	IPCC Source Category	Gas	Emissions in 1990	Emissions in 2011	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2011	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 CO <sub>2</sub> eq	Gg CO <sub>2</sub> eq	%	%	%	%		%	%	%	%	%	%
1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	428.70	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	5,966.57	1.00	5.00	5.10	0.53	0.28	-0.04	0.11	0.15	-0.21	0.26	0.07
1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	5,403.02	1.00	2.50	2.69	0.25	0.06	0.06	0.10	0.14	0.16	0.21	0.04
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	CO2	2,013.71	1,533.54	10.00	2.50	10.31	0.27	0.08	-0.01	0.03	0.39	-0.03	0.39	0.15
1.A.2	Manufacturing Industries & Construction - Coal	CO2	871.24	377.76	2.00	5.00	5.39	0.04	0.00	-0.01	0.01	0.02	-0.05	0.05	0.00
1.A.2	Manufacturing Industries & Construction - Pet Coke	CO2	184.67	191.50	5.00	5.00	7.07	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2,042.55	2.50	2.50	3.54	0.13	0.02	0.02	0.04	0.13	0.05	0.14	0.02
1.A.2	Manufacturing Industries & Construction - Non-Renewable Waste	CO2	0.00	29.88	1.00	5.00	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	CO2	4,959.65	11,008.98	1.00	2.50	2.69	0.52	0.27	0.11	0.20	0.28	0.26	0.39	0.15
1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	153.31	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	1,183.33	10.00	5.00	11.18	0.23	0.05	-0.02	0.02	0.30	-0.08	0.31	0.10
1.A.4.a	Commercial/Institutional - Coal	CO2	2.56	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	135.73	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	906.22	2.50	2.50	3.54	0.06	0.00	0.01	0.02	0.06	0.03	0.07	0.00
1.A.4.b	Residential - Liquid Fuels	CO2	1,099.66	3,072.66	10.00	5.00	11.18	0.60	0.36	0.03	0.06	0.79	0.17	0.81	0.65
1.A.4.b	Residential - Coal	CO2	2,483.57	932.77	5.00	10.00	11.18	0.18	0.03	-0.03	0.02	0.12	-0.30	0.32	0.10
1.A.4.b	Residential - Petcoke	CO2	75.68	33.81	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.A.4.b	Residential - Peat	CO2	3,123.37	1,033.63	10.00	20.00	22.36	0.40	0.16	-0.04	0.02	0.26	-0.80	0.84	0.71
1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,359.20	2.50	2.50	3.54	0.08	0.01	0.02	0.02	0.09	0.05	0.10	0.01
1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	713.79	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	966.27	1.50	1.50	2.12	0.04	0.00	0.00	0.02	0.04	0.00	0.04	0.00
2.A.2	Lime Production	CO2	214.08	199.06	5.00	5.00	7.07	0.02	0.00	0.00	0.00	0.03	0.00	0.03	0.00
2.A.3	Limestone Use	CO2	0.15	1.04	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	0.07	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	0.83	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	72.49	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	53.49	10.00	5.00	11.18	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	<b>Total CO2</b>		<b>32,423.99</b>	<b>37,664.48</b>	<b>0.65</b>			<b>1.16</b>	<b>1.34</b>					<b>1.44</b>	<b>2.07</b>

	IPCC Source Category	Gas	Emissions in 1990 Gg CO <sub>2</sub> eq	Emissions in 2011 Gg CO <sub>2</sub> eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Emissions Uncertainty Squared as % of Emissions in 2011 %	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	0.12	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	1.93	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	2.36	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	1.17	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	0.84	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	0.13	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	0.75	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	0.04	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	37.16	17.62	1.00	50.00	50.01	0.02	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	0.28	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	3.36	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	0.01	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	0.28	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	1.67	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	8.87	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.4.b	Residential - Coal	CH4	165.07	61.24	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 - Petcoke	CH4	0.17	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	CH4	191.22	63.64	10.00	50.00	50.99	0.06	0.00	0.00	0.00	0.02	-0.12	0.12	0.02
1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.50	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.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	1.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A	Biomass	CH4	13.43	14.81	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B	Fugitive Emissions	CH4	131.26	27.79	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	2,572.06	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 Fermentation - Non-dairy Cattle	CH4	5,630.17	5,221.02	1.00	15.00	15.03	1.36	1.86	-0.01	0.09	0.13	-0.17	0.22	0.05
4.A	Enteric Fermentation - Other Livestock	CH4	1,088.95	645.84	1.00	30.00	30.02	0.34	0.11	-0.01	0.01	0.02	-0.26	0.27	0.07
4.B.1	Manure Management - Dairy Cattle	CH4	608.23	474.76	1.00	15.00	15.03	0.12	0.02	0.00	0.01	0.01	-0.04	0.04	0.00
4.B.1	Manure Management - Non-dairy Cattle	CH4	1,279.75	1,106.56	1.00	15.00	15.03	0.29	0.08	0.00	0.02	0.03	-0.06	0.07	0.00
4.B	Manure Management - Other Livestock	CH4	465.65	551.19	1.00	30.00	30.02	0.29	0.08	0.00	0.01	0.01	0.04	0.04	0.00
6.A	Waste - Solid Waste Disposal on land (abc)	CH4	1,173.05	830.85	34.64	34.64	31.13	0.45	0.20	-0.01	0.02	0.74	-0.24	0.78	0.60
6.B	Waste - Waste Water Handling	CH4	14.73	16.32	10.00	30.00	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.00	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
	<b>Total CH4</b>		<b>13,674.13</b>	<b>11,628.82</b>				<b>1.68</b>	<b>2.82</b>					<b>0.88</b>	<b>0.77</b>

	IPCC Source Category	Gas	Emissions in 1990	Emissions in 2011	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2011	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	Emissions in Trend in Total Emissions	Combined Trend Uncertainty Squared
			Gg CO <sub>2</sub> eq	Gg CO <sub>2</sub> eq	%	%	%	%		%	%	%	%	%	%
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	49.53	1.00	50.00	50.01	0.04	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	84.08	1.00	50.00	50.01	0.07	0.01	0.00	0.00	0.00	0.07	0.07	0.00
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	N2O	4.65	3.32	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	1.86	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	0.38	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	0.11	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 - Non-Renewable Waste	N2O	0.49	1.11	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	N2O	61.77	108.58	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	1.67	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	2.96	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	0.01	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	N2O	0.58	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	N2O	0.13	0.49	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	7.77	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1.A.4.b	Residential - Coal	N2O	12.18	4.52	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 - Petcoke	N2O	0.15	0.07	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	4.38	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	0.74	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.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	71.60	10.00	50.00	50.99	0.06	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1.A	Biomass	N2O	5.48	13.94	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 Management - Liquid Systems (d)	N2O	63.87	62.84	11.22	100.00	100.63	0.11	0.01	0.00	0.00	0.02	-0.01	0.02	0.00
4.B.13	Manure Management - Solid Storage (d)	N2O	371.24	374.69	11.22	100.00	100.63	0.66	0.43	0.00	0.01	0.11	-0.02	0.11	0.01
4.D.1	Agricultural Soils - Direct Soil Emissions (d)	N2O	3,021.86	2,762.22	11.22	100.00	100.63	4.83	23.36	-0.01	0.05	0.79	-0.69	1.05	1.11
4.D.2	Agricultural Soils - Pasture, Range & Paddock (d)	N2O	2,868.35	2,611.47	11.22	100.00	100.63	4.57	20.88	-0.01	0.05	0.75	-0.68	1.01	1.02
4.D.3	Agricultural Soils - Indirect Emissions (d)	N2O	1,380.91	1,308.50	11.22	50.00	51.24	1.17	1.36	0.00	0.02	0.38	-0.12	0.39	0.15
6.B	Waste - Waste Water Handling	N2O	111.71	141.35	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	0.57	10.00	10.00	14.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	<b>Total N2O</b>		<b>9,112.03</b>	<b>7,619.08</b>				<b>6.79</b>	<b>46.05</b>					<b>1.53</b>	<b>2.35</b>

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2011 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2011 %	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	Consumption of Halocarbons & SF6	HFC	1.31	538.61	20.00	10.00	22.36	0.21	0.04	0.01	0.01	0.28	0.10	0.29	0.09
2.F	Consumption of Halocarbons & SF6	PFC	0.09	13.20	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	48.29	15.00	5.00	15.81	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	<b>Total HFC, PFC &amp; SF6</b>		<b>36.91</b>	<b>600.10</b>				<b>0.21</b>	<b>0.04</b>					<b>0.29</b>	<b>0.09</b>
<b>Total all gases</b>			<b>55,247.07</b>	<b>57,512.48</b>	<b>50.25</b>										<b>5.27</b>
					<b>Overall Uncertainty in Emissions</b>		<b>7.09</b>					<b>Trend Uncertainty</b>		<b>2.30</b>	

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 2011 including LULUCF (continued on following pages)**

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2011 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2011 %	Combined Emissions Uncertainty Squared	Type A Sensitivity %	Type B Sensitivity %	Total Emissions due to AD %	Uncertainty in Trend to EF %	Total Emissions due in Emissions Uncertainty in Trend in %	Combined Uncertainty in Trend in Total Emissions %	Combined Trend Uncertainty Squared 0
1.A.1	Energy Industries - Liquid Fuels	CO2	1,268.51	428.70	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	5,966.57	1.00	5.00	5.10	0.57	0.32	-0.04	0.11	0.16	-0.21	0.27	0.07	
1.A.1	Energy Industries - Gaseous Fuels	CO2	1,880.66	5,403.02	1.00	2.50	2.69	0.27	0.07	0.07	0.10	0.15	0.17	0.22	0.05	
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	CO2	2,013.71	1,533.54	10.00	2.50	10.31	0.29	0.09	-0.01	0.03	0.41	-0.03	0.41	0.17	
1.A.2	Manufacturing Industries & Construction - Coal	CO2	871.24	377.76	2.00	5.00	5.39	0.04	0.00	-0.01	0.01	0.02	-0.05	0.05	0.00	
1.A.2	Manufacturing Industries & Construction - Pet Coke	CO2	184.67	191.50	5.00	5.00	7.07	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00	
1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2,042.55	2.50	2.50	3.54	0.13	0.02	0.02	0.04	0.14	0.05	0.15	0.02	
1.A.2	Manufacturing Industries & Construction - Non-Renewable Waste	CO2	0.00	29.88	1.00	5.00	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
1.A.3	Transport - Oil	CO2	4,959.65	11,008.98	1.00	2.50	2.69	0.55	0.30	0.11	0.21	0.30	0.28	0.41	0.17	
1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	153.31	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	1,183.33	10.00	5.00	11.18	0.25	0.06	-0.02	0.02	0.32	-0.08	0.33	0.11	
1.A.4.a	Commercial/Institutional - Coal	CO2	2.56	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	135.73	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	906.22	2.50	2.50	3.54	0.06	0.00	0.01	0.02	0.06	0.03	0.07	0.00	
1.A.4.b	Residential - Liquid Fuels	CO2	1,099.66	3,072.66	10.00	5.00	11.18	0.64	0.41	0.04	0.06	0.83	0.19	0.85	0.72	
1.A.4.b	Residential - Coal	CO2	2,483.57	932.77	5.00	10.00	11.18	0.19	0.04	-0.03	0.02	0.13	-0.31	0.33	0.11	
1.A.4.b	Residential - Petcoke	CO2	75.68	33.81	5.00	5.00	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	
1.A.4.b	Residential - Peat	CO2	3,123.37	1,033.63	10.00	20.00	22.36	0.43	0.18	-0.04	0.02	0.28	-0.82	0.87	0.75	
1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1,359.20	2.50	2.50	3.54	0.09	0.01	0.02	0.03	0.09	0.05	0.10	0.01	
1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	713.79	10.00	5.00	11.18	0.15	0.02	0.00	0.01	0.19	0.00	0.19	0.04	
2.A.1	Cement Production	CO2	884.00	966.27	1.50	1.50	2.12	0.04	0.00	0.00	0.02	0.04	0.00	0.04	0.00	
2.A.2	Lime Production	CO2	214.08	199.06	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	1.04	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	0.07	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	0.83	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	72.49	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	-3,269.70	-4,252.94	51.00	114.00	124.89	-9.87	97.43	-0.02	-0.08	-5.83	-1.97	6.16	37.90	
5.B.1	LULUCF - Cropland remaining Cropland	CO2	20.00	16.95	22.57	69.15	72.74	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.00	
5.B.2	LULUCF - Total Land converted to Cropland	CO2	0.00	329.34	18.63	69.15	71.61	0.44	0.19	0.01	0.01	0.16	0.43	0.46	0.21	
5.C.1	LULUCF - Grassland Remaining Grassland	CO2	602.37	542.95	12.18	90.00	90.82	0.92	0.84	0.00	0.01	0.18	-0.13	0.22	0.05	
5.C.2	LULUCF - Grassland in Transition	CO2	-108.80	-322.79	31.52	80.27	86.23	-0.52	0.27	0.00	-0.01	-0.27	-0.32	0.42	0.18	
5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	47.10	33.94	12.47	51.53	53.02	0.03	0.00	0.00	0.00	0.01	-0.01	0.02	0.00	
5.D.2	LULUCF - Total Land converted to Wetland	CO2	0.00	-0.75	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	39.06	75.00	84.56	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	10.29	9.56	39.06	75.00	84.56	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.00	
5.F.1	LULUCF - Other Land remaining Other Land	CO2	0.00	0.00	31.49	90.00	95.35	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	-1.06	-138.19	53.91	71.56	89.60	-0.23	0.05	0.00	0.00	-0.20	-0.19	0.27	0.07	
6.C	Waste - Waste Incineration	CO2	82.97	53.49	10.00	5.00	11.18	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	
	<b>Total CO2</b>		<b>29,724.21</b>	<b>33,882.54</b>	<b>0.63</b>			<b>10.02</b>	<b>100.31</b>					<b>6.38</b>	<b>40.66</b>	

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2011 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2011 %	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	0.12	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	1.93	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	2.36	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	1.17	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	0.84	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	0.13	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	0.75	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	0.04	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	37.16	17.62	1.00	50.00	50.01	0.02	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	0.28	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	3.36	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	0.01	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	0.28	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	1.67	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	8.87	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.4.b	Residential - Coal	CH4	165.07	61.24	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 - Petcoke	CH4	0.17	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	CH4	191.22	63.64	10.00	50.00	50.99	0.06	0.00	0.00	0.00	0.02	-0.13	0.13	0.02
1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.50	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.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	1.01	10.00	50.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A	Biomass	CH4	13.43	14.81	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B	Fugitive Emissions	CH4	131.26	27.79	2.50	10.00	10.31	0.01	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	2,572.06	1.00	15.00	15.03	0.72	0.52	-	0.05	0.07	-0.10	0.12	0.01
4.A.1	Enteric Fermentation - Non-dairy Cattle	CH4	5,630.17	5,221.02	1.00	15.00	15.03	1.46	2.13	-	0.10	0.14	-0.15	0.21	0.04
4.A	Enteric Fermentation - Other Livestock	CH4	1,088.95	645.84	1.00	30.00	30.02	0.36	0.13	-	0.01	0.02	-0.27	0.27	0.07
4.B.1	Manure Management - Dairy Cattle	CH4	608.23	474.76	1.00	15.00	15.03	0.13	0.02	0.00	0.01	0.01	-0.04	0.04	0.00
4.B.1	Manure Management - Non-dairy Cattle	CH4	1,279.75	1,106.56	1.00	15.00	15.03	0.31	0.10	0.00	0.02	0.03	-0.06	0.07	0.00
4.B	Manure Management - Other Livestock	CH4	465.65	551.19	1.00	30.00	30.02	0.31	0.09	0.00	0.01	0.01	0.04	0.05	0.00
5.A	LULUCF - Forest Land	CH4	9.29	7.58	30.00	100.00	104.40	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
6.A	Waste - Solid Waste Disposal on land	CH4	1,173.05	830.85	34.64	34.64	48.99	0.76	0.57	-	0.02	0.77	-0.24	0.81	0.66
6.B	Waste - Waste Water Handling	CH4	14.73	16.32	10.00	30.00	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.00	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
	<b>Total CH4</b>		<b>13,683.42</b>	<b>11,636.40</b>				<b>1.89</b>	<b>3.56</b>					<b>0.91</b>	<b>0.82</b>

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2011 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2011 %	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	49.53	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	84.08	1.00	50.00	50.01	0.08	0.01	0.00	0.00	0.00	0.07	0.07	0.00
1.A.2	Manufacturing Industries & Construction - Liquid Fuels exc Pet Coke	N2O	4.65	3.32	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	1.86	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	0.38	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	0.11	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 - Non-Renewable Waste	N2O	0.49	1.11	2.50	50.00	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.3	Transport - Oil	N2O	61.77	108.58	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	1.67	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	2.96	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	0.01	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	N2O	0.58	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	N2O	0.13	0.49	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	7.77	10.00	50.00	50.99	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
1.A.4.b	Residential - Coal	N2O	12.18	4.52	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	0.07	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	4.38	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	0.74	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.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	71.60	10.00	50.00	50.99	0.07	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1.A	Biomass	N2O	5.48	13.94	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 Management - Liquid Systems	N2O	63.87	62.84	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	374.69	11.22	100.00	100.63	0.70	0.49	0.00	0.01	0.11	-0.01	0.11	0.01
4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3,021.86	2,762.22	11.22	100.00	100.63	5.17	26.68	-0.01	0.05	0.83	-0.63	1.04	1.09
4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2,868.35	2,611.47	11.22	100.00	100.63	4.88	23.85	-0.01	0.05	0.79	-0.62	1.00	1.00
4.D.3	Agricultural Soils - Indirect Emissions	N2O	1,380.91	1,308.50	11.22	50.00	51.24	1.25	1.55	0.00	0.02	0.40	-0.10	0.41	0.17
5.A	LULUCF - Forest Land	N2O	24.78	38.80	30.00	100.00	104.40	0.08	0.01	0.00	0.00	0.03	0.03	0.04	0.00
5.B.2	LULUCF - Land converted to Cropland	N2O	0.00	31.37	30.00	100.00	104.40	0.06	0.00	0.00	0.00	0.03	0.06	0.06	0.00
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	2.57	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	141.35	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	0.57	10.00	10.00	14.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	<b>Total N2O</b>		<b>9,140.40</b>	<b>7,691.81</b>				<b>7.25</b>	<b>52.61</b>					<b>1.52</b>	<b>2.32</b>

	IPCC Source Category	Gas	Emissions in 1990 Gg CO2eq	Emissions in 2011 Gg CO2eq	Activity Data (AD) Uncertainty %	Emission Factor (EF) Uncertainty %	Combined Uncertainty %	Combined Uncertainty as % of Emissions in 2011 %	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	Consumption of Halocarbons & SF6	HFC	1.31	538.61	20.00	10.00	22.36	0.21	0.04	0.01	0.01	0.28	0.10	0.29	0.09
2.F	Consumption of Halocarbons & SF6	PFC	0.09	13.20	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	48.29	15.00	5.00	15.81	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	<b>Total HFC, PFC &amp; SF6</b>		<b>36.91</b>	<b>600.10</b>				<b>0.21</b>	<b>0.04</b>					<b>0.29</b>	<b>0.09</b>
<b>Total all gases</b>			<b>52,584.95</b>	<b>53,810.86</b>					<b>156.53</b>						<b>43.89</b>
					<b>Overall Uncertainty in Emissions</b>			<b>12.51</b>				<b>Trend Uncertainty</b>		<b>6.62</b>	

*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**

<b>IPCC SOURCE AND SINK CATEGORIES</b>	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>HFC</b>	<b>PFC</b>	<b>SF<sub>6</sub></b>
<b>1. Energy</b>						
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
<b>2. Industrial Processes</b>						
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 <sub>6</sub>	NA	NA	NA	NO	NO	NO
F. Consumption of Halocarbons and SF <sub>6</sub>	NA	NA	NA	All	All	All
G. Other	NO	NO	NO	NO	NO	NO
<b>3. Solvent and Other Product Use</b>	All	NA	NE	NA	NA	NA
<b>4. Agriculture</b>						
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
<b>5. Land-Use Land-Use Change and Forestry</b>						
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
<b>6. Waste</b>						
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
<b>7. Other</b>	NO	NO	NO	NA	NA	NA
<b>Article 3.3 Afforestation and Deforestation</b>	All	All	All	NA	NA	NA
<b>Memo Items:</b>						
<b>International Bunkers</b>						
Aviation	All	All	All	NA	NA	NA
Marine	All	All	All	NA	NA	NA
<b>Multilateral Operations</b>	NO	NO	NO	NA	NA	NA
<b>CO<sub>2</sub> Emissions from Biomass</b>	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 1990-2011 are shown in Table 2.1. The estimates reported here show some changes on those reported in the 2012 submission, which reflect recalculations that are fully described in subsequent chapters. The trends in the principal emission components, shown as CO<sub>2</sub> 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 55,247.07 Gg CO<sub>2</sub> eq in 1990 to 70,170.49 Gg CO<sub>2</sub> eq in 2001 and then decreased slightly to 68,207.53 Gg CO<sub>2</sub> eq in 2004. Total emissions increased again in 2005 to 69,450.64 Gg CO<sub>2</sub> eq and then decreased for six consecutive years. The largest annual change occurred from 2008 to 2009 when emissions decreased by 5,783.16 Gg CO<sub>2</sub> eq from 67,608.02 to 61,824.86 Gg CO<sub>2</sub> equivalent, a reduction of 8.6 per cent. Total emissions in 2011 were 4.1 per cent lower than in 1990 and 18.0 per cent lower than the peak level in 2001. The estimated total for 2011 is 57,512.48 Gg CO<sub>2</sub> eq, equating to 3,980.08 Gg CO<sub>2</sub> eq or 6.5 per cent lower than that for 2010. Inter annual changes to national total emission estimates are shown in Figure 2.1.

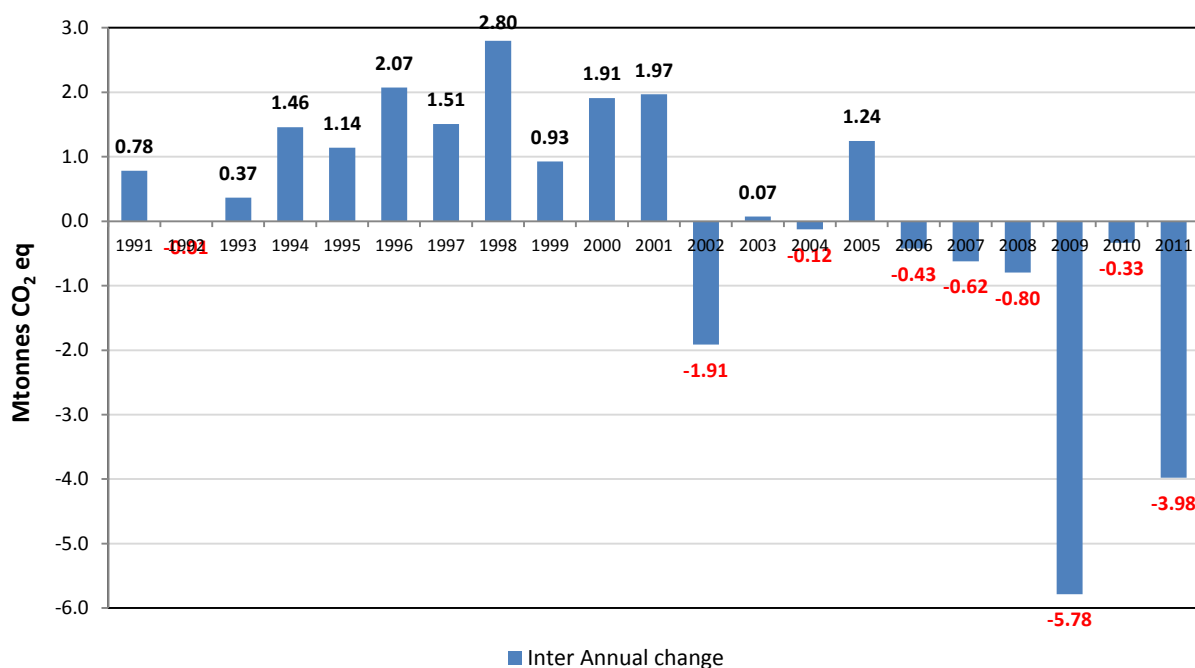


Figure 2.1 Inter annual change in national total emissions 1990-2011

In 2011, the total *Energy* sector accounted for 64.2 per cent of total emissions, *Agriculture* contributed 30.8 per cent while a further 3.1 per cent emanated from *Industrial Processes*, 1.8 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<sub>2</sub> emissions in 2011 (96.6 per cent and 3.1 per cent), CH<sub>4</sub> emissions are produced mainly in the *Agriculture* (90.9 per cent) and *Waste* (7.3 per cent) sectors and most of the N<sub>2</sub>O emissions are generated in *Agriculture* and *Energy* (93.4 per cent and 4.7 per cent, respectively).

The large increase in emissions during the period 1990-2001 was clearly driven by the growth in CO<sub>2</sub> emissions from energy use. CO<sub>2</sub> 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<sub>2</sub> 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 was due largely to increased emissions from road transport and from electricity generation from two new peat-fired stations. The declining trend between 2005 and 2008 is largely attributable to decreases in the agriculture and waste sectors and in 2008 to reduced emissions from mineral products in the industrial processes sector. In addition, 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 and further decreased in 2010 and 2011 to reach the level pre-1994.

**Table 2.1. Greenhouse Gas Emissions 1990, 1995, 2000-2011 (Gg CO<sub>2</sub> equivalent)**

(a) Emissions by Gas

<b>GREENHOUSE GAS EMISSIONS</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>Change from base to latest reported year</b>
CO <sub>2</sub> emissions including net CO <sub>2</sub> from LULUCF	29,724.21	33,367.24	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	13.99%
CO <sub>2</sub> emissions excluding net CO <sub>2</sub> from LULUCF	32,423.99	35,232.54	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	16.16%
CH <sub>4</sub> emissions including CH <sub>4</sub> from LULUCF	13,683.42	13,931.81	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	-14.96%
CH <sub>4</sub> emissions excluding CH <sub>4</sub> from LULUCF	13,674.13	13,919.68	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	-14.96%
N <sub>2</sub> O emissions including N <sub>2</sub> O from LULUCF	9,140.40	9,660.59	9,527.34	9,020.46	8,647.39	8,570.40	8,389.69	8,172.84	8,039.12	7,792.78	7,700.93	7,610.75	7,894.39	7,691.81	-15.85%
N <sub>2</sub> O emissions excluding N <sub>2</sub> O from LULUCF	9,112.03	9,620.61	9,482.03	8,969.38	8,597.74	8,511.06	8,331.49	8,116.04	7,982.68	7,735.93	7,631.68	7,541.40	7,823.01	7,619.08	-16.38%
HFCs	1.31	54.60	259.81	279.85	309.24	382.20	416.04	475.81	548.66	535.67	566.66	523.33	559.30	538.61	41079.90%
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	14076.58%
SF <sub>6</sub>	35.51	82.93	54.35	67.84	67.73	115.43	68.65	101.63	62.90	65.52	56.68	38.24	34.51	48.29	35.98%
<b>Total (including LULUCF)</b>	<b>52,584.95</b>	<b>57,172.56</b>	<b>66,949.32</b>	<b>68,796.90</b>	<b>66,859.38</b>	<b>66,849.58</b>	<b>65,680.00</b>	<b>66,878.28</b>	<b>66,320.97</b>	<b>65,041.07</b>	<b>64,900.29</b>	<b>58,821.44</b>	<b>57,380.28</b>	<b>53,810.86</b>	<b>2.33%</b>
<b>Total (excluding LULUCF)</b>	<b>55,247.07</b>	<b>58,985.74</b>	<b>68,203.02</b>	<b>70,170.49</b>	<b>68,258.96</b>	<b>68,331.28</b>	<b>68,207.53</b>	<b>69,450.64</b>	<b>69,025.50</b>	<b>68,405.86</b>	<b>67,608.02</b>	<b>61,824.86</b>	<b>61,492.56</b>	<b>57,512.48</b>	<b>4.10%</b>

(b) Emissions by IPCC Source Category

<b>GREENHOUSE GAS SOURCE AND SINK CATEGORIES</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>Change from base to latest reported year</b>
1. Energy	30,970.47	33,845.38	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	19.27%
2. Industrial Processes	3,179.27	3,082.98	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	2,112.45	1,929.88	1,767.37	-44.41%
3. Solvent and Other Product Use	80.03	85.39	79.04	77.91	75.60	74.39	73.92	74.07	75.10	75.67	74.30	71.88	71.66	72.49	-9.42%
4. Agriculture	19,633.98	20,314.30	19,969.47	19,593.85	19,377.54	19,509.26	19,313.37	18,855.69	18,721.84	18,282.37	18,145.04	17,930.55	17,994.84	17,691.16	-9.90%
5. LULUCF	-2,662.12	-1,813.19	-1,253.70	-1,373.59	-1,399.58	-1,481.71	-2,527.36	-2,572.36	-2,704.53	-3,364.79	-2,707.74	-3,003.42	-4,112.27	-3,701.62	39.05%
6. Waste	1,383.32	1,657.68	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	-24.63%
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total (including LULUCF)</b>	<b>52,584.95</b>	<b>57,172.56</b>	<b>66,949.32</b>	<b>68,796.90</b>	<b>66,859.38</b>	<b>66,849.58</b>	<b>65,680.00</b>	<b>66,878.28</b>	<b>66,320.97</b>	<b>65,041.07</b>	<b>64,900.29</b>	<b>58,821.44</b>	<b>57,380.28</b>	<b>53,810.86</b>	<b>2.33%</b>

## 2.2 Trends by Gas

Emissions of CO<sub>2</sub> accounted for 65.5 per cent of the total (excluding LULUCF) of 57,512.48 Gg CO<sub>2</sub> equivalent in 2011, with CH<sub>4</sub> and N<sub>2</sub>O contributing 20.2 per cent and 13.2 per cent, respectively. The combined emissions of HFC, PFC and SF<sub>6</sub> accounted for approximately 1.0 per cent of total emissions in 2011. In 1990 emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and the combined emissions of HFCs, PFCs and SF<sub>6</sub> accounted for 58.7, 24.8, 16.5 and less than 0.01 per cent, respectively of total emissions of 55,247.07 Gg CO<sub>2</sub> equivalent.

CO<sub>2</sub> is the most significant contributor to the greenhouse gas emissions with *1.A.1 Energy Industries* responsible for 31.3 per cent of total CO<sub>2</sub> emissions in 2011. *1.A.3 Transport* represents a share of 29.6 per cent, *1.A.4 Other Sectors* has a share of 24.5 per cent, *1.A.2 Manufacturing Industries and Construction* has an 11.1 per cent share and the remainder of CO<sub>2</sub> emissions (3.4 per cent share) fall into other sectors. Emissions of CO<sub>2</sub> increased from 32,423.99 Gg in 1990 to 37,664.48 Gg in 2011, which equates to an increase of 16.2 per cent. The main driver behind this increase in emissions is primarily fuel combustion in Transport followed by Energy Industries. Over the period 1990-2011, emissions of CO<sub>2</sub> from transport, predominantly road traffic in Ireland, increased by 122.3 per cent. This trend is exaggerated somewhat in later years by so-called fuel-tourism. In 2011 it is estimated that approximately 9 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<sub>2</sub> from *1.A.1 Energy Industries* increased by 5.7 per cent, further adding to the increase in CO<sub>2</sub> emissions over the 1990-2011 period. In addition, even though Ireland has only a small number of energy intensive industries, CO<sub>2</sub> emissions from combustion in the industrial sector *1.A.2 Manufacturing Industries and Construction* increased by 5.9 per cent between 1990 and 2011.

Methane is the second most significant contributor to greenhouse gas emissions in Ireland which is due to the large population of cattle. In 2011 emissions of CH<sub>4</sub> were 11,628.82 Gg CO<sub>2</sub> equivalent, indicating a decrease of 15 per cent on the 1990 level of 13,674.13 Gg CO<sub>2</sub> equivalent. Emissions of CH<sub>4</sub> increased progressively from 1990, reaching a peak in 1998 of 14,418.62 Gg CO<sub>2</sub> 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<sub>4</sub> emissions decreased as a result of falling livestock numbers due to reform of the Common Agricultural Policy (CAP). However, total CH<sub>4</sub> emissions in the period 2001-2011 fluctuated to some extent on a yearly basis. This trend is a direct result of fluctuating CH<sub>4</sub> emissions from *1.A.4 Other Sectors* and *1.B.Fugitive Emissions from Fuels*. The main contributor to the CH<sub>4</sub> trend has been Agriculture and in 2011 the sector accounted for 90.9 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 emissions from Agriculture decreased by 12.8 per cent between 1990 (11,927.75 Gg CO<sub>2</sub> equivalent) and 2011 (10,571.44 Gg CO<sub>2</sub> equivalent). Another significant source of methane emissions is Waste sector, especially from landfill gas in category *6.A Solid Waste Disposal on Land*. CH<sub>4</sub> emissions from Waste decreased from 8.7 per cent share of total methane emissions (1,173.05 Gg CO<sub>2</sub> equivalent) in 1990 to 7.3 per cent share (847.17 Gg CO<sub>2</sub> equivalent) in 2011. 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<sub>2</sub>O decreased by 19.6 per cent from their 1990 level of 9,112.03 Gg CO<sub>2</sub> equivalent in 1990 to 7,619.08 Gg CO<sub>2</sub> equivalent in 2011. Similar to CH<sub>4</sub>, emissions of N<sub>2</sub>O increased during the 1990s to reach peak level of 10,302.81 Gg CO<sub>2</sub> 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<sub>2</sub>O 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 93.4 per cent share of the total N<sub>2</sub>O emissions (7,119.72 Gg CO<sub>2</sub> equivalent) in 2011. This reflects an increase from 84.6 per cent share (7,706.22 Gg CO<sub>2</sub> equivalent) in 1990 despite being a lower absolute number. Emissions from processes in chemical industry used to be the second largest contributor to the trend contributing 11.4 per cent to total N<sub>2</sub>O emissions in 1990 and an average of 8.6 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 4.6 per cent and 1.4 per cent respectively to the rest of the N<sub>2</sub>O trend.

Emissions of the F-gases (HFCs, PFCs and SF<sub>6</sub>) were 600.10 Gg CO<sub>2</sub> equivalent in 2011 compared to 36.91 Gg CO<sub>2</sub> equivalent in 1990, a 16 fold increase over the time series. However F-gas emissions only account for approximately one 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.2 Foam Blowing* is also an important component of the trend. Emissions from HFCs increased from 1.31 Gg CO<sub>2</sub> equivalent in 1990 reaching 548.66 Gg CO<sub>2</sub> equivalent in 2006 and has remained at this level for the remainder of the time series (538.61 Gg CO<sub>2</sub> in 2011).

Emissions of PFCs show an increasing trend from 0.09 Gg CO<sub>2</sub> equivalent in 1990 up to 130.82 Gg CO<sub>2</sub> 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<sub>2</sub> 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 2011 (13.20 Gg CO<sub>2</sub> equivalent in 2011).

SF<sub>6</sub> is used in a diverse number of 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<sub>6</sub> were 35.51 Gg CO<sub>2</sub> equivalent and 48.29 Gg CO<sub>2</sub> equivalent in 1990 and 2011, respectively. However, emissions of SF<sub>6</sub> peaked in 1997 at 132.20 Gg CO<sub>2</sub> equivalent following a steady increase in emissions from 1990. The increase over the period 1990-1997 was largely due to increased use of the gas in *2.F.7 Semiconductor Manufacture* and *2.F.8 Electrical Equipment*. Similar to PFCs, semiconductor manufacturers have undertaken to reduce the use of SF<sub>6</sub> through gas substitution and new process technologies. In *2.F.8 Electrical Equipment*, where SF<sub>6</sub> is used for electrical insulation, arc quenching and current interruption, a leak reduction programme has been in place since 1997.

## 2.3 Trends by IPCC Sector

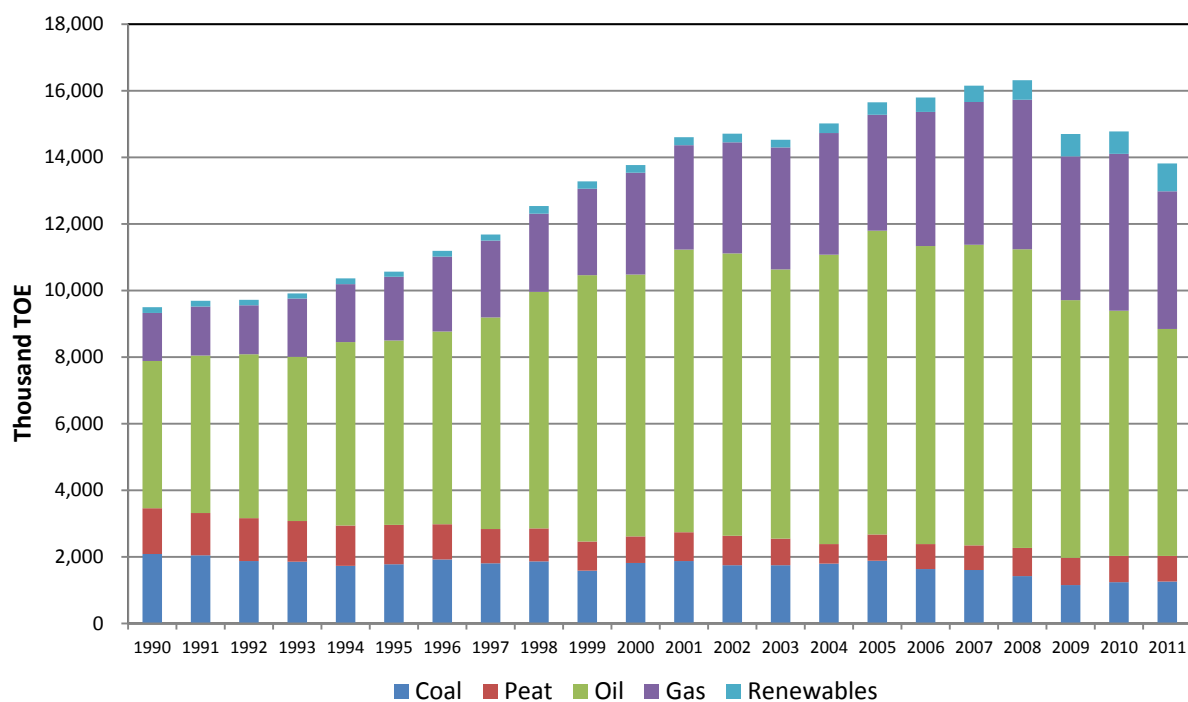
Greenhouse gas emissions broken down by IPCC sector are presented in Table 2.1 (b). It can be seen that the largest contribution is from the *Energy* sector, which in 2011 contributes 64.2 per cent of total greenhouse gas emissions (excluding *LULUCF*). The second largest sector is *Agriculture*, which accounted for 30.8 per cent of total greenhouse gas emissions in

2011. Emissions from *Industrial Processes*, *Waste* and *Solvent and Other Product Use* accounted for 3.1 per cent, 1.8 per cent and 0.1 per cent, respectively of total emissions in 2011. 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.

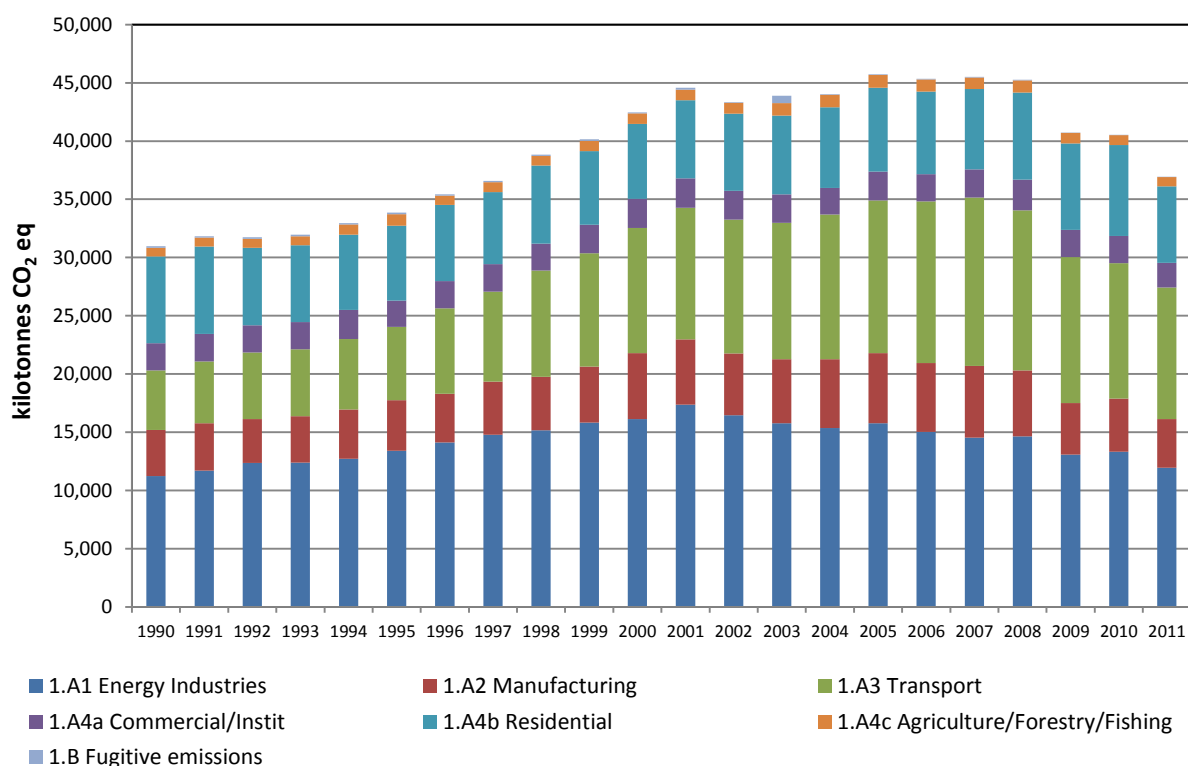
### 2.3.1 Trends in Energy (IPCC Sector 1)

Emissions from the *Energy* sector increased by 19.3 per cent from 30,970.47 Gg CO<sub>2</sub> equivalent in 1990 to 36,938.87 Gg CO<sub>2</sub> equivalent in 2011. 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 45,732.42 Gg CO<sub>2</sub> equivalent. A major decrease occurred between 2008 and 2009 when the sectoral emissions fell by 10.0 per cent and continued decreasing by further 9.3 per cent to 36,938.87 Gg CO<sub>2</sub> equivalent in 2011.

*1.A.1 Energy Industries* accounted for 20.3 per cent and 20.7 per cent of total national greenhouse gas emissions in 1990 and 2011, respectively. Total greenhouse gas emissions from this sub-sector increased by 54.5 per cent from 11,238.54 CO<sub>2</sub> equivalent in 1990 to 17,364.19 CO<sub>2</sub> 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<sub>2</sub> equivalent in 2004. Emissions subsequently increased in 2005 to 15,770.30 Gg CO<sub>2</sub> 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 15,028.57 Gg CO<sub>2</sub> 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 (14,535.37 Gg CO<sub>2</sub> equivalent) are largely a result of the displacement of oil by natural gas. In 2008, emissions increased by 0.8 per cent or 117.54 Gg CO<sub>2</sub> equivalent to 14,652.91 Gg CO<sub>2</sub> equivalent, then decreased in 2009 by 10.8 per cent to 13,077.67 Gg CO<sub>2</sub> 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 13,333.36 Gg CO<sub>2</sub> equivalent which reflects a reduction in the share of renewables in gross electricity consumption from 14.3 per cent in 2009 to 12.9% in 2010. Wind and hydro resources were less in 2010 which resulted in more electricity generation from coal and gas-fired power stations. In 2011, gross electricity consumption fell and the share of renewables increased to 19.4 per cent resulting in a reduction from *Energy Industries* of 10.6 per cent to 11,924.48 Gg CO<sub>2</sub> equivalent. These combined factors led to an overall decrease in emissions from the *Energy* sector of 8.9 per cent. 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) 1990-2011**



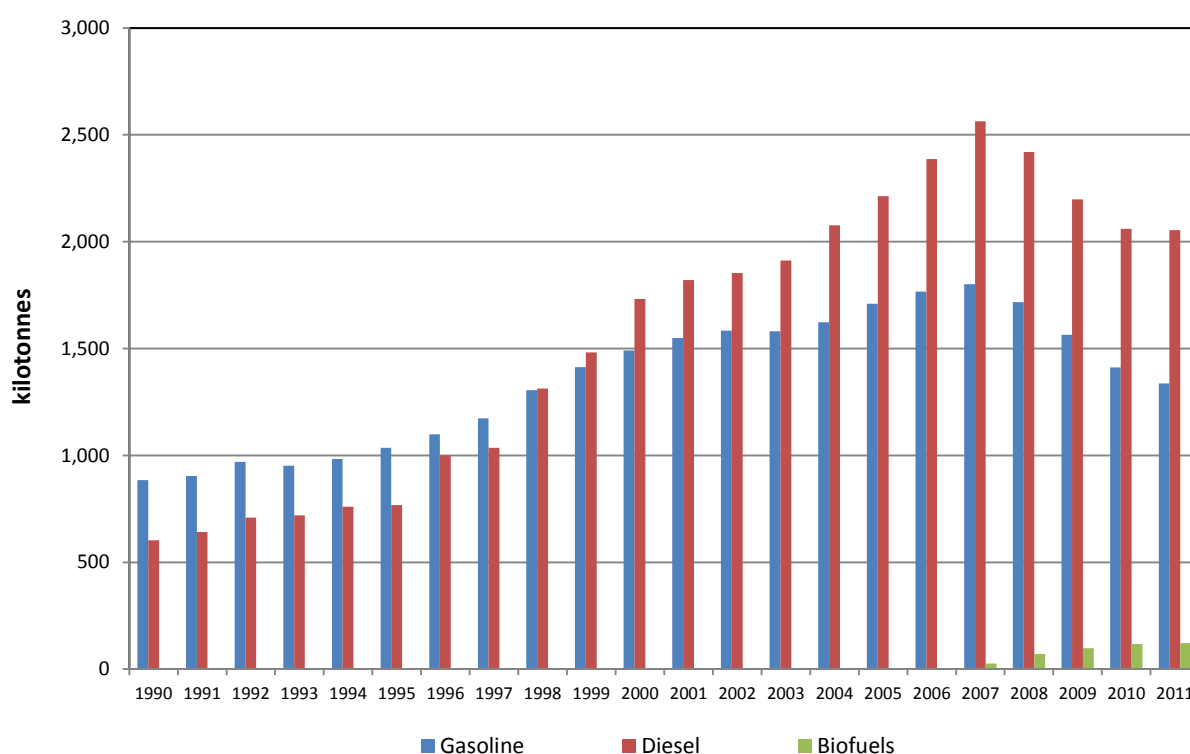
**Figure 2.3 Trend in Emissions from Energy 1990-2011**

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<sub>2</sub> equivalent) and 7.3 per cent (4,196.25 Gg CO<sub>2</sub> equivalent) of total national greenhouse gas emissions in 1990 and 2011, respectively. However, the trend

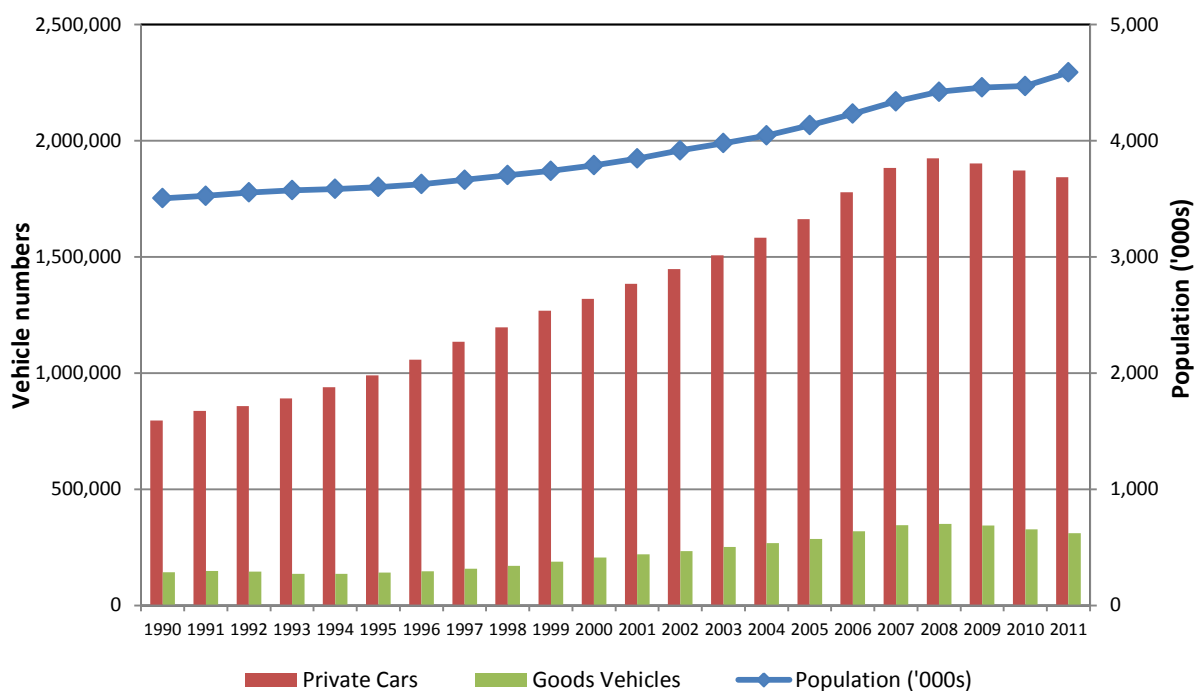
shows an increase of 5.9 per cent over the same period as a result of large increases in use of petroleum coke and natural gas in *1.A.2.F Other Industries*.

Fuel combustion emissions in *1.A.3 Transport* accounted for 9.3 per cent and 19.6 per cent of total national greenhouse gas emissions in 1990 and 2011, respectively. The overall sectors emissions increased by 120.5 per cent from 5,121.44 Gg CO<sub>2</sub> equivalent in 1990 to 11,290.44 Gg CO<sub>2</sub> equivalent in 2011. This is largely accounted for by a 126.4 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 9 per cent of automotive fuels in 2011. 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 3.19 million tonnes CO<sub>2</sub> equivalent lower in 2011 than in 2007. This represents a decrease of 22.0 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 62.6 per cent between 1990 (51.73 Gg CO<sub>2</sub> equivalent) and 2011 (19.34 Gg CO<sub>2</sub> equivalent), having peaked in 2006 at 77.31 Gg CO<sub>2</sub> equivalent. However, their overall effect on transport emission trends is negligible.



**Figure 2.4 Fuel use in Road Transport 1990-2011**



**Figure 2.5 Vehicle numbers and Census of Population 1990-2011**

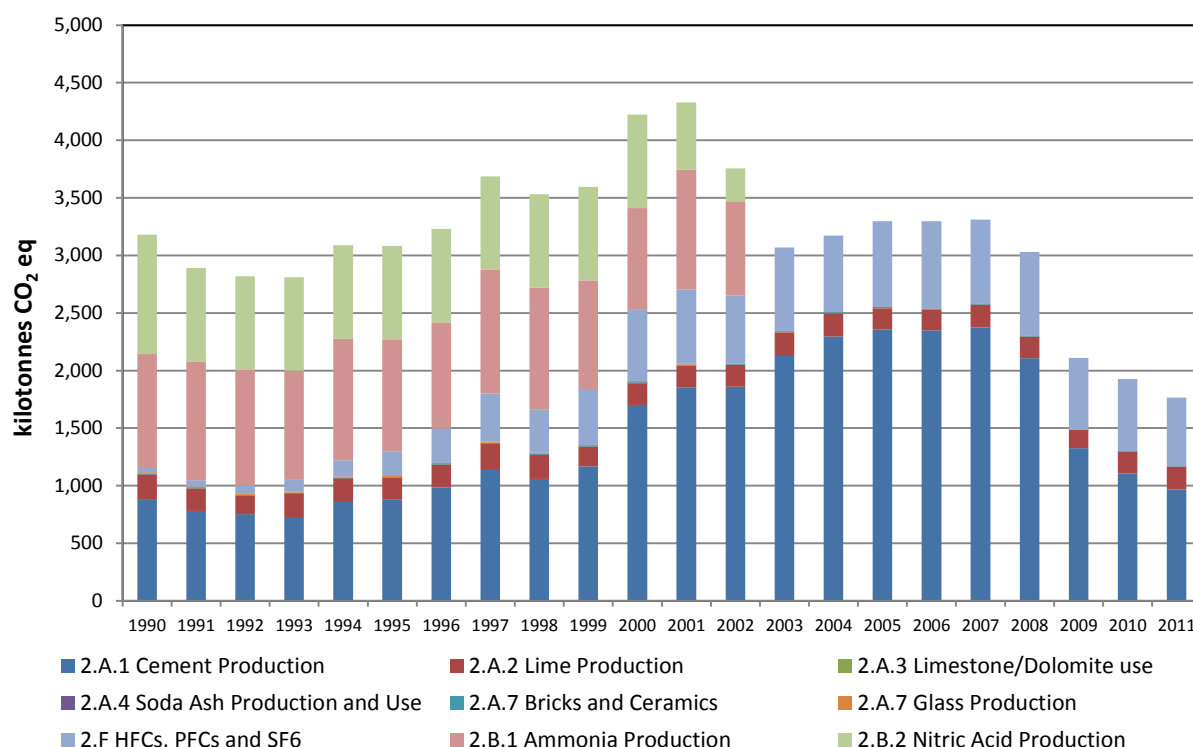
Emissions from category *1.A.4 Other Sectors* decreased by 9.8 per cent from 10,518.03 Gg CO<sub>2</sub> equivalent in 1990 to 9,482.91 Gg CO<sub>2</sub> equivalent in 2011. Emissions from the Commercial (1.A.4.a), Residential (1.A.4.b) and Agriculture/Forestry/Fisheries (1.A.4.c) sub-categories decreased by 9.8, 11.5 and 1.3 per cent respectively. Although residential fossil fuel consumption increased by 11.9 per cent from 1990 to 2011 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<sub>2</sub> from coal and peat use in the residential sector decreased by 61.8 per cent between 1990 and 2011 while those from oil and natural gas increased by 216.7 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 3.1 per cent in 2011. Total emissions from the sector were 3,179.27 Gg CO<sub>2</sub> equivalent in 1990 and 1,767.37 Gg CO<sub>2</sub> equivalent in 2011. This is a decrease of 44.4 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 63.0 per cent. By the late 1990's (1995 to 1999) this proportion had fallen to 52.9 per cent on average of total emissions from the sector. In 1990 emissions from *2.B. Chemical Industry* were 2,025.63 Gg CO<sub>2</sub> equivalent, however by 2000 they had reduced by 16.3 per cent to 1,694.75 Gg CO<sub>2</sub> equivalent. 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<sub>2</sub> in 1990 to 1,700.90 Gg CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>, bringing the level of emissions in 2011 similar to those pre-1996.



**Figure 2.6 Trend in Emissions from Industrial Processes 1990-2011**

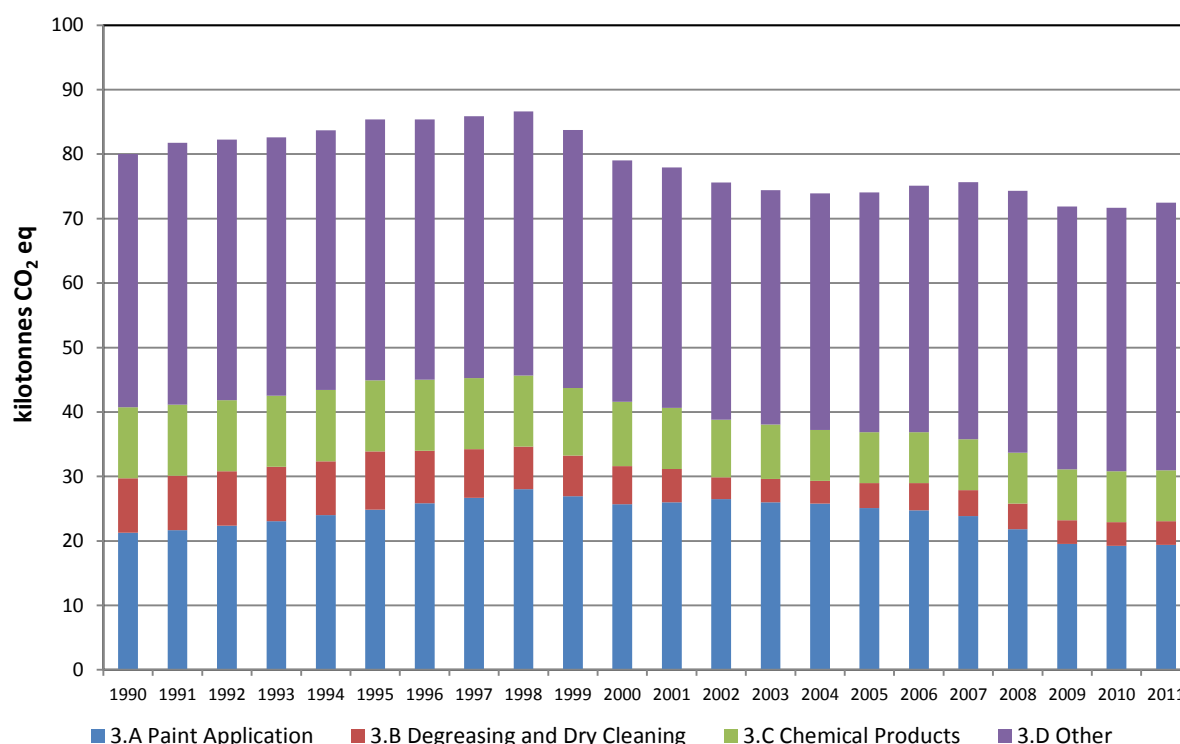
The closure of Ireland's ammonia and nitric acid plants in 2003 and 2002 significantly changed the level of process emissions in Ireland. As a result CO<sub>2</sub> emissions from cement production (2.A.1) became the single major component of sector emissions and these emissions increased steadily during the period of economic growth up to 2007, the year when they reached a peak of 2,374.06 Gg CO<sub>2</sub> equivalent. Emissions from cement manufacture decreased in line with the economic downturn since 2007, accounting for 69.5, 62.8, 57.3 and 54.7 per cent of total emissions from *Industrial Processes* in 2008, 2009, 2010 and 2011, respectively. 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 11.4 per cent of total sector emissions in 2011. 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<sub>6</sub>* were estimated to be 600.10 Gg CO<sub>2</sub> equivalent in 2011, compared to 36.91 Gg CO<sub>2</sub> equivalent in 1990. This represents a 16 fold increase over the time series with the result that the contribution of this category to the sectoral total for *Industrial Processes* increased from 1.2 per cent in 1990 to 34.0 per cent in 2011 as that from cement production decreased.

### 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 2011 do not affect the overall trend in greenhouse gases in Ireland. The CO<sub>2</sub> emissions from this source were estimated to be 80.03 Gg CO<sub>2</sub> equivalent in 1990 and 72.49 Gg CO<sub>2</sub> equivalent in 2011, a decrease of 9.4

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 57.3 per cent of total sectoral emissions in 1990 and 2011, respectively. The contribution of sub-category, *3.A Paint Application*, to overall emissions from the sector grew slightly from 26.6 per cent in 1990 to 26.9 per cent share. 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 5.1 per cent and 10.9 per cent, respectively of total overall emissions in the sector in 2011. The emissions from both sub-categories show a downward trend over the time-series 1990-2011: 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 1990-2011**

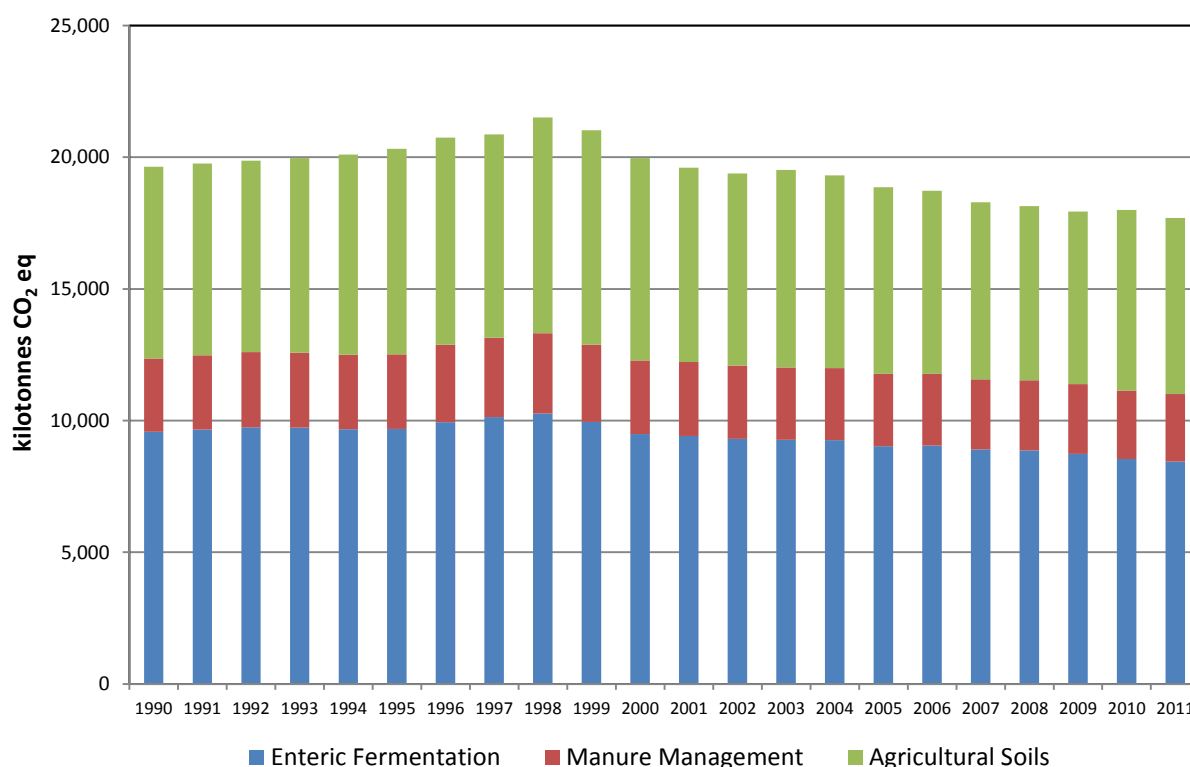
### 2.3.4 Trends in Agriculture (IPCC Sector 4)

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 19,633.98 Gg CO<sub>2</sub> equivalent in 1990 and 17,691.16 Gg CO<sub>2</sub> equivalent in 2011, a reduction of 9.9 per cent. The emissions from *Agriculture* decreased by 0.3 million tonnes (1.2 per cent) in 2011. 2010 and 2011 saw a substantial increase in nitrous oxide emissions due to increased fertiliser sales (up 18 and 13 per cent on 2009, respectively). This increase in nitrous oxide emissions was offset by the continuing decline in total cattle and sheep numbers in 2011 while swine numbers have increased relative to 2009 levels. Total emissions from the *Agriculture* sector increased by 9.6 per cent from 1990 to 1998, reflecting an increase in animal numbers and increased synthetic nitrogen use on farms. Following this peak in emission levels of 21,512.82 Gg CO<sub>2</sub> equivalent in 1998, emissions from the sector decreased by 17.8 per cent to 17,691.16 Gg CO<sub>2</sub> 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.

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<sub>4</sub> from enteric fermentation and manure management expressed in CO<sub>2</sub> equivalents was 11,927.75 Gg in 1990. This increased by 7.4 per cent to reach 12,806.51 Gg CO<sub>2</sub> equivalent in 1998 and subsequently decreased by 17.5 per cent to 10,571.44 Gg CO<sub>2</sub> equivalent in 2011. Cattle account for 88.7 per cent of CH<sub>4</sub> emissions in Irish agriculture in 2011.

The emissions of N<sub>2</sub>O from the Agriculture sector follow similar trends to those of CH<sub>4</sub> 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<sub>2</sub>O emissions (93.9 per cent of the sector N<sub>2</sub>O emissions in 2011). Nitrous oxide emissions in the sector increased from 7,706.22 Gg CO<sub>2</sub> equivalent in 1990 by 13.0 per cent in the period 1990-1998 with emissions in 1998 totalling 8,706.32 Gg CO<sub>2</sub> equivalent. Nitrous oxide emissions totalling 7,119.72 CO<sub>2</sub> equivalent in 2011 represent a reduction of 18.2 per cent on the 1998 level and 7.6 per cent on the 1990 level. Crops contribute very little to N<sub>2</sub>O 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 1990-2011**

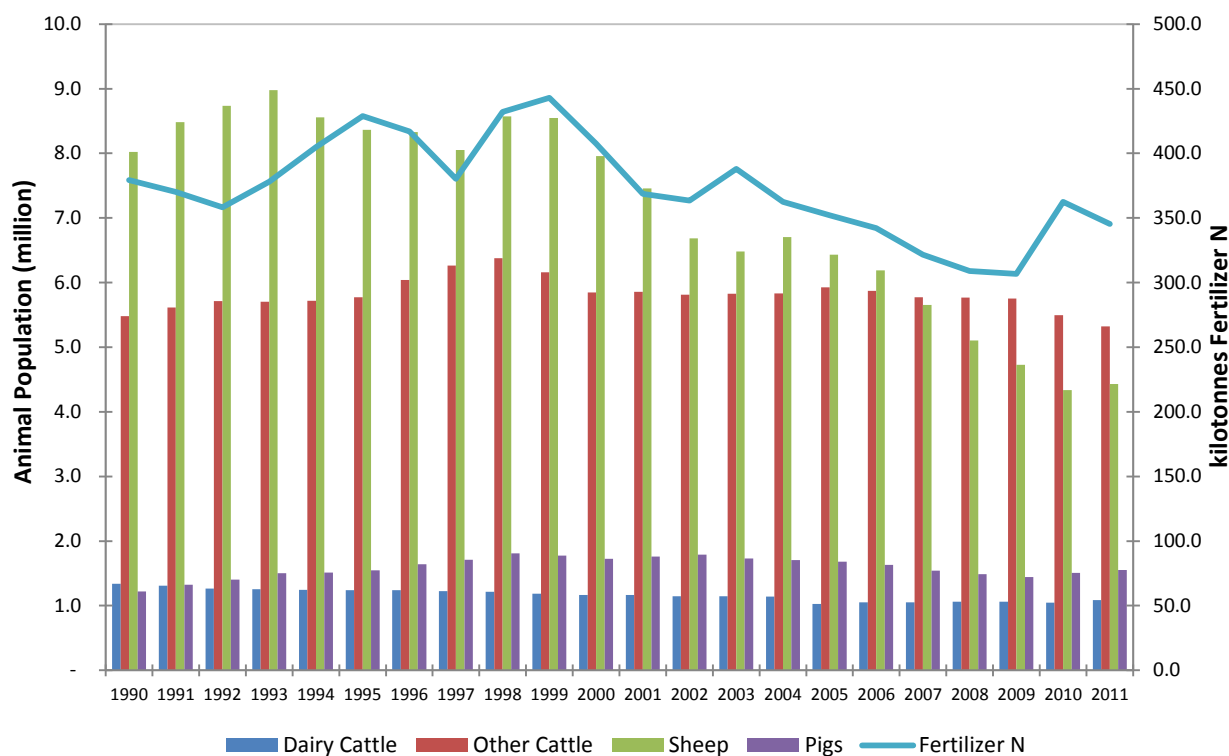
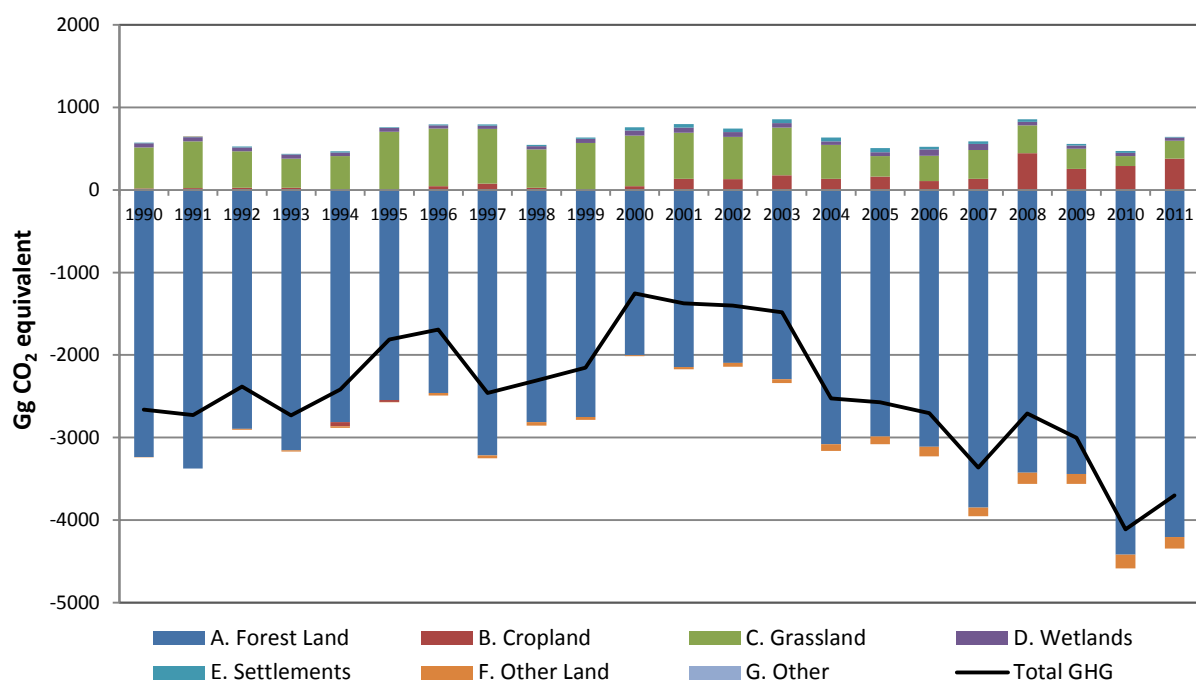


Figure 2.9 Principal Drivers of Emissions from Agriculture 1990-2011

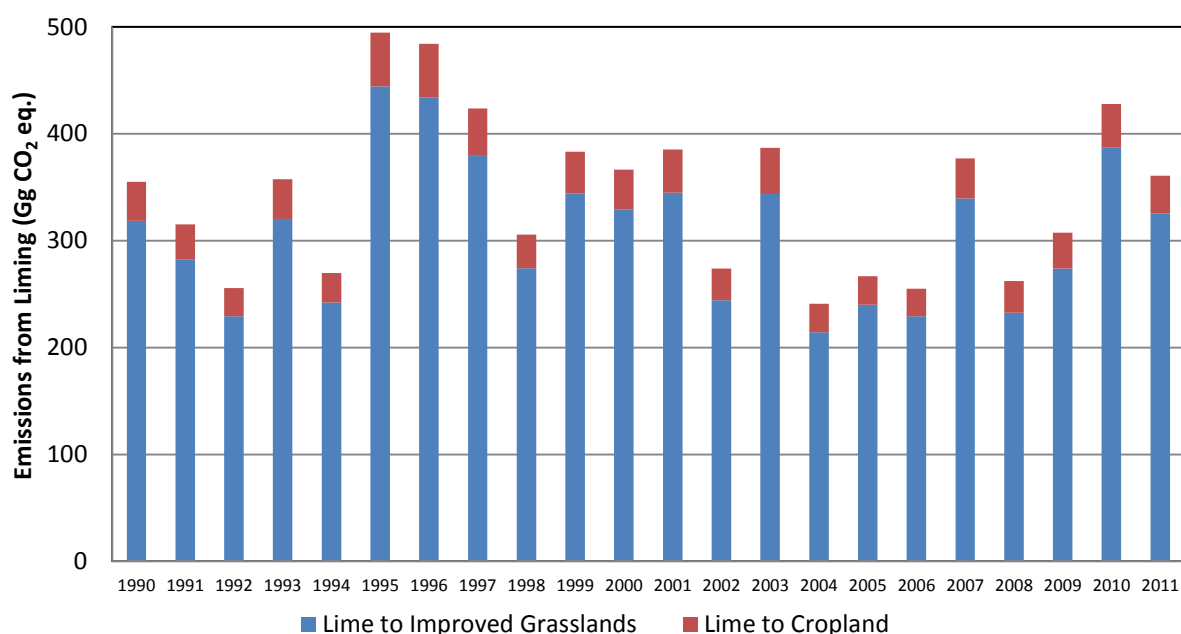
### 2.3.5 Trends in Land Use, Land Use Change and Forestry (IPCC Sector 5)

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<sub>2</sub>. 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<sub>2</sub> 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<sub>2</sub>, as can be seen in as can be seen 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- 2011.

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<sub>2</sub> 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 2009-2011 compared to the earlier time series.



**Figure 2.10 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2011**



**Figure 2.11 Trend in Emissions from Liming on Grasslands and Cropland 1990-2011**

### 2.3.6 Trends in Waste (IPCC Sector 6)

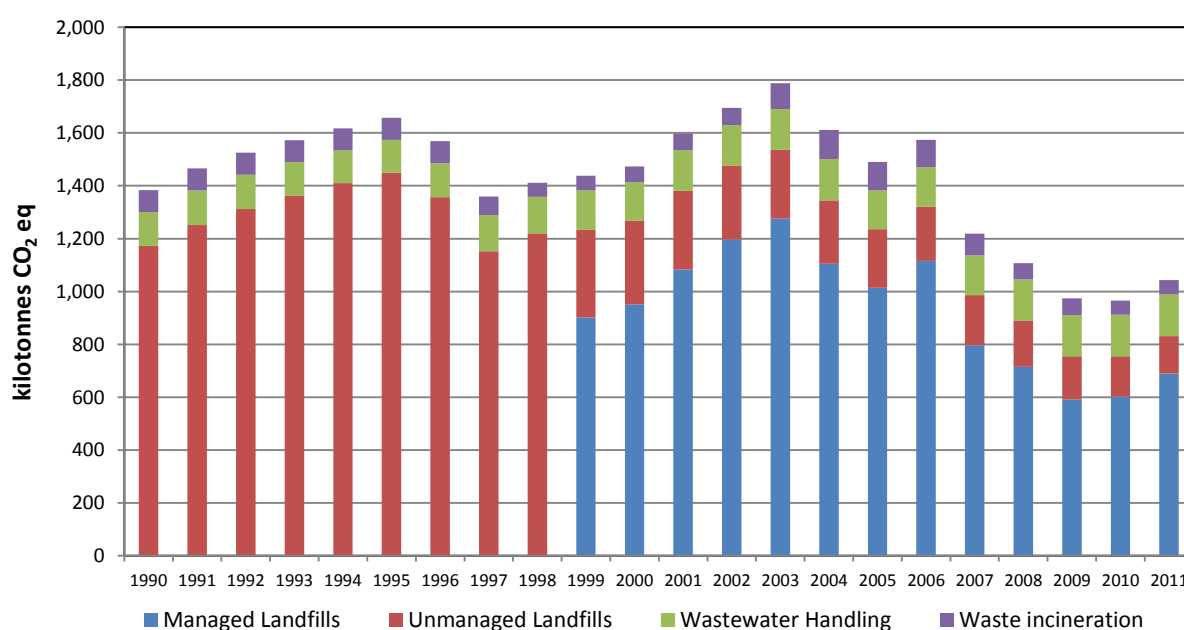
The *Waste* sector remains an important source of CH<sub>4</sub> emissions (Figure 2.12) due to the continued dominance of landfills as a means of solid waste disposal in Ireland. Emissions from the waste sector increased by 29.2 per cent from 1,383.32 Gg CO<sub>2</sub> equivalent in 1990 to 1,787.87 Gg CO<sub>2</sub> equivalent in 2003 (peak) and then decreased by 41.7 per cent to 1,042.58 Gg CO<sub>2</sub> equivalent in 2011. Overall, emissions in the *Waste* sector have decreased by 24.6 per cent from 1990 to 2011. The main contributor to trends in the *Waste* sector is the CH<sub>4</sub> 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 30.9 per cent by 2011, 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 37.3 per cent between 2007 and 2011 to 1.32 million tonnes. The proportion of organic materials in MSW has decreased from 39 per cent in 1990 to 35.6 per cent in 2011. The proportions of paper and textiles changed from 31 per cent and 10 per cent, respectively in 1990 to 21.9 per cent and 6.3 per cent, respectively in 2011, reflecting a significant diversion of paper products from landfills. This reduces CH<sub>4</sub> 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<sub>4</sub> generated. This offset from flares and utilisation was 67.2 per cent in 2011, hence there was 12.5 fold increase in flaring and utilisation since 1996 (9.1 per cent first year of methane recovery).

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from *6.B Wastewater Handling* accounted for 126.43 Gg CO<sub>2</sub> equivalent in 1990 and 157.68 Gg CO<sub>2</sub> equivalent in 2011 (24.7 per cent increase on 1990), which equates to 9.1 and 15.1 per cent of total emissions from the waste sector, respectively. The contribution of this sub-category to overall sectoral trends is negligible.

This submission now includes emissions from *6.C Waste Incineration* for the first time 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 1990-2011. Emissions from *6.C Waste Incineration* accounted for 83.84 Gg CO<sub>2</sub> equivalent in 1990 and 54.06 Gg CO<sub>2</sub> equivalent in 2011 (35.5 per cent decrease on 1990) which equates to 6.1 and 5.2 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 1990-2011*

## 2.4 Emissions of Indirect Greenhouse Gases

The total emissions of SO<sub>2</sub>, NO<sub>x</sub>, NMVOC and CO for the years 1990 to 2011 are summarised in Table 2.2 and Figure 2.13. As in the case of CO<sub>2</sub>, the emissions of SO<sub>2</sub>, NO<sub>x</sub> 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. Substantial decreases have occurred in the emissions of SO<sub>2</sub> (87.2 per cent) and CO (68.6 per cent). Significant reductions have also taken place in NMVOC emissions (48.4 per cent) and emissions of NO<sub>x</sub> in 2011 were 42.8 per cent lower than those in 1990.

*Table 2.2. Emissions of NO<sub>x</sub>, SO<sub>2</sub>, NMVOC and CO 1990-2011 (Tonnes)*

	NO <sub>x</sub>	SO <sub>2</sub>	NMVOC	CO
1990	121,799.36	182,250.42	84,245.58	400,410.28
1991	124,172.95	180,612.74	85,153.28	402,189.92
1992	133,573.44	169,116.43	85,498.45	390,485.74
1993	123,806.53	160,120.88	82,279.05	358,297.55
1994	122,303.02	174,951.77	80,593.55	335,451.84
1995	121,730.27	160,866.50	78,844.92	312,763.46
1996	126,083.42	148,645.60	83,200.48	318,951.67
1997	126,129.87	166,078.79	82,546.10	303,678.77
1998	130,710.98	177,312.65	83,771.95	313,294.48
1999	130,572.74	158,614.13	75,742.02	278,184.54
2000	134,194.90	139,453.65	69,930.67	250,943.20
2001	136,391.57	134,113.35	67,728.72	240,193.68
2002	127,302.47	101,216.96	63,012.96	221,022.55
2003	126,335.31	79,071.22	60,374.97	209,396.46
2004	127,013.46	71,686.88	57,433.88	199,602.87
2005	126,579.88	71,051.14	55,617.41	189,488.64
2006	121,932.03	61,140.23	54,403.73	180,904.51
2007	119,396.69	55,349.63	52,647.49	169,397.04
2008	108,057.44	45,440.86	50,160.32	156,721.27
2009	85,880.68	32,350.33	47,264.93	149,849.75
2010	78,072.97	26,130.38	44,975.83	138,119.89
2011	69,623.08	23,314.56	43,464.31	125,712.57

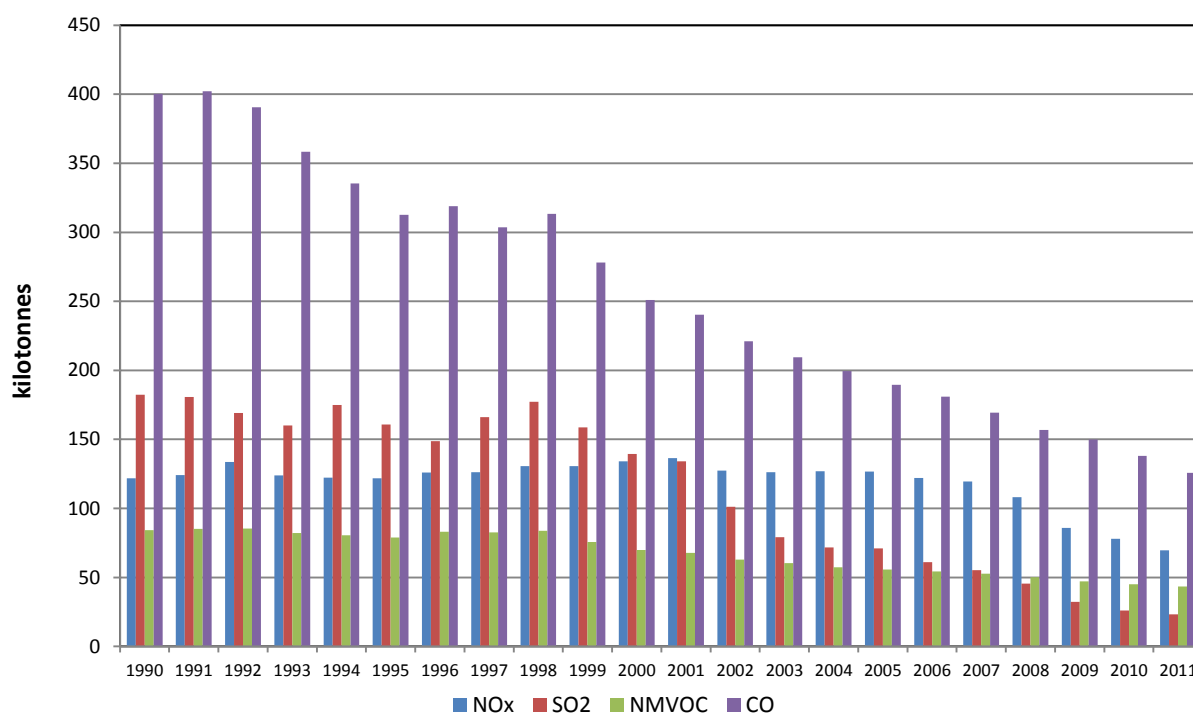
Total SO<sub>2</sub> emissions decreased from 182,250 tonnes in 1990 to 23,315 tonnes in 2011. This decrease in emissions reflects the economic downturn, reductions in the sulphur content of fuels, fuel switching and use of abatement technologies. Power stations were the principal source of SO<sub>2</sub> emissions up to 2009 after which the commercial/residential (1.A.4.a, 1.A.4.b) sectors contributed a comparable amount to the total emissions (37.4 per cent compared to 40.1 per cent from power stations in 2011). Combustion sources in the industrial (1.A.2) sector largely account for the remainder of emissions, with a contribution of 16.3 per cent in 2011. In 1990, coal combustion accounted for 51.6 per cent of SO<sub>2</sub> emissions and fuel oil contributed 30.8 per cent. By 2011, the share of SO<sub>2</sub> emissions from coal had increased to 51.9 per cent and that from fuel oil had decreased to 12.9 per cent.

Road transport is the principal source of NO<sub>x</sub> emissions, contributing approximately 49.6 per cent of the total in 2011. The power generation sector is the other main source of NO<sub>x</sub> emissions, accounting for 11.4 per cent of emissions in 2011. The reductions in NO<sub>x</sub> 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 70.6 per cent of the 2011 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<sub>x</sub>, 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<sub>2</sub>, NO<sub>x</sub> 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 1990-2011*



## Chapter Three

### Energy

#### 3.1 Overview of Energy Sector

The *Energy* source category covers all combustion sources of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 2011 remain largely as described in the 2012 NIR except for the inclusion of emission estimates from waste to energy MSW incinerator reported in Energy Industries (1.A.1.a) and also Residential burning of charcoal for cooking (1.A.4.b) for the first time. As for all years since 2005, CO<sub>2</sub> estimates reported under the EU Emissions Trading Scheme (ETS) for 2011 are used to achieve complete bottom-up results in respect of some important sub-categories in this sector for the 2011 inventory. 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 (64.2 per cent) of greenhouse gas emissions in Ireland in 2011, with CO<sub>2</sub> 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 32.4 per cent, 11.4 per cent, 30.6 per cent and 25.7 per cent respectively to the sector total in 2011. 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.1 of Annex C shows the national energy balance sheets for 2011, 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 2011 example indicates the same form of expanded balance sheet as previously used for all years from 1990 to 2010. 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 1990-2011 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.1 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. The relevant activity data are represented by the disaggregated entries below TPER (Total Primary Energy Requirement) in Table C.1 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<sub>2</sub> 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.1 of Annex C. The application of the Sectoral Approach and the Reference Approach is now described with reference to 2011 data and their results are then compared for CO<sub>2</sub>, 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**

<b>1 Energy</b>	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>
<i>A. Fuel Combustion</i>			
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
<i>B. Fugitive Emissions from Fuels</i>			
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<sub>2</sub> emissions in most countries. In Ireland, emissions of CO<sub>2</sub> from fuel combustion contributed to 63.2 per cent of total emissions in 2011. The CO<sub>2</sub> 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<sub>2</sub> released on combustion can therefore be readily ascertained. Only small amounts of CH<sub>4</sub> and N<sub>2</sub>O are associated with fuel combustion activities. The emissions of these gases are generally not quantified with the same reliability as the emissions of CO<sub>2</sub> because the rates of CH<sub>4</sub> and N<sub>2</sub>O 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.1 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 2011 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<sub>2</sub> 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. The CO<sub>2</sub> 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 93.1 per cent of the total in 2011. The CO<sub>2</sub> 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 2011.

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<sub>2</sub> emissions and emission factors that is now fully utilised for the national inventory compilation. The fuel combustion CO<sub>2</sub> 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<sub>2</sub> emissions. Default CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> emissions and fuel combustion in 2011 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O emissions using the appropriate IPCC emission factors mentioned in the previous section.

The CO<sub>2</sub> emissions for sub-category 1.A.1.a obtained from AEIRs 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<sub>2</sub> emissions compiled in the ETS database according to fuel type for all installations that constituted sub-category 1.A.1.a in 2011 are aggregated to report the CO<sub>2</sub> 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 for the first time in 2011, 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emission estimates received from the ETS participants, along with the emissions of CH<sub>4</sub> and N<sub>2</sub>O 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.

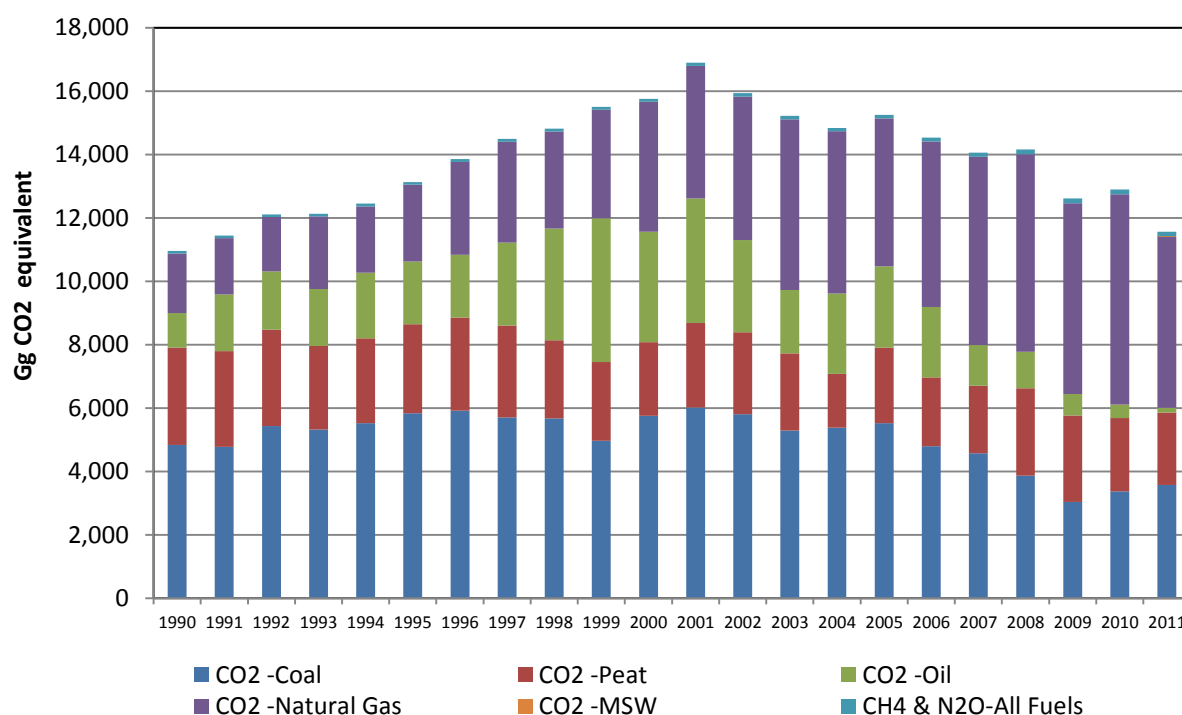
Figure 3.1 shows the trend in emissions from 1.A.1.a Public Electricity and Heat Production over the period 1990-2011, which account for 96.8 per cent of the total for category 1.A.1. The emissions from this sub-category in 2011 at 11,562.68 Gg CO<sub>2</sub> eq, show a substantial decrease of 10.4 per cent on the 2010 emissions (12,901.42 Gg CO<sub>2</sub> eq) due to a considerable increase in electricity generated by renewable wind energy replacing electricity generated by natural gas.

One small oil refinery accounts for the emissions reported under 1.A.1.b Petroleum Refining. The emissions from this category in 2011 at 285.42 Gg CO<sub>2</sub> eq. also show a decrease of 8.1 per cent on the 2010 emissions (310.46 Gg CO<sub>2</sub> eq.). The reported CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O emissions are estimated by the inventory agency using the IPCC default emission factors. Because high-pressure gas, low-pressure gas and residual fuel oil 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 2011 at 93.39 Gg CO<sub>2</sub> eq. show a substantial decrease of 23.1 per cent on the 2010 emissions (121.48 Gg CO<sub>2</sub> eq.). The 2011 values for CO<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O 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 2011 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<sub>2</sub> 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 1990-2011**

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

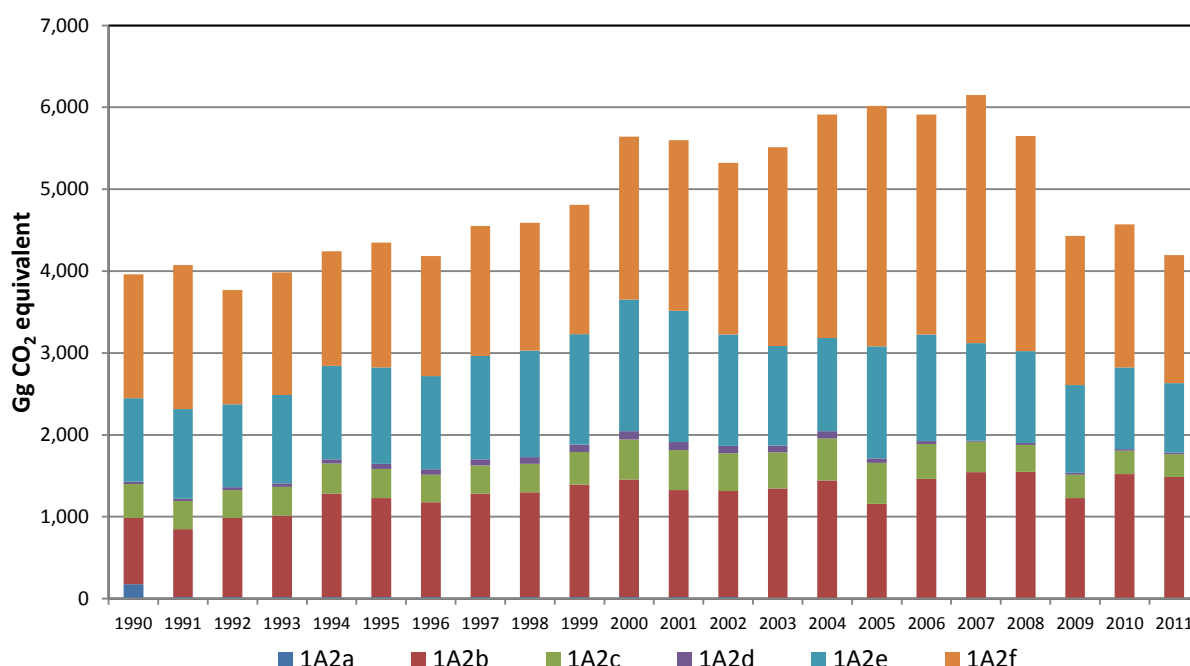
The revised and expanded annual energy balance sheets published by SEAI incorporate a mapping of industrial fuel use in combustion into the CRF sub-categories a-f under 1.A.2 Manufacturing Industries and Construction. This facilitates the complete disaggregation of emissions in this source category for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

The combustion CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> emission factor for petroleum coke since 2005. Petroleum coke is used

in sub-categories 1.A.2.b, e and f. The IPCC default emission factor of 97.5 t CO<sub>2</sub>/TJ compares well with the year specific emission factors which vary from 92.93 to 95.13 CO<sub>2</sub>/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 categories 1.A.2.e and 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<sub>2</sub>/TJ in 2001. However the implied emission factor in 2011 is 70.76 t CO<sub>2</sub>/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<sub>2</sub>/TJ in 1990 to 81.51 t CO<sub>2</sub>/TJ in 2007, but then decreases substantially to 74.70 t CO<sub>2</sub>/TJ in 2011 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 1990-2011. The emissions from this category in 2011 show an 8.2 per cent decrease on the 2010 emissions, continuing a large decrease between 2008 and 2009 of 21.6 per cent reflecting the impact of the recent economic downturn in Ireland particularly in the cement production sector. Decreases in 2011 are primarily from sub-categories 1.A.2.e Food Processing and 1.A.2.f Other industries (cement production) with an annual decrease of 10.9 per cent and 10.4 per cent, respectively between 2010 and 2011.



**Figure 3.2 Emissions from 1.A.2 Manufacturing Industries and Construction 1990-2011**

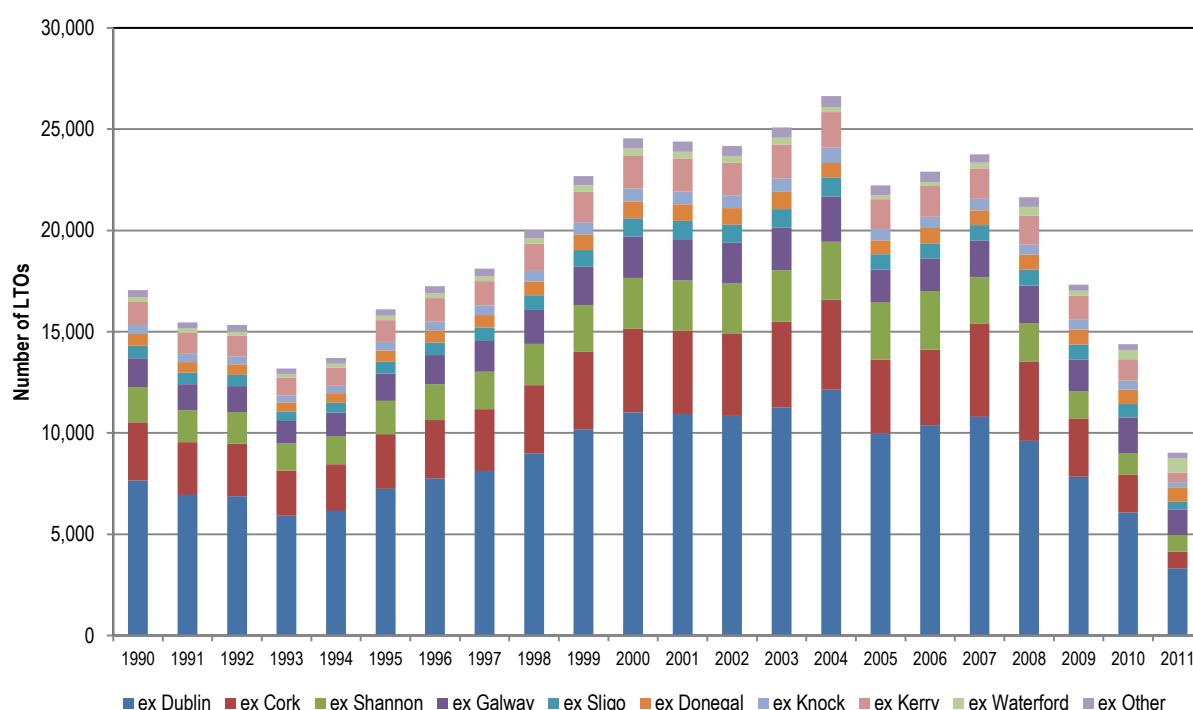
### 3.2.1.3 Transport (1.A.3)

#### 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 2011 where airport pair data are available. This is the second 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 2012 for the year 2011. This data is fully consistent with data received from the IAA in 2011 for all years from 2004 to 2010. 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 of 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 3.3 Number of LTOs from Irish airports 1990-2011**

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<sub>4</sub> and N<sub>2</sub>O by aircraft type. CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O emissions from road traffic are estimated in the COPERT 4v.9.1 model (Gkatzoflias et al., 2011), 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 of N<sub>2</sub>O emissions for the years 1993 to 1998, on average over 200 per cent increase, and smaller increases for the years 1999 to 2006, on average a 27 per cent increase. This recalculation is due to a revision in the COPERT model software between version 8.0 and 9.1 that affects primarily gasoline passenger cars (EURO I technology). This explains the relatively small revisions to the years preceding 1993 and the years post 2006 when the number of these vehicles in use is small or not occurring. Tables 3.5 and 3.8 show the impact of recalculations for N<sub>2</sub>O. However, because emissions of CH<sub>4</sub> and N<sub>2</sub>O are considerably smaller than CO<sub>2</sub>, the impact on the total for 1.A.3.b Road Transportation sector is small.

The COPERT 4v.9.1 model estimates emissions of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O emissions estimates. The resultant 2011 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.

### 3.2.1.3.3 Railways and Navigation (1.A.3.c) and (1.A.3.d)

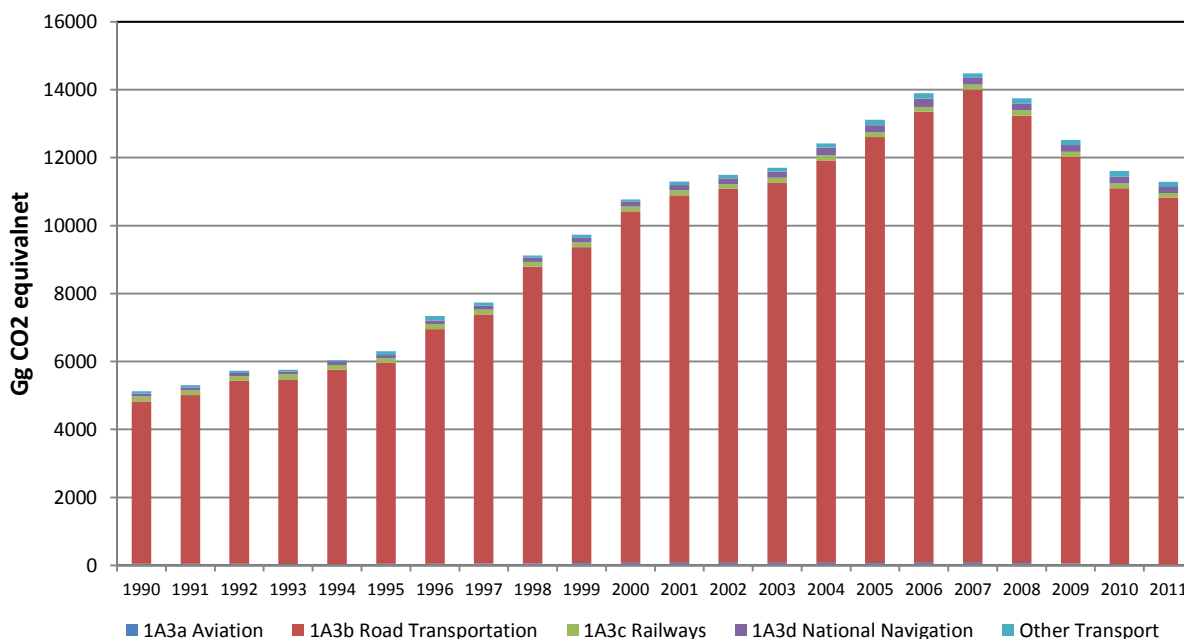
The CO<sub>2</sub> emissions under 1.A.3.c Railways and 1.A.3.d Navigation are calculated from the amount of oil used by these activities as recorded in the energy balance and the country specific emission factors for oil. The emissions of CH<sub>4</sub> and N<sub>2</sub>O are estimated using the IPCC 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 <sub>2</sub> t/TJ	Reference	CH <sub>4</sub> kg/TJ	N <sub>2</sub> O 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<sub>2</sub> and the default values for CH<sub>4</sub> and N<sub>2</sub>O referred to in section 3.2.1 are used.

Figure 3.4 shows the trend in emissions from 1.A.3 Transport over the period 1990-2011. Road transport accounts for 95.7 per cent of the sectoral emissions in 2011. Overall Transport emissions increased by 182.8 per cent between 1990 (5,121.44 Gg CO<sub>2</sub> equivalent) and 2007 (14,481.79 Gg CO<sub>2</sub> equivalent) and since declined by 22.0 per cent by 2011 (11,290.44 Gg CO<sub>2</sub> equivalent), reflecting the impact of the recent economic downturn in Ireland.



*Figure 3.4 Emissions from 1.A.3 Transport 1990-2011*

### 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 69.5 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 1990-2011. 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 this sector decreased from 2010 to 2011 by 13.7 per cent which is attributed to milder than normal winter months with the largest sub-category, residential, decreasing by 15.6 per cent.

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<sub>2</sub>, including that for petroleum coke referred to in section 3.2.1.2, and IPCC default values for CH<sub>4</sub> and N<sub>2</sub>O. 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<sub>2</sub>, but it is important in relation to CH<sub>4</sub> or N<sub>2</sub>O 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.

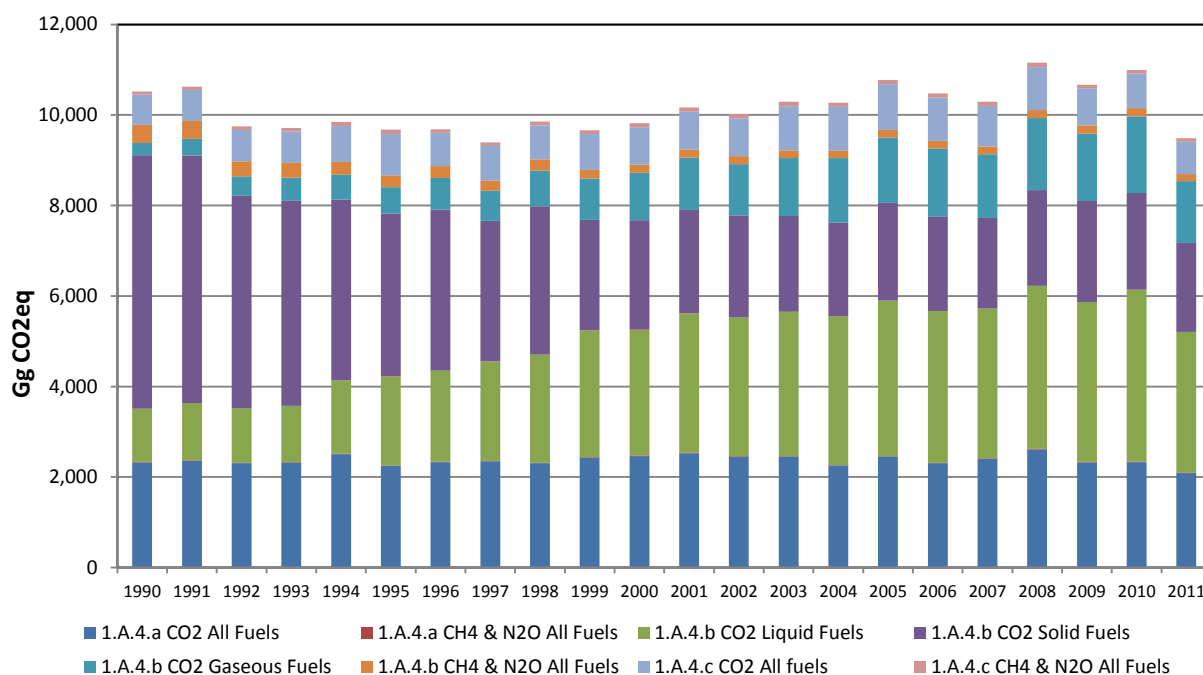
Emissions from charcoal used for cooking are now reported in sub-category 1.A.4.b for all years for the first time in this submission following the identification of a potential problem raised by the ERT in the 2012 GHG annual expert review. The quantity of charcoal used in Ireland was provided by the 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 <sub>2</sub> t/TJ	Reference	CH <sub>4</sub> kg/TJ	N <sub>2</sub> O 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 <sub>2</sub>	111,833	2006 IPCC Guidelines Table 1.3 Chapter 1
Residential	Charcoal	CH <sub>4</sub>	200	2006 IPCC Guidelines Table 2.5 Chapter 2 1996 IPCC Guidelines Table 1-7 Vol III
Residential	Charcoal	N <sub>2</sub> O	1	2006 IPCC Guidelines Table 2.5 Chapter 2 1996 IPCC Guidelines Table 1-8 Vol III



**Figure 3.5 Emissions from 1.A.4 Other Sectors 1990-2011**

### 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 they will soon come into production.

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 1990-2011 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<sub>2</sub> and CH<sub>4</sub> 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 2011.

### 3.3 IPCC Reference Approach for CO<sub>2</sub> Emissions from Energy Use

The IPCC Reference Approach is a top-down methodology for CO<sub>2</sub> 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<sub>2</sub> emissions from fuel combustion activities. The calculation sheet for the Reference Approach (Table 1.A (b) of the 2011 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<sub>2</sub> 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<sub>2</sub> 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 2011 are very minor, indicating that in the Reference Approach, energy use and CO<sub>2</sub> emissions were 0.98 per cent and 0.79 per cent higher 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 2011.

### 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<sub>2</sub> 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<sub>2</sub> from biomass combustion are not included in national totals of greenhouse gases because it is assumed that an equivalent amount of CO<sub>2</sub> 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub>, 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 above, from total jet kerosene fuel sales compiled by SEAI. In 2011, 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<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O respectively, have been used to estimate emissions.

### 3.6 Quality Assurance and Quality Control

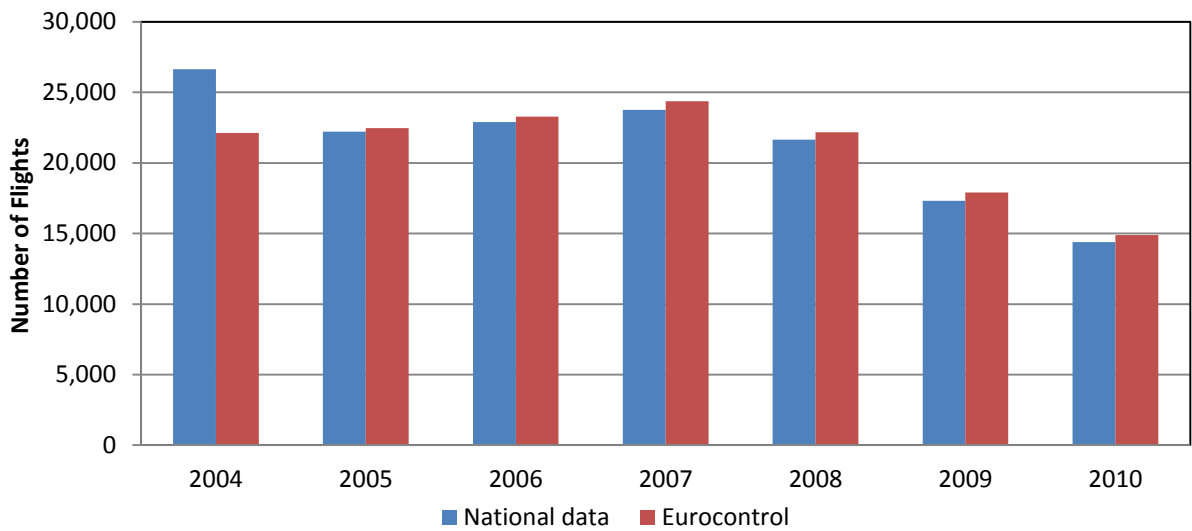
Extensive QA/QC procedures have again been followed for the Energy sector during the present reporting cycle by fully implementing the plan that underpins Ireland's formal national system. The inventory agency continues to apply a system of quality control checks

and documentation spreadsheets 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.

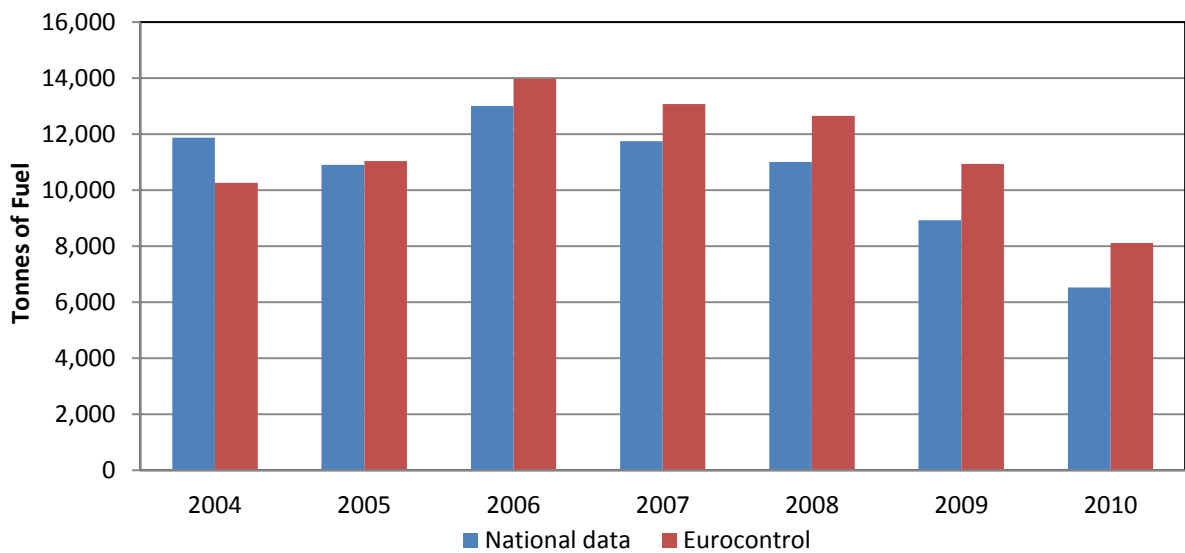
The quality checks at inventory level build on the extensive upgrading and quality control of energy balances completed by SEAI in recent years. This work, together with further collaboration with inventory experts and thorough evaluation of the SEAI role in relation to the national system and QA/QC procedures, has resulted in substantial improvements that are now taken into account in the emissions for Energy for the years 1990 through 2011 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 Change and Environmental Research Programme (CCERP) of the EPA, which acts as the competent authority for the ETS in Ireland. Following receipt of the raw ETS data from CCERP, the inventory experts allocate the CO<sub>2</sub> estimates and corresponding energy amounts to the appropriate sub-categories for CRF reporting and then return the compilation to the CCERP 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<sub>2</sub> values are transferred directly to the national inventory and consistency of results is guaranteed. In the case where the CO<sub>2</sub> 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.

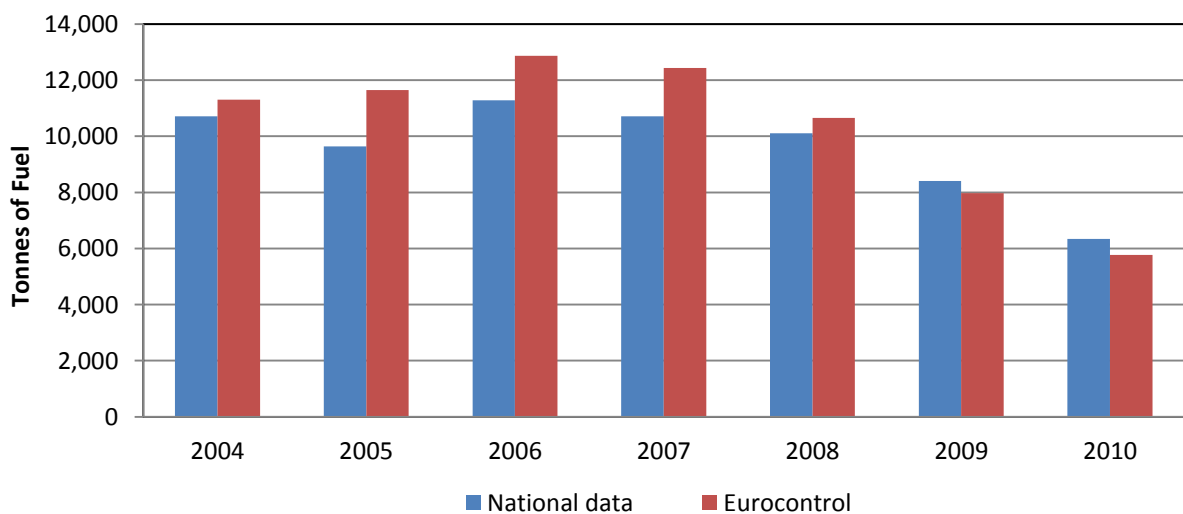
The inventory agency completed a verification exercise comparing civil aviation flight and LTO fuel estimates for 2004 to 2010 using data sourced from Eurocontrol through the EU's Working Group 1 of the Climate Change Committee and national data. The verification exercise showed close agreement between 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 3.6 National LTO data and Eurocontrol LTO data for 2004-2010*



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



*Figure 3.8 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 1990-2010 to account for the following revisions and improvements:

### 1.A.1 Energy Industries

- Biomass use in sub-category 1.A.1.a is now disaggregated into 3 fuels; Landfill Gas (LFG), Wood and from 2011, Municipal Solid Waste (MSW). There is no change in emissions due to this revised split;
- A revision to energy data in sub-category 1.A.1.b for 2010 onwards as a result of natural gas consumption being included in this sector for the first time.

The impact has been to increase total Energy Industries GHG emissions by 0.04 per cent in 2010 and refinery sub-category emissions by 1.7 per cent.

### 1.A.2 Manufacturing Industries and Construction

- Revisions to sub-categories in 1.A.2.a to f, were a result of natural gas reallocation within the sub-categories of this sector from 1990 to 1999;
- Sub-category 1.A.2.d emissions decreased ranging from 63 per cent in 1991 to 2.6 per cent in 1999 and
- Sub-category 1.A.2.f emissions increased by 1.8 per cent in 1991 to 1.1 per cent in 1999.

Overall, any changes to emissions from this sector were minor with emissions in 2010 increasing by 0.44 per cent.

### 1.A.3 Transport

- Revisions to the road transport, 1.A.3.b sub-category are mainly due to methodological change of implementing the most recent COPERT 4 model (version 9.1), replacing version 8.0. Specifically, this has increased emissions of N<sub>2</sub>O and CH<sub>4</sub> from passenger cars between 1993 and 1998;
- A minor revision to energy data has led to a small decrease in CO<sub>2</sub> emissions from LPG and diesel fuels;
- The sub-category *other transport* (1.A.3.e) now includes biomass use from *Railways*. The CRF Reporter tool does not allow the addition of biomass under the sub-category for *Railways*, 1.A.3.c. This is only included in the latest year 2011.

The total impact of these revisions on the transport sector is an increase in total GHG emissions of 0.8 per cent in 1990 and a 0.02 per cent reduction in 2010. The impact is more significant when looking at the individual GHGs, where the percentage increases in 1998 for N<sub>2</sub>O and CH<sub>4</sub> are 281 per cent and 3.6 per cent respectively. The revised estimates due to the COPERT model change are clearly shown in Tables 3.7 and 3.8.

### 1.A.4 Other Sectors

Revised fuel data, in particular, gasoil (in all 3 sub-categories 1.A.4.a-c), natural gas in 1.A.4.a and coal in 1.A.4.b has led to small recalculations for these sub-categories across the time-series.

- The largest recalculations in commercial/institutional (1.A.4.a) occurred in 2007, an increase in emissions of 0.7 per cent;
- The largest recalculations in residential (1.A.4.b) occurred in 2009, an increase in emissions of 0.3 per cent;

- The largest recalculations in agriculture/forestry/fisheries (1.A.4.c) occurred in 2007, an increase in emissions of 1.0 per cent.

This submission also includes the use of Charcoal in the residential sector 1.A.4.b, for cooking, following the recommendation from the previous annual inventory review in September 2012.

#### *1.C.1.B International Bunkers*

Emissions of CH<sub>4</sub> and N<sub>2</sub>O have been estimated for the first time, following a recommendation from a previous annual inventory review, in Marine Bunkers (1.C.1.B) for all years from 1990 to 2011.

### **3.8 Improvements in Energy**

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

- Disaggregating biomass fuel used in Public Electricity and Heat Production 1.A.1.a into Landfill Gas (LFG), Wood and Municipal Solid Waste (MSW);
- Including emissions from the newly commissioned waste to energy plant in Public Electricity and Heat Production 1.A.1.a;
- Revising the road transport model used to estimate CH<sub>4</sub> and N<sub>2</sub>O emissions from COPERT 4 version 8.0 to COPERT 4 version 9.1;
- Including emissions from charcoal used for cooking in the Residential sub-category 1.A.4.b for all years following the potential problem raised in the annual inventory review in 2012;
- Estimating emissions of CH<sub>4</sub> and N<sub>2</sub>O from Marine Bunkers 1.C.1 for all years following a recommendation from a previous annual inventory review.

### **3.9 Planned Improvements in Energy**

The changes referred to above for 2011 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<sub>2</sub> 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 2011 submission. No substantial changes are foreseen for inventory submissions relating to the last year of the Kyoto Protocol commitment period 2008-2012 other than responding to the annual review processes under the UNFCCC and the EU and updating the road transport model version as made available by the developers. It is planned to use COPERT 4 version 10.0, or a revised update, for the 2014 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
Estimates in 2012 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	13,328.09
1.A.2.	Manuf Ind and Constn	3,961.19	4,073.89	3,768.28	3,986.23	4,242.17	4,347.14	4,182.16	4,549.95	4,588.91	4,809.73	5,641.70	5,598.68	5,322.37	5,514.42	5,911.40	6,019.11	5,910.29	6,147.33	5,648.66	4,430.12	4,549.04
1.A.3.	Transport	5,117.54	5,297.80	5,715.46	5,684.58	5,910.35	6,170.97	7,154.56	7,484.37	8,776.45	9,695.80	10,730.34	11,259.60	11,453.46	11,663.80	12,387.18	13,080.58	13,865.79	14,478.47	13,742.71	12,525.92	11,605.54
1.A.4.	Other Sectors	10,517.87	10,627.05	9,747.64	9,713.44	9,845.18	9,677.75	9,684.11	9,397.53	9,853.95	9,664.92	9,817.29	10,161.68	10,018.02	10,291.16	10,268.86	10,775.65	10,477.06	10,258.39	11,155.16	10,648.61	10,995.97
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
1	Total	30,966.23	31,825.13	31,717.83	31,884.60	32,832.41	33,711.44	35,251.51	36,319.65	38,478.64	40,082.09	42,414.87	44,475.85	43,316.59	43,857.27	44,002.11	45,702.21	45,328.57	45,479.15	45,250.69	40,717.57	40,509.98
Recalculated 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
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
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
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
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
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	40,118.30	42,457.80	44,513.18	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
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	
1.A.2.	Manuf Ind and Constn	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	-0.01	-0.01	0.44
1.A.3.	Transport	0.08	0.14	0.21	1.27	2.15	2.16	2.53	3.40	3.90	0.37	0.37	0.33	0.33	0.28	0.26	0.23	0.19	0.02	0.01	-0.01	-0.02
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.32	-0.02	0.18	-0.02
1.B.	Fugitive Emissions	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
1	Total	0.01	0.02	0.04	0.23	0.39	0.40	0.51	0.70	0.89	0.09	0.10	0.08	0.09	0.08	0.07	0.07	0.06	0.08	0.00	0.04	0.05

**Table 3.6. Percentage Change in CO<sub>2</sub> 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
<b>Estimates in 2012 Submission (Gg CO<sub>2</sub>eq)</b>																					
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	13,170.78
1.A.2. Manuf Ind and Constn	3,942.64	4,055.14	3,752.29	3,969.39	4,225.46	4,329.84	4,163.94	4,531.23	4,568.93	4,789.35	5,617.89	5,573.79	5,298.41	5,489.40	5,884.02	5,988.24	5,881.05	6,118.58	5,622.18	4,407.59	4,525.74
1.A.3. Transport	5,022.04	5,200.81	5,613.48	5,578.38	5,798.96	6,053.41	7,023.33	7,343.52	8,617.28	9,532.89	10,561.04	11,082.23	11,280.19	11,492.64	12,212.97	12,906.25	13,688.87	14,287.75	13,595.84	12,386.77	11,475.61
1.A.4. Other Sectors	10,030.97	10,146.40	9,325.52	9,299.73	9,457.57	9,304.86	9,330.70	9,072.96	9,516.40	9,377.72	9,527.65	9,878.68	9,737.54	10,017.45	10,002.13	10,494.46	10,205.13	9,996.04	10,871.42	10,371.66	10,725.20
1.B. Fugitive Emissions	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
1 Total	30,154.26	31,019.69	30,971.03	31,145.09	32,116.26	33,005.59	34,549.83	35,640.57	37,783.14	39,432.94	41,756.95	43,801.26	42,661.99	42,643.25	43,364.34	45,046.23	44,682.03	44,809.00	44,584.88	40,092.13	39,897.33
<b>Recalculated Estimates in 2013 Submission (Gg CO<sub>2</sub>eq)</b>																					
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
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
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
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
1.B. Fugitive Emissions	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
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	39,432.97	41,760.44	43,798.78	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
<b>Percentage Change in CO<sub>2</sub> Emissions due to Recalculations</b>																					
1.A.1. Energy Industries	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	0.04
1.A.2. Manuf Ind and Constn	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	-0.01	-0.01	0.44
1.A.3. Transport	-0.01	-0.02	0.02	-0.02	0.02	0.01	0.00	0.02	0.01	-0.01	0.01	-0.02	0.00	-0.01	-0.01	0.00	0.00	0.00	-0.01	-0.03	-0.04
1.A.4. Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.31	-0.02	0.18	0.00
1.B. Fugitive Emissions	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
1 Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.07	-0.01	0.04	0.05

**Table 3.7. Percentage Change in CH<sub>4</sub> 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
<b>Estimates in 2012 Submission (Gg CO<sub>2</sub>eq)</b>																					
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
1.A.2. Manuf Ind and Constr	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	8.88	8.15	7.02	7.30
1.A.3. Transport	36.29	37.41	40.27	36.48	34.95	37.58	38.70	37.42	38.31	37.72	35.08	33.72	30.68	28.89	27.47	26.14	25.15	23.95	22.30	20.35	18.25
1.A.4. Other Sectors	378.85	370.28	315.41	307.15	272.07	246.31	245.80	216.09	228.55	176.38	175.92	168.06	165.45	157.23	154.20	161.18	156.74	152.92	164.16	171.85	168.40
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
1 Total	557.39	546.29	488.86	476.51	435.98	409.69	407.52	372.30	372.63	317.86	312.29	310.56	281.39	828.45	263.51	261.07	245.15	252.89	251.95	240.36	231.12
<b>Recalculated Estimates in 2013 Submission (Gg CO<sub>2</sub>eq)</b>																					
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
1.A.2. Manuf Ind and Constr	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
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
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
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
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
<b>Percentage Change in CH<sub>4</sub> Emissions due to Recalculations</b>																					
1.A.1. Energy Industries	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
1.A.2. Manuf Ind and Constr	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	0.19	0.16	-0.47	0.60
1.A.3. Transport	2.73	1.82	2.33	2.79	3.06	2.97	3.61	3.46	3.61	4.04	4.73	5.15	5.21	5.95	6.28	5.99	6.19	6.66	6.42	6.30	6.08
1.A.4. Other Sectors	0.01	0.01	0.01	0.02	0.00	0.03	0.03	0.00	0.05	0.00	0.07	0.21	0.07	0.03	0.04	0.06	0.09	0.34	-0.16	0.58	-0.90
1.B. Fugitive Emissions	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
1 Total	0.19	0.13	0.20	0.23	0.25	0.29	0.36	0.35	0.40	0.48	0.57	0.67	0.61	0.21	0.68	0.64	0.69	0.84	0.47	0.93	-0.16

**Table 3.8. Percentage Change in N<sub>2</sub>O 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
<b>Estimates in 2012 Submission (Gg CO<sub>2</sub>eq)</b>																					
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	151.49
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	19.87	18.33	15.51	16.00
1.A.3. Transport	59.21	59.59	61.71	69.73	76.45	79.98	92.53	103.43	120.86	125.19	134.23	143.65	142.59	142.27	146.74	148.20	151.77	166.77	124.57	118.80	111.67
1.A.4. Other Sectors	108.05	110.37	106.70	106.56	115.53	126.58	107.61	108.48	109.00	110.82	113.72	114.94	115.03	116.48	112.53	120.01	115.20	109.42	119.58	105.11	102.37
1.B. Fugitive Emissions	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
1 Total	254.58	259.15	257.94	263.00	280.17	296.16	294.16	306.78	322.87	331.29	345.63	364.04	373.21	385.58	374.26	394.90	401.39	417.26	413.86	385.07	381.53
<b>Recalculated Estimates in 2013 Submission (Gg CO<sub>2</sub>eq)</b>																					
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
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
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
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
1.B. Fugitive Emissions	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
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
<b>Percentage Change in N<sub>2</sub>O Emissions due to Recalculations</b>																					
1.A.1. Energy Industries	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
1.A.2. Manuf Ind and Constn	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	0.20	0.13	-0.42	0.60
1.A.3. Transport	5.49	12.89	16.10	103.76	163.31	164.48	193.94	243.52	281.34	27.68	28.04	26.24	25.39	23.10	21.24	19.14	16.61	1.02	0.98	0.74	0.61
1.A.4. Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.01	1.05	-0.11	-0.01	-0.29
1.B. Fugitive Emissions	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
1 Total	1.28	2.96	3.85	27.51	44.56	44.42	61.00	82.10	105.32	10.46	10.89	10.36	9.70	8.52	8.33	7.18	6.28	0.69	0.27	0.21	0.13



## 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<sub>2</sub> or adipic acid production in the case of N<sub>2</sub>O, 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<sub>2</sub> 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 1990-2011.

The process CO<sub>2</sub> 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<sub>2</sub> 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<sub>6</sub> 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<sub>6</sub>*. Actual emissions are only required in source categories *2.C Metal Production* and *2.E Production of Halocarbons and SF<sub>6</sub>*. There is no production of halocarbons or SF<sub>6</sub> in Ireland and therefore source category *2.F Consumption of Halocarbons and SF<sub>6</sub>* is the only relevant source category of HFC, PFC and SF<sub>6</sub> emissions in the country. All relevant sub-categories are fully covered in Ireland's inventories (Table 4.1), as described below.

Table 4.2 presents the estimates of greenhouse gas emissions for *Industrial Processes* over the period 1990-2011 for the relevant sources in Ireland. They indicate contributions of 5.8

per cent and 3.1 per cent to total national emissions in 1990 and 2011, 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<sub>6</sub> to the total emissions for *Industrial Processes* remains small and highly variable from year to year. Emissions of HFC show a steady increase up to 2006, with more constant emissions from 2006 onwards. This trend is primarily due to the steady growth in emissions from air conditioning and refrigeration. Since 2006 emissions of HFC have shown a fluctuating trend as a result of fluctuations in the use of different refrigerants.

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.

Emissions of SF<sub>6</sub> are dominated by semiconductor manufacture, and remain variable from year to year. A summary of the emissions from the Industrial Processes sector is given in Table 4.2 for the period 1990-2011.

**Table 4.1. Level 3 Source Category Coverage for Industrial Processes**

<b>2. Industrial Processes</b>	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>HFC</b>	<b>PFC</b>	<b>SF<sub>6</sub></b>
<b>A. Mineral Products</b>						
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>B. Chemical Industry</b>						
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
<b>C. Metal Production</b>						
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 <sub>6</sub> Use in Aluminium and Magnesium Foundries	NA	NA	NA	NA	NA	NO
5. Other	NO	NO	NO	NO	NO	NO
<b>D. Other Production</b>						
1. Pulp and Paper	NA	NA	NA	NA	NA	NA
2. Food and Drink	NE	NA	NA	NA	NA	NA
<b>E. Production of Halocarbons and SF<sub>6</sub></b>						
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 <sub>6</sub>						
1. Refrigeration and Air Conditioning Equipment	NA	NA	NA	All	All	All
2. Foam Blowing	NA	NA	NA	All	All	All
3. Fire Extinguishers	NA	NA	NA	All	All	All
4. Aerosols/ Metered Dose Inhalers	NA	NA	NA	All	All	All
5. Solvents	NA	NA	NA	NO	NO	NO
6. Semiconductor Manufacture	NA	NA	NA	All	All	All
7. Electrical Equipment	NA	NA	NA	NO	NO	All
8. 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 1990-2011**

	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
2.A.1 Cement Production	CO <sub>2</sub>	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
2.A.2 Lime Production	CO <sub>2</sub>	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
2.A.3 Limestone & Dolomite Use	CO <sub>2</sub>	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
2.A.4 Soda Ash Production & Use	CO <sub>2</sub>	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
2.A.7 Glass Production	CO <sub>2</sub>	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
2.A.7 Other Mineral Products	CO <sub>2</sub>	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
2.B.1 Ammonia Production*	CO <sub>2</sub>	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	0.30	NO	NO	NO	NO	NO	NO	NO	NO
2.B.2 Nitric Acid Production*	N <sub>2</sub> O	kt CO <sub>2</sub> 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
Emissions of HFC	HFC	Gg CO <sub>2</sub> eq	1.31	7.11	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
Emissions of PFC	PFC	Gg CO <sub>2</sub> 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
Emissions of SF <sub>6</sub>	SF <sub>6</sub>	Gg CO <sub>2</sub> 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	68.7	101.6	62.9	65.5	56.7	38.2	34.5	48.3
Total Industrial Processes			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

## 4.2 Emissions from Mineral Products (2.A)

The IPCC Level 3 emission source categories relevant under 2.A *Mineral Products* in 2011 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<sub>2</sub> emissions from these activities amounted to 1,167.27 Gg, in 2011 of which cement production accounted for 82.8 per cent.

### 4.2.1 Cement Production (2.A.1)

During the cement manufacturing process, calcium carbonate in the cement kiln feed (typically CaCO<sub>3</sub> in limestone) undergoes calcination at high temperature to produce lime (CaO) and CO<sub>2</sub>. The activated lime that results from this process combines with silica in the kiln feed to form cement clinker. The emissions of CO<sub>2</sub> are usually calculated from the amount of clinker produced and the stoichiometric ratio of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions and corresponding clinker production data are also available for all cement plants for the years 2004 through 2011 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<sub>2</sub> estimates in accordance with Decision 2004/156/EC. Total process emissions for cement production in 2011 were 966.27 Gg CO<sub>2</sub>. The plant-specific emission factors for process CO<sub>2</sub> emissions in 2011 ranged from 0.516 to 0.536 t CO<sub>2</sub>/ t clinker with a weighted average of 0.535 t CO<sub>2</sub>/ t clinker, which is very similar to the 2010 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<sub>2</sub> emissions for cement production overall may therefore be considered consistent for the period 1990-2011. 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<sub>2</sub> from cement production have declined by 59.3 per cent since 2007, falling from a peak of 2,374.06 Gg CO<sub>2</sub> in 2007, to 966.27 Gg CO<sub>2</sub> in 2011. This is a reflection of the recent economic downturn.

#### 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<sub>2</sub> 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<sub>2</sub> emissions in *Industrial Processes*. The CO<sub>2</sub> estimates for lime production in 2011 have been obtained from the ETS returns to the EPA. The implied emission factor for aggregated lime production was 0.762 t CO<sub>2</sub>/t lime in 2011, 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<sub>2</sub>/t lime produced with an average of 0.82 t CO<sub>2</sub>/t lime. EU ETS data for the years 2005 to 2011 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 as recommended by the previous annual review report.

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

The CO<sub>2</sub> emissions reported under this category refer to those emissions associated with the use of limestone (CaCO<sub>3</sub>) 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<sub>2</sub> 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<sub>2</sub>/t limestone, which is the stoichiometric ratio of CO<sub>2</sub> to CaCO<sub>3</sub>. 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,  $\text{Na}_2\text{CO}_3$ ) 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 2005-2011 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  $\text{CO}_2$ /t soda ash, indicated by the ETS data. This approach has allowed a full 1990-2011 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 as recommended by the previous annual review report.

#### 4.2.5 Other Mineral Products (2.A.7)

The emissions of  $\text{CO}_2$  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  $\text{CO}_2$  emissions has been developed; glass production ceased in Ireland in 2009. The production of bottle glass was the major source of emissions. The  $\text{CO}_2$  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  $\text{CO}_2$ /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  $\text{CO}_2$  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  $\text{CO}_2$ /t  $\text{Na}_2\text{CO}_3$  and 0.267 t  $\text{CO}_2$ /t  $\text{K}_2\text{CO}_3$ , 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  $\text{CO}_2$  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 2005-2011 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  $\text{CO}_2$ /tonne carbonate input while the emission factor for ceramic tiles averages 0.062 tonne  $\text{CO}_2$ /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. The notation key used in CRF and Annex F are now consistent as recommended in the previous annual review report [FCCC/ARR/2011/IRL](#). 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<sub>2</sub> and N<sub>2</sub>O from ammonia (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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>/TJ, the value for indigenous natural gas, which equates to 2.3 tonne CO<sub>2</sub>/tonne natural gas. The CO<sub>2</sub> 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<sub>2</sub>O emitted during the production process. Four units at this plant produced 338,000 tonnes of nitric acid in 1990 with associated N<sub>2</sub>O 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<sub>6</sub> 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<sub>6</sub> 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 HFC, PFC and SF<sub>6</sub> were likely to be small.

In 2000, the EPA commissioned special studies on HFC, PFC and SF<sub>6</sub> 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 HFC, PFC and SF<sub>6</sub> 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 HFC, PFC and SF<sub>6</sub> 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<sub>6</sub>) 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) is used for this submission with some minor recalculations due to the availability of new data. Recalculations for HFCs, PFCs and SF<sub>6</sub> are discussed in section 4.6.

Emission estimates for 1990-2011 are shown in Table 4.3. In 2011, air conditioning (stationary and mobile combined) and refrigeration (2.F.1) account for some 56.7 per cent of the total F-gas emission. The emission estimates clearly indicate that the combined emissions of HFC, PFC and SF<sub>6</sub> 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<sub>6</sub> fluctuate significantly. This trend is determined principally by their use in the manufacture of semiconductors, 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<sub>6</sub> emissions also generally decline but with large fluctuations.

#### 4.4.2 HFC, PFC and SF<sub>6</sub> Time-Series 1990-2011

In the following sections a brief description is provided for the activities for which emissions of HFCs PFCs and SF<sub>6</sub> are estimated for the time-series 1990-2011. Total emissions of the main three F-gases reached 600.10 Gg CO<sub>2</sub> eq. in 2011 and were 4.9 per cent lower than the previous year and by 21.0 per cent lower than at their peak in 2006 (at 759.87 Gg CO<sub>2</sub> eq.). Emissions increased steadily between 1995 and 2006 mainly due to increasing emissions of HFCs from refrigeration and mobile air-conditioning and PFC and SF<sub>6</sub> emissions from the semi-conductor industry.

HFC emissions are reported from seven sources:

- 2.F.1 Refrigeration and Air-Conditioning*
- 2.F.1 Mobile Air Conditioning*
- 2.F.2 Foams*
- 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<sub>6</sub> 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*

Additional information is provided in O'Doherty and McCulloch (2002), O'Leary *et al.* (2002) and Adams *et al.* (2005). The CRF sectors *2C Metal Production*, *2E Production of Halocarbons and SF<sub>6</sub>*, *2.F.5 Solvents* and *2.F.6 Other applications using ODS substitutes* are not applicable to 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 56.7 per cent share were the largest source of total F-gases emissions in 2011. They reached the level of 340.49 Gg CO<sub>2</sub> eq. in 2011 which was 7.6 per cent lower

than in the previous year and 11.0 per cent lower than the sector's peak in 2008 at 382.56 Gg CO<sub>2</sub> eq.

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). 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 and HFC-152a. Potential emissions from the sector are calculated using a Tier 1 approach as follows:

$$\text{Potential emissions} = \text{production} + \text{import} - \text{export} - \text{destruction}$$

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. In Ireland there is no known destruction of HFCs. Recovered gas is used either in other equipment or exported for recycling or destruction.

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 sales data and information on market shares, which are applied to calculate estimates of total HFC 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 HFC 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)

HFC emissions from this sector totalled 28.41 Gg CO<sub>2</sub> eq. in 2011 and accounted for 4.7 per cent of the total emissions from F-gases. Emissions from this sector in 2011 increased by 3.2 per cent from the previous year a continuation of the rising trend in the time series.

There are two forms of foam blowing included in this sector, open-cell foam and closed-cell foam. Only closed-cell blowing is of importance in Ireland. Closed-cell foams are imported into Ireland for use in applications including packaging and furniture manufacture. Some of the products include refrigerators (insulation), insulated trucks, other insulation materials, cars, mattresses and toys as well as some packaging and cushioning foams on products. However, not all such foam has necessarily been blown with HFCs. The diverse range of products that could potentially contain HFCs makes it extremely difficult to obtain detailed reliable information for reliable emission estimates. This is acknowledged by the IPCC Good Practice Guidance, in which it is stated that where emissions occur only from imported closed-cell foam, expert judgement or international HFC/PFC production and consumption

data sets can be used to develop national emission estimates. Therefore in the estimation of emissions from this category the inventory agency uses the global sales data for closed-cell foam blowing applications from the Alternative Fluorocarbon Environmental Assessment Study (AFEAS). The HFCs for which emission estimates are made are HFC-134a, HFC-125 and HFC-143a.

The bank of HFCs present in closed-cell foam and foam products in Ireland is estimated based on Irish GDP relative to the GDP of all OECD countries. A default emission factor of 4.5 per cent of the original HFC charged per year (IPCC, 2000) is used to calculate in-life emissions. Product lifetime is estimated at 20 years, however as HFCs have only been in use since 1991 for foam blowing applications, it is assumed that there are no losses from decommissioning until and including 2011. Currently there is no specific destruction of HFCs from foam carried out in Ireland, and any goods containing HFC foams collected at local authority facilities are exported for gas recovery.

#### 4.4.2.3 Fire Extinguishers (2.F.3)

HFC emissions from this sub-category were 74.16 Gg CO<sub>2</sub> eq. in 2011 and accounted for 12.4 per cent of the total emissions from F-gases. Emissions from fire extinguishers in 2011 decreased by 13.4 per cent from the previous year a continuation of the falling trend in the time series.

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 military applications, records offices, bank vaults and oil production facilities. There are a number of companies operating these systems in Ireland. The primary HFC used is HFC-227ea with a minor quantity of HFC-23 also utilised. 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 have been provided by the industry and it is assumed that 97.5 per cent of product is HFC-227ea and the remainder is HFC-23. Estimates of annual growth factors based on a value of 12.5 per cent from 2000 are used to calculate the quantity of these HFCs in new systems. The emission calculation methodology used for this category is a Tier 3a emission model. The model uses three emission factors for actual emissions to describe the three stages where emissions may occur. The first of these stages is product manufacturing (0.5 per cent), which covers losses during the manufacture, storage, transport and installation of the end product. The second stage factor covers lifetime emissions, combining operational and accidental releases which for the period 1990 to 2000 is assumed to be 4.9 per cent, falling to 2.5 per cent in 2005 and remains at this value for each subsequent year. The third stage factor (0.1 per cent) covers the disposal of the product due to decommissioning. Potential emissions account for the total available product.

Sectoral background data for HFC-23 and HFC-227ea has been provided for all years from 1990-2011 in this submission in the CRF Tables following a recommendation from the previous annual review reports. Emissions data are also provided according to actual emissions from manufacturing, from stocks and from disposal.

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

HFC emissions from these combined sub-categories in 2011 accounted for 15.5 per cent of the total emissions from F-gases. Trends for the two sources fluctuated reaching their peak in 2005 at 119.84 Gg CO<sub>2</sub> eq. and declined by 28.7 per cent to 93.09 Gg CO<sub>2</sub> eq. in 2011.

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 HFC's 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 last year's submission 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 to 2011, 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. The HFCs used in MDI's in Ireland are HFC 134a and HFC-227. 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 HFC134a based on industry returns and Adams *et al.* (2005). Imported products on the other hand can contain HFC134a and HFC-227. As a result there is no emissions from manufacture in for HFC-227 in CRF Table2(II).Fs2. Total emissions are calculated based on reported manufacturing losses (for HFC134a) in conjunction with in-life emissions. An emission factor of 50 per cent per annum is used to estimate in-life emissions from MDIs, which is consistent with good practice guidance for the category.

#### 4.4.2.5 Semiconductor Manufacture (2.F.7)

HFC emissions from this sub-category accounted for 2.46 Gg CO<sub>2</sub> eq. or 0.4 per cent of the total emissions from F-gases and were 27.0 per cent lower than the previous year emissions and 80.2 per cent lower than their peak at 12.38 Gg CO<sub>2</sub> eq. in 2000.

This sub-category is the only source of reported PFC emissions and accounted for 13.20 Gg CO<sub>2</sub> eq. or 2.2 per cent of the total emissions from F-gases in 2011. PFC emissions from this sub-category decreased from the previous year from 37.02 Gg CO<sub>2</sub> eq. or by 64.4 per cent and by 95.7 per cent from their peak at 305.41 Gg CO<sub>2</sub> 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.

SF<sub>6</sub> emissions from this sub-category accounted for 23.22 Gg CO<sub>2</sub> eq. or 3.9 per cent share of the total emissions from F-gases in 2011. Emissions from this sub-category increased by 27.2 per cent from the previous year and remained lower by 71.4 per cent from their peak in 1997 (81.26 Gg CO<sub>2</sub> eq.).

The semiconductor industry uses HFCs, PFCs and SF<sub>6</sub> 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<sub>6</sub> 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<sub>6</sub> in their plants over the full time series 1990-2011.

#### 4.4.2.6 Electrical Equipment (2.F.8)

SF<sub>6</sub> 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<sub>6</sub> emissions from their equipment to the inventory agency on a yearly basis. Emissions are estimated using a Tier 1 approach based on an analysis of opening and closing stocks of SF<sub>6</sub>.

SF<sub>6</sub> emissions reported from this sub-category were 21.70 Gg CO<sub>2</sub> eq. or 3.6 per cent of the total emissions from F-gases in 2011. The trend fluctuated significantly to peak in 2003 at 38.45 Gg CO<sub>2</sub> eq. and then decreased in 2008 to 10.90 Gg CO<sub>2</sub> eq. and remained at similar levels for the next two years before increasing significantly between 2010 (at 12.91 Gg CO<sub>2</sub> eq.) and 2011 by 68.1 per cent. 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<sub>6</sub> 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.

#### 4.4.2.7 Other Emission Sources (2.F.9)

SF<sub>6</sub> 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 (Other- gas-air tracers are not occurring since 2004) in 2011 accounted for 3.38 Gg CO<sub>2</sub> eq. or 0.6 per cent share of the total emissions from F-gases in 2011.

This category includes emissions of SF<sub>6</sub> 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<sub>6</sub> was previously used as an insulation gas in double-glazing, however its use has been phased out in response to regulations on F gases 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<sub>6</sub> 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 for the bank of SF<sub>6</sub> in double glazed windows manufactured and installed prior to 1990 (back to 1978 when double glazing was introduced

in Ireland) which will contribute to installed leakage losses throughout the time series 1990-2011.

SF<sub>6</sub> 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. In previous submissions a transcription error occurred whereby the estimate suggested an accumulation of the stock of SF<sub>6</sub>. For this submission it is therefore 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<sub>6</sub> is used as a cushioning agent in sports shoes. The use of SF<sub>6</sub> 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<sub>6</sub> in sports goods in Ireland, a population-proxy is used to estimate emissions based on UK inventory data for the release of SF<sub>6</sub> 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<sub>6</sub> in sporting goods was discontinued in 2007, however emissions from their disposal will continue based on an average lifetime of eight years.

The remaining minor uses of SF<sub>6</sub> 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<sub>4</sub> emissions from enteric fermentation in cattle. The latter source is considered negligible in an Irish context. The use of SF<sub>6</sub> in leak detection was previously a relatively large source in the period 1990-2004. However the company who used SF<sub>6</sub> for the purpose of leak detection has since ceased trading and this sub category is no longer a source of emissions of SF<sub>6</sub> in the Irish inventory.

## 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<sub>6</sub> 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 1995-2011 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.1 Refrigeration and air conditioning* 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.

## 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.

## 4.7 Recalculations for *Industrial Processes*

Recalculations in the Industrial Processes sector in this submission are confined to HFCs in 2.F.2 Foams and HFCs from 2.F.3 Fire Extinguishers. Recalculations for 2.F.2 Foams are due to small changes in OECD and Ireland GDP proxy data between 2001 and 2010. Recalculations for 2.F.3 Fire Extinguishers are due to a minor error in the emission calculation spread sheet in relation to the disposal factor for all years from 1990 to 2010. The total impact of recalculations in these sub-categories is to increase total GHG emissions by 0.66 per cent in 1990 and 0.43 per cent in 2009 and to decrease emissions in 2010 by 0.66 per cent. The overall impact of these recalculations on the total sectoral emissions is negligible resulting in a reduction of 0.19 per cent in 2010. The results of the recalculations are given by category and gas in Table 4.4 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<sub>2</sub> emissions estimates that are reported under the EU emissions trading scheme as the most reliable data for emission sources within category 2.A. The agency plans to continue the practice of outsourcing contracts on a periodic basis to comprehensively re-examine and extend the inventory time-series for emissions of F-gases. It intends to conduct a study in 2013 in time for reporting estimates of F-gases for 1990-2012 in the 2014 submission. The study will also address any outstanding issues raised during the annual inventory review process. This approach has been found to be an efficient way of improving, developing and adopting the latest research and information relevant to inventory compilation.

**Table 4.3. Emissions of HFC, PFC and SF<sub>6</sub> from Industrial Processes 1990-2011 (Gg CO<sub>2</sub> 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
2.F.1 Refrigeration and Air-Conditioning	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
2.F.1 Mobile Air Conditioning	NO	NO	NO	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
2.F.2 Foams	NO	NO	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
2.F.3 Fire-extinguishers	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
2.F.4 Aerosols	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
2.F.4 Metered Dose Inhalers	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
2.F.7 Semiconductor manufacture	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
<b>TOTAL HFC</b>	<b>1.31</b>	<b>7.11</b>	<b>9.90</b>	<b>15.13</b>	<b>27.73</b>	<b>54.60</b>	<b>91.85</b>	<b>153.44</b>	<b>217.03</b>	<b>223.94</b>	<b>259.81</b>	<b>279.85</b>	<b>309.24</b>	<b>382.20</b>	<b>416.04</b>	<b>475.81</b>	<b>548.66</b>	<b>535.67</b>	<b>566.66</b>	<b>523.33</b>	<b>559.30</b>	<b>538.61</b>
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
<b>TOTAL PFC</b>	<b>0.09</b>	<b>7.62</b>	<b>15.15</b>	<b>30.21</b>	<b>45.27</b>	<b>75.38</b>	<b>103.09</b>	<b>130.82</b>	<b>61.87</b>	<b>195.93</b>	<b>305.41</b>	<b>295.98</b>	<b>212.40</b>	<b>228.79</b>	<b>182.43</b>	<b>168.34</b>	<b>148.32</b>	<b>130.58</b>	<b>106.20</b>	<b>65.57</b>	<b>37.02</b>	<b>13.20</b>
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
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
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	0.28	0.28	0.28	0.28	0.27	0.27	0.27	0.26
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
2.F.9 Other - sporting goods	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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
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	NO	NO	NO
<b>TOTAL SF<sub>6</sub></b>	<b>35.51</b>	<b>40.74</b>	<b>45.97</b>	<b>55.46</b>	<b>64.94</b>	<b>82.93</b>	<b>102.17</b>	<b>132.20</b>	<b>93.09</b>	<b>67.38</b>	<b>54.35</b>	<b>67.84</b>	<b>67.73</b>	<b>115.43</b>	<b>68.65</b>	<b>101.63</b>	<b>62.90</b>	<b>65.52</b>	<b>56.68</b>	<b>38.24</b>	<b>34.51</b>	<b>48.29</b>
<b>TOTAL HFC, PFC and SF<sub>6</sub></b>	<b>36.91</b>	<b>55.48</b>	<b>71.03</b>	<b>100.80</b>	<b>137.93</b>	<b>212.92</b>	<b>297.10</b>	<b>416.47</b>	<b>371.99</b>	<b>487.25</b>	<b>619.56</b>	<b>643.67</b>	<b>589.37</b>	<b>726.42</b>	<b>667.12</b>	<b>745.78</b>	<b>759.87</b>	<b>731.76</b>	<b>729.53</b>	<b>627.13</b>	<b>630.83</b>	<b>600.10</b>

**Table 4.4. Percentage Change in Total Emissions from Industrial Processes due to Recalculations 1990-2010**

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Estimates in 2012 Submission (Gg CO <sub>2</sub> eq)																							
2.A.1	Cement Production	CO <sub>2</sub>	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
2.A.2	Lime Production	CO <sub>2</sub>	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
2.A.3	Limestone and Dolomite Use	CO <sub>2</sub>	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
2.A.4	Soda Ash Production and Use	CO <sub>2</sub>	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
2.A.7	Bricks and Tiles	CO <sub>2</sub>	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
2.A.7	Glass Production	CO <sub>2</sub>	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
2.B.1	Ammonia Production	CO <sub>2</sub>	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
2.B.2	Nitric Acid Production	N <sub>2</sub> O	1035.4	812.4	812.4	812.4	812.4	812.4	812.4	812.2	812.2	812.2	812.4	584.4	292.2	NO	NO	NO	NO	NO	NO	NO	NO
2.F.7	Consumption of Halocarbons and SF <sub>6</sub>	HFCs	1.3	7.1	9.8	15.0	27.5	54.4	91.5	153.1	216.6	223.4	259.2	279.1	308.4	381.2	414.9	474.5	547.1	533.9	564.7	521.1	563.0
2.F.7	Consumption of Halocarbons and SF <sub>6</sub>	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
2.F.7	Consumption of Halocarbons and SF <sub>6</sub>	SF <sub>6</sub>	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
2	Total		3179.3	2890.6	2819.9	2810.4	3088.5	3082.7	3230.5	3686.6	3530.7	3595.4	4222.5	4329.9	3755.0	3068.0	3173.0	3297.2	3297.1	3310.4	3029.1	2110.2	1933.6
Recalculated Estimates in 2013 Submission (Gg CO <sub>2</sub> eq)																							
2.A.1	Cement Production	CO <sub>2</sub>	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
2.A.2	Lime Production	CO <sub>2</sub>	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
2.A.3	Limestone and Dolomite Use	CO <sub>2</sub>	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
2.A.4	Soda Ash Production and Use	CO <sub>2</sub>	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
2.A.7	Bricks and Tiles	CO <sub>2</sub>	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
2.A.7	Glass Production	CO <sub>2</sub>	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
2.B.1	Ammonia Production	CO <sub>2</sub>	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
2.B.2	Nitric Acid Production	N <sub>2</sub> O	1035.4	812.4	812.4	812.4	812.4	812.4	812.4	812.2	812.2	812.2	812.4	584.4	292.2	NO	NO	NO	NO	NO	NO	NO	NO
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	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
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	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
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	SF <sub>6</sub>	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
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
Percentage Change in Total Emissions due to Recalculations																							
2.A.1	Cement Production	CO <sub>2</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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	NA
2.B.1	Ammonia Production	CO <sub>2</sub>	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	NA	NA	NA	NA	NA	NA	NA
2.B.2	Nitric Acid Production	N <sub>2</sub> O	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	NA	NA	NA	NA	NA	NA	NA
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	HFCs	0.00	0.66	0.96	0.95	0.71	0.47	0.35	0.25	0.21	0.24	0.24	0.27	0.28	0.27	0.28	0.29	0.28	0.33	0.35	0.43	-0.66
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	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
2.F.	Consumption of Halocarbons and SF <sub>6</sub>	SF <sub>6</sub>	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	Total		0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.07	0.11	-0.19

## Chapter Five

### Solvent and Other Product Use

#### 5.1 Overview of Solvent and Other Product Use Sector

The IPCC source sector, *Solvent and Other Product 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<sub>2</sub>O 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<sub>2</sub> 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<sub>2</sub> from the combustion of fuels (Section 3.2), where the CO<sub>2</sub> 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<sub>2</sub> emission estimates are derived from NMVOCs by assuming that 85 per cent of the mass of NMVOCs is converted to CO<sub>2</sub>.

The activity data used for computing estimates of CO<sub>2</sub> 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 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<sub>2</sub> 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<sub>2</sub> 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* 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<sub>2</sub> emissions from Solvent and Other Product Use for the period 1990-2011 are presented in Table 5.1. The largest contributor to overall emissions is the source category 3D Other Use of Solvents which accounts for 57% of NMVOC emissions in 2011. It is estimated that approximately two thirds of emissions from this source category are attributable to domestic solvent use. Emissions from domestic solvent use have increased in recent years, 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 3A Paint Application is a significant source of NMVOC, accounting for 27 per cent of total NMVOC emissions in 2011. Emissions from this source category have substantially fallen since 2002 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.

### 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 period 2007-2010 and are due to the use of revised population statistics and GDP estimates for Ireland. The total impact of recalculations in this sector is presented in Table 5.2 below.

**Table 5.1. Estimates of NMVOC and CO<sub>2</sub> Emissions from Solvent and Other Product Use 1990-2011**

Year	3A Paint Application	3B Degreasing, dry cleaning, electronics	3C Chemical Products and Manufacturing & Processing	3D Other Use of Solvents	Total NMVOC emissions	Estimated CO <sub>2</sub> from NMVOC
	Mg NMVOC					Gg CO <sub>2</sub>
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	8,636	2,022	3,370	12,838	26,866	83.73
2000	8,251	1,890	3,203	12,017	25,361	79.04
2001	8,334	1,669	3,035	11,961	24,999	77.91
2002	8,503	1,081	2,868	11,806	24,258	75.60
2003	8,345	1,158	2,700	11,667	23,870	74.39
2004	8,272	1,142	2,532	11,773	23,719	73.92
2005	8,044	1,246	2,532	11,943	23,765	74.07
2006	7,937	1,364	2,532	12,264	24,097	75.10
2007	7,648	1,304	2,532	12,794	24,278	75.67
2008	7,001	1,270	2,532	13,037	23,840	74.30
2009	6,266	1,178	2,532	13,088	23,064	71.88
2010	6,179	1,178	2,532	13,104	22,992	71.66
2011	6,226	1,178	2,532	13,323	23,259	72.49

**Table 5.2 Recalculations for Solvent and Other Product Use 1990-2010**

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Estimates in 2012 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	6.24	6.16	
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	
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	
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	13.08	13.10	
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	23.04	22.97	
3	Estimated CO <sub>2</sub> 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	74.31	71.80	71.59	
Recalculated 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	
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	
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	
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	
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	
3	Estimated CO <sub>2</sub> 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	
Percentage Change in Total Emissions due to Recalculations																							
3.A	Paint Application	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	0.36	0.31	
3.B	Degreasing, dry cleaning, electronics	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	
3.C	Chemical Products and Manufacturing & Processing	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	
3.D	Other Use of Solvents	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	-0.01	0.02	0.02
3	Total NMVOC emissions	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	-0.01	0.11	0.09
3	Estimated CO <sub>2</sub> from NMVOC	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	-0.01	0.11	0.09

## Chapter Six

### Agriculture

#### 6.1 Overview of Agriculture Sector

The IPCC Level 3 source categories in *Agriculture*, where CH<sub>4</sub> and N<sub>2</sub>O 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 1990-2011 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<sup>1</sup>.

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<sub>4</sub> 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<sub>3</sub> 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) and SI 610 of 2010 (DEHLG, 2010), 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. Minor revisions to animal populations of poultry and swine between 2007 and 2010 have been made since the last submission and revisions to indirect emissions of N<sub>2</sub>O from atmospheric deposition have been implemented due to a revision of the national NH<sub>3</sub> inventory model. In addition, a reallocation of N<sub>2</sub>O emissions from Animal Manure Applied to Soils (4.D.1.2) to sub-category Sewage sludge (4.D.1.6) was made following a recommendation from a previous annual inventory review. Finally, a revision to indirect emissions of N<sub>2</sub>O from leaching and run-off was made due a reduction in the amount

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<sup>1</sup> <http://www.agriculture.gov.ie/farmerschemespayments/crosscompliance/>

of nitrogen volatilised as ammonia in the NH<sub>3</sub> model due to a double count of some poultry; broilers and layers in the previous submission. These amendments resulted in a minor change in overall 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.

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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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<sub>2</sub> emissions from Liming of Agricultural Lands included in category 5.B and 5.C of LULUCF (Chapter Seven)*

In 2011, the emissions from Agriculture were 17,691.16 Gg CO<sub>2</sub> equivalent or 30.8 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 9.9 per cent. Methane accounted for 59.8 per cent and N<sub>2</sub>O accounted for 40.2 per cent of the emissions in the sector in 2011. The CH<sub>4</sub> emissions from enteric fermentation in cattle and the N<sub>2</sub>O emissions associated with large inputs of chemical and organic nitrogen to agricultural soils are the major emission categories.

## 6.2 CH<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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) and SI 610 of 2010 (DEHLG, 2010)). The results of this research (O'Mara, 2006) 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<sub>4</sub> 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 et. al., 2006).

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 2011. 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) and SI 610 of 2010 (DEHLG, 2010)). 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). 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 (2006), 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 *unités fourragère 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<sub>l</sub>). 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<sub>l</sub> 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);

$NE_i$  (MJ) required per kg milk =  $0.376 * \text{fat content} + 0.209 * \text{protein content} + 0.948$ ;

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

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

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, 2006).

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). 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, 2006). 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 (2006) 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<sub>mg</sub>.

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, 2006). 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 3<sup>rd</sup> February of their third year (O'Mara, 2006). 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 1990–2011 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<sub>4</sub>/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 indicate little change between 1990 and 2011, except in the case of male cattle in the category of animals greater than two years old. The reduction in emission factors for this animal category is 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<sub>4</sub> Emission Factors for 1990, 2007- 2011**

	Enteric Fermentation (kg/head/year)						Manure Management (kg/head/year)					
	1990	2007	2008	2009	2010	2011	1990	2007	2008	2009	2010	2011
Dairy cows	101.38	109.81	109.99	108.54	112.59	112.77	21.60	20.58	20.61	20.42	20.80	20.82
Suckler cows	74.03	73.87	74.92	72.78	73.14	74.27	14.25	14.08	14.30	13.83	13.92	14.17
Male cattle < 1 year	30.46	29.69	29.71	29.77	29.11	29.82	8.41	7.91	7.92	7.90	7.88	7.91
Male cattle 1 - 2 years	62.22	59.19	59.07	58.57	59.96	58.01	16.89	14.02	13.95	13.88	14.25	13.53
Male cattle > 2 years	55.08	38.58	36.98	38.84	39.79	38.29	5.16	2.25	2.02	2.28	2.38	2.20
Female cattle < 1 year	27.05	27.77	27.59	27.58	26.99	27.61	8.41	7.91	7.92	7.90	7.88	7.91
Female cattle 1 - 2 years	53.54	46.60	47.00	47.71	48.62	47.93	14.93	9.91	10.08	10.44	10.76	10.38
Female cattle > 2 years	21.65	22.42	22.55	22.63	22.63	22.72	0.33	0.34	0.34	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 in each case on the basis of animal weight, as shown in Table G.2 of Annex G. 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<sub>4</sub> Emissions from Manure Management (4.B)

### 6.3.1 CH<sub>4</sub> Emissions from Manure Management in Cattle

The decomposition of the organic material in animal manures may be a significant source of CH<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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 2006). 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, 2006) 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 ( $B_0$ ) 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  $0.24 \text{ m}^3 \text{ CH}_4/\text{kg VS}$  (the value for dairy cattle in the IPCC good practice guidance) for  $B_0$  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 (2006). 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 $\text{CH}_4$ Emissions from Manure Management in Other Livestock

The estimation of  $\text{CH}_4$  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  $B_0$  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  $\text{CH}_4$  emissions from livestock are included in the national inventory.

## 6.4 $\text{N}_2\text{O}$ 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  $\text{CH}_4$  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 2011 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  $\text{N}_2\text{O}$  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<sub>2</sub>O emissions from manure management in Ireland. The N<sub>2</sub>O emissions from manures managed in liquid and solid storage systems in 2011 amounted to 1.41 Gg N<sub>2</sub>O.

## 6.5 N<sub>2</sub>O Emissions from Agricultural Soils (4.D)

Agricultural soils are the principal source of N<sub>2</sub>O 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<sub>2</sub>O. 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<sub>2</sub>O 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 1990-2011 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<sub>2</sub>O to be reported in CRF sub-category 4.D.1 Direct Soil Emissions may be calculated in a Tier 1 approach from

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

where

$N_2O_{\text{direct}}$  = the direct emissions of N<sub>2</sub>O

$F_{\text{SN}}$  = amount of synthetic fertiliser nitrogen applied to soils, adjusted for the amount that volatilises as NH<sub>3</sub> and NO<sub>x</sub>

$F_{\text{AM}}$  = amount of animal manure nitrogen applied directly to soils, adjusted for the amount that volatilises as NH<sub>3</sub> and NO<sub>x</sub>

$F_{\text{S}}$  = amount of organic nitrogen in sludge applied to agricultural soils

$F_{\text{BN}}$  = amount of nitrogen fixed by nitrogen-fixing crops

$F_{\text{CR}}$  = amount of nitrogen in crop residues returned to soils

$F_{\text{OS}}$  = the area of cultivation of organic soils

$EF_1$  = N<sub>2</sub>O emission factor for emissions from direct nitrogen inputs (kg N<sub>2</sub>O-N/kg N)

$EF_2$  = N<sub>2</sub>O emission factor for emissions from cultivation of organic soils (kg N<sub>2</sub>O-N/kg N)

The estimates of direct N<sub>2</sub>O emissions from agricultural soils for the years 1990-2011 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<sub>2</sub>O emissions in Ireland reported in sub-category 4.D.1 *Direct Soil Emissions* therefore becomes

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

Where

$$F_{\text{SN}} = N_{\text{fert}} * (1 - \text{Frac}_{\text{GASF}})$$

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

$$F_{\text{S}} = \text{SS}_I * \text{NSSF}$$

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

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

and

$N_{fert}$  = total amount of synthetic fertiliser nitrogen applied to soils (kg N)

$Frac_{GASF}$  = fraction of synthetic fertiliser nitrogen that volatilises as  $NH_3$  (0.029 in 2011)

$N_{ex}$  = total amount of animal manure nitrogen excreted by livestock (kg N)

$Frac_{GRAZ}$  = fraction of  $N_{ex}$  that is excreted by livestock during grazing (0.616 in 2011)

$Frac_{GASM1}$  = fraction of animal manure nitrogen that volatilises as  $NH_3$  during housing, manure storage and landspreading (0.359 in 2011)

$N_2O-N_{hs}$  = amount of animal manure nitrogen emitted as  $N_2O$  in housing and storage (kg  $N_2O-N$ )

$SS_i$  = 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, 2012). 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 2011 values of  $Frac_{GASM1}$  and  $Frac_{GASM2}$  are 0.363 and 0.056, respectively indicating an overall volatilisation rate of 0.174 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 0.036 and 0.363, respectively in 2011 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 al, 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  $N_2O_{\text{direct}}$  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 2011. 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 1990-2011.

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 2011 for category 4.D.1 *Direct Soil Emissions* amounted to 8.91 Gg, of which synthetic fertilisers accounted for 6.54 Gg, 2.12 Gg was due to land spreading of animal manures and sewage sludge and crops (N-fixing and crop residue) produced 0.25 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 the 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 0.62 for  $Frac_{GRAZ}$  in 2011, 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 2011 was 8.42 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 and animal manures 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

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

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

where

$N_2O_{\text{indirect-dep}}$  = the indirect emissions of  $N_2O$  due to atmospheric nitrogen deposition

$N_2O_{\text{indirect-leach}}$  = 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 2011)

$\text{Frac}_{\text{LEACH}}$  = fraction of synthetic fertiliser nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2011)

$\text{EF}_4$  =  $\text{N}_2\text{O}$  emission factor for nitrogen inputs from atmospheric deposition

$\text{EF}_5$  =  $\text{N}_2\text{O}$  emission factor for nitrogen leaching

The expressions for the indirect emissions of  $\text{N}_2\text{O}$  due to atmospheric nitrogen deposition ( $\text{N}_2\text{O}_{\text{indirect-dep}}$ ) and the indirect emissions of  $\text{N}_2\text{O}$  due to nitrogen leaching ( $\text{N}_2\text{O}_{\text{indirect-leach}}$ ) 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  $\text{Frac}_{\text{GASM1}}$  and  $\text{Frac}_{\text{GASM2}}$ . There is no contribution to  $\text{N}_2\text{O}_{\text{indirect-dep}}$  from  $F_S$ , the nitrogen input from sludge spreading, but  $F_S$  increases  $\text{N}_2\text{O}_{\text{indirect-leach}}$  through its inclusion in  $F_{\text{AM}}$ . The default value for  $\text{Frac}_{\text{LEACH}}$ , 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  $\text{Frac}_{\text{LEACH}}$  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  $\text{EF}_4$  and  $\text{EF}_5$  (0.01 kg  $\text{N}_2\text{O}$ -N/kg  $\text{NH}_3$ -N emitted for synthetic fertilizer and animal waste nitrogen and 0.025 kg  $\text{N}_2\text{O}$ -N/kg N leached) are used to estimate indirect  $\text{N}_2\text{O}$  emissions. Total indirect emissions in 2011 amounted to 4.22 Gg  $\text{N}_2\text{O}$ , or approximately 47 per cent of direct emissions from soils (sub-category 4.D.1).

## 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  $\text{CH}_4$  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  $\text{N}_2\text{O}$  from manure management and agricultural soils. A comparison of the uncertainties associated with emission estimates prior to the use of Tier 2 methodologies for  $\text{CH}_4$  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  $\text{N}_2\text{O}$  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 1990–2011 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 1990–2011.

**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 <sub>4</sub>	1	20	1	15
4.A Other Cattle	CH <sub>4</sub>	1	30	1	15
4.A Other Livestock	CH <sub>4</sub>	1	50	1	30
4.B Dairy Cattle	CH <sub>4</sub>	32	50	1	15
4.B Other Cattle	CH <sub>4</sub>			1	15
4.B Other Livestock	CH <sub>4</sub>			1	30
4.B Liquid System	N <sub>2</sub> O	32	100	11.2	100
4.B Solid Storage and Dry lot	N <sub>2</sub> O				
4.D Direct Soil emissions	N <sub>2</sub> O	32	100	11.2	100
4.D Pasture Rand and Paddock	N <sub>2</sub> O				
4.D Indirect Emissions	N <sub>2</sub> O				

## 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<sub>3</sub> 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<sub>4</sub> and NH<sub>3</sub>. 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, resulting in an overall increase of GHG emissions of 0.48 per cent in 2010. Minor revisions to animal populations of poultry and swine between 2007 and 2010 were made as well as amendments to indirect emissions of N<sub>2</sub>O from atmospheric deposition due to a change in the NH<sub>3</sub> model inputs. In addition, a reallocation of N<sub>2</sub>O emissions was made from Animal Manure Applied to Soils (4.D.1.2) to sub-category sewage sludge (4.D.1.6), following a previous annual inventory review recommendation. Finally, a revision to indirect emissions of N<sub>2</sub>O from leaching and run-off (4.D.3.2) was made following a reduction in the amount of nitrogen volatilised as ammonia in the NH<sub>3</sub> model due to a double count of some poultry; broilers and layers in the previous submission.

The net effect of the revisions to livestock statistics and nitrogen model values is an increase in agricultural CH<sub>4</sub> emissions of 0.61 per cent in 2010. N<sub>2</sub>O emissions from agriculture have

been revised across the time-series from a 0.01 per cent reduction in 1990 to a 0.27 per cent increase in 2010. Additional information on recalculations is provided in the CRF Table 8(b) for the relevant years and in Table 6.5 below.

## 6.9 Improvements in Agriculture

The key to developing better estimates of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O emissions associated directly with animal production, such as those from enteric fermentation and manure management. However, this is not possible for estimating N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O from soils.

The EPA and the Department of Agriculture, Food and the Marine are actively pursuing the opportunities for both CH<sub>4</sub> and N<sub>2</sub>O emissions research in Ireland with a number of projects being currently funded or about to commence. It is also envisaged that as a result of this research, feed intake parameters and assumed nitrogen content of feeds will be reviewed and updated as necessary. In preparation for the next submission Ireland will investigate the applicability of developing Tier 2 estimates of CH<sub>4</sub> from enteric fermentation and manure management from sheep as recommended in the previous annual inventory review report. Ireland will also investigate the possibility of estimating ammonia emissions from the spreading of sewage sludge on agricultural land using an appropriate emission factor if available and adjusting the parameter F<sub>s</sub> (amount of organic nitrogen in sludge applied to agricultural soils).

**Table 6.5. Percentage change in emissions from Agriculture due to Recalculations (1990-2010)**

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
			Estimates in 2012 Submission (Gg)																				
4.A	Enteric Fermentation	CH <sub>4</sub>	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	422.70	416.12	404.58
4.B	Manure Management	CH <sub>4</sub>	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	105.03	105.07	103.52	101.61
4.B	Manure Management	N <sub>2</sub> O	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	1.50	1.51	1.49	1.43
4.D.1	Direct Soil emissions	N <sub>2</sub> O	9.76	9.60	9.36	9.73	10.30	10.83	10.72	10.08	11.11	11.23	10.46	9.70	9.57	10.09	9.69	9.41	9.04	8.62	8.38	8.28	9.28
4.D.2	Pasture Range and Paddock	N <sub>2</sub> O	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	8.82	8.74	8.50
4.D.3	Indirect emissions	N <sub>2</sub> O	4.45	4.46	4.47	4.54	4.65	4.76	4.80	4.73	5.02	4.98	4.70	4.53	4.50	4.59	4.46	4.36	4.31	4.17	4.13	4.12	4.27
4	Total Methane	CH <sub>4</sub>	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	529.07	527.77	519.64	506.19
4	Total Nitrous oxide	N <sub>2</sub> O	24.86	24.92	24.90	25.31	26.00	26.68	26.92	26.48	28.09	27.87	26.33	25.33	25.06	25.68	25.14	24.39	23.94	23.18	22.84	22.62	23.48
4	Total (CO <sub>2</sub> eq)	CO <sub>2</sub> eq	19,635	19,758	19,863	19,965	20,099	20,316	20,741	20,860	21,514	21,020	19,971	19,595	19,379	19,511	19,315	18,857	18,723	18,295	18,162	17,926	17,910
			Recalculated Estimates in 2013 Submission (Gg)																				
4.A	Enteric Fermentation	CH <sub>4</sub>	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
4.B	Manure Management	CH <sub>4</sub>	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
4.B	Manure Management	N <sub>2</sub> O	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
4.D.1	Direct Soil emissions	N <sub>2</sub> O	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
4.D.2	Pasture Range and Paddock	N <sub>2</sub> O	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
4.D.3	Indirect emissions	N <sub>2</sub> O	4.45	4.47	4.48	4.55	4.66	4.76	4.81	4.74	5.03	4.99	4.70	4.54	4.50	4.59	4.47	4.36	4.32	4.17	4.13	4.13	4.29
4	Total Methane	CH <sub>4</sub>	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
4	Total Nitrous oxide	N <sub>2</sub> O	24.86	24.92	24.89	25.30	25.99	26.68	26.92	26.48	28.08	27.86	26.32	25.33	25.05	25.68	25.14	24.38	23.93	23.16	22.83	22.63	23.55
4	Total (CO <sub>2</sub> eq)	CO <sub>2</sub> eq	19,634	19,757	19,862	19,964	20,097	20,314	20,740	20,858	21,513	21,018	19,969	19,594	19,378	19,509	19,313	18,856	18,722	18,282	18,145	17,931	17,995
			Percentage Change in Total Emissions due to Recalculations																				
4.A	Enteric Fermentation	CH <sub>4</sub>	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	-0.01	0.55
4.B	Manure Management	CH <sub>4</sub>	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	-0.34	-0.56	0.23	0.88
4.B	Manure Management	N <sub>2</sub> O	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	-0.46	-0.02	0.47	1.16
4.D.1	Direct Soil emissions	N <sub>2</sub> O	-0.09	-0.10	-0.10	-0.10	-0.10	-0.10	-0.11	-0.12	-0.11	-0.10	-0.11	-0.12	-0.12	-0.12	-0.13	-0.13	-0.12	-0.17	-0.04	-0.06	0.12
4.D.2	Pasture Range and Paddock	N <sub>2</sub> O	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	-0.12	-0.10	0.17	
4.D.3	Indirect emissions	N <sub>2</sub> O	0.12	0.13	0.13	0.13	0.14	0.14	0.15	0.15	0.14	0.14	0.15	0.16	0.15	0.15	0.17	0.16	0.16	0.11	0.14	0.22	0.51
4	Total Methane	CH <sub>4</sub>	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	-0.07	-0.13	0.04	0.61
4	Total Nitrous oxide	N <sub>2</sub> O	-0.01	-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	-0.07	-0.04	0.01	0.27
4	Total (CO <sub>2</sub> eq)	CO <sub>2</sub> eq	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.07	-0.10	0.02	0.48



## 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 7.1. 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. These changes have been made in response to previous annual review recommendations. 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<sub>2</sub> 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 reporting under the convention, 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<sub>2</sub> emissions, is another important source included in the LULUCF sector. Emissions of N<sub>2</sub>O 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<sub>2</sub>O and CH<sub>4</sub> 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 1990-2011 in all IPCC land categories, as indicated by Table 7.1. 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 1990-2011. 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 (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 more detailed report on the work undertaken to report on the LULUCF sector is available (O'Brien, 2007).

**Table 7.1. 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 <sub>2</sub>			CH <sub>4</sub>	N <sub>2</sub> O
	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*

The 1990-2011 inventory submission for LULUCF follows the same general approach and methodologies as those used for the submissions from 2008 to 2012. However, in response to previous annual inventory review reports (ARR) for [2010](#) and [2011](#) 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 there has been 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 5A to 5F, reported land use transition based on a 20-year transition. The new approach adopted now reports all land areas converted to another land use after the 1<sup>st</sup> of January 1990, and lands not subject to land use change before the 1<sup>st</sup> of January 1990. For example, forest land remaining forests (5A) 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 the Kyoto Protocol.

The estimates of emissions and removals from LULUCF over the period 1990-2011 are presented in Table 7.2 for all land-use categories. The LULUCF sector is 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<sub>2</sub> 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<sub>2</sub> 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<sub>4</sub> and N<sub>2</sub>O 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 7.3 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 7.4 records the land-use changes among the various categories over the period 1990-2011 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 7.1 and Section 7.3.1). 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 7.1 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 7.3.4) 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 7.2.3).

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 7.3 details the data sources used to estimate land use areas and soil types typical of each land use type.

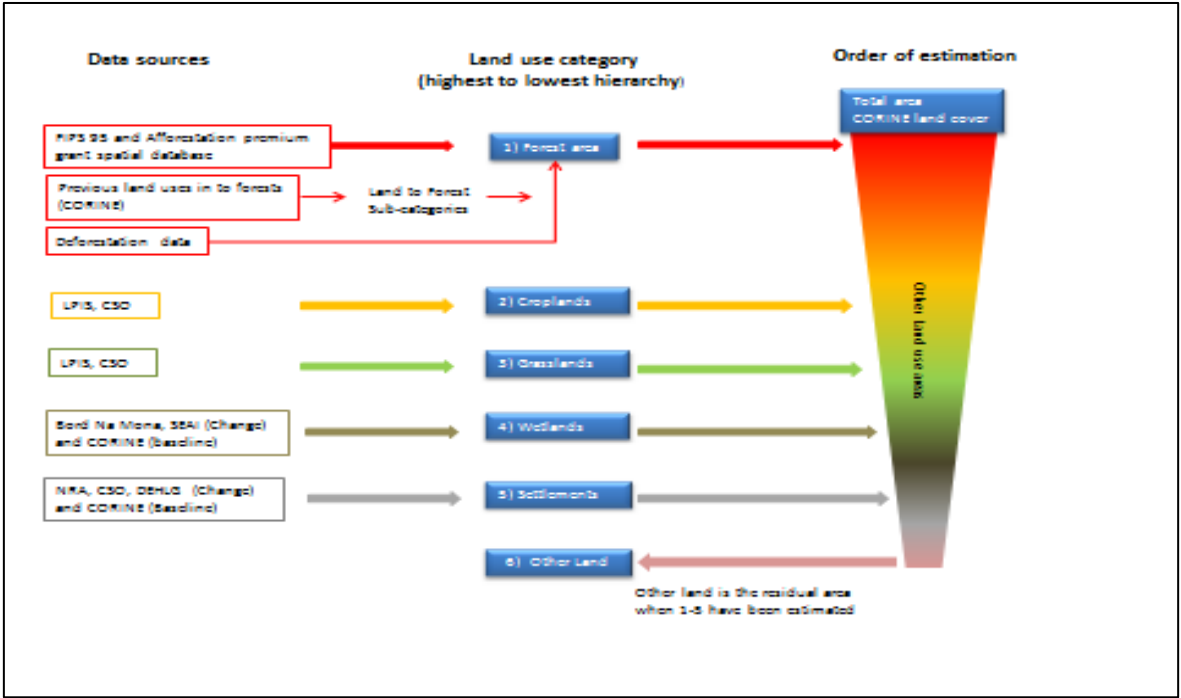


Figure 7.1: Methodologies and hierarchy of determining land use areas and transitions

See table 7.3 for a detailed description of data sources. Other Land is derived from the land not included in the forest, cropland, wetland and settlement areas. This includes natural grasslands not used for agricultural purposes 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 58.2 per cent of total area in 1990, followed by *Wetland* accounting for 17.2 per cent. The *Other Land* category is the next largest at 9.7 per cent, followed by *Forest Land* at 6.8 per cent and *Cropland* and *Settlements* accounting for the remaining 5.7 and 1.4 per cent respectively. The major land-use changes since 1990 have been the conversion of Grassland and Wetland to Forest Land and Grassland to Other Land reflecting a decrease in reported agricultural utilisation. In 2011, Grassland accounts for 53.6 per cent of the land area, Wetland 15.3 per cent, Other Land 13.1 per cent. Forest has increased to 10.5 per cent of land area, with Cropland at 5.1 per cent and Settlement increase to 1.6 per cent.

**Table 7.2. Emissions<sup>a</sup> and Removals<sup>a</sup> from Land Use Land-Use Change and Forestry 1990-2011 (Gg CO<sub>2</sub> 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 2013 Submission (Gg CO <sub>2</sub> eq.)																						
<b>5.A Forest Land</b>	<b>-3,235.6</b>	<b>-3,374.8</b>	<b>-2,895.0</b>	<b>-3,154.8</b>	<b>-2,815.3</b>	<b>-2,546.8</b>	<b>-2,461.4</b>	<b>-3,217.8</b>	<b>-2,813.1</b>	<b>-2,749.8</b>	<b>-2,001.3</b>	<b>-2,144.5</b>	<b>-2,095.9</b>	<b>-2,293.8</b>	<b>-3,081.2</b>	<b>-2,989.8</b>	<b>-3,111.4</b>	<b>-3,850.0</b>	<b>-3,424.3</b>	<b>-3,441.7</b>	<b>-4,417.8</b>	<b>-4,206.6</b>
5.A.1 Forest Land remaining Forest Land (CO <sub>2</sub> )	-3,287.6	-3,368.4	-2,820.7	-3,024.4	-2,593.6	-2,216.2	-1,985.0	-2,574.0	-2,000.7	-1,748.0	-787.5	-712.9	-44.7	-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 <sub>2</sub> )	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 <sub>4</sub> and N <sub>2</sub> O)	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
<b>5.B Cropland</b>	<b>20.0</b>	<b>21.2</b>	<b>25.6</b>	<b>25.6</b>	<b>-49.9</b>	<b>-21.9</b>	<b>43.9</b>	<b>78.4</b>	<b>24.8</b>	<b>0.4</b>	<b>46.7</b>	<b>136.1</b>	<b>130.8</b>	<b>178.2</b>	<b>136.7</b>	<b>162.8</b>	<b>109.3</b>	<b>133.3</b>	<b>445.4</b>	<b>256.8</b>	<b>295.8</b>	<b>380.9</b>
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	118	20.2
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 <sup>b</sup>	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
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
<b>5.C Grassland</b>	<b>493.6</b>	<b>568.2</b>	<b>441.2</b>	<b>355.0</b>	<b>409.1</b>	<b>706.4</b>	<b>698.0</b>	<b>661.4</b>	<b>468.6</b>	<b>568.8</b>	<b>611.9</b>	<b>557.9</b>	<b>511.9</b>	<b>577.0</b>	<b>409.5</b>	<b>248.2</b>	<b>306.4</b>	<b>351.3</b>	<b>338.2</b>	<b>243.2</b>	<b>114.4</b>	<b>216.9</b>
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	666.5	539.7
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 <sup>b</sup>	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	239.5	232.5	273.9	387.3	325.5
<b>5.D Wetlands</b>	<b>50.7</b>	<b>49.0</b>	<b>49.1</b>	<b>47.4</b>	<b>45.4</b>	<b>43.8</b>	<b>41.5</b>	<b>39.9</b>	<b>38.5</b>	<b>49.3</b>	<b>63.4</b>	<b>61.5</b>	<b>58.8</b>	<b>56.1</b>	<b>42.5</b>	<b>45.7</b>	<b>74.4</b>	<b>71.4</b>	<b>40.8</b>	<b>39.4</b>	<b>39.7</b>	<b>35.8</b>
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
<b>5.E Settlements</b>	<b>10.3</b>	<b>9.6</b>	<b>9.7</b>	<b>10.2</b>	<b>12.0</b>	<b>9.8</b>	<b>12.5</b>	<b>13.7</b>	<b>14.7</b>	<b>15.8</b>	<b>37.3</b>	<b>42.9</b>	<b>40.9</b>	<b>45.3</b>	<b>46.6</b>	<b>50.8</b>	<b>34.3</b>	<b>32.8</b>	<b>30.4</b>	<b>19.8</b>	<b>23.4</b>	<b>9.6</b>
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
<b>5.F Other Land</b>	<b>-1.1</b>	<b>0.3</b>	<b>-13.2</b>	<b>-14.4</b>	<b>-17.5</b>	<b>-4.5</b>	<b>-28.2</b>	<b>-35.7</b>	<b>-42.1</b>	<b>-36.5</b>	<b>-11.9</b>	<b>-27.7</b>	<b>-46.4</b>	<b>-45.0</b>	<b>-82.1</b>	<b>-90.7</b>	<b>-118.1</b>	<b>-104.3</b>	<b>-138.8</b>	<b>-121.6</b>	<b>-168.7</b>	<b>-139.0</b>
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	-28.2	-35.7	-42.1	-36.5	-11.9	-27.7	-46.4	-45.0	-82.1	-90.7	-118.1	-104.3	-138.8	-121.6	-168.7	-139.0
<b>5.G G. Other</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>
<b>TOTAL LULUCF CO<sub>2</sub> (net emissions/removals)</b>	<b>-2,699.8</b>	<b>-2,762.0</b>	<b>-2,417.0</b>	<b>-2,773.4</b>	<b>-2,459.6</b>	<b>-1,865.3</b>	<b>-1,747.6</b>	<b>-2,507.4</b>	<b>-2,354.8</b>	<b>-2,195.6</b>	<b>-1,307.2</b>	<b>-1,440.9</b>	<b>-1,453.2</b>	<b>-1,564.0</b>	<b>-2,599.4</b>	<b>-2,634.5</b>	<b>-2,766.4</b>	<b>-3,427.6</b>	<b>-2,783.2</b>	<b>-3,076.6</b>	<b>-4,204.9</b>	<b>-3,782.8</b>
<b>TOTAL LULUCF GHGs (net emissions/removals)</b>	<b>-2,662.1</b>	<b>-2,726.5</b>	<b>-2,382.6</b>	<b>-2,730.9</b>	<b>-2,416.2</b>	<b>-1,813.2</b>	<b>-1,693.7</b>	<b>-2,460.1</b>	<b>-2,308.5</b>	<b>-2,152.0</b>	<b>-1,253.9</b>	<b>-1,373.9</b>	<b>-1,399.9</b>	<b>-1,482.1</b>	<b>-2,528.0</b>	<b>-2,572.9</b>	<b>-2,705.2</b>	<b>-3,365.4</b>	<b>-2,708.4</b>	<b>-3,004.1</b>	<b>-4,113.1</b>	<b>-3,702.5</b>

<sup>a</sup> positive values indicate emissions and negative values indicate removals

<sup>b</sup> the emissions from lime application to cropland and grassland are reported in CRF Table 5(IV) rather than under Cropland and Grassland in CRF Tables 5.B and 5.C, respectively. These emissions are included in the sub-totals for 5.B.1 Cropland remaining Cropland and 5.C.1 Grassland remaining Grassland

**Table 7.3. Land Use Categories**

Land Use Category	Definition and Coverage	Area 1990 (ha)	Area 2011 (ha)	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	743,611	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 Otherland	Grassland & Wetland
Cropland	Permanent crops and tillage areas (including setaside) recorded by the Central Statistics Office (CSO)	404,563	364,100	Central Statistics Office (CSO), CORINE Land Cover, LPIS (Land Parcels 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 (rough grazing) in use as recorded by CSO annual statistics, with extrapolation of long term trends to estimate values in 2010 and 2011	4,140,385	3,811,220	CSO, CORINE Land Cover LPIS (Land Parcels information System)  General Soil Map for Ireland	Cropland	Other Land
Wetlands	Natural unexploited wetlands	1,226,498	1,091,239	CORINE Land Cover General Soil Map for Ireland	Peatlands	Forestry
Peatland	Wetland areas commercially exploited for public and private extraction of peat and areas used for domestic harvesting of peat	73,451	52,934	Bord na Mona (BNM) area statistics; Expert opinion	Wetlands, Grassland	Grassland
Settlements	Urban areas, roads, airports and the footprint of industrial, commercial/institutional and residential buildings	98,145	115,130	CORINE Land Cover; National Roads Authority (NRA) road construction statistics; CSO housing stock, house completions and other construction floor area statistics; General Soil Map		
Other Land	Natural grasslands not in use for agricultural purposes, water bodies, bare rock	687,669	933,551	CORINE, (includes natural grasslands not in use for agricultural purposes, water bodies, bare rock etc.)	Grassland	
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 7.4. Land Use Matrices 1990-2011(ha) Change**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>1989</b>	<b>465,278</b>	<b>4,129,585</b>	<b>424,648</b>	<b>74,051</b>	<b>1,234,375</b>	<b>1,308,426</b>	<b>97,777</b>	<b>686,072</b>	<b>7,111,785</b>

<b>Forest</b>	465,278	-4,737	-1,582	-320	-8,696	-9,016	10	-472	<b>449,482</b>
<b>Grassland</b>	4,737	4,129,585	-18,475	-61	0	-61	310	2,689	<b>4,118,785</b>
<b>Cropland</b>	1,582	18,475	424,648	0	0	0	28	0	<b>444,732</b>
<b>Managed Wetland</b>	320	61	0	74,051	219	74,270	0	0	<b>74,651</b>
<b>Unmanaged Wetland</b>	8,696	0	0	-219	1,234,375	1,234,156	0	0	<b>1,242,852</b>
<b>Settlements</b>	-10	-310	-28	0	0	0	97,777	-20	<b>97,408</b>
<b>Other land</b>	472	-2,689	0	0	0	0	20	686,072	<b>683,876</b>
<b>1990</b>	<b>481,074</b>	<b>4,140,385</b>	<b>404,563</b>	<b>73,452</b>	<b>1,225,898</b>	<b>1,299,350</b>	<b>98,145</b>	<b>688,269</b>	<b>7,111,785</b>

<b>Forest</b>	481,074	-5,736	-1,915	-320	-10,594	-10,914	10	-572	<b>461,948</b>
<b>Grassland</b>	5,736	4,140,385	-929	-61	0	-61	282	-14,896	<b>4,130,516</b>
<b>Cropland</b>	1,915	929	404,563	0	0	0	25	0	<b>407,432</b>
<b>Managed Wetland</b>	320	61	0	73,452	563	74,015	0	0	<b>74,395</b>
<b>Unmanaged Wetland</b>	10,594	0	0	-563	1,225,898	1,225,335	0	0	<b>1,235,929</b>
<b>Settlements</b>	-10	-282	-25	0	0	0	98,145	-18	<b>97,809</b>
<b>Other land</b>	572	14,896	0	0	0	0	18	688,269	<b>703,756</b>
<b>1991</b>	<b>500,201</b>	<b>4,150,253</b>	<b>401,694</b>	<b>72,508</b>	<b>1,215,867</b>	<b>1,288,375</b>	<b>98,480</b>	<b>672,782</b>	<b>7,111,785</b>

<b>Forest</b>	500,201	-5,002	-1,670	-320	-9,198	-9,518	10	-499	<b>483,522</b>
<b>Grassland</b>	5,002	4,150,253	2,618	-61	0	-61	286	22,692	<b>4,180,790</b>
<b>Cropland</b>	1,670	-2,618	401,694	0	0	0	26	0	<b>400,771</b>
<b>Managed Wetland</b>	320	61	0	72,508	163	72,671	0	0	<b>73,052</b>
<b>Unmanaged Wetland</b>	9,198	0	0	-163	1,215,867	1,215,704	0	0	<b>1,224,903</b>
<b>Settlements</b>	-10	-286	-26	0	0	0	98,480	-19	<b>98,140</b>
<b>Other land</b>	499	-22,692	0	0	0	0	19	672,782	<b>650,607</b>
<b>1992</b>	<b>516,879</b>	<b>4,119,716</b>	<b>402,616</b>	<b>71,964</b>	<b>1,206,832</b>	<b>1,278,796</b>	<b>98,821</b>	<b>694,957</b>	<b>7,111,785</b>

<b>Forest</b>	516,879	-4,791	-1,600	-320	-8,799	-9,119	10	-478	<b>500,902</b>
<b>Grassland</b>	4,791	4,119,716	12,797	-61	0	-61	306	2,558	<b>4,140,108</b>
<b>Cropland</b>	1,600	-12,797	402,616	0	0	0	28	0	<b>391,446</b>
<b>Managed Wetland</b>	320	61	0	71,964	343	72,307	0	0	<b>72,688</b>
<b>Unmanaged Wetland</b>	8,799	0	0	-343	1,206,832	1,206,489	0	0	<b>1,215,288</b>
<b>Settlements</b>	-10	-306	-28	0	0	0	98,821	-20	<b>98,457</b>
<b>Other land</b>	478	-2,558	0	0	0	0	20	694,957	<b>692,897</b>
<b>1993</b>	<b>532,857</b>	<b>4,099,324</b>	<b>413,785</b>	<b>71,241</b>	<b>1,198,376</b>	<b>1,269,616</b>	<b>99,185</b>	<b>697,018</b>	<b>7,111,785</b>

**Table 7.4. Land Use Matrices 1990-2011(ha) Change (continued)**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>Forest</b>	532,857	-5,830	-1,946	-320	-10,772	-11,092	10	-582	<b>513,418</b>
<b>Grassland</b>	5,830	4,099,324	-1,504	-61	0	-61	380	5,705	<b>4,109,674</b>
<b>Cropland</b>	1,946	1,504	413,785	0	0	0	34	0	<b>417,269</b>
<b>Managed Wetland</b>	320	61	0	71,241	167	71,408	0	0	<b>71,788</b>
<b>Unmanaged Wetland</b>	10,772	0	0	-167	1,198,376	1,198,209	0	0	<b>1,208,980</b>
<b>Settlements</b>	-10	-380	-34	0	0	0	99,185	-25	<b>98,736</b>
<b>Other land</b>	582	-5,705	0	0	0	0	25	697,018	<b>691,919</b>
<b>1994</b>	<b>552,295</b>	<b>4,088,974</b>	<b>410,301</b>	<b>70,693</b>	<b>1,187,771</b>	<b>1,258,464</b>	<b>99,634</b>	<b>702,117</b>	<b>7,111,785</b>

<b>Forest</b>	552,295	-6,846	-2,371	-140	-13,375	-13,515	0	-645	<b>528,918</b>
<b>Grassland</b>	6,846	4,088,974	1,381	-30	0	-30	392	-7,462	<b>4,090,101</b>
<b>Cropland</b>	2,371	-1,381	410,301	0	0	0	35	0	<b>411,326</b>
<b>Managed Wetland</b>	140	30	0	70,693	650	71,343	0	0	<b>71,513</b>
<b>Unmanaged Wetland</b>	13,375	0	0	-650	1,187,771	1,187,121	0	0	<b>1,200,495</b>
<b>Settlements</b>	0	-392	-35	0	0	0	99,634	-26	<b>99,181</b>
<b>Other land</b>	645	7,462	0	0	0	0	26	702,117	<b>710,250</b>
<b>1995</b>	<b>575,672</b>	<b>4,087,847</b>	<b>409,277</b>	<b>69,873</b>	<b>1,175,046</b>	<b>1,244,919</b>	<b>100,086</b>	<b>693,984</b>	<b>7,111,785</b>

<b>Forest</b>	575,672	-6,028	-2,098	-140	-11,819	-11,959	0	-563	<b>555,024</b>
<b>Grassland</b>	6,028	4,087,847	9,418	-30	0	-30	497	39,628	<b>4,143,387</b>
<b>Cropland</b>	2,098	-9,418	409,277	0	0	0	45	0	<b>402,001</b>
<b>Managed Wetland</b>	140	30	0	69,873	1,047	70,920	0	0	<b>71,090</b>
<b>Unmanaged Wetland</b>	11,819	0	0	-1,047	1,175,046	1,173,999	0	0	<b>1,185,818</b>
<b>Settlements</b>	0	-497	-45	0	0	0	100,086	-32	<b>99,513</b>
<b>Other land</b>	563	-39,628	0	0	0	0	32	693,984	<b>654,952</b>
<b>1996</b>	<b>596,319</b>	<b>4,032,307</b>	<b>416,552</b>	<b>68,656</b>	<b>1,164,274</b>	<b>1,232,930</b>	<b>100,660</b>	<b>733,017</b>	<b>7,111,785</b>

<b>Forest</b>	596,319	-3,164	-1,143	-140	-6,377	-6,517	0	-276	<b>585,219</b>
<b>Grassland</b>	3,164	4,032,307	-1,260	-30	0	-30	544	12,689	<b>4,047,414</b>
<b>Cropland</b>	1,143	1,260	416,552	0	0	0	49	0	<b>419,004</b>
<b>Managed Wetland</b>	140	30	0	68,656	732	69,388	0	0	<b>69,558</b>
<b>Unmanaged Wetland</b>	6,377	0	0	-732	1,164,274	1,163,542	0	0	<b>1,169,919</b>
<b>Settlements</b>	0	-544	-49	0	0	0	100,660	-36	<b>100,031</b>
<b>Other land</b>	276	-12,689	0	0	0	0	36	733,017	<b>720,640</b>
<b>1997</b>	<b>607,420</b>	<b>4,017,200</b>	<b>414,100</b>	<b>67,754</b>	<b>1,158,629</b>	<b>1,226,383</b>	<b>101,289</b>	<b>745,394</b>	<b>7,111,785</b>

**Table 7.4. Land Use Matrices 1990-2011(ha) Change (continued)**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>Forest</b>	607,420	-3,612	-1,293	-140	-7,229	-7,369	0	-321	<b>594,825</b>
<b>Grassland</b>	3,612	4,017,200	-4,754	-30	0	-30	587	10,985	<b>4,027,600</b>
<b>Cropland</b>	1,293	4,754	414,100	0	0	0	53	0	<b>420,200</b>
<b>Managed Wetland</b>	140	30	0	67,754	731	68,485	0	0	<b>68,655</b>
<b>Unmanaged Wetland</b>	7,229	0	0	-731	1,158,629	1,157,898	0	0	<b>1,165,127</b>
<b>Settlements</b>	0	-587	-53	0	0	0	101,289	-38	<b>100,610</b>
<b>Other land</b>	321	-10,985	0	0	0	0	38	745,394	<b>734,768</b>
<b>1998</b>	<b>620,015</b>	<b>4,006,800</b>	<b>408,000</b>	<b>66,853</b>	<b>1,152,131</b>	<b>1,218,984</b>	<b>101,967</b>	<b>756,020</b>	<b>7,111,785</b>

<b>Forest</b>	620,015	-3,534	-1,267	-140	-7,081	-7,221	0	-313	<b>607,680</b>
<b>Grassland</b>	3,534	4,006,800	-5,777	-30	0	-30	629	-8,956	<b>3,996,200</b>
<b>Cropland</b>	1,267	5,777	408,000	0	0	0	57	0	<b>415,100</b>
<b>Managed Wetland</b>	140	30	0	66,853	1,144	67,997	0	0	<b>68,167</b>
<b>Unmanaged Wetland</b>	7,081	0	0	-1,144	1,152,131	1,150,987	0	0	<b>1,158,067</b>
<b>Settlements</b>	0	-629	-57	0	0	0	101,967	-41	<b>101,241</b>
<b>Other land</b>	313	8,956	0	0	0	0	41	756,020	<b>765,330</b>
<b>1999</b>	<b>632,350</b>	<b>4,017,400</b>	<b>400,900</b>	<b>65,539</b>	<b>1,146,194</b>	<b>1,211,733</b>	<b>102,694</b>	<b>746,709</b>	<b>7,111,785</b>

<b>Forest</b>	632,350	-4,308	-1,570	-327	-8,619	-8,946	171	-185	<b>617,512</b>
<b>Grassland</b>	4,308	4,017,400	816	-75	0	-75	517	-30,066	<b>3,992,900</b>
<b>Cropland</b>	1,570	-816	400,900	0	0	0	46	0	<b>401,700</b>
<b>Managed Wetland</b>	327	75	0	65,539	1,628	67,167	0	0	<b>67,569</b>
<b>Unmanaged Wetland</b>	8,449	0	0	-1,628	1,146,194	1,144,566	0	0	<b>1,153,014</b>
<b>Settlements</b>	-171	-517	-46	0	0	0	102,694	-34	<b>101,926</b>
<b>Other land</b>	356	30,066	0	0	0	0	34	746,709	<b>777,165</b>
<b>2000</b>	<b>647,188</b>	<b>4,041,900</b>	<b>400,100</b>	<b>63,509</b>	<b>1,139,203</b>	<b>1,202,712</b>	<b>103,462</b>	<b>716,424</b>	<b>7,111,785</b>

<b>Forest</b>	647,187	-4,239	-1,547	-327	-8,488	-8,815	171	-179	<b>632,579</b>
<b>Grassland</b>	4,239	4,041,900	16,113	-75	0	-75	738	26,385	<b>4,089,300</b>
<b>Cropland</b>	1,547	-16,113	400,100	0	0	0	66	0	<b>385,600</b>
<b>Managed Wetland</b>	327	75	0	63,509	1,542	65,051	0	0	<b>65,453</b>
<b>Unmanaged Wetland</b>	8,317	0	0	-1,542	1,139,203	1,137,661	0	0	<b>1,145,978</b>
<b>Settlements</b>	-171	-738	-66	0	0	0	103,462	-48	<b>102,438</b>
<b>Other land</b>	349	-26,385	0	0	0	0	48	716,424	<b>690,437</b>
<b>2001</b>	<b>661,795</b>	<b>3,994,500</b>	<b>414,600</b>	<b>61,565</b>	<b>1,132,257</b>	<b>1,193,822</b>	<b>104,486</b>	<b>742,582</b>	<b>7,111,785</b>

**Table 7.4. Land Use Matrices 1990-2011(ha) Change (continued)**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>Forest</b>	661,795	-4,116	-1,505	-327	-8,254	-8,581	171	-166	<b>647,598</b>
<b>Grassland</b>	4,116	3,994,500	9,865	-75	0	-75	661	31,333	<b>4,040,400</b>
<b>Cropland</b>	1,505	-9,865	414,600	0	0	0	59	0	<b>406,300</b>
<b>Managed Wetland</b>	327	75	0	61,565	1,546	63,111	0	0	<b>63,513</b>
<b>Unmanaged Wetland</b>	8,083	0	0	-1,546	1,132,257	1,130,711	0	0	<b>1,138,794</b>
<b>Settlements</b>	-171	-661	-59	0	0	0	104,486	-43	<b>103,550</b>
<b>Other land</b>	337	-31,333	0	0	0	0	43	742,582	<b>711,630</b>
<b>2002</b>	<b>675,992</b>	<b>3,948,600</b>	<b>422,900</b>	<b>59,617</b>	<b>1,125,550</b>	<b>1,185,167</b>	<b>105,421</b>	<b>773,706</b>	<b>7,111,785</b>

<b>Forest</b>	675,992	-2,329	-910	-327	-4,858	-5,185	171	12	<b>667,752</b>
<b>Grassland</b>	2,329	3,948,600	13,785	-75	0	-75	837	-2,176	<b>3,963,300</b>
<b>Cropland</b>	910	-13,785	422,900	0	0	0	75	0	<b>410,100</b>
<b>Managed Wetland</b>	327	75	0	59,617	1,545	61,162	0	0	<b>61,564</b>
<b>Unmanaged Wetland</b>	4,688	0	0	-1,545	1,125,550	1,124,004	0	0	<b>1,128,692</b>
<b>Settlements</b>	-171	-837	-75	0	0	0	105,421	-55	<b>104,283</b>
<b>Other land</b>	158	2,176	0	0	0	0	55	773,706	<b>776,094</b>
<b>2003</b>	<b>684,232</b>	<b>3,933,900</b>	<b>435,700</b>	<b>57,670</b>	<b>1,122,236</b>	<b>1,179,906</b>	<b>106,559</b>	<b>771,488</b>	<b>7,111,785</b>

<b>Forest</b>	684,232	-2,522	-974	-327	-5,224	-5,551	171	-7	<b>675,350</b>
<b>Grassland</b>	2,522	3,933,900	-11,846	-75	0	-75	886	61,414	<b>3,986,800</b>
<b>Cropland</b>	974	11,846	435,700	0	0	0	80	0	<b>448,600</b>
<b>Managed Wetland</b>	327	75	0	57,670	1,542	59,212	0	0	<b>59,614</b>
<b>Unmanaged Wetland</b>	5,054	0	0	-1,542	1,122,236	1,120,694	0	0	<b>1,125,748</b>
<b>Settlements</b>	-171	-886	-80	0	0	0	106,559	-58	<b>105,364</b>
<b>Other land</b>	177	-61,414	0	0	0	0	58	771,488	<b>710,309</b>
<b>2004</b>	<b>693,114</b>	<b>3,881,000</b>	<b>422,800</b>	<b>55,726</b>	<b>1,118,554</b>	<b>1,174,280</b>	<b>107,754</b>	<b>832,837</b>	<b>7,111,785</b>

<b>Forest</b>	693,114	-2,629	-1,010	-133	-5,621	-5,755	171	-17	<b>683,875</b>
<b>Grassland</b>	2,629	3,881,000	-37,896	-88	0	-88	1,055	14,501	<b>3,861,200</b>
<b>Cropland</b>	1,010	37,896	422,800	0	0	0	95	0	<b>461,800</b>
<b>Managed Wetland</b>	133	88	0	55,726	216	55,942	0	0	<b>56,164</b>
<b>Unmanaged Wetland</b>	5,451	0	0	-216	1,118,554	1,118,338	0	0	<b>1,123,789</b>
<b>Settlements</b>	-171	-1,055	-95	0	0	0	107,754	-69	<b>106,364</b>
<b>Other land</b>	188	-14,501	0	0	0	0	69	832,837	<b>818,593</b>
<b>2005</b>	<b>702,353</b>	<b>3,900,800</b>	<b>383,800</b>	<b>55,288</b>	<b>1,113,149</b>	<b>1,168,437</b>	<b>109,144</b>	<b>847,251</b>	<b>7,111,785</b>

**Table 7.4. Land Use Matrices 1990-2011(ha) Change (continued)**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>Forest</b>	702,353	-2,386	-804	-133	-4,448	-4,581	17	93	<b>694,692</b>
<b>Grassland</b>	2,386	3,900,800	-4,086	-88	0	-88	1,231	21,857	<b>3,922,100</b>
<b>Cropland</b>	804	4,086	383,800	0	0	0	111	0	<b>388,800</b>
<b>Managed Wetland</b>	133	88	0	55,288	195	55,483	0	0	<b>55,704</b>
<b>Unmanaged Wetland</b>	4,117	0	0	-195	1,113,149	1,112,955	0	0	<b>1,117,072</b>
<b>Settlements</b>	-17	-1,231	-111	0	0	0	109,144	-80	<b>107,704</b>
<b>Other land</b>	238	-21,857	0	0	0	0	80	847,251	<b>825,713</b>
<b>2006</b>	<b>710,014</b>	<b>3,879,500</b>	<b>378,800</b>	<b>54,872</b>	<b>1,108,896</b>	<b>1,163,768</b>	<b>110,583</b>	<b>869,120</b>	<b>7,111,785</b>

<b>Forest</b>	710,015	-2,137	-718	-133	-3,956	-4,090	5	103	<b>703,179</b>
<b>Grassland</b>	2,137	3,879,500	-668	-88	0	-88	1,268	-19,649	<b>3,862,500</b>
<b>Cropland</b>	718	668	378,800	0	0	0	114	0	<b>380,300</b>
<b>Managed Wetland</b>	133	88	0	54,872	265	55,137	0	0	<b>55,358</b>
<b>Unmanaged Wetland</b>	3,659	0	0	-265	1,108,896	1,108,631	0	0	<b>1,112,291</b>
<b>Settlements</b>	-5	-1,268	-114	0	0	0	110,583	-83	<b>109,113</b>
<b>Other land</b>	194	19,649	0	0	0	0	83	869,119	<b>889,044</b>
<b>2007</b>	<b>716,852</b>	<b>3,896,500</b>	<b>377,300</b>	<b>54,386</b>	<b>1,105,204</b>	<b>1,159,590</b>	<b>112,054</b>	<b>849,490</b>	<b>7,111,785</b>

<b>Forest</b>	716,852	-1,792	-625	-133	-3,429	-3,562	66	-42	<b>710,897</b>
<b>Grassland</b>	1,792	3,896,500	49,614	-88	0	-88	992	63,189	<b>4,012,000</b>
<b>Cropland</b>	625	-49,614	377,300	0	0	0	89	0	<b>328,400</b>
<b>Managed Wetland</b>	133	88	0	54,386	275	54,661	0	0	<b>54,882</b>
<b>Unmanaged Wetland</b>	3,385	0	0	-275	1,105,204	1,104,929	0	0	<b>1,108,314</b>
<b>Settlements</b>	-66	-992	-89	0	0	0	112,054	-65	<b>110,841</b>
<b>Other land</b>	85	-63,189	0	0	0	0	65	849,490	<b>786,451</b>
<b>2008</b>	<b>722,806</b>	<b>3,781,000</b>	<b>426,200</b>	<b>53,889</b>	<b>1,102,051</b>	<b>1,155,940</b>	<b>113,266</b>	<b>912,573</b>	<b>7,111,785</b>

<b>Forest</b>	722,806	-1,989	-665	-133	-3,656	-3,789	18	-26	<b>716,355</b>
<b>Grassland</b>	1,989	3,781,000	-16,770	-88	0	-88	727	7,342	<b>3,774,200</b>
<b>Cropland</b>	665	16,770	426,200	0	0	0	65	0	<b>443,700</b>
<b>Managed Wetland</b>	133	88	0	53,889	252	54,141	0	0	<b>54,363</b>
<b>Unmanaged Wetland</b>	3,656	0	0	-252	1,102,051	1,101,799	0	0	<b>1,105,455</b>
<b>Settlements</b>	-18	-727	-65	0	0	0	113,266	-47	<b>112,409</b>
<b>Other land</b>	26	-7,342	0	0	0	0	47	912,573	<b>905,304</b>
<b>2009</b>	<b>729,257</b>	<b>3,787,800</b>	<b>408,700</b>	<b>53,415</b>	<b>1,098,647</b>	<b>1,152,062</b>	<b>114,124</b>	<b>919,842</b>	<b>7,111,785</b>

**Table 7.4. Land Use Matrices 1990-2011(ha) Change (continued)**

	Forest	Grassland	Cropland	Managed Wetland <sup>1</sup>	Unmanaged Wetlands	Total Wetlands <sup>2</sup>	Settlements	Other land	Total
<b>Forest</b>	729,256	-2,454	-831	-133	-4,606	-4,739	55	-220	<b>721,067</b>
<b>Grassland</b>	2,454	3,787,800	-55,613	-88	0	-88	618	42,403	<b>3,777,574</b>
<b>Cropland</b>	831	55,613	408,700	0	0	0	56	0	<b>465,200</b>
<b>Managed Wetland</b>	133	88	0	53,415	245	53,660	0	0	<b>53,882</b>
<b>Unmanaged Wetland</b>	4,605	0	0	-245	1,098,647	1,098,402	0	0	<b>1,103,007</b>
<b>Settlements</b>	-55	-618	-56	0	0	0	114,124	-40	<b>113,355</b>
<b>Other land</b>	220	-42,403	0	0	0	0	40	919,843	<b>877,701</b>
<b>2010</b>	<b>737,446</b>	<b>3,798,026</b>	<b>352,200</b>	<b>52,948</b>	<b>1,094,287</b>	<b>1,147,235</b>	<b>114,893</b>	<b>961,986</b>	<b>7,111,785</b>

<b>Forest</b>	737,446	-1,996	-665	-133	-3,659	-3,792	81	-23	<b>731,050</b>
<b>Grassland</b>	1,996	3,798,026	12,577	-88	0	-88	136	-27,814	<b>3,784,833</b>
<b>Cropland</b>	665	-12,577	352,200	0	0	0	12	0	<b>340,300</b>
<b>Managed Wetland</b>	133	88	0	52,948	244	53,192	0	0	<b>53,414</b>
<b>Unmanaged Wetland</b>	3,659	0	0	-244	1,094,287	1,094,043	0	0	<b>1,097,701</b>
<b>Settlements</b>	-81	-136	-12	0	0	0	114,893	-9	<b>114,656</b>
<b>Other land</b>	23	27,814	0	0	0	0	9	961,986	<b>989,832</b>
<b>2011</b>	<b>743,841</b>	<b>3,811,220</b>	<b>364,100</b>	<b>52,482</b>	<b>1,090,872</b>	<b>1,143,354</b>	<b>115,130</b>	<b>934,140</b>	<b>7,111,785</b>

<sup>1</sup> Managed Wetland in this context is a sub-category of Wetland remaining Wetland which is managed for the purpose of peat extraction for fuel and horticultural use. Unmanaged Wetland is Wetland in an undisturbed state or Wetland that may have been disturbed in the past but not actively managed since 1990.

<sup>2</sup> Total Wetlands is the sum of Managed Wetland and Unmanaged Wetland.

## 7.3 Forest Land (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 is due for completion in 2013. 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 7.2 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 7.2 (also see section 7.3.4.1).

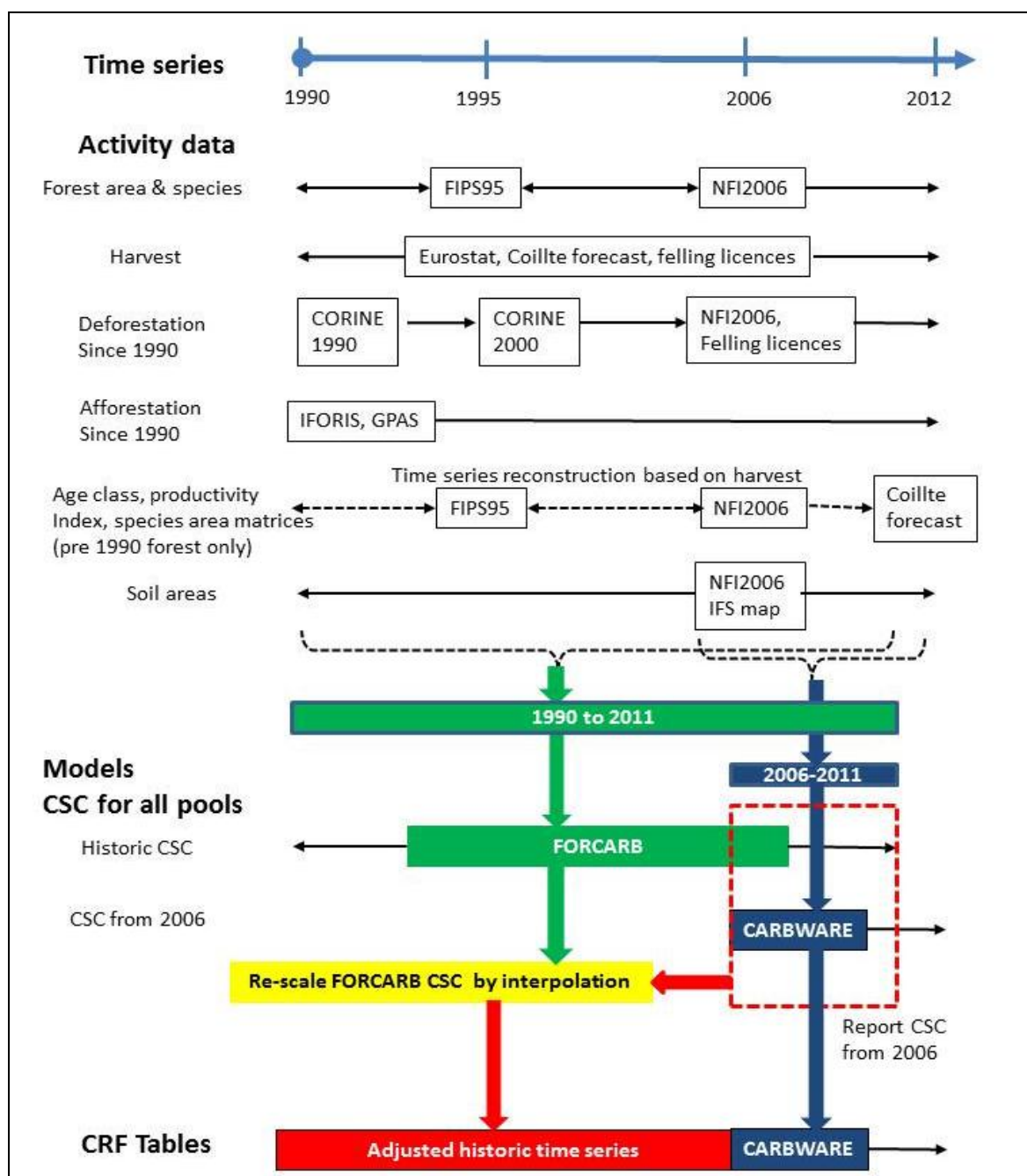


Figure 7.2 Activity data and models used to derive CSC for forest lands

Figure 7.2 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 7.2 indicated interpolation and adjustment of the historic data against CARBWARE outputs to ensure a consistent representation of the entire time series.

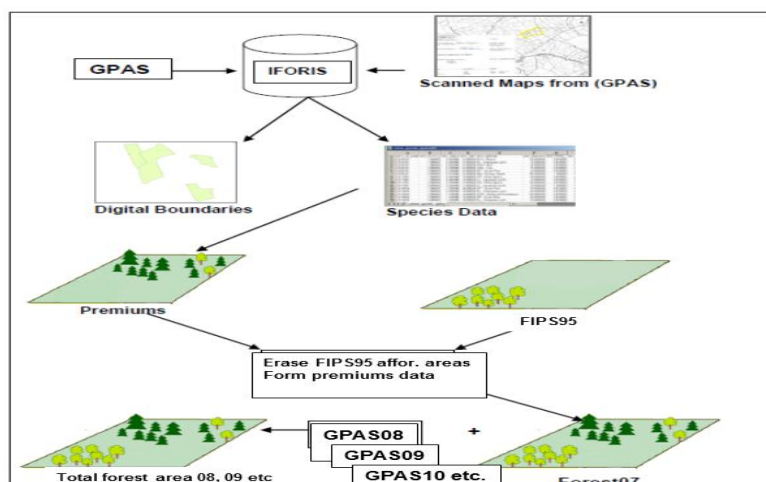
## 7.3.2 Detailed Description of Activity Data

### 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 7.2 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 approach 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). 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). 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** 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 carried out in 2005 and 2006 using a sampling approach, based on a randomised systematic grid sample design. This system is also designed to track land use change trends when the inventory is repeated in 2013. 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 7.4). 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.

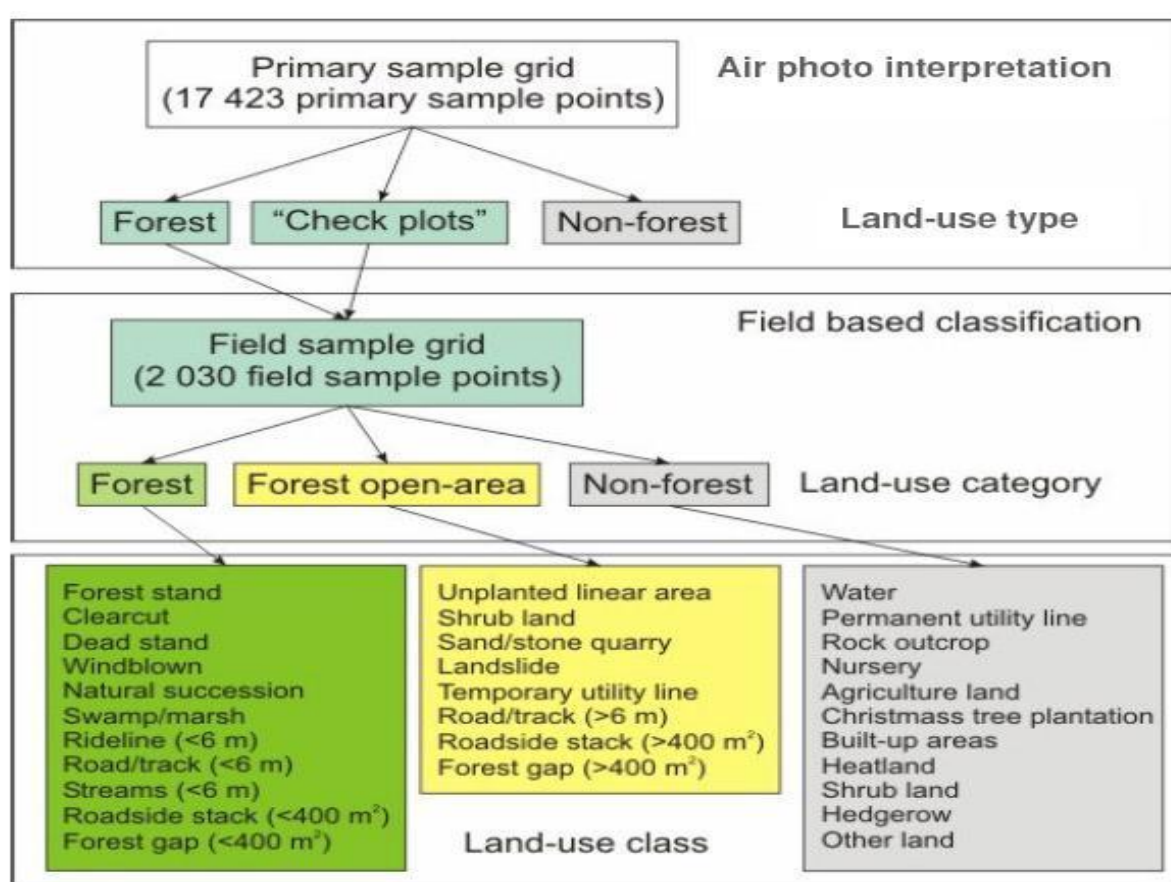
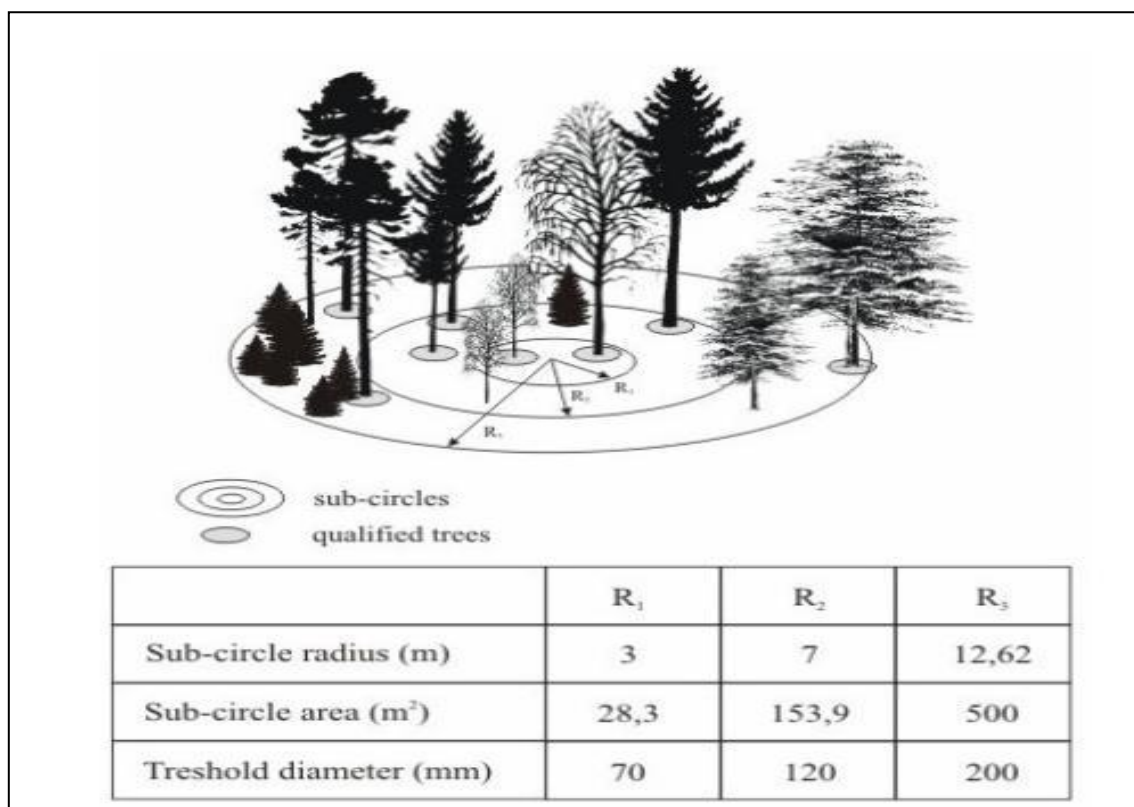


Figure 7.4 Overview of the NFI classification system (taken from NFI, 2007a)

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). The primary focus of the interpretation is to identify forest land. 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 in 2010 (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<sup>2</sup> (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 7.5). Individual trees in the plot are mapped and tree metric 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 7.5)<sup>2</sup>. 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.



*Figure 7.5 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.

<sup>2</sup> Note: The concentric plot sampling approach used (see Fig 7.5) has implications for uncertainty (see validation and uncertainty sections)

#### 7.3.2.4 Harvests, Restocking and Deforestation

Harvest data are compiled using data national data submitted to the FAO and EUROSTAT. Harvest from lands converted to forest land (i.e. all forests established since 1990) 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. Activity data relating to the removal of timber from NFI permanent sample plots in the lands converted to forests (CRF 5A2) and AR (Ch 11) categories was obtained from felling licence information in respect of private sector forests and from the Coillte forest sub-compartment forecast inventory for State forests. The total timber volumes harvested from the areas afforested since 1990 was 184,729 m<sup>3</sup> in 2007, 326,565 m<sup>3</sup> in 2008, 119,072 m<sup>3</sup> in 2009, 234,252 m<sup>3</sup> in 2010 and 284,906 in 2011. 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.

To derive harvest since 2007 from post-1990 Coillte (State owned) forests, the NFI sample plot co-ordinates and Coillte sub-compartment polygons were intersected to produce a layer representing NFI-Coillte plots with harvest management statistics (Figure 7.6). Harvested volume and basal area removed during harvest was assigned to individual NFI plots, representing 400 ha, based on Coillte Forecast plans. The total volume removed in a given year was validated against independently derived FAO/Eurostat data and Coillte sales invoice information. An EventsTable table for use in the CARBWARE database was created for input into the stand modification functions within the CARBWARE model to simulate the harvesting of trees. A final validation was performed on the individual tree tables (see Figure 7.6) to ensure adequate timber was removed during a thinning simulation. It will be possible in the future to re-evaluate the activity data 'ground truthed data' from repeat NFI inventories of harvested plots, where adjustment can be made to the harvest volumes based on new PSP information.

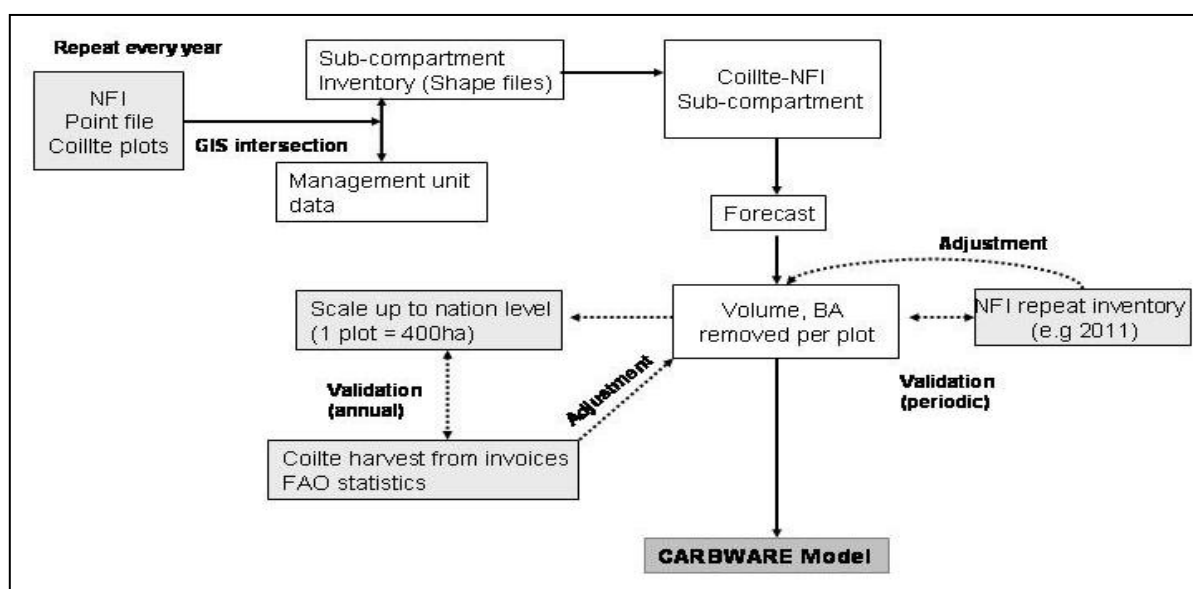


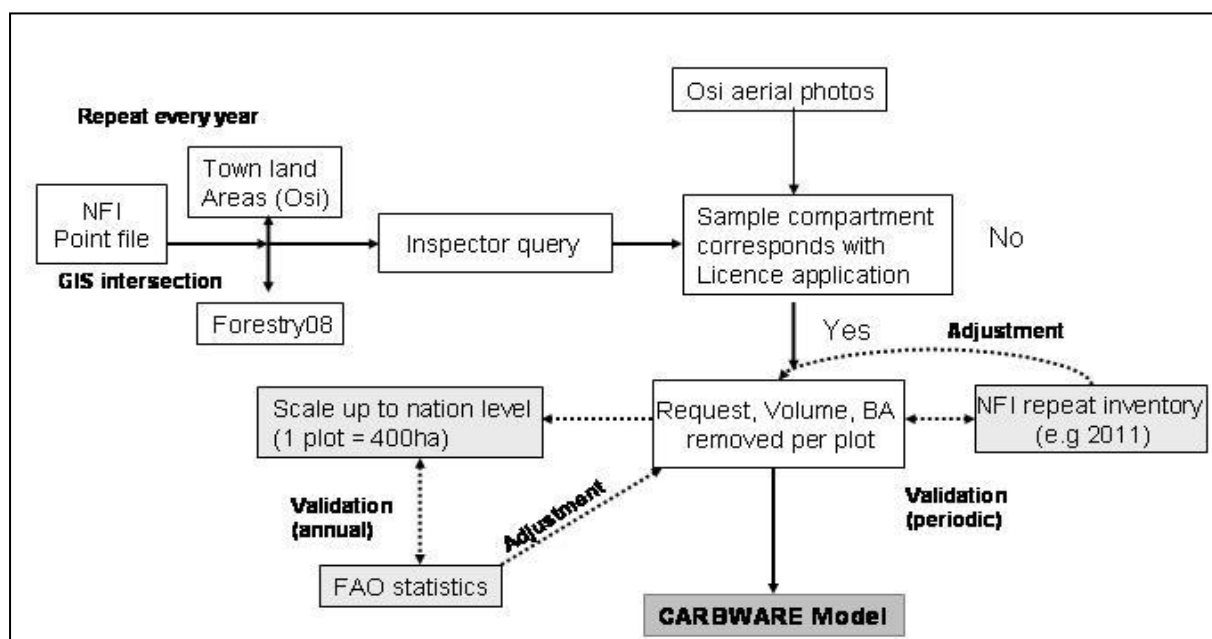
Figure 7.6 Methodology used to derive harvest information for post-1990 State Forests

To derive harvests from private forests, a GIS layer was created by intersection of Town land boundaries and names (OSI) and the GPAS layer compartments (see Figure 7.7) that

contain NFI plots. This layer contains attributes which identifies permanent sample plots which may be subjected to harvesting activities as supplied on felling licence application forms (Figure 7.7). Once this layer is updated every year the Forest Service carries out the following checks:

- i. Forest inspectors open the GIS attribute table to check if the Town land in question (as specified on felling licence application) contains a sample compartment;
- ii. If there is a sample compartment in the Town land, then an aerial photo layer is used to locate the compartment as indicated in the OS map in the hardcopy of the felling licence application;
- iii. Once the compartment is located, a shaded area within or covering the entire area should be identified once the GIS layer is switched on. The shaded area will contain a unique number which is used as a reference (name - FID number);
- iv. The inspector can then contact the contractor or owner to obtain information on area, species, volume and basal area removed due to harvest.

The scaled up total volume removed in a given year was compared against independently derived FAO/Eurostat information and adjusted if required. An 'EventsTable' table for in the CARBWARE database was created for input into the stand modification functions within the CARBWARE model to simulate the harvesting of trees. A final validation was performed on the individual tree tables to ensure adequate timber was removed during a thinning simulation. It will be possible in the future to re-evaluate the activity data 'ground truthed data' from repeat NFI inventories of harvested plots.



*Figure 7.7 Procedure used to derive harvest activity data for private forested areas*

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 from 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 exercise 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 onwards

New data from the Forest Service shows that some forest land is converted to land categories other than settlements and this information is used to derive carbon stock changes for the relevant land categories for the 2012 submission. These activity data come from felling licence applications and are limited to the years 2006 to 2011. The Forestry Act legally requires a formal application to the Forest Service to fell trees under either a limited or a general felling license. General felling licences cover forestry activities associated with silvicultural management, such as thinnings or clearfell and replanting. Limited felling licences now capture areas and volumes felled and land use transitions for all forest land converted to other land uses.

All activities carried out under a general felling licence are not considered to represent deforestation. However, 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 due in 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.

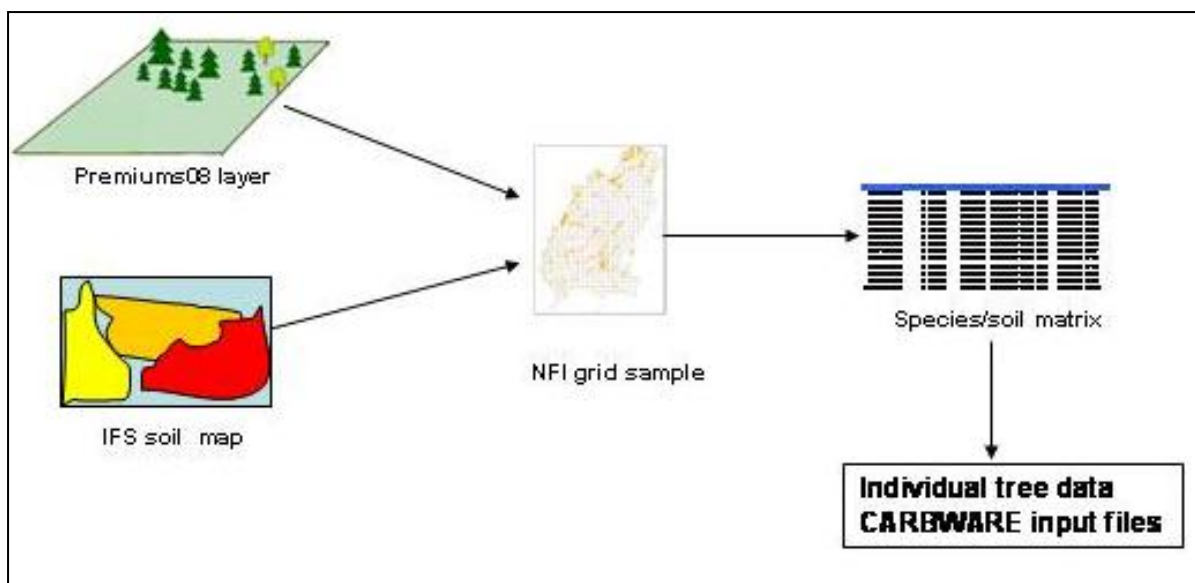
A QA exercise conducted in 2010 highlighted that 134 to 268 ha per year of land deforested since 2006 was not included in the felling licence records, if forests were less than 10 years old. Felling stands younger than 10 years old are not subject to the forestry act felling licence application. However, 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 has been compiled to capture the land use change and soil categories. The biomass, litter and DOM losses associated with deforestation are based on the NFI, PSP average of all 10 year old forest areas.

#### 7.3.2.5 Activity Data for Afforestation Areas after 2006

Activity data of land afforested since 2007, after the completion of the first NFI, was derived by GIS analysis of the updated Premium Layer (Figure 7.2), a digitised map of indicative forest soils (IFS) and intersection with NFI grid co-ordinates (Figure 7.8). The resulting species/soil matrix was used to derive productivity classes and individual tree height values based on CARBWARE growth models (see Annex K). These tables were used as inputs into the CARBWARE software to generate carbon gains and losses (see Figure 7.9)

The soils and land cover datasets were derived from a number of map sources, remotely-sensed and ground-truthed data. A land cover map with a minimum resolution of 1 ha was derived using aerial photography and satellite imagery (Fealy et al., 2006). The land cover mapping exercise used the known occurrence of grassland types in Ireland and their relation to soils. Thematic classes include grassland, bog and heath, rocky complexes, bare rock, forest (unenclosed) and scrub, urban land, coastal complexes, and water bodies. The land cover dataset was derived primarily from remotely sensed data, including 1995 Landsat TM satellite imagery, 1995 black and white stereo aerial photography and 2001 ETM satellite imagery.

The digital soil mapping project delivered soil and subsoil/parent material maps by extending information obtained from various surveys using a soil cover model (Fealy et al., 2006). Over 40 per cent of the dataset is a direct derivative of the National Soil Survey (Gardiner and Radford 1980) and has a minimum mapping unit of 1 ha. Subsequently, the FIPS-IFS project produced a first-approximation soil classification for those areas not previously surveyed by the National Soil Survey (NSS), using a methodology based on remote sensing and GIS. A modelling approach was then adopted to produce a projected map for Ireland using a modular system based on different soil/peat forming factors, such as sub-soils, parent material, vegetation and topography (Fealy et al., 2006 and Loftus et al., 2002). These maps were then combined to create a predictive model of soil/peat occurrence, which is represented in GIS map form.



*Figure 7.8 Procedure to derive activity data for Afforestation Areas after 2006*

### 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 7.2 and 7.9). 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), software was developed to facilitate reporting of pools using model functions and input activity data (Figure 7.9). 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 2013.

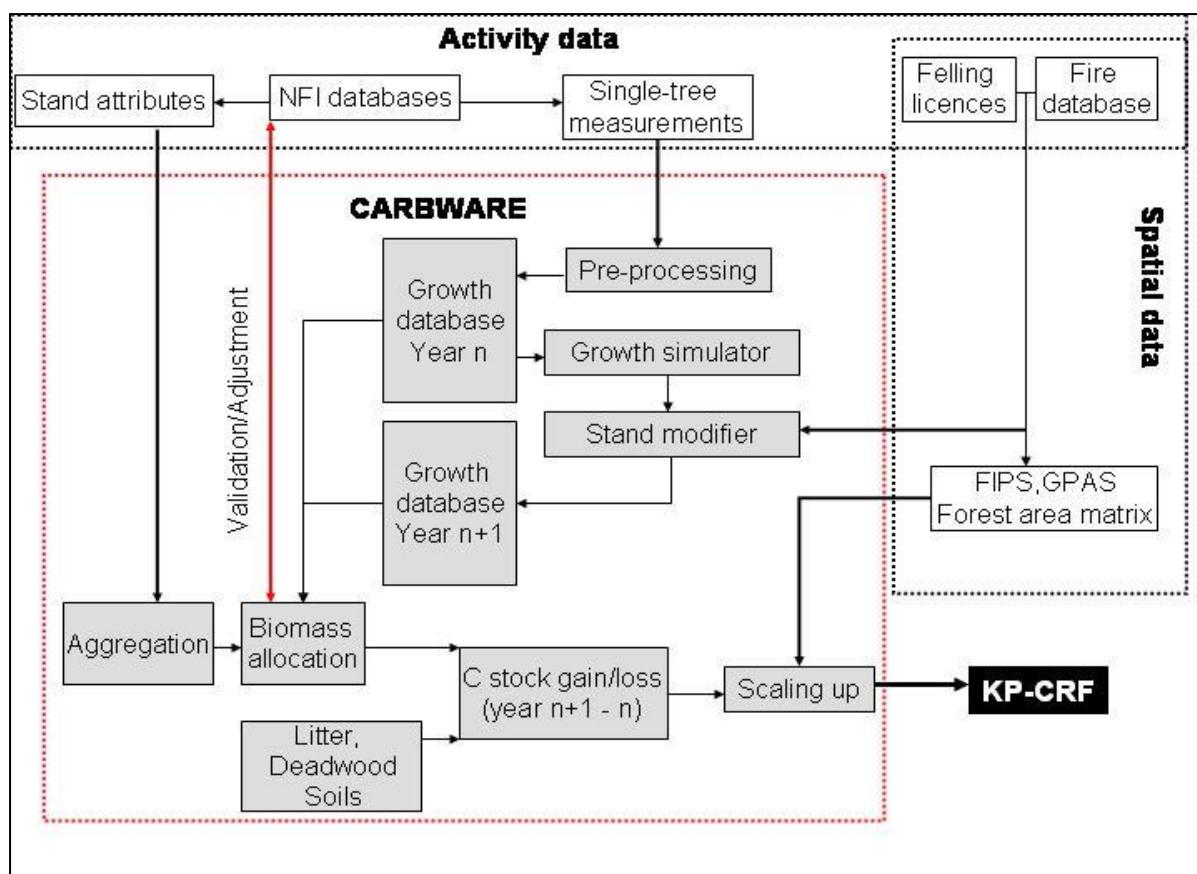


Figure 7.9 Schematic Overview of CARBWARE Functionality<sup>3</sup>

### 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):

$$\Delta C_{lu} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{Li} + \Delta C_{Dw} + \Delta C_{So} \dots \dots \dots (7.1)$$

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

<sup>3</sup> 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

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.

#### 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

$$\Delta C = \Delta C_G + \Delta C_L \dots\dots\dots(7.2)$$

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

$$\Delta C_G = GTOTAL \times CF \dots\dots\dots(7.3)$$

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:

$$GTOTAL_{AB} = AB_n - AB_{n-1} \dots\dots\dots(7.4)$$

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 7.8). 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 7.8), 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 ( $L_{fire}$ ):

$$\Delta C_{L(AB)} = L_{timber} + L_{HR} + L_{LF} + L_{mort(AB)} + L_{fire} \dots\dots\dots(7.5)$$

$L_{timber}$  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:

$$L_{HR} = AG - L_{timber} \dots\dots\dots(7.6)$$

$L_{LF}$  reflects the transfer of carbon from the AB pool to the litter pool. This is calculated in the allocation module (Figure 7.8), based on nationally derived leaf/needle biomass (LB) and the foliage turnover rates ( $F_t$ ) (Tobin et al., 2006):

$$L_{LF} = LB \times F_t \dots\dots\dots(7.7)$$

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 ( $L_{fire}$ ):

$$\Delta C_{L(BB)} = L_{HRroot} + L_{mort(BB)} + L_{fire} \dots\dots\dots(7.8)$$

$L_{HRroot}$  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 were not based on NFI measurements, but rather felling licence volume estimates. The carbon stock losses in the AB and BB pools for deforestation were calculated from the standing volume (V) of the forest stand, as specified on the limited felling licence application, 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  $1.68 \text{ t/t}^{-1}$ , a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2 (Black et al., 2009), as follows

$$TOTAL_{(AB)} = (V \times D \times BEF \times CF) \times 1/(1-R) \dots\dots\dots(7.9)$$

$$TOTAL_{(BB)} = TOTAL_{(AB)} \times R \dots\dots\dots(7.10)$$

Volume (V) of stands was derived from felling licence statistics. 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.

## b) Litter Carbon Stock Change

Net litter stock change ( $\Delta C_{Li}$ ) was calculated based on litter inputs (gains) due to litterfall ( $L_{LF}$ ), as given by equation 7.7, harvest residue litter input ( $L_{HR}$ ) in equation 7.6, mortality litter inputs ( $M_{li}$ ), and losses associated with decomposition of the litter pool ( $L_{decomp}$ ):

$$\Delta C_{Li} = (L_{LF} + L_{HR} + M_{Li}) - L_{decomp} \dots\dots\dots(7.11)$$

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 ( $L_{mort(tim)}$ ):

$$M_{Li} = L_{mort(AB)} - L_{mort(tim)} \dots\dots\dots(7.12)$$

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):

$$L_{decomp} = 1 - \left[ \sum [L_{LF}, L_{HR}, M_{Li}, L_{old}]^{-D_{Li}} \right] \dots\dots\dots (7.13)$$

$$L_{old} = \sum \left[ \{ (L_{LF}, L_{HR}, M_{Li})_{n-1, n-2, n-x} \}, L_{ini} \right]^{-D_{Li}} \dots\dots\dots (7.14)$$

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):

$$\text{Deforested } \Delta C_{Li} = L_{old} \times -1 \dots\dots\dots(7.15)$$

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 ( $\Delta C_{DW}$ ) 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 ( $D_{DW}$ ):

$$\Delta C_{DW} = (L_{tr} + M_{timber} + L_{mort(BB)} + L_{HRroot}) - D_{DW} \dots\dots\dots(7.16)$$

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  $L_{tr}$ :

$$L_{tr} = L_{timber} \times RF \dots\dots\dots(7.17)$$

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 7.18 based on decomposition factors of 0.095 for stumps and 0.076 for roots (Tobin et al., 2007):

$$D_{DW} = 1 - \left[ \sum [L_{tr}, M_{timber}, DL_{old}]^{-D_{log \times t}} + \sum [L_{mort(BB)}, L_{HRroot}, DS_{old}]^{-D_{St}} \right] \dots\dots\dots (7.18)$$

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

$$DL_{old} = \sum_i [VL_i \times DDC_i \times CF]^{-D_{log \times t}} + \left[ \sum (L_{tr}, M_{timber})_{(n-1, n-2, n-x)}^{-D_{log}} \right] \dots\dots\dots (7.19)$$

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 7.16 and Figure 7.8) 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):

$$DS_{old} = \sum_j [VS_j \times DDC_j \times CF]^{D_{St} \times t} + \sum [L_{mort(BB)}, L_{HRroot}]_{(n-1, n-2, \dots, x)}^{D_{St}} \dots \dots \dots (7.20)$$

where VS is the stump volume of the specific decay class ( $j$ ,  $n=4$ ), DDC is the density of the specific decay class ( $j$ ) 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 7.16 and Figure 7.8) 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 7.8). 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

$$\text{Deforested } \Delta C_{DW} = (DL_{old} + DS_{old}) \times -1 \dots \dots \dots (7.21)$$

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 7.22 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.

$$\Delta C_{So} = \sum_i (A_i \times EF_{soil}) \dots \dots \dots (7.22)$$

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<sup>-1</sup>.yr<sup>-1</sup> 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,

$$\Delta C_{So} = \sum_j (A_j \times EF_{soil} \times SD) \dots \dots \dots (7.23)$$

and

$$SD = \frac{\text{depth(cm)}}{30\text{cm}} \dots \dots \dots (7.24)$$

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 7.4), 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 7.4). 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 7.4 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:

$$\frac{R_3^2}{R_i^2} \dots \dots \dots (7.25)$$

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  $\frac{R_3^2}{R_i^2} \times n_i$ , 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 7.25).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \dots\dots\dots(7.26)$$

where  $n_{ij} \times EF_{ij}$  is the product of the expansion factor for the  $j$ th tree in the  $i$ th class, and  $\hat{N}_{ij}$  is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 7.26 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:

$$GTOTAL_{(AB)} = \frac{\sum [AB_{ij} \times EXF_{ij}] \times 20}{1000} \dots\dots\dots(7.27)$$

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:

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

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 ratio (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 than 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) 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 an intersection of NFI and Coillte sub-compartments as described by Black et al., 2012 (see table 7.5). 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 7.5. 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 7.6). The matrix was modified for the period 2000-2012 using NFI and Coillte sub-compartment information as described by Black et al, 2012 (Table 7.6).

**Table 7.6. Yield class, silviculture and rotation criteria selected for periods 1990-1999 and 2000-2011**

<b>Period :1990-1999 (Source FIPS 95)</b>				
<b>Species cohort</b>	<b>Yield class</b>	<b>Proportion of cohort</b>	<b>Silviculture</b>	<b>Rotation</b>
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
<b>Period :2000-2012 (Source NFI-Coillte intersect)</b>				
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.

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:

$$St = Mt \left[ \frac{1 - e^{-k_s(k_t - t)}}{1 - e^{-k_s k_t}} \right] \dots \dots \dots (7.28)$$

where:

$$Mt = \frac{Cm}{Rm} \ln \left[ 1 + \frac{Co}{Cm} e^{Rmt} \right] \dots \dots \dots (7.29)$$

where:

$Mt$  is Monteith's function,  $C_m$  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  $C_m$ ,  $R_m$ ,  $C_o$ ,  $k_s$  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:

$$\Delta C_b = St_{n+1} - St_n \dots \dots \dots (7.30)$$

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 2011 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 from soils were not rescaled because this was derived directly using eq. 7.23 and 7.24 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 (5.A.1)

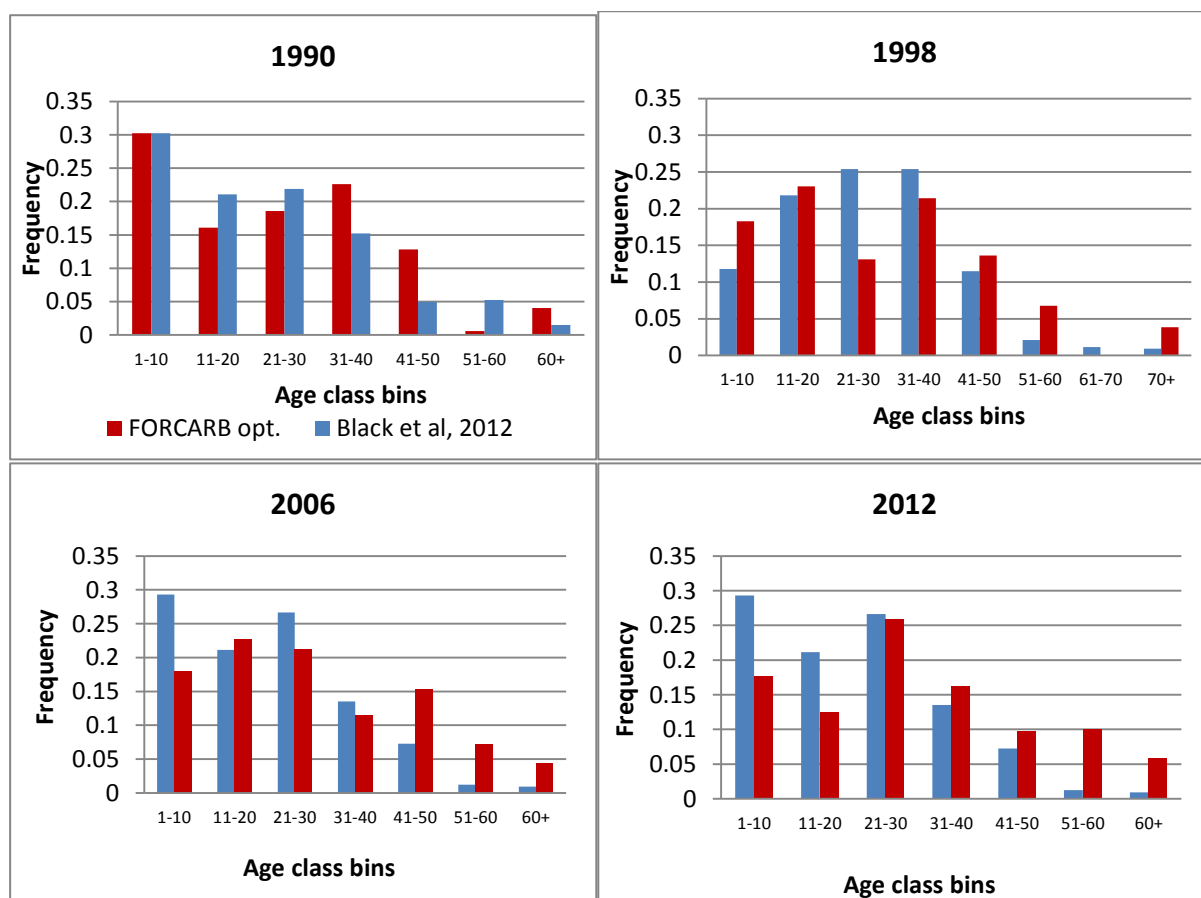
Table 7.7 shows the net biomass, dead organic matter, soil C and to CO<sub>2</sub> emissions/removals for the time series 1990-2011 for forest land remaining forest land (i.e. all forest established before 1990 reported in CRF 5.A.1). For the historical time series 1990 to 2006, the adjusted FORCARB estimates reported. For the 2007 to 2011 time series, the CARBWARE model estimates are reported (Table 7.7).

Table 7.7. Time series for the forest category 5.A.1

Forests remaining forest (since 1990)											
	Area (kHa)		CSC (Gg C)						Net CO <sub>2</sub> Gg Total	Harvests <sup>1</sup> (M m <sup>3</sup> )	
			Living biomass			DOM	Mineral Soils	Organic soils			
Year	Total	Organic	Gain	Loss	Net	Net	Net	Net		EUROSTAT	Modelled
1990	465.26	277.88	2565.91	-1594.31	971.60	25.56	NO	-72.89	-3388.98	1.68	1.68
1991	465.24	277.86	2594.36	-1612.33	982.03	27.17	NO	-72.78	-3433.55	1.77	1.77
1992	465.22	277.85	2622.09	-1805.25	816.84	36.53	NO	-72.67	-2862.57	2.08	2.08
1993	465.20	277.84	2638.98	-1725.34	913.64	6.67	NO	-72.45	-3108.85	2.10	2.10
1994	465.18	277.83	2649.71	-1858.02	791.68	14.43	NO	-72.33	-2690.54	2.29	2.28
1995	464.84	277.63	2659.61	-1968.17	691.44	21.25	NO	-72.16	-2348.60	2.38	2.38
1996	464.51	277.43	2667.25	-2038.88	628.37	25.01	NO	-71.86	-2132.22	2.46	2.46
1997	464.18	277.23	2678.37	-1874.85	803.52	-8.18	NO	-71.39	-2654.50	2.32	2.31
1998	463.84	277.03	2699.85	-2078.83	621.02	7.42	NO	-71.22	-2043.14	2.64	2.63
1999	463.51	276.83	2711.45	-2152.54	558.91	-1.90	NO	-70.84	-1782.65	2.78	2.77
2000	462.65	276.32	2700.29	-2371.87	328.42	-20.03	NO	-69.88	-874.55	3.01	3.00
2001	461.79	275.81	2758.91	-2445.44	313.47	-2.00	NO	-69.71	-886.45	2.84	2.82
2002	460.94	275.30	2712.30	-2520.63	191.68	1.55	NO	-69.23	-454.63	2.91	2.90
2003	460.08	274.78	2700.37	-2448.49	251.88	-20.63	NO	-67.76	-599.42	3.00	2.99
2004	459.22	274.27	2684.97	-2295.74	389.23	-46.59	NO	-67.50	-1008.85	2.85	2.83
2005	458.37	273.76	2701.93	-2465.91	236.03	-35.69	NO	-66.22	-491.76	2.94	2.92
2006	458.13	273.62	2701.92	-2501.37	200.55	-30.78	NO	-65.57	-382.05	2.97	2.95
2007	457.95	273.51	2802.74	-2380.47	422.27	-52.99	NO	-64.76	-1116.56	2.80	2.90
2008	457.92	273.50	2781.18	-2574.19	206.98	-23.63	NO	-63.08	-440.98	1.90	2.12
2009	457.87	273.47	2747.47	-2576.65	170.82	-64.37	NO	-62.44	-161.36	2.46	2.50
2010	457.84	273.45	2730.16	-2305.54	424.62	-72.17	NO	-61.02	-1068.60	2.65	2.78
2011	457.81	273.43	2678.12	-2411.90	266.22	-72.59	NO	-59.27	-492.66	2.61	2.90

<sup>1</sup> 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 7.10). Figure 7.10 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 7.10).



*Figure 7.10 Validation of optimised age-class distributions*

It can be seen from Figure 7.10 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 from 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 7.7) and rescaled using their 1 IPCC GPG (2006) time series overlap approaches:

- Living biomass gains (*LBgain*, Gg C) from the 2007 to 2011 time series for the CARBWARE and FORCARB model outputs were compared. The ratio (2.146) of the total CARBWARE and FORCARB *LBgain* values for 2007-2011 was used to adjust the time series:

$$LB\ gain_{adj} = LB\ gain_{ini} \times 2.146 \dots \dots \dots (eq\ 7.31)$$

where, *LBgain<sub>adj</sub>* is the adjusted living biomass gain value and *LBgain<sub>ini</sub>* 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:

$$LB\ loss_{adj(1990)} = LBgain_{adj(1990)} \times \frac{LB\ loss_{ini(1990)}}{LBgain_{ini(1990)}} \dots \dots \dots (eq\ 7.32)$$

- For dead organic matter (DOM), the ratio (0.519) of the average CARBWARE to average FORCARB values for 2007-2011 was used to adjust the time series:

$$DOM_{adj} = DOM_{ini} \times 0.519 \dots \dots \dots (eq\ 7.33)$$

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

Figure 7.11 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 7.7. Both time series show the same trend but the adjusted values show a higher net removal of CO<sub>2</sub>. This is due to fundamental differences in the model input variables and the spatial scale at which 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 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 than those imposed under current management practice (Black et al., 2007; 2012);
- Predefined stocking rates in the FORCARB model, which is generally underestimated, 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.

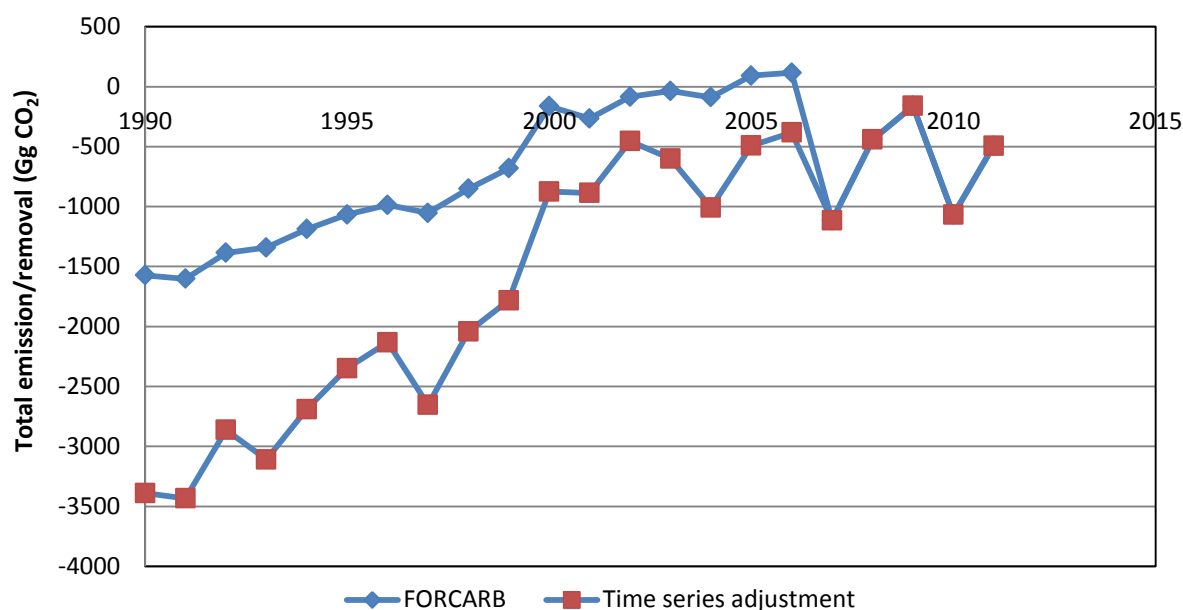


Figure 7.11 Adjusted time series<sup>4</sup> for forest category 5.A.1

#### 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.

#### 7.3.4.3 Organic Soils

Emissions from the drainage of organic soils are reported using eq. 7.23 and 7.24, described in section 7.2. Forest soils<sup>5</sup> 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 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).

<sup>4</sup> The final adjusted time series comprises of adjusted FORCARB estimates for the period 1990-2006 and CARBWARE estimated for the period 2007-2011.

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

**Table 7.8. Area (in kha) and emissions from different organic soils types over the time series for forest land remaining forests**

Year	Total Area <sup>1</sup>	Mineral	Organic	Open area <sup>2</sup>	Sites <50 years old (excl open area) <sup>3</sup>	Organic soils <sup>4</sup>	Organo-mineral soil <sup>5</sup>	Mineral soils <sup>6</sup>	Mineral tC	Organic tC	Organo-mineral tC	Total tC <sup>7</sup>	t CO <sub>2</sub>
	(kHa)												
1990	465.26	187.38	277.88	41.44	302.85	107.57	28.81	80.04	NO	-63464.68	-9425.26	-72889.94	-267263.10
1991	465.24	187.37	277.86	41.45	302.39	107.40	28.77	79.59	NO	-63367.25	-9410.79	-72778.04	-266852.83
1992	465.22	187.37	277.85	41.45	301.92	107.24	28.72	79.15	NO	-63269.84	-9396.32	-72666.16	-266442.59
1993	465.20	187.36	277.84	41.45	301.01	106.91	28.64	78.28	NO	-63078.57	-9367.92	-72446.49	-265637.11
1994	465.18	187.35	277.83	41.45	300.55	106.75	28.59	77.84	NO	-62981.18	-9353.45	-72334.63	-265226.99
1995	464.84	187.21	277.63	41.50	299.83	106.49	28.52	77.33	NO	-62830.43	-9331.07	-72161.50	-264592.15
1996	464.51	187.08	277.43	41.05	298.57	106.05	28.41	76.06	NO	-62567.52	-9292.02	-71859.55	-263485.01
1997	464.18	186.95	277.23	41.10	297.41	105.32	28.29	75.45	NO	-62137.97	-9255.77	-71393.74	-261777.05
1998	463.84	186.81	277.03	41.15	296.69	105.06	28.23	74.96	NO	-61988.32	-9233.48	-71221.80	-261146.60
1999	463.51	186.68	276.83	41.20	295.08	104.50	28.07	73.61	NO	-61652.29	-9183.43	-70835.72	-259730.98
2000	462.65	186.33	276.32	41.33	292.61	103.00	27.84	72.38	NO	-60771.19	-9106.55	-69877.74	-256218.40
2001	461.79	185.99	275.81	41.45	291.93	102.76	27.77	72.21	NO	-60629.02	-9085.25	-69714.27	-255618.99
2002	460.94	185.64	275.30	41.58	289.91	102.05	27.58	70.79	NO	-60210.65	-9022.56	-69233.21	-253855.11
2003	460.08	185.30	274.78	41.71	285.25	99.81	27.14	67.54	NO	-58886.68	-8877.48	-67764.16	-248468.59
2004	459.22	184.95	274.27	41.84	284.14	99.42	27.03	66.98	NO	-58656.87	-8842.83	-67499.70	-247498.89
2005	458.37	184.61	273.76	41.97	279.51	97.50	26.59	63.52	NO	-57526.22	-8698.66	-66224.88	-242824.57
2006	458.13	184.51	273.62	42.00	277.12	96.67	26.07	61.81	NO	-57035.38	-8538.02	-65573.40	-240435.79
2007	457.95	184.44	273.51	42.03	274.79	95.57	25.56	60.42	NO	-56384.00	-8380.48	-64764.48	-237469.75
2008	457.92	184.43	273.50	42.03	271.25	93.19	24.66	59.07	NO	-54981.51	-8103.43	-63084.94	-231311.44
2009	457.87	184.41	273.47	42.04	269.46	92.29	24.21	58.11	NO	-54449.32	-7993.74	-62443.06	-228957.89
2010	457.84	184.40	273.45	42.05	266.36	90.10	23.65	56.87	NO	-53158.39	-7857.48	-61015.87	-223724.85
2011	457.81	184.38	273.43	42.04	260.63	87.61	22.87	52.90	NO	-51689.77	-7580.08	-59269.85	-217322.78

<sup>1</sup> Total area includes open areas

<sup>2</sup> Adjusted area for 10 % open area within forest areas (roads, extraction routes, biodiversity etc).

<sup>3</sup> No emissions from organic soils on sites older than 50 years old, (Data source NFI)

<sup>4</sup> 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 7.23.

<sup>5</sup> Organo-mineral soils are mineral soils with an organic overlay of < 30cm. These include peaty podsoles and peaty gleys (Source NFI). These areas are used in eq 7.24

<sup>6</sup> Mineral soils are shown not to be a source and are reported as zero (NA). These include brown earths, podsoles, gleys, brown podsolics, lithosols etc. (Source NFI).

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

#### 7.3.4.4 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 2011. 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 7.9). 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 7.9). 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<sup>-1</sup>, equivalent to 149,450 kg biomass d.wt ha<sup>-1</sup>. The average C stock for litter and deadwood is estimated to be 14.1 tC ha<sup>-1</sup>, equivalent to 28,263 kg biomass d.wt ha<sup>-1</sup>. 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<sup>-1</sup>, equivalent to 90,526 kg biomass d.wt ha<sup>-1</sup>. The average C stock for litter and deadwood is estimated to be 6.5 tC ha<sup>-1</sup>, equivalent to 12,959 kg biomass d.wt ha<sup>-1</sup>;
- 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 7.9. 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)						
	Prop area		biomass	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Gg CO <sub>2</sub> eq	Prop area		biomass	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Gg CO <sub>2</sub> eq
	Fire area	burned						Fire area	burned					
	Ha							Ha						
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

#### 7.3.4.5 Emissions of N<sub>2</sub>O from Fertilization

Ireland does not report separately the emissions of N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O from Drainage

Tier 1 estimates of N<sub>2</sub>O 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 2007 (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  $\pm 5$  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 into 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<sub>2</sub>O emissions from forest soils contributes emissions of 23.1 to 22.7 Gg CO<sub>2</sub> equivalents for the years 1990 to 2011. The slight decrease in emission is due to the over reduction of forest area in this category (Table 7.10) 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<sub>2</sub>O emissions associated with the drainage of organic forest soils following conversion to forest land. Recent unpublished national research does show that there are N<sub>2</sub>O 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<sub>2</sub>O (Tables 7.10a and b).

*Table 7.10.a. The area activity data and N<sub>2</sub>O emissions from drainage of forest land remaining forest land*

<b>F-F (pre-1990)</b>										
<b>Year</b>	<b>Total Area</b>	<b>Open area</b>	<b>No drain</b>	<b>Mineral</b>	<b>Organic N-poor</b>	<b>Organic N-rich</b>	<b>Mineral</b>	<b>Organic N-poor</b>	<b>Organic N-rich</b>	<b>Total Organic</b>
	<b>Area (kHa)</b>						<b>Mg N<sub>2</sub>O</b>			
<b>1990</b>	465.3	41.4	65.0	105.4	221.5	31.8	<b>9.94</b>	34.81	30.02	<b>64.84</b>
<b>1991</b>	465.2	41.4	65.0	105.4	221.5	31.8	<b>9.94</b>	34.81	30.02	<b>64.83</b>
<b>1992</b>	465.2	41.4	65.0	105.4	221.5	31.8	<b>9.94</b>	34.81	30.02	<b>64.83</b>
<b>1993</b>	465.2	41.5	65.0	105.4	221.5	31.8	<b>9.94</b>	34.81	30.02	<b>64.83</b>
<b>1994</b>	465.2	41.5	65.0	105.4	221.5	31.8	<b>9.93</b>	34.81	30.02	<b>64.82</b>
<b>1995</b>	464.8	41.5	65.0	105.3	221.3	31.8	<b>9.93</b>	34.78	29.99	<b>64.76</b>
<b>1996</b>	464.5	41.0	65.0	105.3	221.4	31.8	<b>9.93</b>	34.79	30.00	<b>64.78</b>
<b>1997</b>	464.2	41.1	64.9	105.2	221.2	31.8	<b>9.92</b>	34.75	29.97	<b>64.72</b>
<b>1998</b>	463.8	41.1	64.9	105.1	221.0	31.8	<b>9.91</b>	34.72	29.94	<b>64.67</b>
<b>1999</b>	463.5	41.2	64.8	105.0	220.8	31.7	<b>9.90</b>	34.69	29.92	<b>64.61</b>
<b>2000</b>	462.7	41.3	64.6	104.8	220.2	31.7	<b>9.88</b>	34.61	29.85	<b>64.46</b>
<b>2001</b>	461.8	41.5	64.5	104.5	219.7	31.6	<b>9.86</b>	34.53	29.78	<b>64.31</b>
<b>2002</b>	460.9	41.6	64.3	104.3	219.2	31.5	<b>9.83</b>	34.45	29.71	<b>64.16</b>
<b>2003</b>	460.1	41.7	64.2	104.0	218.7	31.4	<b>9.81</b>	34.37	29.64	<b>64.00</b>
<b>2004</b>	459.2	41.8	64.0	103.8	218.2	31.4	<b>9.79</b>	34.29	29.57	<b>63.85</b>
<b>2005</b>	458.4	42.0	63.9	103.5	217.7	31.3	<b>9.76</b>	34.21	29.50	<b>63.70</b>
<b>2006</b>	458.1	42.0	63.8	103.5	217.5	31.3	<b>9.76</b>	34.18	29.48	<b>63.66</b>
<b>2007</b>	458.0	42.0	63.8	103.4	217.4	31.2	<b>9.75</b>	34.17	29.46	<b>63.63</b>
<b>2008</b>	457.9	42.0	63.8	103.4	217.4	31.2	<b>9.75</b>	34.16	29.46	<b>63.63</b>
<b>2009</b>	457.9	42.0	63.8	103.4	217.4	31.2	<b>9.75</b>	34.16	29.46	<b>63.62</b>
<b>2010</b>	457.8	42.0	63.8	103.4	217.4	31.2	<b>9.75</b>	34.16	29.45	<b>63.61</b>
<b>2011</b>	457.8	42.0	63.8	103.4	217.3	31.2	<b>9.75</b>	34.15	29.45	<b>63.61</b>

Table 7.10.b. The area activity data and N<sub>2</sub>O emissions from drainage of forest land converted to forest land

F-L(post-1990)										
Year	Total Area <sup>1</sup>	Open area	No drain	Mineral	Organic N-poor	Organic N-rich	Mineral	Organic N-poor	Organic N-rich	Total Organic
	Area (kHa)						Mg N <sub>2</sub> O			
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	251.9	30.0	25.2	69.9	101.7	25.1	6.59	15.99	23.66	39.65
2007	258.9	30.8	25.9	71.8	104.6	25.8	6.77	16.43	24.32	40.75
2008	264.9	31.5	26.5	73.5	107.0	26.4	6.93	16.81	24.88	41.69
2009	271.4	32.8	27.1	75.1	109.4	27.0	7.08	17.19	25.44	42.63
2010	279.6	32.2	28.1	77.9	113.4	28.0	7.35	17.82	26.37	44.19
2011	280.6	42.1	27.1	75.1	109.3	27.0	7.08	17.18	25.43	42.61

### 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 7.11). 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 is 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<sub>2</sub> gases are listed in Table 7.11. The combined uncertainties of the products of the respective parameters associated with each component pool are calculated using equation 7.34 (equation 6.4 of the IPCC good practice guidance):

$$U_{\text{total}} = \sqrt{U_1^2 + U_2^2 + U_3^2 + U_n^2} \dots\dots\dots(7.34)$$

where  $U_{\text{total}}$  is the combined uncertainty of the product of the input values  $U_1$ ,  $U_2$ ,  $U_3$  and  $U_n$  given table 7.11. The calculated percentage uncertainties for pools are given in Table 7.12 which 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 7.11 as the sum of the uncertainties for carbon pools using equation 7.35 (equation 6.3 of the IPCC good practice guidance):

$$U_{\text{total}} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + (U_n \times x_n)^2}}{|x_1 + x_2 + x_n|} \dots\dots\dots(7.35)$$

where  $U_{\text{total}}$  is the combined uncertainty,  $U_1$ ,  $U_2$  and  $U_n$  are the uncertainties of pool estimates (Table 7.14) and  $x_1$ ,  $x_2$  and  $x_n$  are the mean values for the respective pools reported in the CRF tables.

**Table 7.11. 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 Tier 1 (Table 2.3, 2.3.1 Chapter 2, AFULO GPG 2006)
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	% s.d. of ration of CABWARE/FORECARB
K	re-scaling of FORECARB	DOM	28.50	% s.d. of ration of CABWARE/FORECARB
L	N2O	N <sub>2</sub> O area	12.30	Conf. interval of NFI analysis
M	N2O	N <sub>2</sub> O emissions		not specified in Tier 1 GPG 2003

**Table 7.12 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 7.34	17.2	A+B+C+D+E+J
DOM	DOM	Eq 7.34	22.2	D+E+F+K
SO	Soils	Eq 7.34	90.0	D+G
Fires	Fire	Eq 7.34	59.4	H+I
N <sub>2</sub> O	Drainage of soils	Eq. 7.34	12.3	L

For deriving uncertainties for code C in Table 7.11, CARBWARE DBH and H growth models were validated using some of the repeated NFI permanent sample plot data taken in 2009 and 2010. These represent repeat measurement of 350 plots taken at a 3-5 year interval. To date 1/5 of the all NFI sample plots have been re-evaluated. 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 to 12 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 7.13). Stratified cohort groups all had lower empirical excess error (Table 7.13), 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 theoretically 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 7.13). Larch and FBG showed a 27 per cent lower and 128 per cent higher growth rate than the model prediction, respectively.

This analysis (Table 7.13) 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 7.13. NFI external validation of CARBWARE models

Cohort	<12 cm	12-20	20-30	30-40	>40 cm	All classes
<i>Spruce</i>						
Accuracy	- 0.42	0.09	0.28	0.09	-0.73	0.17 (4.8%)
Precision	1.94	1.90	1.86	1.91	2.09	2.04
P-value	<0.01	<b>0.37</b>	<b>0.14</b>	<b>0.55</b>	0.03	<b>0.36</b>
$E_{imp}$						9.8 %
N	204	1234	1092	226	48	2804
<i>Pines</i>						
Accuracy	-0.30	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	<b>0.23</b>	<b>0.52</b>	<0.01	ND	<b>0.29</b>
$E_{imp}$						0.4 %
N	56	342	379	44	6	827
<i>Larch</i>						
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	<b>0.05</b>	ND	ND	<0.001
$E_{imp}$						7.9 %
N	8	54	36	4	0	102
<i>OC</i>						
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	<b>0.544</b>	<b>0.05</b>	0.02	ND	<b>0.06</b>
$E_{imp}$						14.7 %
N	5	77	66	31	19	198
<i>FGB</i>						
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	<b>0.20</b>	<0.001	<0.0001	<0.0001	ND	<0.0001
$E_{imp}$						8.7 %
N	64	194	183	35	19	495
<i>SGB</i>						
Accuracy	ND	-0.28	-0.23	-0.67	-1.24	-0.50 (-30.5 %)
Precision	ND	1.27	1.73	1.70	1.91	1.68
P-value	ND	<b>0.37</b>	<b>0.75</b>	<b>0.17</b>	<0.001	<b>0.11</b>
$E_{imp}$						55.1%

Tier 1 time series trend analysis was also conducted as specified in section 6.3 of the IPCC good practice guidance for LULUCF (Table 7.14). 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 7.7 and Figure 7.9.

**Table 7.14. Uncertainty analysis for forest land remaining forest land since 1990 category<sup>6</sup>**

Year	Category	Year emission/reductions (Gg CO <sub>2</sub> eq)	Base year emission/reductions (Gg CO <sub>2</sub> eq)	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	-3388.98	-3388.98	19.46	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
	<b>Total</b>	<b>-3,254.32</b>	<b>-3,254.32</b>	<b>18.10</b>	<b>1.00</b>	<b>na</b>
1991	CRF 5A.1	-3433.55	-3388.98	19.39	0.94	1.32
	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
	<b>Total</b>	<b>-3,338.72</b>	<b>-3,254.32</b>	<b>18.09</b>	<b>1.00</b>	<b>2.59</b>
1992	CRF 5A.1	-2862.57	-3388.98	19.94	0.95	-15.53
	CRF 5A II	23.18	23.18	12.30	0.00	-0.01
	CRF5(V)	46.05	111.48	59.36	0.05	-58.69
	<b>Total</b>	<b>-2,793.34</b>	<b>-3,254.32</b>	<b>18.17</b>	<b>1.00</b>	<b>-14.17</b>
1993	CRF 5A.1	-3108.85	-3388.98	20.08	0.92	-8.27
	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
	<b>Total</b>	<b>-2,992.82</b>	<b>-3,254.32</b>	<b>18.05</b>	<b>1.00</b>	<b>-8.04</b>
1994	CRF 5A.1	-2690.54	-3388.98	20.60	0.89	-20.61
	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
	<b>Total</b>	<b>-2,560.75</b>	<b>-3,254.33</b>	<b>18.09</b>	<b>1.00</b>	<b>-21.31</b>
1995	CRF 5A.1	-2348.60	-3388.98	21.20	0.85	-30.70
	CRF 5A II	23.15	23.18	12.30	0.00	-0.11
	CRF5(V)	145.59	111.48	59.36	0.15	30.59
	<b>Total</b>	<b>-2,179.86</b>	<b>-3,254.32</b>	<b>18.75</b>	<b>1.00</b>	<b>-33.02</b>
1996	CRF 5A.1	-2132.22	-3388.98	21.73	0.82	-37.08
	CRF 5A II	23.16	23.18	12.30	0.01	-0.08
	CRF5(V)	161.92	111.48	59.36	0.17	45.24
	<b>Total</b>	<b>-1,947.13</b>	<b>-3,254.32</b>	<b>19.37</b>	<b>1.00</b>	<b>-40.17</b>
1997	CRF 5A.1	-2654.50	-3388.98	21.07	0.91	-21.67
	CRF 5A II	23.14	23.14	12.30	0.00	0.00
	CRF5(V)	88.56	111.48	59.36	0.09	-20.57
	<b>Total</b>	<b>-2,542.80</b>	<b>-3,254.36</b>	<b>18.00</b>	<b>1.00</b>	<b>-21.86</b>
1998	CRF 5A.1	-2043.14	-3388.98	22.38	0.94	-39.71
	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
	<b>Total</b>	<b>-1,973.30</b>	<b>-3,254.32</b>	<b>17.86</b>	<b>1.00</b>	<b>-39.36</b>
1999	CRF 5A.1	-1782.65	-3388.98	23.74	0.94	-47.40
	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
	<b>Total</b>	<b>-1,721.44</b>	<b>-3,254.32</b>	<b>17.78</b>	<b>1.00</b>	<b>-47.10</b>
2000	CRF 5A.1	-874.55	-3388.98	35.59	0.84	-74.19
	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
	<b>Total</b>	<b>-755.79</b>	<b>-3,254.32</b>	<b>20.55</b>	<b>1.00</b>	<b>-76.78</b>
2001	CRF 5A.1	-886.45	-3388.98	34.23	0.72	-73.84
	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
	<b>Total</b>	<b>-672.59</b>	<b>-3,254.32</b>	<b>26.93</b>	<b>1.00</b>	<b>-79.33</b>

<sup>6</sup> Note that uncertainties for category 5A(II) and 5A(V) include land in the forest remaining forest land category only.

**Table 7.14 Uncertainty analysis for forest land remaining forest land since 1990 category<sup>7</sup> (continued)**

Year	Category	Year emission/reductions (Gg CO <sub>2</sub> eq)	Base year emission/reductions (Gg CO <sub>2</sub> eq)	Combined uncertainty in year (±%)	Contribution to total variance in year (fraction)	Mean trend in year in relation to base-year (% mean trend)
2002	CRF 5A.1	-454.63	-3388.98	56.87	0.90	-86.59
	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
	<b>Total</b>	<b>-387.84</b>	<b>-3,254.32</b>	<b>18.66</b>	<b>1.00</b>	<b>-88.08</b>
2003	CRF 5A.1	-599.42	-3388.98	46.00	0.63	-82.31
	CRF 5A II	22.88	23.18	12.30	0.01	-1.28
	CRF5(V)	270.54	111.48	59.36	0.37	142.67
	<b>Total</b>	<b>-306.00</b>	<b>-3,254.32</b>	<b>35.83</b>	<b>1.00</b>	<b>-90.60</b>
2004	CRF 5A.1	-1008.85	-3388.98	33.44	0.78	-70.23
	CRF 5A II	22.83	23.18	12.30	0.01	-1.52
	CRF5(V)	157.62	111.48	59.36	0.22	41.39
	<b>Total</b>	<b>-828.40</b>	<b>-3,254.32</b>	<b>23.67</b>	<b>1.00</b>	<b>-74.54</b>
2005	CRF 5A.1	-491.76	-3388.98	54.64	0.88	-85.49
	CRF 5A II	22.77	22.77	12.30	0.01	0.00
	CRF5(V)	-57.32	111.48	59.36	0.11	-151.41
	<b>Total</b>	<b>-526.30</b>	<b>-3,254.73</b>	<b>20.06</b>	<b>1.00</b>	<b>-83.83</b>
2006	CRF 5A.1	-382.05	-3388.98	66.48	0.87	-88.73
	CRF 5A II	22.76	23.18	12.30	0.01	-1.82
	CRF5(V)	57.32	111.48	59.36	0.12	-48.59
	<b>Total</b>	<b>-301.98</b>	<b>-3,254.32</b>	<b>21.55</b>	<b>1.00</b>	<b>-90.72</b>
2007	CRF 5A.1	-1116.56	-3388.98	30.84	0.89	-67.05
	CRF 5A II	22.75	23.18	12.30	0.01	-1.86
	CRF5(V)	64.43	111.48	59.36	0.10	-42.20
	<b>Total</b>	<b>-1,029.37</b>	<b>-3,254.32</b>	<b>18.02</b>	<b>1.00</b>	<b>-68.37</b>
2008	CRF 5A.1	-440.98	-3388.98	55.91	0.88	-86.99
	CRF 5A II	22.75	23.18	12.30	0.01	-1.87
	CRF5(V)	50.08	111.48	59.36	0.11	-55.08
	<b>Total</b>	<b>-368.15</b>	<b>-3,254.32</b>	<b>19.65</b>	<b>1.00</b>	<b>-88.69</b>
2009	CRF 5A.1	-161.36	-3388.98	147.76	0.42	-95.24
	CRF 5A II	22.74	23.18	12.30	0.08	-1.88
	CRF5(V)	-28.05	111.48	59.36	0.50	-125.16
	<b>Total</b>	<b>-166.66</b>	<b>-3,254.32</b>	<b>19.97</b>	<b>1.00</b>	<b>-94.88</b>
2010	CRF 5A.1	-1068.60	-3388.98	31.85	0.75	-68.47
	CRF 5A II	22.74	23.18	12.30	0.01	-1.89
	CRF5(V)	182.29	111.48	59.36	0.24	63.52
	<b>Total</b>	<b>-863.57</b>	<b>-3,254.32</b>	<b>24.61</b>	<b>1.00</b>	<b>-73.46</b>
2011	CRF 5A.1	-492.66	-3388.98	53.70	0.86	-85.46
	CRF 5A II	22.74	23.18	12.30	0.01	-1.90
	CRF5(V)	67.81	111.48	59.36	0.13	-39.18
	<b>Total</b>	<b>-402.12</b>	<b>-3,254.32</b>	<b>21.38</b>	<b>1.00</b>	<b>-87.64</b>

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

Table 7.15 shows the net biomass, dead organic matter, soil C and net CO<sub>2</sub> emissions/removals for the time series 1990-2011 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 7.15). The methods used and values reported in category 5.A.2 are now fully consistent and comparable with KP emission/removals reported for AR activities, for the years 2008-2011 (see chapter 11).

<sup>7</sup> Note that uncertainties for category 5A(II) and 5A(V) include land in the forest remaining forest land category only.

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.

Table 7.15. Time series for forest category 5.A.2 <sup>8</sup>

Lands converted to forest land (since 1990)

Year	Area (kHa)		CSC (Gg C)						Net CO <sub>2</sub> Gg Total	Harvests <sup>1</sup> ( M m <sup>3</sup> )	
	Total	Organic	Living biomass			DOM	Mineral Soils	Organic soils		Thinnings	Modelled
			Gain	Loss	Net	Net	Net	Net			
1990	15.82	9.85	0.00	-0.33	-0.33	0.01	NO	-4.57	17.90	NO	
1991	34.96	20.72	20.58	-0.91	19.67	0.13	NO	-9.35	-38.35	NO	
1992	51.66	30.87	43.90	-1.65	42.25	0.36	NO	-14.09	-104.57	NO	
1993	67.66	39.30	64.97	-2.52	62.45	0.63	NO	-17.89	-165.67	NO	
1994	87.12	49.83	93.41	-6.18	87.23	6.02	NO	-22.92	-257.87	NO	
1995	110.83	66.96	131.35	-11.05	120.30	12.63	NO	-30.60	-375.22	NO	
1996	131.81	78.82	175.95	-16.22	159.73	18.63	NO	-36.39	-520.59	NO	
1997	143.25	84.16	222.26	-21.82	200.43	24.34	NO	-38.93	-681.40	NO	
1998	156.17	90.99	271.07	-28.69	242.38	31.04	NO	-41.86	-849.07	NO	
1999	168.84	97.12	324.90	-37.09	287.82	39.14	NO	-44.45	-1035.85	NO	
2000	184.54	105.45	390.60	-46.09	344.52	46.47	NO	-48.04	-1257.44	NO	
2001	200.00	114.97	460.90	-54.51	406.39	50.81	NO	-52.16	-1485.12	NO	
2002	215.06	122.89	533.37	-74.37	459.01	65.29	NO	-55.56	-1718.69	NO	
2003	224.15	129.17	620.33	-84.41	535.92	68.92	NO	-58.49	-2003.27	NO	
2004	233.89	135.15	706.35	-112.20	594.14	85.67	NO	-61.25	-2268.07	NO	
2005	243.99	137.63	804.98	-122.21	682.77	87.32	NO	-62.96	-2592.81	NO	
2006	251.89	142.08	906.57	-179.61	726.96	108.20	NO	-65.04	-2823.76	NO	
2007	258.90	146.04	1005.35	-302.20	703.15	137.12	NO	-67.00	-2835.33	0.18	0.18
2008	264.88	149.41	1144.92	-410.44	734.48	176.11	NO	-68.47	-3087.75	0.33	0.33
2009	271.38	152.58	1239.06	-452.65	786.41	198.55	NO	-69.69	-3356.02	0.12	0.12
2010	279.60	160.74	1320.77	-454.83	865.94	195.60	NO	-70.70	-3633.10	0.23	0.23
2011	286.03	164.09	1412.71	-492.37	920.34	199.65	NO	-71.90	-3843.04	0.28	0.28

<sup>8</sup> 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

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.

To reflect the potential change in afforestation of more productive lands in recent years, land use transition and soil type matrices were derived using the 2006 national forest inventory (NFI). NFI permanent sample plot (PSP) point co-ordinates, representing forest areas (see Chapter 11) were superimposed on the CORINE 1990 Land Cover Map of Ireland (level 6). 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 0.3 per cent of the total area converted to forest in any given year. Additional disaggregation into soil types under each land use transition is also applied to enable the calculation of emissions from organic soils (see Table 7.17)

### 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 7.15) and rescaled using tier 1 IPCC GPG (2006) time series overlap approaches:

- Living biomass gains (*LB<sub>gain</sub>*, Gg C) from the 2007 to 2011 time series for the CARBWARE and FORCARB model outputs were compared. The ratio (1.686) of the total CARBWARE and FORCARB *LB<sub>gain</sub>* values for 2007-2011 was used to adjust the time series:

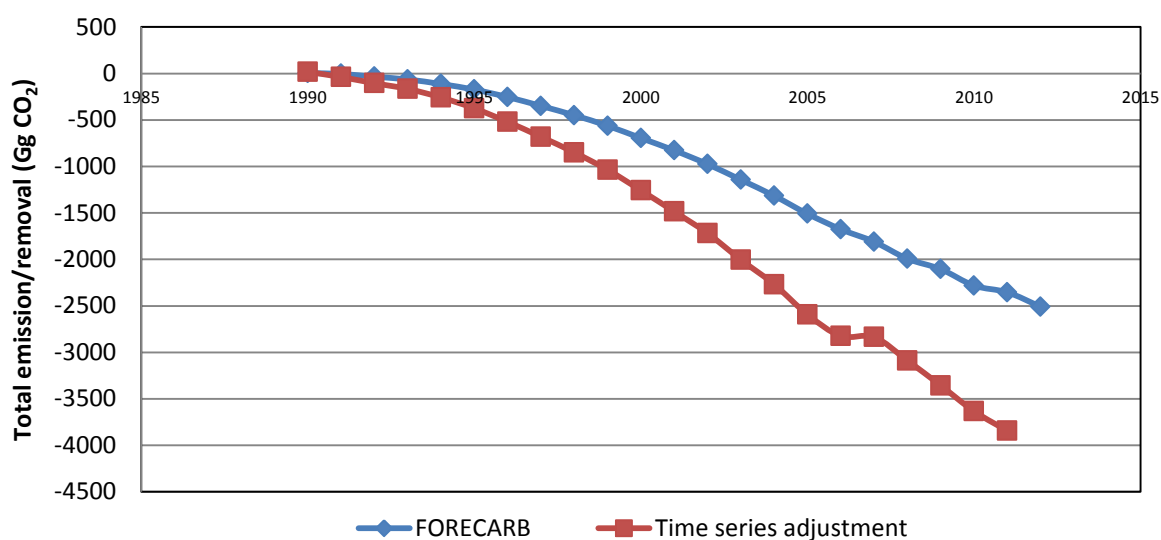
$$LB\ gain_{adj} = LB\ gain_{ini.} \times 1.686 \dots \dots \dots (eq\ 7.36)$$

where, *LB<sub>gain<sub>adj</sub></sub>* is the adjusted living biomass gain value and *LB<sub>gain<sub>ini</sub></sub>* 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 (*LB<sub>loss</sub>*) were also determined using equation 7.36 but using a ratio of 2.002 scaled using the ratio of living biomass losses of the total CARBWARE and FORCARB *LB<sub>loss</sub>* values for 2007-2011. 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 (1.322) of the average CARBWARE to average FORCARB values for 2007-2011 was used to adjust the time series:  
 $DOM_{adj} = DOM_{ini.} \times 1.322 \dots \dots \dots (eq\ 7.37);$
- There were no adjustments to the soil EF, since the FORCARB and CARBWARE estimates were identical.

Figure 7.12 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 7.16. Both time series show the same trend but the adjusted values show a higher net removal of CO<sub>2</sub>. This

is due to fundamental differences in the model input variables and the spatial scale at which 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 2007-2011.



*Figure 7.12 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 7.16). 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 7.16. Area (in kha) and emissions from different organic soils types over the time series for land converted to forests**

Year	Total Area <sup>1</sup>	Mineral	Organic	Open area <sup>2</sup>	Organic soils <sup>3</sup>	Organo-mineral soil <sup>4</sup>	Mineral soils <sup>5</sup>	tC Mineral	Organic tC	Organo-mineral tC	Total tC	Gg CO <sub>2</sub>
	Area (kHa)											
1990	15.82	5.97	9.85	1.88	6.57	2.10	5.26	NO	-3878.07	-688.06	-4566.13	-16.74
1991	34.96	14.24	20.72	4.16	12.83	5.42	12.55	NO	-7572.47	-1772.71	-9345.18	-34.27
1992	51.66	20.80	30.87	6.15	19.75	7.44	18.32	NO	-11653.58	-2434.68	-14088.26	-51.66
1993	67.66	28.36	39.30	8.05	24.99	9.63	24.99	NO	-14742.77	-3151.44	-17894.22	-65.61
1994	87.12	37.29	49.83	10.37	32.56	11.34	32.85	NO	-19211.44	-3709.07	-22920.50	-84.04
1995	110.83	43.87	66.96	13.19	43.01	15.98	38.65	NO	-25375.10	-5228.37	-30603.47	-112.21
1996	131.81	52.99	78.82	15.69	52.01	17.43	46.69	NO	-30683.13	-5702.92	-36386.05	-133.42
1997	143.25	59.08	84.16	17.05	55.83	18.32	52.05	NO	-32939.64	-5992.61	-38932.26	-142.75
1998	156.17	65.18	90.99	18.58	59.47	20.70	57.43	NO	-35085.05	-6770.31	-41855.35	-153.47
1999	168.84	71.72	97.12	20.09	62.62	22.95	63.18	NO	-36943.57	-7507.40	-44450.97	-162.99
2000	184.54	79.09	105.45	21.96	67.16	25.74	69.68	NO	-39622.71	-8421.29	-48044.00	-176.16
2001	200.00	85.03	114.97	23.80	72.39	28.90	74.91	NO	-42709.07	-9453.57	-52162.64	-191.26
2002	215.06	92.17	122.89	25.59	76.64	31.62	81.20	NO	-45217.66	-10345.15	-55562.81	-203.73
2003	224.15	94.98	129.17	26.67	80.89	32.91	83.68	NO	-47723.83	-10766.57	-58490.40	-214.46
2004	233.89	98.74	135.15	27.83	84.82	34.25	86.99	NO	-50041.10	-11204.71	-61245.81	-224.57
2005	243.99	102.50	137.63	29.03	88.64	32.61	90.30	NO	-52297.73	-10666.62	-62964.35	-230.87
2006	251.89	105.82	142.08	29.97	91.51	33.66	93.23	NO	-53991.69	-10526.61	-65044.19	-238.50
2007	258.90	108.77	146.04	30.81	94.06	34.60	95.82	NO	-55494.50	-10819.61	-66999.10	-245.66
2008	264.88	112.14	152.74	31.71	94.27	40.94	97.95	NO	-55618.63	-12855.65	-68474.28	-251.07
2009	271.38	115.54	155.85	32.38	95.23	43.37	100.41	NO	-56184.43	-13501.97	-69686.40	-255.52
2010	279.60	118.62	160.98	33.21	96.68	46.21	103.51	NO	-57039.29	-13656.69	-70695.98	-259.22
2011	286.03	121.93	164.09	34.37	98.19	47.74	105.72	NO	-57933.70	-13962.36	-71896.06	-263.62

<sup>1</sup> Total area includes open areas

<sup>2</sup> Open area within forest areas (roads, extraction routes, biodiversity etc).

<sup>3</sup> 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 7.23.

<sup>4</sup> 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 7.24

<sup>5</sup> Mineral soils are shown not to be a source and are reported as zero (NO). These include brown earths, podsols, gleys, brown podsols, 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<sub>2</sub>O from Fertilization

Ireland does not report separately the emissions of N<sub>2</sub>O 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<sub>2</sub>O emissions from fertilizer applications are reported under agriculture. The notation key IE is therefore used in CRF Table 5(l).

#### 7.3.5.6 Emissions of N<sub>2</sub>O 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 7.17). However, the uncertainty relating to N<sub>2</sub>O 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 7.11 and 7.12) was the uncertainty due to re-adjustments, where the LB and DOM (Codes J and K Table 7.11), which were 3.7 and 9.0 per cent for lands converted to forest land.

**Table 7.17. Uncertainty analysis of lands converted to forest land as reported in CRF 5.A.2**

Year	Category	Year emission/reductions (Gg CO <sub>2</sub> eq)	Base year emission/reductions (Gg CO <sub>2</sub> eq)	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
	<b>Total</b>	<b>17.90</b>	<b>17.90</b>	<b>84.21</b>	<b>1.00</b>	<b>na</b>
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	
	<b>Total</b>	<b>-38.35</b>	<b>17.90</b>	<b>36.43</b>	<b>1.00</b>	<b>-314.30</b>
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	
	<b>Total</b>	<b>-104.57</b>	<b>17.90</b>	<b>51.36</b>	<b>1.00</b>	<b>-684.30</b>
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	
	<b>Total</b>	<b>-165.67</b>	<b>17.90</b>	<b>42.96</b>	<b>1.00</b>	<b>-1025.75</b>
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	
	<b>Total</b>	<b>-257.87</b>	<b>17.90</b>	<b>36.43</b>	<b>1.00</b>	<b>-1540.94</b>
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	
	<b>Total</b>	<b>-375.22</b>	<b>17.90</b>	<b>33.90</b>	<b>1.00</b>	<b>-2196.64</b>
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	
	<b>Total</b>	<b>-520.59</b>	<b>17.90</b>	<b>30.38</b>	<b>1.00</b>	<b>-3008.93</b>
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	
	<b>Total</b>	<b>-681.40</b>	<b>17.90</b>	<b>26.75</b>	<b>1.00</b>	<b>-3907.51</b>
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	
	<b>Total</b>	<b>-849.07</b>	<b>17.90</b>	<b>24.59</b>	<b>1.00</b>	<b>-4844.41</b>
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	
	<b>Total</b>	<b>-1,035.85</b>	<b>17.90</b>	<b>22.89</b>	<b>1.00</b>	<b>-5888.09</b>
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	
	<b>Total</b>	<b>-1,257.44</b>	<b>17.90</b>	<b>21.75</b>	<b>1.00</b>	<b>-7126.31</b>
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	
	<b>Total</b>	<b>-1,485.12</b>	<b>17.90</b>	<b>21.13</b>	<b>1.00</b>	<b>-8398.49</b>
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	
	<b>Total</b>	<b>-1,718.69</b>	<b>17.90</b>	<b>20.34</b>	<b>1.00</b>	<b>-9703.68</b>

**Table 7.17. Uncertainty analysis of lands converted to forest land as reported in CRF 5A.2 (continued)**

Year	Category	Year emission/reductions (Gg CO <sub>2</sub> eq)	Base year emission/reductions (Gg CO <sub>2</sub> eq)	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	-2003.27	17.90	19.79	1.00	-11293.84
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	<b>Total</b>	<b>-2,003.27</b>	<b>17.90</b>	<b>19.79</b>	<b>1.00</b>	<b>-11293.84</b>
2004	CRF 5A.1	-2268.07	17.90	19.19	1.00	-12773.48
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	<b>Total</b>	<b>-2,268.07</b>	<b>17.90</b>	<b>19.19</b>	<b>1.00</b>	<b>-12773.48</b>
2005	CRF 5A.1	-2592.81	17.90	18.80	1.00	-14588.02
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	<b>Total</b>	<b>-2,592.81</b>	<b>17.90</b>	<b>18.80</b>	<b>1.00</b>	<b>-14588.02</b>
2006	CRF 5A.1	-2823.76	17.90	18.37	1.00	-15878.51
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	<b>Total</b>	<b>-2,823.76</b>	<b>17.90</b>	<b>18.37</b>	<b>1.00</b>	<b>-15878.51</b>
2007	CRF 5A.1	-2835.33	17.90	18.10	1.00	-15943.17
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	0.00	0.00	0.00	0.00	
	<b>Total</b>	<b>-2,835.33</b>	<b>17.90</b>	<b>18.10</b>	<b>1.00</b>	<b>-15943.17</b>
2008	CRF 5A.1	-3087.75	17.90	17.54	0.97	-17153.63
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	-28.31	0.00	52.20	0.03	
	<b>Total</b>	<b>-3,116.06</b>	<b>17.90</b>	<b>17.39</b>	<b>1.00</b>	<b>-17511.85</b>
2009	CRF 5A.1	-3356.02	17.90	17.21	0.99	-18852.66
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	-16.22	0.00	52.20	0.01	
	<b>Total</b>	<b>-3,372.24</b>	<b>17.90</b>	<b>17.13</b>	<b>1.00</b>	<b>-18943.32</b>
2010	CRF 5A.1	-3633.10	17.90	17.13	0.92	-20400.92
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	-108.05	0.00	52.20	0.08	
	<b>Total</b>	<b>-3,741.14</b>	<b>17.90</b>	<b>16.71</b>	<b>1.00</b>	<b>-21004.66</b>
2011	CRF 5A.1	-3843.04	17.90	17.06	0.93	-21574.04
	CRF 5A II	0.00	0.00	0.00	0.00	
	CRF5(V)	-91.72	0.00	52.20	0.07	
	<b>Total</b>	<b>-3,934.76</b>	<b>17.90</b>	<b>16.71</b>	<b>1.00</b>	<b>-22086.56</b>

Table 7.17 shows that the uncertainty of estimates for land converted to forest land was 84 per cent in 1990, decreasing to 16 per cent by 2011. 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. The development of the new methodology resulted in an increase in the reported area of deforestation from 1.38 to 7.92

kha in 2008, with a further 0.19 kha being deforested in 2009, 0.12 kha in 2010 and 0.26 kha in 2011 (see chapter 11 and Table 7.18). New deforestation trends show a marked increase in deforestation from 2000 onward 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 mid 2005 to 2007. The increase in conversion of forest land to other lands in 2008- to 2010 is associated with an increase in the sale of units of forest land for erection of telecommunication masts, quarries and wind farm developments during this period. 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 regarding applications to leave forest lands submitted on an annual basis.

The final deforestation trends for the period 1990 to 2011 were derived using a combination of the approaches described above (and see Annex H).

**Table 7.18. 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 to 2011 (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	7.288	1.753	3.801	0.393	1.097	0.001	1.354	1.015	1.036	0.344
2007	7.626	2.078	3.816	0.408	1.102	0.001	1.651	1.312	1.057	0.357
2008	7.921	2.132	3.898	0.410	1.169	0.001	1.695	1.356	1.159	0.365
2009	8.118	2.186	3.903	0.410	1.187	0.003	1.695	1.356	1.332	0.417
2010	8.242	2.244	3.943	0.410	1.242	0.050	1.696	1.356	1.361	0.428
2011	8.499	2.475	3.943	0.410	1.323	0.103	1.696	1.356	1.538	0.605

\* 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):

$$C_{L(Total)} = C_{L(AB)} + C_{L(BB)} = TOTAL_{(Biomass)} lost \quad (7.3.8)$$

The carbon stock **losses (C<sub>L</sub>)** in the **above ground (AB)** and **below ground (BB)** pools were calculated from the standing volume (V) of the forest stand, as specified on the limited felling licence application, 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<sup>-1</sup>, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2, as described in Eq 7.9 and 7.10 above). The limited felling licence records provide information of deforestation area (including open areas), species, age, standing volume before clearfell, soil type and land use transition (e.g. grassland or settlement) for each forest stand that is deforested as required by the Forestry act of 1946. The higher BEF was used to reflect for the younger age class of forest deforested.

The volume of timber associated with harvest was derived from limited felling licence records archived on a database since 2006 (see Table 7.18). There is, however, no activity data for deforestation data prior to 2006. Therefore, mean implied emission factors for the period 2006-2011 (biomass gains and losses) are applied to area data to derive estimated of losses in the years before 2006.

The accumulated litter and DOM pool was assumed to be immediately oxidised when deforestation occurs. Mean implied emission factors for the period 2006-2010 are applied to area data to derive estimates of losses in the years before 2006. 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 1<sup>st</sup> 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. Verifiable information demonstrating that 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.

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. 7.23 and 7.24, described in section 7.2. It is plausible, that drains are blocked and emission cease since land use conversion from forests into these categories, but it is **conservatively assumed** that emission from these soils continue following deforestation. Emissions from 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 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 and 2011 consistent with 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 (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 usually 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 CSO data. These lands are likely reported as under grass by farmers to the CSO, and therefore included in the grassland land use category. In 2012, 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. 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*. As indicated in section 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*. 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*.

### 7.4.2 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 13.6 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:

$$\Delta C = A * [ (C_{\text{after}} - C_{\text{before}}) + \Delta C_{\text{growth}} ] \quad (7.2)$$

$$\Delta C = A * [ (13.6 * 0.5 - 0.0) + 5.0 ]$$

### 7.4.3 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 is 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 7.4.1 will also analyse the validity of this assumption.

Carbon stock changes in mineral soils are estimated using Equation 7.1. 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 opinion it is assumed that no cultivation occurs on organic soils, as discussed in 7.4.1.

### 7.4.4 N<sub>2</sub>O Emissions in Cropland

Soil disturbance associated with land-use conversions to cropland result in minor emissions of N<sub>2</sub>O. 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 7.1 for the land-use and soil type converted to cropland, and the soil C: N ratio as follows:

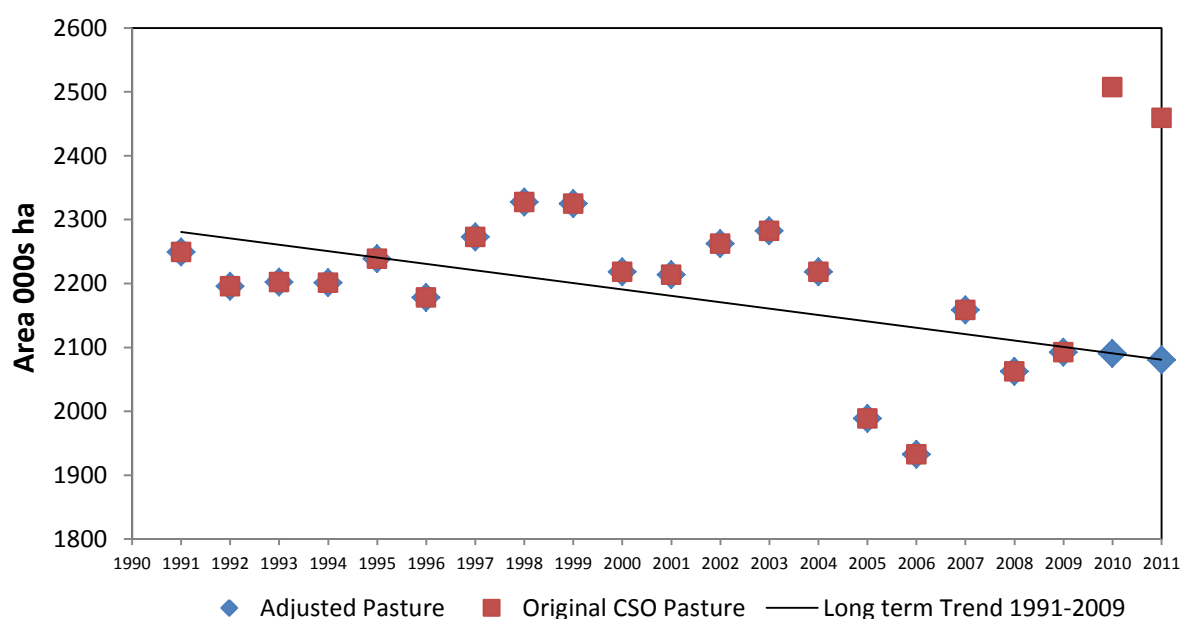
$$N_2O = (\Delta C / R_{C:N}) * 44/28 \quad (7.3)$$

where  $\Delta C$  is the annual change in carbon stocks given by Equation 7.1 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 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 were 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 both 2010 and 2011. 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 2013 submission, it has been decided to extrapolate the long trend trends observed in the pasture area to estimated area for both 2010 and 2011. Figure 7.13 shows the original data and the impact of the adjustment. The research noted in section 7.4.1 will also analyse this issue and present a more robust solution than the simple extrapolation approach adopted for the 2013 submission.



*Figure 7.13 Plot of original CSO data for Pasture areas and adjusted data for 2010 and 2011 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 may be quite intensively 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. Given the uncertainty of the area of unused grassland, it was decided to include this type of grassland

in the category *5.F Other Land*. When there is a demand for new grassland for use as rough grazing, it is met by a conversion from *5.F Other Land* to unimproved grassland. Overall, the area of improved pasture has been increasing slightly and the area of rough grazing, or unimproved grassland has been decreasing. This is probably in response to government policy for sheep farming, which in recent years has sought to decrease over grazing on vulnerable commonage and mountain areas. 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 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 managed 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 data exists to quantify the impact.

There is a strong dynamic of lands moving between grassland and cropland (with a knock 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 grassland to cropland leads to a net loss of carbon from the soil, and also a loss of living biomass when the Tier 1 default methods are applied.

The research and analysis noted in 7.4.1 is expected to have significant impact on the estimation of land use change within grasslands and croplands. It is anticipated that a recalculation of the 2013 submission will be required next year because of this, with a backwards re-analysis of agricultural areas.

## 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 category *5.C.2.5 Other Land Converted to Grassland* is the most important conversion category in most years while some conversions from cropland and 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 7.2 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 ( $\Delta C$  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 category *5.C.2.5 Other Land converted to Grassland* is in effect the transition of unmanaged native grassland to improved or unimproved pasture, as indicated in section 7.5.1 above. There is a change in carbon stock associated with conversion to improved grassland, as the land is invariably subject to ploughing and reseeded. This is accounted for through Equation 7.2 as 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, using the default values<sup>9</sup>.

Table 7.7 in section 7.3.7 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 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 7.5). Table 7.6 shows the adjustment factors applied to the default SOC<sub>ref</sub> 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 7.6 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 7.2.

#### 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 currently obtained from the Irish Business and Employers Federation. Limestone is the standard form of the application. The CO<sub>2</sub> 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 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.

### 7.6 Wetlands (5.D)

#### 7.6.1 Wetland Areas

Wetlands as applied to Ireland refer to natural unexploited wetlands while peatlands 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 7.3). Previously, unmanaged wetlands areas were not reported to the UNFCCC In the 2012 submission, *5.D.1 Wetlands Remaining Wetlands* have been

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<sup>9</sup> 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.

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 7.3). In the 2013 submission, *5.D.1 Wetlands Remaining Wetlands* have been subdivided into two categories: Exploited Wetlands Remaining Wetlands and Unexploited Wetlands Remaining Wetlands.

#### 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. In previous submissions, this demand was met by an adjustment in “Other Land” area.

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<sup>-1</sup>, (see 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 7.3 proceeds in 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 reclamation 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 reserve. 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 7.7). 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 this 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<sup>3</sup> for peat m<sup>-3</sup> (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 2011.

**Table 7.19. Area Statistics for Peatlands (ha)**

<b>Peatland Category</b>	<b>1985-1990</b>	<b>1991-1995</b>	<b>1996-2000</b>	<b>2001-2005</b>	<b>2006-2008</b>	<b>Vegetation Cover</b>
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
<b>Cutaway Areas</b>						
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	
<b>Total owned (at end of period)</b>	<b>84,738</b>	<b>82,792</b>	<b>80,134</b>	<b>79,760</b>	<b>79,495</b>	

## 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 7.7. 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 7.7 in section 7.3.7 above gives the area of forest land converted to wetlands for the years 1990-2010. 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  $0.6 \text{ t C ha}^{-1}\text{yr}^{-1}$  up to equilibrium of  $3 \text{ t C ha}^{-1}$ .

#### 7.6.2.2 Soils

The  $\text{CO}_2$  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 7.7), 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  $0.2 \text{ t C/ha}$ , 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- $\text{CO}_2$ Gases

In the submissions prior to 2006, no estimate was reported for  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  due to the drainage of peatlands are now reported and utilise the IPCC Tier 1 approach.

## 7.7 Settlements (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.

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.

### 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. 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 7.7 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 deforested areas.

## 7.8 Other Land (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 but for Ireland this category includes areas of natural grassland which are an available reserve for rough grazing but which are not grazed in the inventory year. As indicated above in section 7.5.1, when the demand for areas of pasture in a particular year is less than in the previous year, surplus areas of improved or unimproved pasture are allowed to revert to rough grazing, which are then not recorded as “in use” as grassland by CSO statistics. For area accounting purposes, such lands are assumed to be in transition and are assigned to category *5.F.2.3 Grassland Converted to Other Land* in a manner that maximises the area in *5.F.1 Other Land Remaining Other Land*. With the inclusion of unmanaged wetlands areas in LULUCF reporting in this submission, 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 unmanaged wetlands. 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 7.5 while Table 7.6 is used to apply the SOC adjustment factors and the carbon stock change is calculated using Equation 7.1. The default emission factor of 0.25 t C/ha is used to calculate carbon loss from organic soils.

Table 7.7 shows the transition of forest land to other land, which are not classified as crop, grassland, settlements or wetlands. These forest conversions are small areas being converted to quarries or telecommunication masts. More recently, these areas also include forest conversions into wind farms, but these are only the areas for roads and turbine platforms. Areas in the turbulence zone are generally clearfelled and replanted.

Table 7.7 in section 7.3.7 above gives the area of forest land converted to other land for the years 1990-2010. 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<sup>-1</sup> in the year of conversion.

## 7.9 Uncertainty in non-forest LULUCF 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 7.20. 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 2011 uncertainty for the estimate of emissions and removals within the Cropland category is the uncertainty in the emission factor for the loss of carbon due to conversion to Cropland from other land uses, most notably improved Grassland, accounting for approximately 90 per cent 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 cropland remaining cropland (5.B.1) 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 cropland is of the order of 10 per cent, 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 long term crop rotation practices. In previous years, an area of “set-aside” was a major component of the area reported as “Other Crops”. However, due to changes in the EU Area Payment Scheme, this statistic is no longer a reliable measure of “set-aside”. In addition, the practice of land leasing gives cropland farmers access to 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 undertaken 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 this opinion. It is considered to be probable that the GIS analysis findings are an artefact. This introduces an 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 1,500 ha. The emission factors associated with drainage of organic soils are such that it is important to address this potential underestimate of emissions. Additional research is required to resolve this issue; and this work will be undertaken in 2013.

### 7.9.2 Uncertainty in Grassland

Grassland has the potential for large uncertainty by virtue of large areal extent, and 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 per cent 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 are utilised agricultural area. This means natural grassland is not reported in this category except those used for rough grazing. Carbon stock changes are estimated using tier 1 methodologies is based on inter annual changes in reported areas.
- The area of drained organic soils under grassland is based on the proportion of 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 2013. Preliminary findings indicate that the default IPCC Tier 1 emission factor may be as much as an order of magnitude in error under conditions in Ireland. This introduces considerable uncertainty in the analysis of emissions, which cannot be quantified at this time. We look forward to the publication of the IPCC Wetlands Supplement to help inform the analysis. In the meantime the IPCC default factor will be used, 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 Wetland

Drainage of organic soils within wetland land is important by virtue of uncertainty in areal extent and emission factors. Uncertainty analysis reveals that these two components contribute in equal measure to overall uncertainty. However, there is significant 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 80 kha of land of which 60 kha 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 per cent of the market. This is largely confirmed by 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 extraction 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 underestimation of emissions, there is insufficient data to adopt a revised country specific EF. We look forward to the publication of the IPCC wetlands Supplement 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 man made 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 in the “Other Land” category by default as they would not be captured in Agricultural or Forestry statistics.

No reporting of potential change in soil carbon during conversion to settlement. The revised 2006 IPCC guidelines provide some additional insight into this potential source of emissions. This will be considered for inclusion in future submissions.

#### 7.9.5 Uncertainty in Other Land

The Other Land category is the residual area required to maintain a reporting of constant total national land area. As such, this category will attract a cascade of uncertainty in estimate of land use areas from the other categories.

**Table 7.20. 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		%	%		
5A	Forest land	CO <sub>2</sub>	15.0	50.0		
5.B.1	Cropland Remaining Cropland	CO <sub>2</sub>	22.6	69.1	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008	Default value from IPCC GPG
5.B.2	Cropland In Transition	CO <sub>2</sub>	18.6	69.1	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 <sub>2</sub>	12.2	90.0	Farm Structure Survey 2007, Teagasc Soil and Sub-soil Map 2008	Default value from IPCC GPG
5.C.2	Grassland in Transition	CO <sub>2</sub>	31.5	80.3	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 <sub>2</sub>	12.5	51.5	CORINE 2000, BnM expert opinion	Default value from IPCC GPG
5.D.2	Land Converted to Wetland	CO <sub>2</sub>	2.5	50.0	Deforestation data, Chapter 7.3	Country Specific value cf Chapter 7.3
5.E.1	Settlement remaining Settlement	CO <sub>2</sub>	39.1	75.0	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 <sub>2</sub>	39.1	75.0	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 <sub>2</sub>	31.5	90.0	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 <sub>2</sub>	53.9	71.6	Uncertainty in Other Land Area based on combined uncertainty of land use change in other land use categories	Default value from IPCC GPG
5A	Forest Land	CH <sub>4</sub>	30.0	100.0		
5A	Forest Land	N <sub>2</sub> O	30.0	100.0		
5.B.2	Cropland In Transition	N <sub>2</sub> O	30.0	100.0	From LULUCF GPG, Page 3.50	Default value from IPCC GPG
5.C.2	N2O from drained Organic Soils under grassland	N <sub>2</sub> O	90.8	100.0	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 <sub>2</sub> O	92.2	100.0	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-organic 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 7.10, 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 7.9, 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 annual inventory review reports (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 7.20 and 7.21.

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 7.13).

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 2010 in the 2012 submission using the Locator Tool (Table 7.21).

*Table 7.21. 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 <sub>2</sub>	260.65	IE,NO,NA	Mg/kg biomass	159 to 8.3
Fire CH <sub>4</sub>	1.14	IE,NO,NA	Mg/kg biomass	0.29 to 0.03
Fire N <sub>2</sub> O	0.01	IE,NO,NA	Mg/kg biomass	0.008 to <0.001
N <sub>2</sub> O 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. 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 5.A.2 were compared to other countries with similar forest characteristics for the inventory year 2010 in the 2012 submission (Table 7.22).

*Table 7.22. Comparison 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 <sub>2</sub>	151.7	IE,NO,NA	Mg/kg biomass	159 to 8.3
Fire CH <sub>4</sub>	0.66	IE,NO,NA	Mg/kg biomass	0.29 to 0.03
Fire N <sub>2</sub> O	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. 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.

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 7.20):

- 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 7.23 below.

*Table 7.23. Validation of net biome productivity (NBP, i.e. net C emissions/removals) estimates using CARBWARE against eddy covariance derived estimates across 2 chronosequences 2010 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 <sup>-1</sup> yr <sup>-1</sup> )						
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 7.13);
  - 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 estimates include emissions/removals from soils, which in some cases can represent a 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 7.21), CARBWARE overestimated NBP, when compared to eddy covariance. Research from 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.

#### 7.10.1.7 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 1990-2010 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 increase in removals of 299.2 per cent for 2010. The other main recalculations took place in the following categories:

### 5.A. Forest lands CRF

- A change from a stock change model previously used for reporting forest land under convention reporting to the gain loss approach used in the FORCARB and CARBWARE models. In addition, previous model used for forest land was based on BEFs and estimates of standing volume using static yield tables. The new models are more dynamic and more accurately emissions/removals by forest lands as demonstrated following uncertainty and validation analysis. As a result, the IEF for net living biomass changes in forests remaining forests decrease by 59 per cent for the year 2010. However, it is not valid to make such comparisons since the new submission represents an entirely new time series, where age class distributions of areas under forests remaining forest land are different. The same would apply to comparisons made for lands converted to forest land for the year 2010;

### 5.B.-5.E. Forests converted to other land uses

- A correction the deforestation losses and eq 7.9 and 7.10 for calculation of biomass from volume BEFs as recommended by a previous annual review report (ARR 2011). This has made a negligible change to the IEF for living biomass losses in 2010, when submission years are compared;

### 5(V) Wildfires for forest land (CRF 5(V))

- Use of new biomass values associated with forest wildfires. This has resulted in a ca. 200% increase in emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, in 2010, when the current and previous submission estimates are compared;
- Estimates have been made for the regrowth of vegetative cover for all land uses after deforestation events.

Further information on the net effect of the recalculations is presented in CRF table 8(b) and Table 7.24 below.

## 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 1990-2011. This submission also contains estimates for 2008-2011 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<sub>2</sub>

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 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.

### 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 7.24. Percentage Change in Emissions and Removals from LULUCF due to Recalculations 1990-2010**

**2012 Submission (Gg CO<sub>2</sub> eq)**

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Estimates in 2012 Submission (Gg CO <sub>2</sub> eq.)																				
<b>5.A</b>	<b>Forest Land</b>	<b>-371.0</b>	<b>-398.4</b>	<b>-226.9</b>	<b>-281.3</b>	<b>-224.5</b>	<b>-260.0</b>	<b>-234.0</b>	<b>-355.9</b>	<b>-471.1</b>	<b>-505.7</b>	<b>-355.1</b>	<b>-481.9</b>	<b>-623.3</b>	<b>-856.8</b>	<b>-477.9</b>	<b>-635.3</b>	<b>-709.1</b>	<b>-1,194.7</b>	<b>-1,826.7</b>	<b>-1,475.3</b>	<b>-1,371.2</b>
5.A.1	Forest Land remaining Forest Land (CO <sub>2</sub> )	-803.4	-943.3	-660.0	-617.9	-39.2	-145.0	-44.2	63.9	-194.8	-251.7	216.7	346.1	29.5	-792.1	-309.2	-455.9	-448.5	-1,034.1	-1,903.6	-2,143.6	-2,010.2
5.A.2	Land converted to Forest Land (CO <sub>2</sub> )	412.7	521.4	408.6	309.9	66.8	-145.5	-221.6	-449.8	-306.1	-284.4	-604.5	-864.0	-685.7	-104.3	-205.9	-214.5	-296.2	-197.2	39.0	631.0	594.8
5.A	Biomass burning (CH <sub>4</sub> and N <sub>2</sub> O)	2.9	19	12	2.4	2.8	3.8	4.3	2.3	12	10	2.5	5.0	12	7.1	4.1	15	15	17	2.1	12	7.6
5.A	Drainage of soils	16.7	217	23.3	24.2	25.1	26.6	27.5	27.7	28.6	29.3	30.2	31.0	31.8	32.5	33.0	33.6	34.1	34.9	35.8	36.1	36.6
<b>5.B</b>	<b>Cropland</b>	<b>20.0</b>	<b>21.2</b>	<b>25.2</b>	<b>24.8</b>	<b>-50.7</b>	<b>-23.0</b>	<b>42.3</b>	<b>76.8</b>	<b>23.2</b>	<b>-1.3</b>	<b>44.9</b>	<b>133.9</b>	<b>128.2</b>	<b>175.4</b>	<b>133.9</b>	<b>160.0</b>	<b>106.5</b>	<b>130.5</b>	<b>442.4</b>	<b>253.8</b>	<b>252.4</b>
5.B.1	Cropland remaining Cropland	20.0	212	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	-28.6
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	153.9	152.6	197.3	146.7	146.7	146.7	146.7	437.6	255.7	255.7
5.B	Agricultural Lime Application <sup>b</sup>	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	32.1
5.B.2	Emissions from soil disturbance	NA,NO	NA,NO	0.2	3.0	3.0	3.0	4.7	4.7	4.7	4.7	4.7	8.3	10.3	13.4	13.4	13.4	13.4	13.4	25.4	25.4	25.4
<b>5.C</b>	<b>Grassland</b>	<b>493.6</b>	<b>568.2</b>	<b>441.2</b>	<b>355.0</b>	<b>409.1</b>	<b>706.4</b>	<b>698.0</b>	<b>661.4</b>	<b>468.6</b>	<b>568.8</b>	<b>611.9</b>	<b>557.9</b>	<b>511.9</b>	<b>577.1</b>	<b>409.6</b>	<b>248.3</b>	<b>306.4</b>	<b>351.3</b>	<b>338.2</b>	<b>243.2</b>	<b>208.5</b>
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	570.6
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	-31.0	-102.5	-281.4	-204.0	-172.7	-187.0	-290.2	-362.1
5.C	Agricultural Lime Application <sup>b</sup>	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	275.2
<b>5.D</b>	<b>Wetlands</b>	<b>50.7</b>	<b>49.0</b>	<b>49.5</b>	<b>47.4</b>	<b>45.4</b>	<b>43.9</b>	<b>41.4</b>	<b>39.8</b>	<b>38.5</b>	<b>49.3</b>	<b>63.4</b>	<b>61.5</b>	<b>58.8</b>	<b>56.1</b>	<b>42.5</b>	<b>45.7</b>	<b>74.4</b>	<b>71.4</b>	<b>41.5</b>	<b>39.5</b>	<b>39.8</b>
5.D.1	Wetlands remaining Wetlands	47.1	45.5	46.0	43.9	42.0	40.5	38.0	36.5	35.2	46.1	43.5	42.1	39.8	37.6	24.5	27.7	30.8	33.1	35.9	38.7	38.7
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	3.0	-19	-15
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
<b>5.E</b>	<b>Settlements</b>	<b>9.2</b>	<b>8.5</b>	<b>8.6</b>	<b>9.1</b>	<b>11.0</b>	<b>9.8</b>	<b>12.5</b>	<b>13.7</b>	<b>14.7</b>	<b>15.8</b>	<b>37.3</b>	<b>42.9</b>	<b>40.9</b>	<b>45.3</b>	<b>46.6</b>	<b>50.8</b>	<b>34.2</b>	<b>32.9</b>	<b>30.4</b>	<b>19.8</b>	<b>23.3</b>
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
5.E.2	Land converted to Settlements	9.2	8.5	8.6	9.1	11.0	9.8	12.5	13.7	14.7	15.8	37.3	42.9	40.9	45.3	46.6	50.8	34.2	32.9	30.4	19.8	23.3
<b>5.F</b>	<b>Other Land</b>	<b>-1.1</b>	<b>0.3</b>	<b>-13.2</b>	<b>-14.4</b>	<b>-17.5</b>	<b>-4.2</b>	<b>-27.7</b>	<b>-35.0</b>	<b>-41.3</b>	<b>-35.4</b>	<b>-10.3</b>	<b>-25.6</b>	<b>-43.8</b>	<b>-41.8</b>	<b>-78.4</b>	<b>-86.5</b>	<b>-113.7</b>	<b>-99.7</b>	<b>-134.0</b>	<b>-116.7</b>	<b>-183.3</b>
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
5.F.2	Land converted to Other Land	-11	0.3	-13.2	-14.4	-17.5	-4.2	-27.7	-35.0	-41.3	-35.4	-10.3	-25.6	-43.8	-41.8	-78.4	-86.5	-113.7	-99.7	-134.0	-116.7	-183.3
<b>5.G</b>	<b>G. Other</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>
<b>5</b>	<b>TOTAL LULUCF CO<sub>2</sub> (net emissions/removals)</b>	<b>178.1</b>	<b>221.7</b>	<b>256.2</b>	<b>107.6</b>	<b>138.5</b>	<b>436.0</b>	<b>492.5</b>	<b>362.6</b>	<b>-5.1</b>	<b>53.2</b>	<b>351.5</b>	<b>241.4</b>	<b>26.6</b>	<b>-100.7</b>	<b>22.8</b>	<b>-268.2</b>	<b>-353.0</b>	<b>-760.9</b>	<b>-1,174.0</b>	<b>-1,100.9</b>	<b>-1,102.6</b>
<b>5</b>	<b>TOTAL LULUCF GHGs (net emissions/removals)</b>	<b>201.4</b>	<b>248.8</b>	<b>284.4</b>	<b>140.7</b>	<b>172.8</b>	<b>472.8</b>	<b>532.4</b>	<b>400.7</b>	<b>32.7</b>	<b>91.5</b>	<b>392.0</b>	<b>288.7</b>	<b>72.8</b>	<b>-44.8</b>	<b>76.1</b>	<b>-217.0</b>	<b>-301.3</b>	<b>-708.2</b>	<b>-1,108.2</b>	<b>-1,035.7</b>	<b>-1,030.4</b>

**b) 2013 Submission (Gg CO<sub>2</sub> eq)**

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Estimates in 2013 Submission (Gg CO <sub>2</sub> eq.)																				
<b>5.A Forest Land</b>	<b>-3,235.6</b>	<b>-3,374.8</b>	<b>-2,895.0</b>	<b>-3,154.8</b>	<b>-2,815.3</b>	<b>-2,546.8</b>	<b>-2,461.4</b>	<b>-3,217.8</b>	<b>-2,813.1</b>	<b>-2,749.8</b>	<b>-2,001.3</b>	<b>-2,144.5</b>	<b>-2,095.9</b>	<b>-2,293.8</b>	<b>-3,081.2</b>	<b>-2,989.8</b>	<b>-3,111.4</b>	<b>-3,850.0</b>	<b>-3,424.3</b>	<b>-3,441.7</b>	<b>-4,417.8</b>
5.A.1 Forest Land remaining Forest Land (CO <sub>2</sub> )	-3,287.6	-3,368.4	-2,820.7	-3,024.4	-2,593.6	-2,216.2	-1,985.0	-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
5.A.2 Land converted to Forest Land (CO <sub>2</sub> )	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
5.A Biomass burning (CH <sub>4</sub> and N <sub>2</sub> O)	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
5.A Drainage of soils	24.0	25.5	26.1	26.9	26.5	314	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
<b>5.B Cropland</b>	<b>20.0</b>	<b>21.2</b>	<b>25.6</b>	<b>25.6</b>	<b>-49.9</b>	<b>-21.9</b>	<b>43.9</b>	<b>78.4</b>	<b>24.8</b>	<b>0.4</b>	<b>46.7</b>	<b>136.1</b>	<b>130.8</b>	<b>178.2</b>	<b>136.7</b>	<b>162.8</b>	<b>109.3</b>	<b>133.3</b>	<b>445.4</b>	<b>256.8</b>	<b>291.7</b>
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
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
5.B Agricultural Lime Application <sup>b</sup>	36.7	32.5	26.3	37.0	27.5	50.3	50.3	44.3	314	38.9	37.2	40.5	29.7	43.2	26.4	26.8	25.5	37.2	29.7	33.4	36.5
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
<b>5.C Grassland</b>	<b>493.6</b>	<b>568.2</b>	<b>441.2</b>	<b>355.0</b>	<b>409.1</b>	<b>706.4</b>	<b>698.0</b>	<b>661.4</b>	<b>468.6</b>	<b>568.8</b>	<b>611.9</b>	<b>557.9</b>	<b>511.9</b>	<b>577.0</b>	<b>409.5</b>	<b>248.2</b>	<b>306.4</b>	<b>351.3</b>	<b>338.2</b>	<b>243.2</b>	<b>118.5</b>
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
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
5.C Agricultural Lime Application <sup>b</sup>	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
<b>5.D Wetlands</b>	<b>50.7</b>	<b>49.0</b>	<b>49.1</b>	<b>47.4</b>	<b>45.4</b>	<b>43.8</b>	<b>41.5</b>	<b>39.9</b>	<b>38.5</b>	<b>49.3</b>	<b>63.4</b>	<b>61.5</b>	<b>58.8</b>	<b>56.1</b>	<b>42.5</b>	<b>45.7</b>	<b>74.4</b>	<b>71.4</b>	<b>40.8</b>	<b>39.4</b>	<b>39.7</b>
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
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
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
<b>5.E Settlements</b>	<b>10.3</b>	<b>9.6</b>	<b>9.7</b>	<b>10.2</b>	<b>12.0</b>	<b>9.8</b>	<b>12.5</b>	<b>13.7</b>	<b>14.7</b>	<b>15.8</b>	<b>37.3</b>	<b>42.9</b>	<b>40.9</b>	<b>45.3</b>	<b>46.6</b>	<b>50.8</b>	<b>34.3</b>	<b>32.8</b>	<b>30.4</b>	<b>19.8</b>	<b>23.4</b>
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
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
<b>5.F Other Land</b>	<b>-1.1</b>	<b>0.3</b>	<b>-13.2</b>	<b>-14.4</b>	<b>-17.5</b>	<b>-4.5</b>	<b>-28.1</b>	<b>-35.6</b>	<b>-42.0</b>	<b>-36.3</b>	<b>-11.7</b>	<b>-27.4</b>	<b>-46.1</b>	<b>-44.6</b>	<b>-81.6</b>	<b>-90.2</b>	<b>-117.5</b>	<b>-103.7</b>	<b>-138.1</b>	<b>-120.9</b>	<b>-167.9</b>
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
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
<b>5.G G. Other</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>	<b>NE</b>
<b>TOTAL LULUCF CO<sub>2</sub> (net emissions/removals)</b>	<b>-2,699.8</b>	<b>-2,762.0</b>	<b>-2,417.0</b>	<b>-2,773.4</b>	<b>-2,459.6</b>	<b>-1,865.3</b>	<b>-1,747.5</b>	<b>-2,507.3</b>	<b>-2,354.7</b>	<b>-2,195.5</b>	<b>-1,307.0</b>	<b>-1,440.6</b>	<b>-1,452.9</b>	<b>-1,563.6</b>	<b>-2,598.9</b>	<b>-2,633.9</b>	<b>-2,765.7</b>	<b>-3,427.0</b>	<b>-2,782.5</b>	<b>-3,075.9</b>	<b>-4,204.1</b>
<b>TOTAL LULUCF GHGs (net emissions/removals)</b>	<b>-2,662.1</b>	<b>-2,726.5</b>	<b>-2,382.6</b>	<b>-2,730.9</b>	<b>-2,416.2</b>	<b>-1,813.2</b>	<b>-1,693.7</b>	<b>-2,460.1</b>	<b>-2,308.4</b>	<b>-2,151.8</b>	<b>-1,253.7</b>	<b>-1,373.6</b>	<b>-1,399.6</b>	<b>-1,481.7</b>	<b>-2,527.5</b>	<b>-2,572.4</b>	<b>-2,704.5</b>	<b>-3,364.8</b>	<b>-2,707.7</b>	<b>-3,003.4</b>	<b>-4,112.3</b>

*c) Percentage Change*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Percentage Change in Total Emissions due to Recalculations																					
<b>5.A Forest Land</b>	<b>772.1</b>	<b>747.0</b>	<b>1,175.8</b>	<b>1,021.4</b>	<b>1,154.3</b>	<b>879.4</b>	<b>951.7</b>	<b>804.2</b>	<b>497.1</b>	<b>443.7</b>	<b>463.5</b>	<b>345.0</b>	<b>236.3</b>	<b>167.7</b>	<b>544.7</b>	<b>370.6</b>	<b>338.8</b>	<b>222.3</b>	<b>87.5</b>	<b>133.3</b>	<b>222.2</b>
5.A.1 Forest Land remaining Forest Land (CO <sub>2</sub> )	309.2	257.1	327.4	389.5	712.6	1428.5	4,394.9	-4,127.0	927.2	594.5	-463.4	-306.0	-1,506.7	-55.4	179.9	-3.6	-26.4	2.3	-79.2	-93.7	-55.1
5.A.2 Land converted to Forest Land (CO <sub>2</sub> )	-95.7	-107.4	-125.6	-153.5	-485.8	157.9	134.9	515	177.4	264.3	108.0	719	150.6	1820.0	1001.6	1,108.7	853.3	1,337.9	-7,977.6	-630.5	-701.2
5.A Biomass burning (CH <sub>4</sub> and N <sub>2</sub> O)	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	244.9	192.8	192.1	191.3
5.A Drainage of soils	43.2	17.5	12.0	11.1	5.9	18.1	7.3	6.6	13.5	4.4	15.8	16.7	5.6	17.8	15.3	11.4	8.8	7.3	5.6	5.5	5.7
<b>5.B Cropland</b>	<b>0.0</b>	<b>0.0</b>	<b>1.6</b>	<b>3.2</b>	<b>-1.6</b>	<b>-4.9</b>	<b>3.9</b>	<b>2.1</b>	<b>7.1</b>	<b>-131.1</b>	<b>4.1</b>	<b>1.7</b>	<b>2.0</b>	<b>1.6</b>	<b>2.1</b>	<b>1.8</b>	<b>2.6</b>	<b>2.1</b>	<b>0.7</b>	<b>1.2</b>	<b>15.6</b>
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	-26.8
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.B Agricultural Lime Application <sup>b</sup>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7
5.B.2 Emissions from soil disturbance	NA	NA	176.2	26.9	26.9	38.3	34.7	34.7	34.7	34.7	38.9	26.8	25.0	20.9	20.9	20.9	20.9	20.9	11.7	11.7	11.7
<b>5.C Grassland</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>-43.2</b>
5.C.1 Grassland remaining Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5
5.C.2 Land converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	52.5
5.C Agricultural Lime Application <sup>b</sup>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.2
<b>5.D Wetlands</b>	<b>0.1</b>	<b>0.0</b>	<b>-0.8</b>	<b>0.0</b>	<b>-0.1</b>	<b>-0.3</b>	<b>0.3</b>	<b>0.2</b>	<b>0.1</b>	<b>0.0</b>	<b>0.0</b>	<b>-0.1</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>-1.7</b>	<b>-0.1</b>	<b>-0.2</b>
5.D.1 Wetlands remaining Wetlands	0.1	0.0	-0.9	0.0	-0.1	-0.3	0.3	0.2	0.1	0.0	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2
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
5.D Drainage of soils	0.0	0.0	-0.1	0.0	-0.1	-0.1	0.0	0.0	-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
<b>5.E Settlements</b>	<b>11.7</b>	<b>12.6</b>	<b>12.5</b>	<b>11.8</b>	<b>9.8</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.1</b>	<b>-0.4</b>	<b>0.0</b>	<b>0.0</b>	<b>0.5</b>
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
5.E.2 Land converted to Settlements	11.7	12.6	12.5	11.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.4	0.0	0.0	0.5
<b>5.F Other Land</b>	<b>-0.3</b>	<b>NA</b>	<b>0.1</b>	<b>0.1</b>	<b>0.2</b>	<b>NA</b>	<b>1.4</b>	<b>1.6</b>	<b>1.7</b>	<b>NA</b>	<b>NA</b>	<b>7.1</b>	<b>5.2</b>	<b>NA</b>	<b>4.0</b>	<b>4.2</b>	<b>3.3</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>
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
5.F.2 Land converted to Other Land	-0.3	NA	0.1	0.1	0.2	NA	1.4	1.6	1.7	NA	NA	7.1	5.2	NA	4.0	4.2	3.3	NA	NA	NA	NA
<b>5.G G. Other</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>
<b>5 TOTAL LULUCF CO<sub>2</sub> (net emissions/removals)</b>	<b>-1,615.8</b>	<b>-1,345.8</b>	<b>-1,043.5</b>	<b>-2,676.5</b>	<b>-1,875.7</b>	<b>-527.8</b>	<b>-454.8</b>	<b>-791.5</b>	<b>45,641.1</b>	<b>-4,226.0</b>	<b>-471.8</b>	<b>-696.8</b>	<b>-5,554.5</b>	<b>1,453.0</b>	<b>-11,513.6</b>	<b>881.9</b>	<b>683.5</b>	<b>350.4</b>	<b>137.0</b>	<b>179.4</b>	<b>281.3</b>
<b>5 TOTAL LULUCF GHGs (net emissions/removals)</b>	<b>-1,422.0</b>	<b>-1,195.9</b>	<b>-937.8</b>	<b>-2,040.8</b>	<b>-1,498.2</b>	<b>-483.5</b>	<b>-418.1</b>	<b>-713.9</b>	<b>-7,168.8</b>	<b>-2,452.5</b>	<b>-419.8</b>	<b>-575.8</b>	<b>-2,023.1</b>	<b>3,208.4</b>	<b>-3,420.5</b>	<b>1,085.5</b>	<b>797.7</b>	<b>375.1</b>	<b>144.3</b>	<b>190.0</b>	<b>299.1</b>

## 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<sub>4</sub> is the gas concerned. Landfills represent a key emission category in Ireland and the emission estimates of CH<sub>4</sub> 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<sub>4</sub> for some Parties, however in Ireland, all wastewater treatment is aerobic and consequently it is not a source of CH<sub>4</sub> emissions. The anaerobic treatment of sludge is a source of CH<sub>4</sub> emissions and is included in the inventory. N<sub>2</sub>O emissions arising from the production of human sewage are also included. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 1990-2011 have been estimated for the first time in this submission. The annual GHG inventory is now 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 2013 submission shows total GHG emissions of 1,042.58 Gg CO<sub>2</sub> equivalent in the *Waste* sector in 2011, of which 6.A solid waste disposal on land accounts for 79.7 per cent, 6.B waste water handling 15.1 per cent and 6.C waste incineration 5.2 per cent. The latest estimates show that emissions in the *Waste* sector have decreased by 24.6 per cent from 1990 to 2011 mainly due to a 29.2 per cent decrease in CH<sub>4</sub> emissions from 6.A solid waste disposal on land.

Unlike many other developed countries, Ireland has not used waste incineration as a waste management option to any significant extent to date. 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 <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> Generation from Solid Waste Disposal

While the method previously used to estimate and report Ireland's CH<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> emissions from landfills. The model is a simple first-order decay spreadsheet 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<sub>4</sub> and CO<sub>2</sub> 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<sub>4</sub> 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). Four of the six largest landfills and all landfills in four (out of seven) of the landfill groups selected for analysis are closed sites. The six largest landfills account for approximately 36 per cent of the municipal waste disposal in Ireland over the period 1990-2011. This means that the remaining 64 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<sub>4</sub> generation, particularly for the early years of the 1990-2011 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; McCooole et al, 2009; McCooole et al, 2011; McCooole et al, 2012; McCooole 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 13 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 30.2 per cent in 1995 to 23.0 per cent in 2011, which reflects the increase in recycling of paper. The NWD is used to give the values for all years in the period 1995 to 2011. 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 30.2 per cent in 1995. The proportion of organics, the other principal constituent of waste, was estimated in the same way for each year.

### *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 2011. 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

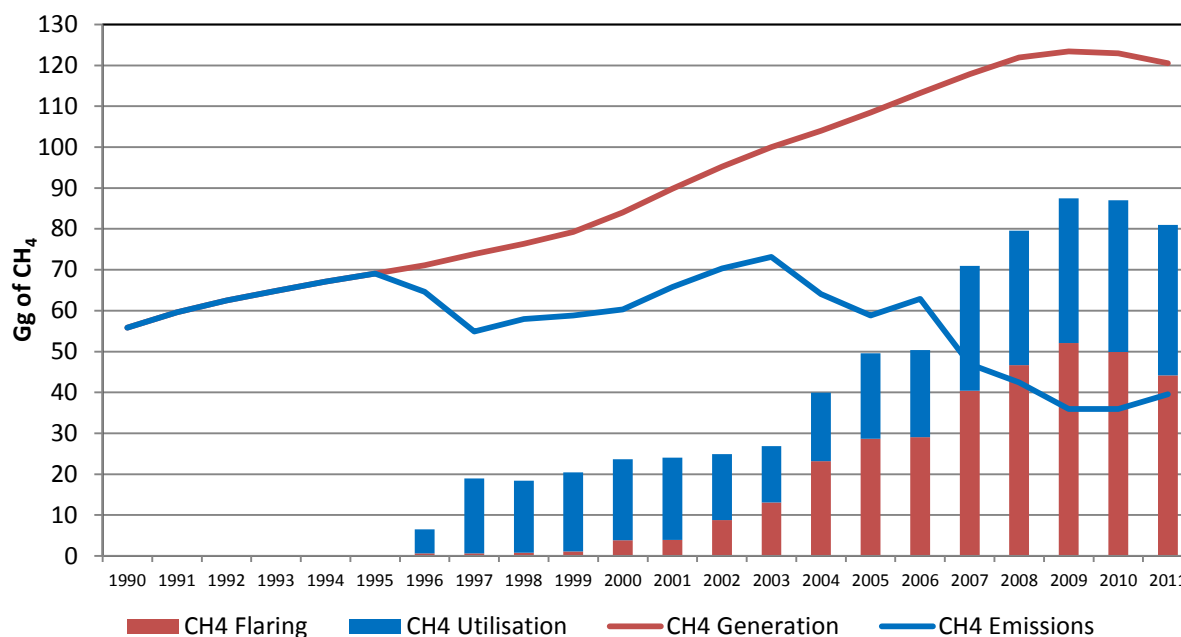
A detailed study was conducted on behalf of the inventory agency by Fehily Timoney Consultants of methane flaring and utilisation for the years 1996-2008 (Ireland's NIR 2010). Following this study, the inventory agency undertook a similar survey of landfill sites in 2010 to collect data for the years 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. The same survey was conducted in subsequent years to obtain data for 2010 and 2011 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<sub>4</sub> flared was calculated from landfill gas volume by accounting for gas temperature (assumed to be ambient air temperature) and 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 ten methane utilisation plants at landfills in Ireland in 2011 with a total of 27 engines. This has increased from 8 plants and 23 engines in 2009 and 6 plants and 20 engines in 2008. 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<sub>4</sub> production, utilisation and flaring are presented in Table 8.2.

**Table 8.2. Methane Emissions from Solid Waste Disposal 1990-2011**

	Methane Generation (Tonnes)	Methane Flaring (Tonnes)	Methane Utilisation (Tonnes)	Methane Recovery (Tonnes)	Per cent Methane Recovery	Methane Emissions (Tonnes)	Methane Emissions (Gg CO <sub>2</sub> eq)
1990	55859.50	0.00	0.00	0.00	0.00	55859.50	1173.05
1991	59606.84	0.00	0.00	0.00	0.00	59606.84	1251.74
1992	62498.51	0.00	0.00	0.00	0.00	62498.51	1312.47
1993	64861.66	0.00	0.00	0.00	0.00	64861.66	1362.09
1994	67141.19	0.00	0.00	0.00	0.00	67141.19	1409.97
1995	69031.40	0.00	0.00	0.00	0.00	69031.40	1449.66
1996	71113.99	598.85	5877.35	6476.19	9.11	64637.80	1357.39
1997	73812.58	591.84	18354.17	18946.01	25.67	54866.57	1152.20
1998	76362.13	770.11	17632.04	18402.15	24.10	57959.98	1217.16
1999	79213.63	1096.60	19317.01	20413.61	25.77	58800.02	1234.80
2000	83999.70	3855.11	19818.49	23673.60	28.18	60326.11	1266.85
2001	89811.72	3900.65	20159.50	24060.15	26.79	65751.57	1380.78
2002	95239.63	8773.44	16107.54	24880.98	26.12	70358.65	1477.53
2003	100027.33	13083.99	13780.67	26864.66	26.86	73162.67	1536.42
2004	103961.12	23180.45	16749.43	39929.88	38.41	64031.24	1344.66
2005	108426.29	28638.38	20947.12	49585.50	45.73	58840.80	1235.66
2006	113238.90	29033.88	21346.10	50379.98	44.49	62858.92	1320.04
2007	117896.53	40395.90	30558.07	70953.98	60.18	46942.55	985.79
2008	121966.77	46639.68	32908.74	79548.42	65.22	42418.35	890.79
2009	123404.43	52050.80	35403.54	87454.33	70.87	35950.09	754.95
2010	122914.74	49886.65	37090.88	86977.53	70.76	35937.21	754.68
2011	120513.93	44205.15	36744.73	80949.88	67.17	39564.05	830.85



*Figure 8.1. Methane Emissions from Solid Waste Disposal 1990-2011*

Table 8.2 and Figure 8.1 present the results for methane emissions from 6.A Solid Waste Disposal. These estimates of CH<sub>4</sub> 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<sub>4</sub> production over the period 1990-2009, reflecting Ireland's strong dependence on solid waste disposal to landfills. The utilisation of CH<sub>4</sub> remained generally constant up to 2006 since becoming established in 1996. The quantity of CH<sub>4</sub> 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<sub>4</sub> 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 70.9 per cent in 2009 after which there was a slight decrease to 67.2 per cent in 2011. Due to the rapidly increasing level of CH<sub>4</sub> flared after 2003, the emissions show a steady decline from the 2003 level of 1,536.42 Gg CO<sub>2</sub>eq to 754.68 Gg CO<sub>2</sub>eq in 2010. Emissions then increased by 10.1 per cent (76.16 CO<sub>2</sub>eq) mainly due to a decrease in methane flaring. The emissions in 2011 are 29.2 per cent lower than in 1990.

## 8.3 Emissions from Wastewater Handling (6.B)

### 8.3.1. CH<sub>4</sub> 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<sub>4</sub>. 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<sub>4</sub> emissions from septic tanks are deemed not to occur in Ireland. Consequently the notation key "NO" is reported for CH<sub>4</sub> and 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°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<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> is derived from the Revised 1996 IPCC Guidelines (equation 11 on page 6.21) using the IPCC default value of 0.6 for B<sub>0</sub>, 0.3 for the fraction of sludge treated and 1.0 for MCF.

The sludge arising from secondary treatment of urban wastewater for the Dublin agglomeration, which accounts for approximately half of the population equivalent served by urban wastewater treatment systems, is thermally dried and pasteurised for use as an organic fertiliser. The CH<sub>4</sub> produced at this plant is used for electricity generation for use on site since 2005. For the remainder of domestic/commercial wastewater sludge, the DOC is calculated using 60g BOD/capita/day population equivalent<sup>10</sup> 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<sub>4</sub> 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<sub>4</sub> 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<sub>2</sub>O 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 in 2011.

### 8.3.2 N<sub>2</sub>O 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<sub>2</sub>O

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<sup>10</sup> 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

emission estimates derived using the IPCC methodology and the accompanying default values.

N<sub>2</sub>O 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<sub>2</sub>O-N/ kg sewage produced) to obtain the quantity of nitrogen in sewage ultimately entering the atmosphere as N<sub>2</sub>O. Emission estimates are provided in Table 8.3.

**Table 8.3. Estimates of N<sub>2</sub>O emissions from human sewage 1990-2011**

Year	Protein (g/day)	Days	Pop (million)	N fraction (IPCC default)	EF (IPCC default)	N <sub>2</sub> O * (Gg)
	A	B	C	D	E	
1990	112	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	4.484	0.16	0.01	0.456

\*emissions calculated as A \* B \* C \* D \* E \* 44 / 28000

## 8.4 Emissions from Waste Incineration (6.C)

Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from waste incineration for all years from 1990-2011 have been estimated for the first time in this submission. The annual GHG inventory is now fully consistent with air pollutant reporting under the Convention on Long Range Transboundary Air Pollution and implements a recommendation 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, incinerated in Ireland 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 t/annum 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.

$$\text{CO}_2 \text{ emissions} = \sum i (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$$

Where:

CO<sub>2</sub> emissions = CO<sub>2</sub> emissions in inventory year (Gg/yr)

SW<sub>i</sub> = total amount of solid waste of type *i* (wet weight) incinerated, Gg/yr

dm<sub>i</sub> = dry matter content in the waste (wet weight) incinerated, (fraction)

CF<sub>i</sub> = fraction of carbon in the dry matter (total carbon content), (fraction)

FCF<sub>i</sub> = fraction of fossil carbon in the total carbon, (fraction)

OF<sub>i</sub> = oxidation factor, (fraction)

44/12 = conversion factor from C to CO<sub>2</sub>

*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<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) 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<sub>4</sub> and N<sub>2</sub>O EFs for Clinical Waste Incineration**

IPCC category	Waste	CH <sub>4</sub> kg/Gg waste	N <sub>2</sub> O 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 are 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; McCooole et al, 2009; McCooole et al, 2010; McCooole et al, 2011; McCooole et al, 2012 and McCooole et al, 2013).

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<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) 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<sub>4</sub> and N<sub>2</sub>O EFs for Solvent (Liquid/Vapour) Waste Incineration**

IPCC category	Waste	CH <sub>4</sub> g/t waste	N <sub>2</sub> O 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<sub>4</sub> generation, CH<sub>4</sub> flared and CH<sub>4</sub> 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<sub>4</sub> 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<sub>4</sub> generation again using equation 6.4, which is combined with uncertainties of 30 per cent and 10 per cent for CH<sub>4</sub> 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 in this submission, resulting in an overall increase of GHG emissions of 6.3 per cent in 1990 and 8.7 per cent in 2010. The following recalculations took place in this submission:

- Revised data for LFG flared at one landfill site for 2010 increased emissions from 6.A.1 solid waste disposal on land by 4.7 per cent in 2010;
- Minor revision to organic product input for 6.B.1 industrial wastewater and 6.B.2.1 domestic and commercial wastewater for 2003 to 2010. This resulted in CH<sub>4</sub> emission reductions of 0.01 to 0.03 per cent;
- Revised protein consumption values from FAOSTAT for Ireland for all years from 1990 to 2010. This resulted in emissions of N<sub>2</sub>O decreasing by 2.0 per cent in 1990 and by 3.0 per cent in 2010;
- Including emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from waste incineration for all years for the first time. Emissions were reported previously as not occurring "NO". This change had the most significant impact to total sectoral emissions in this submission.

The total impact of all the changes above is an increase in GHG emissions from the Waste sector (CO<sub>2</sub> eq) of 6.3 per cent in 1990 to 8.7 per cent in 2010. 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 EPRTTR and this collaboration ensures an element of consistency in environmental reporting in this area.

This submission also provides estimates from sub-category 6.C waste incineration, for the first time for all years from 1990-2011. This important improvement implements a recommendation from a previous annual inventory review. The methodology is described in section 8.4 above and additional detailed information is provided in Tables I.3 and I.4 of Annex I.

*Table 8.6 .Recalculated Estimates for Waste 1990-2010*

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Estimates in 2012 Submission (Gg CO <sub>2</sub> 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	575.2
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	114.0	115.5	120.2	117.4	114.8	111.3	112.4	115.8	118.2	121.6	126.7	125.6	127.3	129.3	131.7	134.2	137.7	141.0	144.1	144.9	145.2
6.C	Waste Incineration	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6	Total	1,301.8	1,382.1	1,447.6	1,494.6	1,539.8	1,575.6	1,484.6	1,288.3	1,355.9	1,378.2	1,415.7	1,529.5	1,628.2	1,688.1	1,499.9	1,384.4	1,472.6	1,141.9	1,050.3	915.6	888.7
Recalculated Estimates in 2013 Submission (Gg CO <sub>2</sub> 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
Percentage Change in Total Emissions due to Recalculations																						
6.A.1	Managed Waste Disposal on Land	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.73
6.A.2	Unmanaged Waste Disposal Sites	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
6.B.1.b	Industrial Wastewater	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	0.00	0.01	0.00	-0.01	-0.02	-0.03	-0.03
6.B.2.b	Domestic & Commercial Wastewater	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	0.00	0.01	0.00	-0.01	-0.02	-0.03	-0.03
6.B.2	Human Sewage	-2.01	0.09	-4.73	-4.94	-5.33	-1.57	0.92	0.45	2.23	3.42	-1.37	4.27	1.49	1.95	0.91	-1.41	-1.56	-3.85	-3.15	-2.98	-2.98
6.C	Waste Incineration	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Total	6.26	6.07	5.40	5.22	5.05	5.21	5.72	5.49	4.10	4.38	4.07	4.52	4.09	5.91	7.47	7.62	6.91	6.79	5.47	6.45	8.66

## 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 2013 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 2013 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 2013 submission CRF tables. The original and revised numerical values of the emissions estimates for the years 1990-2010, 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 give rise to recalculated estimates for the years 1990-2010 included in the 2013 submission are outlined below (Table 10.2 and Figure 10.1).

##### 10.2.1 Recalculations in Energy

###### 1.A.1 Energy Industries

- Biomass use in sub-category 1.A.1.a is now disaggregated into 3 fuels; Landfill Gas (LFG), Wood and from 2011, Municipal Solid Waste (MSW). There is no change in emissions due to this revised split;

- A revision to energy data in sub-category 1.A.1.b for 2010 onwards as a result of natural gas consumption being included in this sector for the first time.

The impact has been to increase total Energy Industries GHG emissions by 0.04 per cent in 2010 and refinery sub-category emissions by 1.7 per cent.

### 1.A.2 Manufacturing Industries and Construction

- Revisions to sub-categories in 1.A.2.a to f, were a result of natural gas reallocation within the sub-categories of this sector from 1990 to 1999;
- Sub-category 1.A.2.d emissions decreased ranging from 63 per cent in 1991 to 2.6 per cent in 1999;
- Sub-category 1.A.2.f emissions increased by 1.8 per cent in 1991 to 1.1 per cent in 1999.

Overall, any changes to emissions from this sector were minor with emissions in 2010 increasing by 0.44 per cent.

### 1.A.3 Transport

- Revisions to the road transport, 1.A.3.b sub-category are mainly due to methodological change of implementing the most recent COPERT 4 model (version 9.1), replacing version 8.0. Specifically, this has increased emissions of N<sub>2</sub>O and CH<sub>4</sub> from passenger cars between 1993 and 1998;
- A minor revision to energy data has led to a small decrease in CO<sub>2</sub> emissions from LPG and diesel fuels;
- The sub-category *other transport* (1.A.3.e) now includes biomass use from *Railways*. The CRF Reporter tool does not allow the addition of biomass under the sub-category for *Railways*, 1.A.3.c. This is only included in the latest year 2011.

The total impact of these revisions on the transport sector is an increase in total GHG emissions of 0.8 per cent in 1990 and a 0.02 per cent reduction in 2010. The impact is more significant when looking at the individual GHGs, where the percentage increases in 1998 for N<sub>2</sub>O and CH<sub>4</sub> are 281 per cent and 3.6 per cent respectively. The revised estimates due to the COPERT model change are clearly shown in Tables 3.7 and 3.8 of chapter 3.

### 1.A.4 Other Sectors

Revised fuel data, in particular, gasoil (in all 3 sub-categories 1.A.4.a-c), natural gas in 1.A.4.a and coal in 1.A.4.b has led to small recalculations for these sub-categories across the time-series.

- The largest recalculations in commercial/institutional (1.A.4.a) occurred in 2007, an increase in emissions of 0.7 per cent;
- The largest recalculations in residential (1.A.4.b) occurred in 2009, an increase in emissions of 0.3 per cent;
- The largest recalculations in agriculture/forestry/fisheries (1.A.4.c) occurred in 2007, an increase in emissions of 1.0 per cent.

This submission also includes the use of charcoal (biomass-solid) in the residential sector 1.A.4.b, for cooking, following the recommendation from the previous annual inventory review in September 2012.

### 1.C.1.B International Marine Bunkers

Emissions of CH<sub>4</sub> and N<sub>2</sub>O have been estimated for the first time, following a recommendation from a previous annual inventory review, in Marine Bunkers (1.C.1.B) for all years from 1990 to 2011.

### 10.2.2 Recalculations in Industrial Processes

Recalculations in the Industrial Processes sector in this submission are confined to HFCs in 2.F.2 Foams and HFCs from 2.F.3 Fire Extinguishers. Recalculations for 2.F.2 Foams are due to small changes in OECD and Ireland GDP proxy data between 2001 and 2010. Recalculations for 2.F.3 Fire Extinguishers are due to a minor error in the emission calculation spread sheet in relation to the disposal factor for all years from 1990 to 2010. The total impact of recalculations in these sub-categories is to increase total GHG emissions by 0.66 per cent in 1990 and 0.43 per cent in 2009 and to decrease emissions in 2010 by 0.66 per cent. The overall impact of these recalculations on the total sectoral emissions is negligible resulting in a reduction of 0.19 per cent in 2010. The results of the recalculations are given by category and gas in Table 4.4 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 2005-2010 and are due to the use of revised population statistics and GDP estimates for Ireland. The total impact of recalculations in this sector is to increase total GHG emissions in 2009 and 2010 by 0.01 per cent. Smaller increases result for 2005 and 2006, with minimal reductions for 2007 and 2008.

### 10.2.4 Recalculations in Agriculture

A number of minor changes were implemented in this submission, resulting in an overall increase of GHG emissions of 0.48 per cent in 2010. Minor revisions to animal populations of poultry and swine between 2007 and 2010 were made as well as amendments to indirect emissions of N<sub>2</sub>O from atmospheric deposition due to a change in the NH<sub>3</sub> model inputs. In addition, a reallocation of N<sub>2</sub>O emissions was made from Animal Manure Applied to Soils (4.D.1.2) to sub-category sewage sludge (4.D.1.6), following a previous annual inventory review recommendation. Finally, a revision to indirect emissions of N<sub>2</sub>O from leaching and run-off (4.D.3.2) was made following a reduction in the amount of nitrogen volatilised as ammonia in the NH<sub>3</sub> model due to a double count of some poultry; broilers and layers in the previous submission.

The net effect of the revisions to livestock statistics and nitrogen model values is an increase in agricultural CH<sub>4</sub> emissions of 0.61 per cent in 2010. N<sub>2</sub>O emissions from agriculture have been revised across the time-series from a 0.01 per cent reduction in 1990 to a 0.27 per cent increase in 2010. 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 1990-2010 due to methodological improvements and in response to recommendations made in the previous annual inventory review report. The impact of these recalculations on total GHG emissions in the LULUCF sector is presented in Table 7.23, chapter 7 and Table 10.2. The other main recalculations took place in the following categories:

### 5.A Forest Land

- A change from a stock change model previously used for reporting forest land under convention reporting to the gain loss approach used in the FORCARB and CARBWARE models. In addition, previous model used for forest land was based on BEFs and estimates of standing volume using static yield tables. The new models are more dynamic and more accurately emissions/removals by forest lands as demonstrated following uncertainty and validation analysis. As a result, the IEF for net living biomass changes in forests remaining forests decrease by 59 per cent for the year 2010. However, it is not valid to make such comparisons since the new submission represents an entirely new time series, where age class distributions of areas under forests remaining forest land are different. The same would apply to comparisons made for lands converted to forest land for the year 2010.

### 5.B.-5.E. Forests converted to other land uses

- A correction to the deforestation losses and equation 7.9 and 7.10 for calculation of biomass from volume BEFs as recommended by the previous annual inventory review report. This has made a negligible change to the IEF for living biomass losses in 2010, when submission years are compared;

### 5(V) Wildfires for forest land (CRF 5(V))

- Use of new biomass values associated with forest wildfires. This has resulted in a ca. 200 per cent increase in emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, in 2010, when the current and previous submission estimates are compared;
- Estimates have been made for the regrowth of vegetative cover for all land uses after deforestation events.

The net effect of the recalculations is outlined in Table 7.23 and Table 10.2.

## 10.2.6 Recalculations in Waste

A number of changes were implemented in this submission, resulting in an overall increase of GHG emissions of 6.3 per cent in 1990 and 8.7 per cent in 2010. The following recalculations took place in this submission;

- Revised data for LFG flared at one landfill site for 2010 increased emissions from 6.A.1 solid waste disposal on land by 4.7 per cent in 2010;
- Minor revision to organic product input for 6.B.1 industrial wastewater and 6.B.2.1 domestic and commercial wastewater for 2003 to 2010. This resulted in CH<sub>4</sub> emission reductions of 0.01 to 0.03 per cent;
- Revised protein consumption values from FAOSTAT for Ireland for all years from 1990 to 2010. This resulted in emissions of N<sub>2</sub>O decreasing by 2.0 per cent in 1990 and by 3.0 per cent in 2010;
- Including emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O from waste incineration for all years for the first time. Emissions were reported previously as not occurring “NO”. This change had the most significant impact to total sectoral emissions in this submission.

The total impact of all the changes above is an increase in GHG emissions from the Waste sector (CO<sub>2</sub> eq) of 6.3 per cent in 1990 to 8.7 per cent in 2010. 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 varies from an increase of 0.15 per cent in 1990 to a maximum increase of 0.61 per cent in 1998 and an increase of 0.29 per cent in 2010, Table 10.2 (c). There is no significant impact on the trend in total emissions (Chapter Two). 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 submission ([UNFCCC, 2007](#)) was an important development in this regard. The majority of the recommendations in the 2007 review report were implemented in the 2008 submission while further recommendations from the 2008, 2009, 2010 and 2011 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 2010 NIR relating to the use of ETS data, which are used extensively in the *Energy* and *Industrial Processes* sectors. Significant improvements have been made in this submission in relation to the agriculture sector, in particular, the revision of the animal population characterisation and the nitrogen excretion rates for livestock. Annex J summarises the issues raised in the 2010 and 2011 annual inventory review reports and Ireland's response to those issues through the 2012 submission and the current submission. It may be stated therefore that the inventory material being submitted in 2013 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. This submission sees the establishment of two new MOU, one of which replaces the two MOU with the Department of Agriculture, Food and the Marine and the other the MOU with the Central Statistics Office (see chapter 13).

An updated national climate change strategy was published in 2007 providing a framework in which internal review of annual inventories will take 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 2012 NIR**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Categories where the 2013 NIR includes major changes in methodological descriptions compared to the 2012 NIR	Sub-categories where changes are reflected in recalculations of previous year estimates	Reference to sub-category, gas, pages in the NIR, Annex
<b>Total (Net Emissions)</b>		✓	
<b>1. Energy</b>		✓	
A. Fuel Combustion (Sectoral Approach)		✓	
1. Energy Industries	✓	✓	Includes emissions from a waste to energy MSW incinerator for 2011
2. Manufacturing Ind & Const		✓	
3. Transport	✓	✓	Road Transport CH <sub>4</sub> and N <sub>2</sub> O. Revised model; COPERT 4 v 8.0 to COPERT 4 v 9.1
4. Other Sectors		✓	
5. Other			
B. Fugitive Emissions from Fuels			
1. Solid Fuels			
2. Oil and Natural Gas			
<b>2. Industrial Processes</b>		✓	
A. Mineral Products			
B. Chemical Industry			
C. Metal Production			
D. Other Production			
E. Production of Halocarbons and SF <sub>6</sub>			
F. Consumption of Halocarbons and SF <sub>6</sub>		✓	
G. Other			
<b>3. Solvent and Other Product Use</b>		✓	
<b>4. Agriculture</b>		✓	
A. Enteric Fermentation		✓	
B. Manure Management		✓	
C. Rice Cultivation			
D. Agricultural Soils	✓	✓	N <sub>2</sub> O emissions from sewage sludge applied to soils is now reallocated to category 4.D.1.6
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues			
G. Other			
<b>5. Land Use, Land-Use Change and Forestry</b>		✓	
A. Forest Land	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
B. Cropland	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
C. Grassland	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
D. Wetlands	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
E. Settlements	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
F. Other Land	✓	✓	New approach now fully consistent with KP Article 3.3 reporting
G. Other			
<b>6. Waste</b>		✓	
A. Solid Waste Disposal on Land		✓	
B. Waste-water Handling			
C. Waste Incineration	✓	✓	Now includes emissions from incineration of clinical waste and from solvent destruction in thermal oxidisers
D. Other			
<b>7. Other (as specified in Summary 1.A)</b>			
<b>Memo Items:</b>		✓	
<b>International Bunkers</b>		✓	
Aviation			
Marine	✓	✓	CH <sub>4</sub> and N <sub>2</sub> O now estimated
<b>Multilateral Operations</b>			
<b>CO<sub>2</sub> Emissions from Biomass</b>		✓	

**Table 10.2. Recalculations by Gas 1990-2010**

**(a) Emissions by Gas 1990–2010 reported in 2012 Submission (Gg CO<sub>2</sub>eq)**

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO <sub>2</sub> (inc net CO <sub>2</sub> from LULUCF)	32,519.35	33,345.88	33,246.00	33,232.66	34,476.78	35,584.59	37,248.99	38,547.10	40,211.55	41,904.67	44,978.57	47,279.23	45,638.51	44,959.58	45,968.10	47,404.85	46,942.86	46,704.21	45,786.73	40,548.31	40,165.36
CO <sub>2</sub> (exc net CO <sub>2</sub> from LULUCF)	32,341.25	33,124.17	32,989.81	33,125.02	34,338.26	35,148.60	36,756.45	38,184.50	40,216.70	41,851.46	44,627.07	47,037.84	45,611.87	45,060.26	45,945.33	47,673.10	47,295.88	47,465.10	46,960.78	41,649.26	41,267.97
CH <sub>4</sub> emissions (inc CH <sub>4</sub> from LULUCF)	13,675.83	13,847.92	13,963.50	13,976.10	13,903.82	13,922.07	14,179.66	14,197.68	14,418.37	13,955.68	13,412.84	13,461.91	13,395.11	13,943.59	13,157.25	12,809.42	12,884.30	12,366.28	12,243.58	11,924.90	11,612.10
CH <sub>4</sub> emissions (exc CH <sub>4</sub> from LULUCF)	13,673.14	13,846.19	13,962.38	13,973.85	13,901.24	13,918.55	14,175.75	14,195.54	14,417.24	13,954.76	13,410.53	13,457.30	13,394.05	13,937.05	13,153.44	12,808.03	12,882.92	12,364.72	12,241.68	11,923.83	11,605.08
N <sub>2</sub> O emissions (inc N <sub>2</sub> O from LULUCF)	9,131.87	8,937.88	8,935.16	9,068.97	9,297.69	9,524.63	9,600.61	9,480.38	9,997.74	9,941.92	9,485.15	8,969.84	8,605.46	8,525.46	8,349.07	8,139.81	8,010.29	7,794.14	7,701.15	7,607.85	7,871.63
N <sub>2</sub> O emissions (exc N <sub>2</sub> O from LULUCF)	9,111.30	8,912.52	8,908.06	9,038.15	9,265.98	9,491.34	9,564.71	9,444.42	9,961.07	9,904.58	9,446.94	8,927.13	8,560.38	8,476.10	8,299.53	8,089.93	7,959.93	7,742.97	7,637.17	7,543.63	7,806.45
HFCs	131	7.06	9.81	14.99	27.53	54.35	91.53	153.05	216.57	223.40	259.18	279.10	308.36	381.18	414.86	474.45	547.10	533.90	564.67	521.07	563.04
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
SF <sub>6</sub>	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
Total including LULUCF	55,363.97	56,187.11	56,215.60	56,378.38	57,816.03	59,243.95	61,326.04	62,641.25	64,999.19	66,288.99	68,495.50	70,353.90	68,227.57	68,154.03	68,140.35	69,098.50	68,595.76	67,594.63	66,459.00	60,705.92	60,283.66
Total excluding LULUCF	55,162.60	55,938.31	55,931.19	56,237.67	57,643.22	58,771.15	60,793.69	62,240.54	64,966.53	66,197.52	68,103.48	70,065.20	68,154.79	68,198.82	68,064.23	69,315.49	68,897.04	68,302.80	67,567.17	61,741.59	61,314.07

**(b) Recalculated Emissions by Gas 1990–2010 reported in 2013 Submission (Gg CO<sub>2</sub>eq)**

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO <sub>2</sub> (inc net CO <sub>2</sub> from LULUCF)	29,724.19	30,444.34	30,657.14	30,433.39	31,962.72	33,367.23	35,092.37	35,748.27	37,915.93	39,711.41	43,382.04	45,657.54	44,222.97	43,591.02	43,454.40	45,144.73	44,632.10	44,151.26	44,235.47	38,649.92	37,136.72
CO <sub>2</sub> (exc net CO <sub>2</sub> 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
CH <sub>4</sub> emissions (inc CH <sub>4</sub> 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
CH <sub>4</sub> emissions (exc CH <sub>4</sub> 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
N <sub>2</sub> O emissions (inc N <sub>2</sub> O from LULUCF)	9,140.40	8,949.49	8,942.51	9,139.15	9,418.77	9,660.59	9,784.97	9,735.96	10,345.23	9,983.00	9,527.34	9,020.46	8,647.39	8,570.40	8,389.69	8,172.84	8,039.12	7,792.78	7,700.93	7,610.75	7,894.39
N <sub>2</sub> O emissions (exc N <sub>2</sub> O from LULUCF)	9,112.03	8,919.97	8,911.96	9,104.37	9,384.25	9,620.61	9,744.61	9,696.08	10,302.81	9,942.53	9,482.03	8,969.38	8,597.74	8,511.06	8,331.49	8,116.04	7,982.68	7,735.93	7,631.68	7,541.40	7,823.01
HFCs	131	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
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
SF <sub>6</sub>	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
Total including LULUCF	52,584.93	53,302.15	53,637.84	53,655.95	55,430.62	57,172.55	59,365.08	60,104.92	63,055.66	64,141.12	66,949.11	68,796.62	66,859.03	66,849.16	65,679.51	66,877.72	66,320.35	65,040.44	64,899.65	58,820.74	57,379.48
Total excluding LULUCF	55,247.07	56,028.64	56,020.48	56,386.86	57,846.82	58,985.74	61,058.81	62,565.07	65,364.15	66,293.12	68,203.02	70,170.49	68,258.96	68,331.28	68,207.53	69,450.64	69,025.50	68,405.86	67,608.02	61,824.86	61,492.56

**(c) Percentage Change in Emissions by Gas 1990-2010**

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO <sub>2</sub> (inc net CO <sub>2</sub> from LULUCF)	-8.60	-8.70	-7.79	-8.42	-7.29	-6.23	-5.79	-7.26	-5.71	-5.23	-3.55	-3.43	-3.10	-3.04	-5.47	-4.77	-4.92	-5.47	-3.39	-4.68	-7.54
CO <sub>2</sub> (exc net CO <sub>2</sub> from LULUCF)	0.26	0.25	0.26	0.25	0.24	0.24	0.23	0.19	0.13	0.13	0.14	0.13	0.14	0.21	0.24	0.22	0.22	0.24	0.12	0.19	0.18
CH <sub>4</sub> emissions (inc CH <sub>4</sub> from LULUCF)	0.06	0.04	0.03	0.05	0.05	0.07	0.08	0.05	0.03	0.03	0.05	0.10	0.03	0.13	0.08	0.04	0.04	-0.01	-0.08	0.07	0.91
CH <sub>4</sub> emissions (exc CH <sub>4</sub> from LULUCF)	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.04	-0.11	0.05	0.79
N <sub>2</sub> O emissions (inc N <sub>2</sub> O from LULUCF)	0.09	0.13	0.08	0.77	130	143	192	2.70	3.48	0.41	0.44	0.56	0.49	0.53	0.49	0.41	0.36	-0.02	0.00	0.04	0.29
N <sub>2</sub> O emissions (exc N <sub>2</sub> O from LULUCF)	0.01	0.08	0.04	0.73	128	136	188	2.66	3.43	0.38	0.37	0.47	0.44	0.41	0.39	0.32	0.29	-0.09	-0.07	-0.03	0.21
HFCs	0.00	0.66	0.96	0.95	0.71	0.47	0.35	0.25	0.21	0.24	0.24	0.27	0.28	0.27	0.28	0.29	0.28	0.33	0.35	0.43	-0.66
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
SF <sub>6</sub>	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
Total including LULUCF	-5.02	-5.13	-4.59	-4.83	-4.13	-3.50	-3.20	-4.05	-2.99	-3.24	-2.26	-2.21	-2.01	-1.91	-3.61	-3.21	-3.32	-3.78	-2.35	-3.11	-4.82
Total excluding LULUCF	0.15	0.16	0.16	0.27	0.35	0.37	0.44	0.52	0.61	0.14	0.15	0.15	0.15	0.19	0.21	0.19	0.19	0.15	0.06	0.13	0.29

**Table 10.3. Recalculations by IPCC Sector 1990-2010**

**(a) Emissions by IPCC Sector 1990 –2010 reported in 2012 Submission (Gg CO<sub>2</sub>eq)**

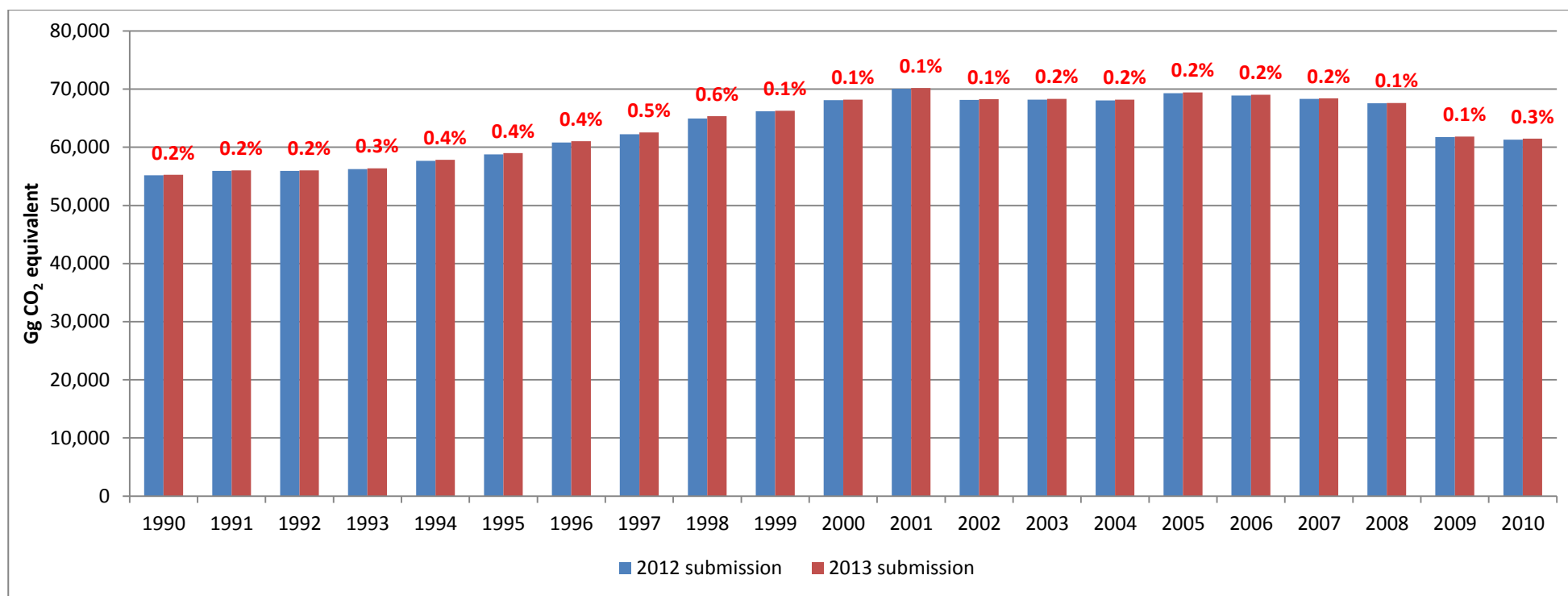
SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Energy	30,966.45	31,825.35	31,718.07	31,884.85	32,832.65	33,711.74	35,251.79	36,319.94	38,479.07	40,120.63	42,415.32	44,532.61	43,317.03	43,857.64	44,002.47	45,702.64	45,329.02	45,479.58	45,251.14	40,717.94	40,510.42
2. Industrial Processes	3,179.27	2,890.58	2,819.91	2,810.41	3,088.51	3,082.73	3,230.46	3,686.58	3,530.66	3,595.44	4,222.47	4,329.90	3,754.95	3,068.02	3,173.00	3,297.22	3,297.06	3,310.43	3,029.12	1,933.62	1,933.62
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	74.31	7180	7159
4. Agriculture	19,635.07	19,758.49	19,863.40	19,965.24	20,098.59	20,315.70	20,741.45	20,859.82	21,514.29	21,019.54	19,970.91	19,595.32	19,378.96	19,510.70	19,314.94	18,857.16	18,723.24	18,295.22	18,162.31	17,926.09	17,909.69
5. LULUCF	20137	248.79	284.41	140.71	172.81	472.80	532.35	400.71	32.66	9147	392.02	288.70	72.78	-44.79	76.12	-216.98	-30128	-708.17	-1108.17	-1035.66	-1030.41
6. Waste	130178	1382.10	1447.56	1494.55	1539.80	1575.59	1484.60	1288.32	1355.88	1378.18	1415.74	1529.45	1628.24	1688.06	1499.90	1384.39	1472.62	141190	1050.28	915.56	888.74
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total exc LULUCF</b>	<b>55,162.60</b>	<b>55,938.31</b>	<b>55,931.19</b>	<b>56,237.67</b>	<b>57,643.22</b>	<b>58,771.15</b>	<b>60,793.69</b>	<b>62,240.54</b>	<b>64,966.53</b>	<b>66,197.52</b>	<b>68,103.48</b>	<b>70,065.20</b>	<b>68,154.79</b>	<b>68,198.82</b>	<b>68,064.23</b>	<b>69,315.49</b>	<b>68,897.04</b>	<b>68,302.80</b>	<b>67,567.17</b>	<b>61,741.59</b>	<b>61,314.07</b>

**(b) Recalculated Emissions by IPCC Sector 1990 –2010 reported in 2013 Submission (Gg CO<sub>2</sub>eq)**

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
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
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	2,112.45	1,929.88
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	7188	7166
4. Agriculture	19,633.98	19,757.29	19,862.18	19,964.05	20,097.27	20,314.30	20,740.00	20,858.36	21,512.82	21,018.09	19,969.47	19,593.85	19,377.54	19,509.26	19,313.37	18,855.69	18,721.84	18,282.37	18,145.04	17,930.55	17,994.84
5. LULUCF	-2,662.14	-2,726.49	-2,382.64	-2,730.91	-2,416.20	-1,813.19	-1,693.72	-2,460.14	-2,308.49	-2,152.00	-1,253.91	-1,373.86	-1,399.93	-1,482.12	-2,528.02	-2,572.92	-2,705.16	-3,365.42	-2,708.38	-3,004.12	-4,113.08
6. Waste	1383.32	1466.04	1525.72	1572.59	1617.51	1657.68	1569.47	1359.04	1411.52	1438.48	1473.30	1598.52	1694.85	1787.87	1612.01	1489.89	1574.34	1219.38	1107.69	974.62	965.69
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total exc LULUCF</b>	<b>55,247.07</b>	<b>56,028.64</b>	<b>56,020.48</b>	<b>56,386.86</b>	<b>57,846.82</b>	<b>58,985.74</b>	<b>61,058.81</b>	<b>62,565.07</b>	<b>65,364.15</b>	<b>66,293.12</b>	<b>68,203.02</b>	<b>70,170.49</b>	<b>68,258.96</b>	<b>68,331.28</b>	<b>68,207.53</b>	<b>69,450.64</b>	<b>69,025.50</b>	<b>68,405.86</b>	<b>67,608.02</b>	<b>61,824.86</b>	<b>61,492.56</b>

**(c) Percentage Change in Emissions by Sector 1990-2010**

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
1. Energy	0.01	0.02	0.04	0.23	0.39	0.40	0.51	0.70	0.89	0.09	0.10	0.08	0.09	0.08	0.07	0.07	0.06	0.08	0.00	0.04	0.05
2. Industrial Processes	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.07	9.25	-0.19
3. Solvent and Other Product Use	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	-0.01	0.11	0.09
4. Agriculture	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.07	-0.10	0.02	0.48
5. LULUCF	-1422.00	-1195.88	-937.76	-2040.76	-1498.21	-483.50	-418.16	-713.95	-7169.23	-2452.69	-419.86	-575.87	-2023.57	3209.35	-3421.11	1085.76	797.89	375.23	144.40	190.07	299.17
6. Waste	6.26	6.07	5.40	5.22	5.05	5.21	5.72	5.49	4.10	4.38	4.07	4.52	4.09	5.91	7.47	7.62	6.91	6.79	5.47	6.45	8.66
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Total exc LULUCF</b>	<b>0.15</b>	<b>0.16</b>	<b>0.16</b>	<b>0.27</b>	<b>0.35</b>	<b>0.37</b>	<b>0.44</b>	<b>0.52</b>	<b>0.61</b>	<b>0.14</b>	<b>0.15</b>	<b>0.15</b>	<b>0.15</b>	<b>0.19</b>	<b>0.21</b>	<b>0.19</b>	<b>0.19</b>	<b>0.15</b>	<b>0.06</b>	<b>0.13</b>	<b>0.29</b>



*Figure 10.1 Impact of Recalculations between annual Submissions 1990-2010*



## **PART II**

### **SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7.1 OF THE KYOTO PROTOCOL**

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## 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 estimates 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 2011 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<sub>2</sub> in 2011 on 286.03 kha of lands subject to afforestation/reforestation since 1990 is estimated at 3,751.32 Gg CO<sub>2</sub> eq while there were net emissions of 29.76 Gg CO<sub>2</sub> eq on a deforested area of 8.49 kha. The overall forest sink for Article 3.3 forest increased from 3,059.43 Gg CO<sub>2</sub>eq in 2008 to 3,751.32 Gg CO<sub>2</sub>eq in 2011, primarily 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 2011 is 13,580.67 CO<sub>2</sub>eq (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. Reported Activities and Pools (CRF Table NIR 1)**

Activity		Change in carbon pool reported <sup>(1)</sup>					Greenhouse gas sources reported <sup>(2)</sup>						
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil	Fertilization <sup>(3)</sup>	Drainage of soils under forest management	Disturbance associated with land-use conversion to croplands	Liming	Biomass burning <sup>(4)</sup>		
							N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	CO <sub>2</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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 2011**

To current inventory year  From previous inventory year		Article 3.3 activities		Article 3.4 activities				Other <sup>(5)</sup>	Total area at the beginning of the current inventory year <sup>(6)</sup>
		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	279.37	0.26						279.63
	Deforestation		8.24						8.24
Article 3.4 activities	Forest Management (if elected)		NA	NA					NA
	Cropland Management <sup>(4)</sup> (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management <sup>(4)</sup> (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation <sup>(4)</sup> (if elected)	NA			NA	NA	NA		NA
Other <sup>(5)</sup>		6.65	0.00	NA	NA	NA	NA	6,817.26	6,823.91
Total area at the end of the current inventory year		286.03	8.50	NA	NA	NA	NA	6,817.26	7,111.79

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 <sup>(3)</sup>
		Associated category in UNFCCC inventory <sup>(1)</sup> is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory <sup>(1),(4)</sup> (including LULUCF)	Other <sup>(2)</sup>	
Specify key categories according to the national level of disaggregation used <sup>(1)</sup>					
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		Net emissions/removals(1)					Accounting Parameters <sup>(7)</sup>	Accounting Quantity <sup>(8)</sup>
		BY(5)	2008	2009	2010	2011		
	(Gg CO <sub>2</sub> equivalent)							
A. Article 3.3 activities								
A.1. Afforestation and Reforestation								-13,691.08
A.1.1. Units of land not harvested since the beginning of the commitment period <sup>(2)</sup>			-3,230.81	-3,429.55	-3,434.86	-3,595.86	-13,691.08	-13,691.08
A.1.2. Units of land harvested since the beginning of the commitment period <sup>(2)</sup>								0.00
Ireland			171.38	89.76	-90.19	-155.45	15.49	0.00
All Harvested AR land (101-114)			IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
A.2. Deforestation			26.45	34.56	19.65	29.76	110.41	110.41
B. Article 3.4 activities								
B.1. Forest Management (if elected)			NA	NA	NA	NA	NA	NA
3.3 offset <sup>(3)</sup>								0.00
FM cap <sup>(4)</sup>								916.67
B.2. Cropland Management (if elected)	0.00		NA	NA	NA	NA	NA	0.00
B.3. Grazing Land Management (if elected)	0.00		NA	NA	NA	NA	NA	0.00
B.4. Revegetation (if elected)	0.00		NA	NA	NA	NA	NA	0.00

### 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 after 1 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 2011 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 2006 onwards.

## 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 from 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 (KPI)**

Forest_Category_Code	Forest_Category_Description
1	Spruce (Pure). Mainly Sitka and Norway spruce
2	Pine (Pure). Predominantly Scots and lodgepole pine
3	Larch (Pure)
4	Other conifers (Pure)
5	Fast growing broadleaves (Pure) such as ash, Alder, Sycamore, Birch
6	Slow growing broadleaves (Pure) such as Oak and Beech
7	Conifer mixes
8	Broadleaf mix
9	Conifer/Broadleaf 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 regenerating 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 7.9 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 from NFI permanent sample plots was obtained from felling licence information in respect of private sector forests and 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 wind farms.

The felling licence applications do not, however, capture illegal deforestation events. It is envisaged that verification of the deforestation activity data will be carried out on completion of the second NFI (end 2012). In addition, a new research project, under the COFORD program has been initiated to develop remote sensing techniques to capture all deforestation events. The issue of not capturing illegal deforestation only applied to years after 2006, since other techniques were used to derive deforestation statistics before 2006 (see sections 7.3.2.4 and 7.3.6 in Chapter 7).

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 1<sup>st</sup> year following conversion of 6 and 5 t C ha<sup>-1</sup>, 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 3,898 ha, 3,903 ha and 3,942 ha in the years 2008, 2009 and 2010 respectively. There were no conversions to grassland in 2011, so emissions from lime application do not occur;
- 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 0.158 Mg/limestone per ha in 2008, 0.186 Mg/ha in 2009 and 0.170 Mg/ha in 2010;
- 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.

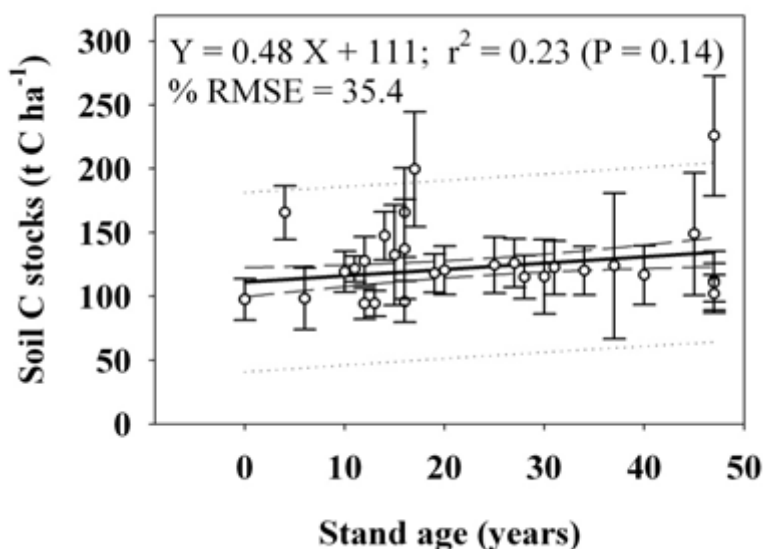
### 11.4.1 Mineral Soils

Changes in mineral soil C pools over time ( $\Delta C_{so}$ ) are not reported because of uncertainty of the magnitude and significance of the sink. These findings are based on two 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 sites 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). Therefore, we opt not to report stock changes for mineral soils because we can demonstrate that the pool is not a source.



**Figure 11.1** Variation in mineral soil carbon stocks and estimation of  $\square C_{so}$  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) 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 7.23 and 7.24 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 stratified sample grid and deforestation statistics (section 7.3.2.4 and Annex H). In addition there are no mineral soils in wetlands;
- Settlement soils were not sampled because of technical difficulties in obtaining sealed soil samples. Deforestation and transition to settlements does occur in Ireland but the soils stocks are assumed not to change following IPCC GPG. No paired settlement plots were identified in the random stratified sample taken;
- Conversion to the other lands category, generally include areas which are not settlements, wetlands or grasslands, such as wind farms and telecommunication masks. No 'other land' soils were sampled because these were not detected in the stratified grid sample;
- 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 examine the contribution of forest and non-forest land uses to uncertainty in the national estimate, 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

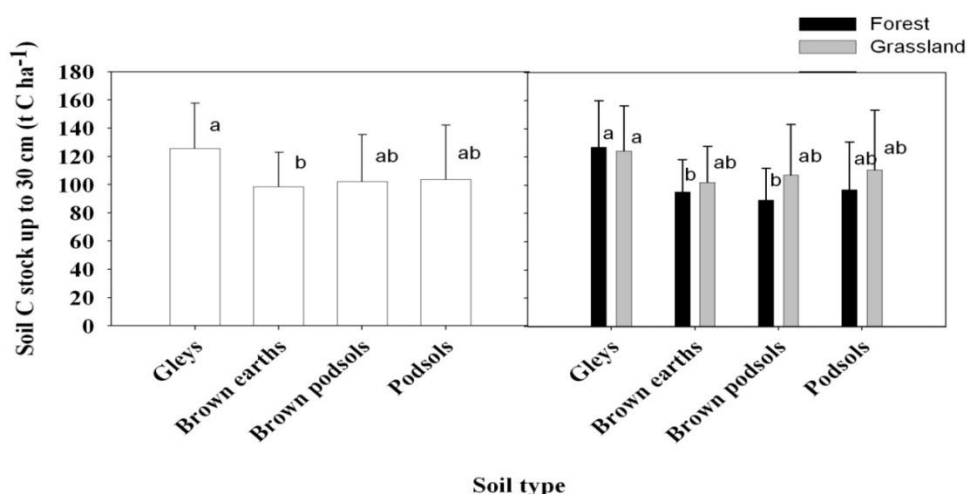
Land uses were first categorized as shown in Table 11.6, and then re-classified either as forest or grassland (Grassland/Forest pair). The forest grassland pair was categorised because there no significant difference soils stock or changes in the different grassland types.

**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). This confirms that there is not difference in the soil C stock when forests, un-managed grasslands, managed grasslands and scrublands are compared.

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. 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 neither a source nor a sink across different mineral soil types. However, research in this area is ongoing and new methods will be developed if new trends emerge.

#### 11.4.1.1 Further justification for omission of mineral soils in Settlement and other Lands

The 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 for land use types occurring under other land category in Ireland (wind farms and telecommunication masts). 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 following deforestation for these categories, the following assumptions have been applied:

- Emissions from organic soil on settlements and other land are now estimated following ERT recommendations. This is a **conservative approach** since GPG states that organic soils should not be relevant. These emissions would account for most wind farm developments since these are located on organic soils;
- For mineral soils, it is acknowledged that conversion to bare soils would result in a net loss of soil C, but this does not occur in Ireland since soils are either:
- Sealed by cement foundations. In this case it can be assumed that there is no emission from soils since soils are not removed and are in effect sealed and the efflux of CO<sub>2</sub> from the soils surface under the foundation would be inhibited. Covered with grass or trees in the case of settlements. These are clearly not likely to be a source based on conclusions drawn from previous ERTs (see above) and evidence for grasslands provided in section 11.4 above.

## 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). 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.

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 7.34 and 7.35 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<sub>2</sub> 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 7.34 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 7.35 in section 7.3.4.7.

**Table 11.8. Uncertainty estimates for individual activity and area data sets**

Code	Parameter	Sub-category <sup>a</sup>	% uncertainty <sup>b</sup>	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 <sup>c</sup>
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 7.35	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
5(KP1)A1.1	17.70	17.26	16.82	16.79
5(KP1)A1.2	45.77	72.54	21.03	10.55
5(KP1)A2	51.21	50.90	50.35	48.29
5(KP2)5	52.20	52.20	52.20	52.20
<b>Total</b>	<b>19.21</b>	<b>18.11</b>	<b>17.08</b>	<b>16.70</b>

Uncertainties were re-evaluated for the 2008, 2009 and 2010 inventory years due to the modification to litter and aboveground biomass algorithms for conifers uncertainty assessments for DBH and H increment models (see Code C Table 11.8).

## 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). All deforestation areas are assumed to be a direct human induced activity since these are derived from legally-binding licence applications under the forestry act.

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 deforestation may be overestimated since forest parcels are usually less than 100 ha, with a mean size of 8 ha (Black et al., 2009a).

In the case where deforestation does occur, but it is not detected using the felling licensing information or there is legal violation of the forestry act, retrospective NFI information can distinguish between clearfell and deforestation. 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 will 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 2013 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 inventories following comments from the 2011 UNFCCC expert review and internal QA/QC checks, these include:

- 1) Emissions from historically deforested forest areas under (D) now include organic soils emissions for other lands and settlements. These transitions represent deforestation for telecommunication masts and wind farms, activities deemed to result in a continued emission of C from organic soils following land use transitions;
- 2) Emissions from burned areas under AR are now based on revised biomass, litter and deadwood inputs, all of which are assumed to be oxidised during wildfire. The recalculation resulted in a ca. 200 per cent increase in emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, in 2010, when the current and previous submission estimates are compared;
- 3) The litter C flow model and leaf biomass equations for conifers were modified as part of the planned improvements to CARBWARE. The litter turnover rate for conifer crops was adjusted from 0.2 to 0.15 (see equation 7.7 in section 7.3.3.1.2(a)) and the parameter *a* in equation 5 (see Table K.1 in Annex K) was corrected in the CARBWARE code from 0.25 to 0.025. This resulted in a decrease C transfer to the litter pool from needle biomass. For example in 2010, the IEF for the Spruce category 1 under AD lands not harvested since the beginning of the commitment period decreased from 1.27 Mg/ha (in the 2012 submission) to 0.55 Mg/ha in this submission. The corresponding net IEF for aboveground biomass increased to 4.73 Mg/ha in this submission, compared to 1.28 Mg/ha in the 2012 submission. These modifications have been subject to validation with national research information (see section 7.3 in Chapter 7);

- 4) The biomass equations for the FGB and SGB species cohorts were modified based on new national research equations (see equations 20 to 30 in Table K.1 of Annex K). This resulted in a change in the IEF across the biomass, litter and deadwood pools. The net IEFs for above, belowground biomass, litter and dead wood pools for the fast growing broadleaf category in 2010 were 1.28, 0.72, 1.27, 0.09 in the 2012 submission, compared to -3.2, 0.01, 1.91 and -0.04.= for this submission;
- 5) The harvests from AR lands since the beginning of the commitment period have been modified based on some repeated NFI plots in 2012 and validation of private and Coillte harvests since 2006 (see Section 7.3, Chapter 7). This has resulted in an increase in the areas harvested (e.g. 9.6 to 11.6 kHa in 2010), the number of different species cohorts and the volumes harvested for the years 2008 to 2010. Most of these increased harvest occurred in 2008 and 2009, where there was a 2 to 83 per cent increase in above ground biomass losses when the previous and current submissions are compared;
- 6) There was a correction to the biomass loss equations (see equations 7.9 and 7.10 in section 7.3.3.1.2) as recommended by the previous annual inventory review report, [ARR IRL 2011](#). However, this had a very small influence on the revised estimates (also see Chapter 7).

## Chapter Twelve

### Information on Accounting of Kyoto Units

#### 12.1 Background Information

Ireland's Standard Electronic Format report for the 2012 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\_2013\_1\_11-1-55 9-4-2013.xls.

The contents of the SEF report (R1) can also be found in Appendix 1 – *SIAR Supplementary Information* of this document.

Ireland has raised an issue with the European Commission (ETS Service Desk) regarding figures in Table 1 and Table 4 of the SEF.

#### 12.2 Summary of Information Reported in the SEF Tables

There was 296,087,557 AAUs in Ireland's domain of the Union Registry at the end of the year 2012, of which 227,556,711 units were in the Party holding account; 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 8,254,737 CERs in the registry at the end of 2012: 5,471,684 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 1,815,061 ERUs in the registry at the end of 2012; 576,178 ERUs were held on the entity holding accounts and 1,238,883 ERUs were held in the retirement account.

There was 503,489 t-CERs in the registry at the end of 2012; 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 306,660,844 tonnes CO<sub>2</sub> eq.

Ireland's assigned amount is 314,184,272 tonnes CO<sub>2</sub>eq.

**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)	<p>Ireland's Standard Electronic Format report for 2012 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.</p> <p>SEF_IE_2013_1_11-1-55 9-4-2013.xls</p> <p>The contents of the SEF report (R1) can also be found in Appendix 1 – <i>SIAR Supplementary Information</i>.</p> <p>Ireland has raised an issue with the European Commission (ETS Service Desk) regarding figures in Table 1 and Table 4 of the SEF.</p>

### 12.3 Discrepancies and notifications

There were no discrepant transactions, no CDM notifications, no non-replacements and no invalid units in 2012 (Table 12.2).

**Table 12.2. Discrepancies and notifications**

Annual Submission Item	Reported for 2012
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	<p>No discrepant transactions, pursuant of 15/CMP.1 annex I.E paragraph 12, occurred in the 2012 reporting period.</p> <p>The contents of the report R2 can also be found in the Appendix 1- <i>SIAR Supplementary Information</i> of this document.</p> <p>Refer to Separate Electronic Attachment "SIAR Reports 2013-IE v 1.0.xls" Worksheet R2.</p> <p>No Report R2 - Discrepant Transaction Report – provided by the European commission as we do not have discrepant transactions.</p>
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	<p>No CDM notifications were received by the National Registry during the 2012 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 &amp; 14.</p> <p>The contents of the Report R3 can also be found in Appendix 1 – <i>SIAR Supplementary Information</i> of this document.</p> <p>Refer to Separate Electronic Attachment "SIAR Reports 2013-IE v 1.0.xls" Worksheet R3.</p>

Annual Submission Item	Reported for 2012
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred during the 2012 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15.  The contents of the Report R4 can be found in Appendix 1 – <i>SIAR Supplementary Information</i> of this document.  Refer to Separate Electronic Attachment “SIAR Reports 2013-IE v 1.0.xls” Worksheet R4.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2012, pursuant of 15/CMP.1 annex I.E paragraph 16.  The contents of the Report R5 can also be found in Appendix 1 – <i>SIAR Supplementary Information</i> of this document.  Refer to Separate Electronic Attachment “SIAR Reports 2013-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 2012
15/CMP.1 annex I.E Publicly accessible information	<p>There was no change regarding publicly accessible information during 2012.</p> <p>The following information is publicly accessible and is available via the homepage of Ireland’s domain on the Union Registry –</p> <p><a href="https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml">https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml</a></p> <p>See also: <a href="#">Public Reports - Emissions Trading Registry :: Environmental Protection Agency, Ireland</a></p> <p>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.</p>
	<b>Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)</b>

	<p>For security reasons and in accordance with Article 75.9 of the Commission Regulation No 920/2010, it is considered that the representative identification information (required by paragraph 45) is held as confidential. For similar security reasons, it is considered that the legal entity contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report.</p> <p>The most up-to-date account information may be accessed from the EUTL public website:</p> <p><a href="http://ec.europa.eu/environment/ets/">http://ec.europa.eu/environment/ets/</a></p>
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**Table 12.3 (Continued) Publicly Accessible Information**

<b>Annual Submission Item</b>	<b>Reported in 2011</b>
	<p><b>JI projects in Ireland (Paragraph 46)</b></p> <p>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.</p>
	<p><b>Holding and transaction information of units (Paragraph 47)</b></p> <p>Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by Commission Regulation.</p> <p>Article 75.1 of the Commission Regulation No 920/2010, as amended, provides that '<i>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 the transaction, held in the EUTL, the Union registry and every 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</i>'.</p> <p>This information may also be accessed from the EUROPA website:</p> <p><a href="http://ec.europa.eu/dgs/clima/mission/index_en.htm">http://ec.europa.eu/dgs/clima/mission/index_en.htm</a></p>

<p>15/CMP.1 annex I.E</p> <p>Publicly accessible information</p>	<p><u>Paragraph 47c</u> Ireland does not host JI projects in line with the National Climate Change Strategy.</p> <p><u>Paragraph 47e</u> Ireland does not perform LULUCF activities and therefore does not issue RMUs</p> <p><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.</p> <p><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.</p> <p><u>Paragraph 47i</u> No ERUs, CERs, AAUs and RMUs have been retired to date</p> <p><u>Paragraph 47k</u> There is no previous commitment period to carry ERUs, CERs, and AAUs over from.</p>
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## 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 2010 submitted on 19 October 2012 is the most recently reviewed inventory for Ireland (FCCC/ARR/2012/IRL, not yet published). The total emissions in 2010 amounted to 60,283,662 tonnes *CO<sub>2</sub> equivalent* and five times this estimate is 301,418,310 tonnes *CO<sub>2</sub> equivalent*. This value is greater than 90 per cent of the assigned amount (282,765,845 tonnes *CO<sub>2</sub> 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<sub>2</sub> 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 activities under Article 3.3 of the Kyoto Protocol on the basis of commitment period accounting. As such, annual accounting for the years 2008, 2009, 2010 and 2011 is not applicable.



## 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.

The two current primary MOU between the inventory agency and the Department of Agriculture, Food and the Marine have been revised and drafted into one new MOU in 2012 to include the provision of key statistics for agriculture, forest areas under the Convention and Kyoto Protocol article 3.3 activities. This new MOU was signed by the Environmental Protection Agency on the 25<sup>th</sup> April 2012 and by the Department of Agriculture, Food and Marine on the 10<sup>th</sup> of May 2012.

The current primary MOU between the inventory agency and the Central Statistics Office (CSO) was revised in 2012 and signed by both organisations on the 13<sup>th</sup> February 2013. This revised MOU sets out a framework for cooperation and assistance in areas of environmental data governance facilitating the free and timely exchange of data between both organisations.

Under the National Atmospheric Inventory System (NAIS), the inventory agency shall review the operation of the system and maintain and update existing MOU as appropriate. The revised MOU described above are in accordance with the continuing review and maintenance of the NAIS.



## 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.

The main change in the registry during 2012 was the transition from the national registry using the GRETA registry software to the Consolidated System of EU Registries (CSEUR).

The changes consequent to this transition are summarised in this chapter and further details, are provided in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR.

Directive 2009/29/EC adopted in 2009, provides for the centralization of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries - in particular Decision 13/CMP.1 and Decision 24/CP.8.

With a view to compliance with the new requirements of Commission Regulation No. 920/2010 and Commission Regulation No. 1193/2011, the registry of EU has undergone a major re-development in addition to implementing the platform shared by the consolidating Parties.

The consolidated platform which implements the national registries in a consolidated manner (including the registry of EU) is called Consolidated System of EU Registries (CSEUR) and was developed together with the new EU registry on the basis the following modalities:

- (1) Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;
- (2) Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;

- (3) Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;
- (4) Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;
- (5) The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;
- (6) The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public would be fulfilled by each Party individually;
- (7) All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:
  - (a) With regards to the data exchange, each national registry connects to the ITL directly and establishes a distinct and secure communication link through a consolidated communication channel (VPN tunnel);
  - (b) The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;
  - (c) With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;
  - (d) The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;
  - (e) In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. During the go-live process, all relevant transaction and holdings data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

The following changes to the national registry of IRELAND have occurred in 2012, as a consequence of the transition to the CSEUR platform:

## 14.2 Contacts

Reporting Item	Reported for 2012
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 2012 reporting period.

## 14.3 Information on Changes in National Registry

Reporting Item	
15/CMP.1 annex II.E paragraph 32.(b) Change of cooperation arrangement	<p>The EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway have decided to operate their registries in a consolidated manner. The Consolidated System of EU Registries (CSEUR) was certified on 1 June 2012 and went to production on 20 June 2012.</p> <p>A 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. This description includes:</p> <ul style="list-style-type: none"> <li>• Readiness Questionnaire</li> <li>• Application Logging</li> <li>• Change Management Procedure</li> <li>• Disaster Recovery</li> <li>• Manual Intervention</li> <li>• Operational Plan</li> <li>• Roles and Responsibilities</li> <li>• Security Plan</li> <li>• Time Validation Plan</li> <li>• Version Change Management</li> </ul> <p>These documents are provided in the accompanying electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR.</p> <p>Please note that these documents are marked as "<i>ETS Limited</i>". These are not public documents and as such, must not be further transmitted or made publicly available.</p> <p>A new central service desk was also set up to support the Registry Administrators of the consolidated system. The new service desk acts as 2nd level of support to the local support provided by the Parties. It also plays a key communication role with the ITL Service Desk with particular regard to connectivity or reconciliation issues.</p>

<p>15/CMP.1 annex II.E paragraph 32.(c) Change to database or the capacity of National Registry</p>	<p>In 2012, the EU registry has undergone a major redevelopment with a view to compliance with the new requirements of Commission Regulation No. 920/2010 and Commission Regulation No. 1193/2011. This redevelopment was in addition to implementing the Consolidated System of EU Registries (CSEUR).</p> <p>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.</p> <p>See the electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR. Please note that these documents are marked as "ETS Limited". These are not public documents and as such, must not be further transmitted or made publicly available.</p> <p>During certification, the consolidated registry was subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES).</p> <p>All tests were executed successfully and resulted in successful certification on 1 June 2012.</p>
<p>15/CMP.1 annex II.E paragraph 32.(d) Change of conformance to technical standards</p>	<p>The overall change to a Consolidated System of EU Registries triggered changes to the registry software and required new conformance testing. 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.</p> <p>See the electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR. Please note that these documents are marked as "ETS Limited". These are not public documents and as such, must not be further transmitted or made publicly available.</p> <p>During certification, the consolidated registry was subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the DES. All tests were executed successfully and resulted in successful certification on 1 June 2012.</p>
<p>15/CMP.1 annex II.E paragraph 32.(e) Change of discrepancies procedures</p>	<p>The overall change to a Consolidated System of EU Registries also triggered changes to discrepancies procedures, as reflected in the updated <b>Manual Intervention Document</b> and the <b>Operational Plan</b>. 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.</p> <p>See the electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR. Please note that these documents</p>

		are marked as "ETS Limited". These are not public documents and as such, must not be further transmitted or made publicly available.
15/CMP.1 annex II.E paragraph 32.(f) Change of Security		<p>The overall change to a Consolidated System of EU Registries also triggered changes to security, as reflected in the updated <b>Security Plan</b>. 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.</p> <p>See the electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR. Please note that these documents are marked as "ETS Limited". These are not public documents and as such, must not be further transmitted or made publicly available.</p> <p>Prior to migration to the CSEUR in June 2012, Ireland engaged external auditors during February/March 2012 to carry out a network and application security test to identify possible security issues and vulnerabilities in the hosted environment for the Irish National Emission Trading Registry.</p> <p>The auditors found that Ireland's National Emission Trading Registry was configured securely. No high risk misconfigurations or security issues were identified. The application performed well in all phases of testing, with consistent security measures applied across the environment.</p>
15/CMP.1 annex II.E paragraph 32.(g) Change of list of publicly available information		<p>There were no changes to publicly available information in 2012.</p> <p>The following information is publicly accessible and is available via the homepage of Ireland's domain on the Union Registry –</p> <p><a href="https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml">https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml</a></p> <p>See also: <a href="#">Public Reports - Emissions Trading Registry :: Environmental Protection Agency, Ireland</a></p> <p>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.</p> <p><b>Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)</b></p>

	<p>For security reasons and in accordance with Article 75.9 of the Commission Regulation No 920/2010, it is considered that the representative identification information (required by paragraph 45) is held as confidential. For similar security reasons, it is considered that the legal entity contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report.</p> <p>The most up-to-date account information may be accessed from the EUTL public website:</p> <p><a href="http://ec.europa.eu/environment/ets/">http://ec.europa.eu/environment/ets/</a></p> <p><b>JI projects in Ireland (Paragraph 46)</b>  Note that no Article 6 (Joint Implementation) project is 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.</p> <p><b>Holding and transaction information of units (Paragraph 47)</b>  Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation.</p> <p>Article 75.1 of the Commission Regulation No 920/2010, as amended, provides that <i>'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 the transaction, held in the EUTL, the Union registry and every 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'</i>.</p> <p>This information may also be accessed from the EUROPA website:</p> <p><a href="http://ec.europa.eu/dgs/clima/mission/index_en.htm">http://ec.europa.eu/dgs/clima/mission/index_en.htm</a></p> <p><u>Paragraph 47c</u>  Ireland does not host JI projects in line with the National Climate Change Strategy.</p> <p><u>Paragraph 47e</u>  Ireland does not perform LULUCF activities and therefore does not issue RMUs</p>
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	<p><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.</p> <p><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.</p> <p><u>Paragraph 47i</u> No ERUs, CERs, AAUs and RMUs have been retired to date</p> <p><u>Paragraph 47k</u> There is no previous commitment period to carry ERUs, CERs, and AAUs over from.</p>
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	<p>Change of Internet Address did occur during the 2012 reporting period:</p> <p>The new internet address of the IRELAND registry is:</p> <p><a href="https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml">https://ets-registry.webgate.ec.europa.eu/euregistry/IE/index.xhtml</a></p>
15/CMP.1 annex II.E paragraph 32.(i) Change of data integrity measure	<p>The overall change to a Consolidated System of EU Registries also triggered changes to data integrity measures, as reflected in the updated <b>Disaster Recovery Plan</b>. 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.</p> <p>See the electronic Appendix 1 <i>SIAR Supplementary Information</i> to the NIR. Please note that these documents are marked as "ETS Limited". These are not public documents and as such, must not be further transmitted or made publicly available.</p>
15/CMP.1 annex II.E paragraph 32.(j) Change of test results	<p>On 2 October 2012 a new software release (Version 4) including functionalities enabling the auctioning of Phase 3 and aviation allowances, a new EU ETS account type (trading account) and a trusted account list went into Production. The trusted account list adds to the set of security measures available in the CSEUR. This measure prevents any transfer from a holding account to an account that is not trusted.</p>
The previous Annual Review Recommendations	<p>No recommendations in <a href="https://www.fccc.europa.eu/arr/2011/IRL">FCCC/ARR/2011/IRL</a> (03/08/2012)</p> <p>The ARR for 2012 is not yet available.</p>



## 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<sub>2</sub> 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<sub>2</sub>. 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

<b>Annex 1 Parties</b>	Countries listed in Annex I to the United Nations Framework Convention on Climate Change
<b>Base year</b>	The year or period under the Kyoto Protocol on which quantified emission limitation or reduction commitments in the commitment period are based.
<b>BOD</b>	Biochemical Oxygen Demand
<b>CARBWARE</b>	A forest model to calculate carbon stock change and growth increment for Irish forests
<b>CFCs</b>	Chlorofluorocarbons
<b>CH<sub>4</sub></b>	Methane
<b>CHP</b>	Combined Heat and Power.
<b>CMMS</b>	Cattle Movement and Monitoring System
<b>CO</b>	Carbon Monoxide
<b>CO<sub>2</sub></b>	Carbon Dioxide
<b>CO<sub>2</sub> equivalent</b>	The equivalent mass as CO <sub>2</sub> of other greenhouse gases converted on the basis of their global warming potential (GWP)
<b>COFORD</b>	National Council for Forest Research and Development
<b>Commitment Period</b>	The years 2008 to 2012 inclusive for which quantified emission limitation or reduction commitments are established under the Kyoto Protocol
<b>COP</b>	Conference of the Parties
<b>CORINAIR</b>	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.
<b>CRF</b>	Common Reporting Format
<b>DAF</b>	Department of Agriculture and Food
<b>DAFM</b>	Department of Agriculture, Food and the Marine
<b>DCENR</b>	Department of Communications, Energy and Natural Resources
<b>DEHLG</b>	Department of Environment Heritage and Local Government
<b>DNDC</b>	DeNitrification-DeComposition, is a computer simulation model of carbon and nitrogen biogeochemistry in agri-ecosystems
<b>EMEP</b>	European Monitoring and Evaluation Programme, a co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe
<b>Emission</b>	(of a greenhouse gas). The release of greenhouse gases into the atmosphere.
<b>Enteric Fermentation</b>	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 <sub>4</sub> as a by product
<b>EUROSTAT</b>	Statistical Agency of the European Union
<b>FAO</b>	Food and Agriculture Organisation of the United Nations
<b>FFS</b>	Farm Facilities Survey
<b>FIPS</b>	Forest Inventory and Planning System
<b>Fluorinated Gases</b>	HFCs, PFCs and SF <sub>6</sub>
<b>Fossil Fuel</b>	Peat, coal, oil and natural gas and associated derivatives
<b>FTA</b>	Fraction of BOD in sludge that degrades anaerobically

<b>GDP</b>	Gross Domestic Product
<b>Gg</b>	Gigagram ( $10^9$ g) = kilo tonne = 1,000 tonnes
<b>Greenhouse Gas</b>	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
<b>GWP</b>	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 <sub>2</sub>
<b>HCFCs</b>	Hydrochlorofluorocarbon
<b>HFCs</b>	Hydrofluorocarbons
<b>HGV</b>	Heavy Goods Vehicle
<b>IEA</b>	International Energy Agency
<b>IEF</b>	Implied Emission Factor
<b>IPC</b>	Integrated Pollution Control
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>IUCC</b>	Information Unit on Climate Change
<b>kt</b>	kilo tonne (1,000 tonnes)
<b>Kyoto Protocol</b>	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
<b>LTO</b>	Landing and Take-off cycle
<b>Montreal Protocol</b>	Protocol on substances that deplete the ozone layer
<b>Mt</b>	million tonnes or mega tonnes
<b>N<sub>2</sub>O</b>	Nitrous Oxide
<b>NBP</b>	Net Biome Productivity
<b>NEE</b>	Net Ecosystem Exchange
<b>NIR</b>	National Inventory Report
<b>NMVOC</b>	Non Methane Volatile Organic Compounds
<b>NO<sub>x</sub></b>	Nitrogen Oxides
<b>NRA</b>	National Roads Authority
<b>OSPAR</b>	Oslo and Paris Convention for the Protection of the Marine Environment
<b>PFCs</b>	Perfluorocarbons
<b>SBSTA</b>	Subsidiary Body for Scientific and Technological Advice
<b>SEAI</b>	Sustainable Energy Authority of Ireland
<b>SF<sub>6</sub></b>	Sulphur Hexafluoride
<b>Sink</b>	The reservoir or pool in which sequestered carbon is stored; the process of sequestration
<b>SO<sub>2</sub></b>	Sulphur Dioxide
<b>Teagasc</b>	Irish Agriculture and Food Development Authority
<b>TPER</b>	Total Primary Energy Requirement
<b>UNECE</b>	United Nations Economic Commission for Europe
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>VOC</b>	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) <sup>a</sup>
Carbon Dioxide	CO <sub>2</sub>	1
Methane	CH <sub>4</sub>	21
Nitrous Oxide	N <sub>2</sub> O	310
Hydrofluorocarbons (HFC)		
HFC-23	CHF <sub>3</sub>	11700
HFC-32	CH <sub>2</sub> F <sub>2</sub>	650
HFC-41	CH <sub>3</sub> F	150
HFC-43-10mee	C <sub>5</sub> H <sub>2</sub> F <sub>10</sub>	1300
HFC-125	C <sub>2</sub> HF <sub>5</sub>	2800
HFC-134	C <sub>2</sub> H <sub>2</sub> F <sub>4</sub> (CHF <sub>2</sub> CHF <sub>2</sub> )	1000
HFC-134a	C <sub>2</sub> H <sub>2</sub> F <sub>4</sub> (CH <sub>2</sub> FCF <sub>3</sub> )	1300
HFC-152a	C <sub>2</sub> H <sub>4</sub> F <sub>2</sub> (CH <sub>3</sub> CHF <sub>2</sub> )	140
HFC-143	C <sub>2</sub> H <sub>3</sub> F <sub>3</sub> (CHF <sub>2</sub> CH <sub>2</sub> F)	300
HFC-143a	C <sub>2</sub> H <sub>3</sub> F <sub>3</sub> (CF <sub>3</sub> CH <sub>3</sub> )	3800
HFC-227ea	C <sub>3</sub> HF <sub>7</sub>	2900
HFC-236fa	C <sub>3</sub> H <sub>2</sub> F <sub>6</sub>	6300
HFC-245ca	C <sub>3</sub> H <sub>3</sub> F <sub>5</sub>	560
Perfluorocarbons(PFC)		
Perfluoromethane	CF <sub>4</sub>	6500
Perfluoroethane	C <sub>2</sub> F <sub>6</sub>	9200
Perfluoropropane	C <sub>3</sub> F <sub>8</sub>	7000
Perfluorobutane	C <sub>4</sub> F <sub>10</sub>	7000
Perfluorocyclobutane	c-C <sub>4</sub> F <sub>8</sub>	8700
Perfluoropentane	C <sub>5</sub> F <sub>12</sub>	7500
Perfluorohexane	C <sub>6</sub> F <sub>14</sub>	7400
Sulphur Hexafluoride	SF <sub>6</sub>	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)**

<b>IPCC SOURCE and SINK CATEGORIES</b>	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>HFC</b>	<b>PFC</b>	<b>SF<sub>6</sub></b>
<b>1. Energy</b>						
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						
<b>2. Industrial Processes</b>						
A. Mineral Products						
B. Chemical Industry						
C. Metal Production						
D. Other Production						
E. Production of Halocarbons and SF <sub>6</sub>						
F. Consumption of Halocarbons and SF <sub>6</sub>						
G. Other						
<b>3. Solvent and Other Product Use</b>						
A. Paint Application						
B. Degreasing and Dry Cleaning						
C. Chemical Products Manufacture & Processing						
D. Other						
<b>4. Agriculture</b>						
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						
<b>5. Land-Use Change and Forestry</b>						
A. Forestry						
B. Cropland						
C. Grassland						
D. Wetland						
E. Settlements						
F. Other Land						
G. Other						
<b>6. Waste</b>						
A. Solid Waste Disposal on Land						
B. Wastewater Handling						
C. Waste Incineration						
D. Other						
<b>7. Other</b>						
<b>Memo Items:</b>						
<b>International Bunkers</b>						
<b>Multilateral Operations</b>						
<b>CO<sub>2</sub> Emissions from Biomass</b>						

The grey cells indicate sources/sinks where no emissions/removals of the various gases are expected



## Annex B

### Key Category Analyses

B.1 2011 Key Category Analysis Level Assessment excluding LULUCF

B.2 2011 Key Category Analysis Level Assessment including LULUCF

B.3 2011 Key Category Analysis Trend Assessment excluding LULUCF

B.4 2011 Key Category Analysis Trend Assessment including LULUCF

**Table B.1 2011 Key Category Analysis Level Assessment excluding LULUCF**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2011 Level assessment %	Cumulative Total %
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10696.23	18.60	18.60
2	1.A.1	Energy Industries - Solid Fuels	CO2	5950.18	10.35	28.94
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	5403.02	9.39	38.34
4	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5221.02	9.08	47.42
5	1.A.4.b	Residential - Liquid Fuels	CO2	3106.47	5.40	52.82
6	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2762.22	4.80	57.62
7	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2611.47	4.54	62.16
8	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2572.06	4.47	66.63
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2042.55	3.55	70.19
10	1.A.4.b	Residential - Solid Fuels	CO2	1966.41	3.42	73.60
11	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1725.04	3.00	76.60
12	1.A.4.b	Residential - Gaseous Fuels	CO2	1359.20	2.36	78.97
13	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1308.50	2.28	81.24
14	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1183.33	2.06	83.30
15	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1106.56	1.92	85.22
16	2.A.1	Cement Production	CO2	966.27	1.68	86.90
17	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	906.22	1.58	88.48
18	6.A	Waste - Solid Waste Disposal on land	CH4	830.85	1.44	89.92
19	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	713.79	1.24	91.17
20	4.A.3	Enteric Fermentation - Sheep	CH4	571.08	0.99	92.16
21	2.F	Consumption of Halocarbons & SF6	HFC	538.61	0.94	93.09
22	4.B.1	Manure Management - Dairy Cattle	CH4	474.76	0.83	93.92
23	1.A.1	Energy Industries - Liquid Fuels	CO2	428.70	0.75	94.67
24	4.B.8	Manure Management - Pigs	CH4	414.29	0.72	95.39
25	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	377.76	0.66	96.04
26	4.B.13	Manure Management - Solid Storage	N2O	374.69	0.65	96.69
27	2.A.2	Lime Production	CO2	199.06	0.35	97.04
28	1.A.3.d	Navigation - Liquid Fuels	CO2	171.78	0.30	97.34
29	1.A.3.e	Other Transport - Gaseous Fuels	CO2	153.31	0.27	97.61
30	6.B	Waste - Waste Water Handling	N2O	141.35	0.25	97.85
31	1.A.4.b	Residential - Solid Fuels	CH4	124.88	0.22	98.07
32	1.A.3.c	Rail Transport - Liquid Fuels	CO2	121.91	0.21	98.28
33	4.B.9	Manure Management - Poultry	CH4	119.41	0.21	98.49
34	1.A.3.b	Road Transport - Liquid Fuels	N2O	91.96	0.16	98.65
35	1.A.1	Energy Industries - Gaseous Fuels	N2O	84.08	0.15	98.79
36	3	Solvent and Other Product Use	CO2	72.49	0.13	98.92
37	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	71.60	0.12	99.04

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2011 Level assessment %	Cumulative Total %
38	4.B.12	Manure Management - Liquid Systems	N2O	62.84	0.11	99.15
39	6.C	Waste - Waste Incineration	CO2	53.49	0.09	99.25
40	1.A.1	Energy Industries - Solid Fuels	N2O	49.53	0.09	99.33
41	2.F	Consumption of Halocarbons & SF6	SF6	48.29	0.08	99.42
42	4.A.6	Enteric Fermentation - Horses	CH4	37.08	0.06	99.48
43	4.A.8	Enteric Fermentation - Pigs	CH4	34.77	0.06	99.54
44	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	29.88	0.05	99.59
45	1.B.2.b	Fugitive emissions - Natural gas	CH4	27.50	0.05	99.64
46	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	19.06	0.03	99.68
47	1.A.3.b	Road Transport - Liquid Fuels	CH4	17.12	0.03	99.70
48	1.A.1	Energy Industries - Other Fuels	CO2	16.39	0.03	99.73
49	6.B	Waste - Waste Water Handling	CH4	16.32	0.03	99.76
50	1.A.3.c	Rail Transport - Liquid Fuels	N2O	14.90	0.03	99.79
51	4.B.3	Manure Management - Sheep	CH4	14.45	0.03	99.81
52	2.F	Consumption of Halocarbons & SF6	PFC	13.20	0.02	99.84
53	1.A.4.b	Residential - Liquid Fuels	CH4	8.95	0.02	99.85
54	1.A.4.b	Residential - Solid Fuels	N2O	8.90	0.02	99.87
55	1.A.4.b	Residential - Liquid Fuels	N2O	7.84	0.01	99.88
56	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	7.51	0.01	99.89
57	1.A.4.b	Residential - Biomass	CH4	5.95	0.01	99.90
58	1.A.4.a	Commercial/Institutional - Biomass	CH4	4.62	0.01	99.91
59	1.A.1	Energy Industries - Biomass	N2O	4.41	0.01	99.92
60	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	3.81	0.01	99.93
61	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	3.70	0.01	99.93
62	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	3.36	0.01	99.94
63	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	2.96	0.01	99.94
64	4.B.6	Manure Management - Horses	CH4	2.88	0.01	99.95
65	1.A.4.b	Residential - Gaseous Fuels	CH4	2.50	0.00	99.95
66	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.36	0.00	99.96
67	1.A.1	Energy Industries - Solid Fuels	CH4	1.93	0.00	99.96
68	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	1.86	0.00	99.96
69	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.85	0.00	99.97
70	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	1.67	0.00	99.97
71	1.A.3.e	Other Transport - Gaseous Fuels	N2O	1.67	0.00	99.97
72	1.A.3.d	Navigation - Liquid Fuels	N2O	1.45	0.00	99.98
73	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.30	0.00	99.98
74	1.A.4.b	Residential - Biomass	N2O	1.17	0.00	99.98
75	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	1.11	0.00	99.98

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Values (Gg CO2 eq)	2011 Level assessment %	Cumulative Total %
76	4.A.4	Enteric Fermentation - Goats	CH4	1.06	0.00	99.98
77	2.A.3	Limestone Use	CO2	1.04	0.00	99.98
78	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	1.01	0.00	99.99
79	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.86	0.00	99.99
80	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	0.84	0.00	99.99
81	2.A.7	Bricks & Ceramics	CO2	0.83	0.00	99.99
82	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.75	0.00	99.99
83	1.A.4.b	Residential - Gaseous Fuels	N2O	0.74	0.00	99.99
84	6.C	Waste - Waste Incineration	N2O	0.57	0.00	99.99
85	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.49	0.00	100.00
86	1.A.1	Energy Industries - Biomass	CH4	0.43	0.00	100.00
87	1.A.3.d	Navigation - Liquid Fuels	CH4	0.34	0.00	100.00
88	1.A.1	Energy Industries - Liquid Fuels	N2O	0.33	0.00	100.00
89	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.29	0.00	100.00
90	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.28	0.00	100.00
91	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.26	0.00	100.00
92	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.15	0.00	100.00
93	4.B.7	Manure Management - Mules and Asses	CH4	0.14	0.00	100.00
94	1.A.1	Energy Industries - Liquid Fuels	CH4	0.12	0.00	100.00
95	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.11	0.00	100.00
96	2.A.4	Soda Ash Production and Use	CO2	0.07	0.00	100.00
97	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.04	0.00	100.00
98	4.B.4	Manure Management - Goats	CH4	0.03	0.00	100.00
99	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.01	0.00	100.00
100	6.C	Waste - Waste Incineration	CH4	0.00	0.00	100.00
101	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	0.00	0.00	100.00
102	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.00	0.00	100.00
103	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.00	0.00	100.00
104	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	100.00
105	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	100.00
106	2.A.7	Glass Production	CO2	0.00	0.00	100.00
107	2.B	Chemical Industry	N2O	0.00	0.00	100.00
108	2.B	Chemical Industry	CO2	0.00	0.00	100.00

**Table B.2 2011 Key Category Analysis Level Assessment including LULUCF**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2011 Level assessment %	Cumulative Total %
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	10696.23	16.91	16.91
2	1.A.1	Energy Industries - Solid Fuels	CO2	5950.18	9.41	26.32
3	1.A.1	Energy Industries - Gaseous Fuels	CO2	5403.02	8.54	34.87
4	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5221.02	8.26	43.12
5	5.A.2	LULUCF - Land converted to Forest Land	CO2	3821.95	6.04	49.17
6	1.A.4.b	Residential - Liquid Fuels	CO2	3106.47	4.91	54.08
7	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	2762.22	4.37	58.45
8	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2611.47	4.13	62.57
9	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2572.06	4.07	66.64
10	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	2042.55	3.23	69.87
11	1.A.4.b	Residential - Solid Fuels	CO2	1966.41	3.11	72.98
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	1725.04	2.73	75.71
13	1.A.4.b	Residential - Gaseous Fuels	CO2	1359.20	2.15	77.86
14	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1308.50	2.07	79.93
15	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1183.33	1.87	81.80
16	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1106.56	1.75	83.55
17	2.A.1	Cement Production	CO2	966.27	1.53	85.08
18	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	906.22	1.43	86.51
19	6.A	Waste - Solid Waste Disposal on land	CH4	830.85	1.31	87.82
20	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	713.79	1.13	88.95
21	4.A.3	Enteric Fermentation - Sheep	CH4	571.08	0.90	89.85
22	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	542.95	0.86	90.71
23	2.F	Consumption of Halocarbons & SF6	HFC	538.61	0.85	91.57
24	4.B.1	Manure Management - Dairy Cattle	CH4	474.76	0.75	92.32
25	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	430.99	0.68	93.00
26	1.A.1	Energy Industries - Liquid Fuels	CO2	428.70	0.68	93.68
27	4.B.8	Manure Management - Pigs	CH4	414.29	0.66	94.33
28	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	377.76	0.60	94.93
29	4.B.13	Manure Management - Solid Storage	N2O	374.69	0.59	95.52
30	5.B.2	LULUCF - Land converted to Cropland	CO2	329.34	0.52	96.04
31	5.C.2	LULUCF - Land converted to Grassland	CO2	322.79	0.51	96.55
32	2.A.2	Lime Production	CO2	199.06	0.31	96.87
33	1.A.3.d	Navigation - Liquid Fuels	CO2	171.78	0.27	97.14
34	1.A.3.e	Other Transport - Gaseous Fuels	CO2	153.31	0.24	97.38
35	6.B	Waste - Waste Water Handling	N2O	141.35	0.22	97.60

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	Absolute Values (Gg CO2 eq)	2011 Level assessment %	Cumulative Total %
36	5.F.2	LULUCF - Land Converted to Other Land	CO2	138.19	0.22	97.82
37	1.A.4.b	Residential - Solid Fuels	CH4	124.88	0.20	98.02
38	1.A.3.c	Rail Transport - Liquid Fuels	CO2	121.91	0.19	98.21
39	4.B.9	Manure Management - Poultry	CH4	119.41	0.19	98.40
40	1.A.3.b	Road Transport - Liquid Fuels	N2O	91.96	0.15	98.55
41	1.A.1	Energy Industries - Gaseous Fuels	N2O	84.08	0.13	98.68
42	3	Solvent and Other Product Use	CO2	72.49	0.11	98.79
43	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	71.60	0.11	98.91
44	4.B.12	Manure Management - Liquid Systems	N2O	62.84	0.10	99.01
45	6.C	Waste - Waste Incineration	CO2	53.49	0.08	99.09
46	1.A.1	Energy Industries - Solid Fuels	N2O	49.53	0.08	99.17
47	2.F	Consumption of Halocarbons & SF6	SF6	48.29	0.08	99.25
48	5.A.1	LULUCF - Forest land Remaining Forest Land	N2O	38.63	0.06	99.31
49	4.A.6	Enteric Fermentation - Horses	CH4	37.08	0.06	99.37
50	4.A.8	Enteric Fermentation - Pigs	CH4	34.77	0.05	99.42
51	5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	33.94	0.05	99.47
52	5.B.2	LULUCF - Land converted to Cropland	N2O	31.37	0.05	99.52
53	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	29.88	0.05	99.57
54	1.B.2.b	Fugitive emissions - Natural gas	CH4	27.50	0.04	99.61
55	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	19.06	0.03	99.65
56	1.A.3.b	Road Transport - Liquid Fuels	CH4	17.12	0.03	99.67
57	5.B.1	LULUCF - Cropland remaining Cropland	CO2	16.95	0.03	99.70
58	1.A.1	Energy Industries - Other Fuels	CO2	16.39	0.03	99.72
59	6.B	Waste - Waste Water Handling	CH4	16.32	0.03	99.75
60	1.A.3.c	Rail Transport - Liquid Fuels	N2O	14.90	0.02	99.77
61	4.B.3	Manure Management - Sheep	CH4	14.45	0.02	99.80
62	2.F	Consumption of Halocarbons & SF6	PFC	13.20	0.02	99.82
63	5.E.2	LULUCF - Land converted to Settlements	CO2	9.56	0.02	99.83
64	1.A.4.b	Residential - Liquid Fuels	CH4	8.95	0.01	99.85
65	1.A.4.b	Residential - Solid Fuels	N2O	8.90	0.01	99.86
66	1.A.4.b	Residential - Liquid Fuels	N2O	7.84	0.01	99.87
67	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	7.51	0.01	99.89
68	1.A.4.b	Residential - Biomass	CH4	5.95	0.01	99.89
69	5.A.1	LULUCF - Forest land Remaining Forest Land	CH4	5.65	0.01	99.90
70	1.A.4.a	Commercial/Institutional - Biomass	CH4	4.62	0.01	99.91
71	1.A.1	Energy Industries - Biomass	N2O	4.41	0.01	99.92

72	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	3.81	0.01	99.92
73	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	3.70	0.01	99.93
74	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	3.36	0.01	99.94
75	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	2.96	0.00	99.94
76	4.B.6	Manure Management - Horses	CH4	2.88	0.00	99.94
77	5.D.2	LULUCF - Land Converted to Wetlands	N2O	2.57	0.00	99.95
78	1.A.4.b	Residential - Gaseous Fuels	CH4	2.50	0.00	99.95
79	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.36	0.00	99.96
80	5.A.2	LULUCF - Land converted to Forest Land	CH4	1.93	0.00	99.96
81	1.A.1	Energy Industries - Solid Fuels	CH4	1.93	0.00	99.96
82	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	1.86	0.00	99.97
83	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.85	0.00	99.97
84	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	1.67	0.00	99.97
85	1.A.3.e	Other Transport - Gaseous Fuels	N2O	1.67	0.00	99.97
86	1.A.3.d	Navigation - Liquid Fuels	N2O	1.45	0.00	99.98
87	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.30	0.00	99.98
88	1.A.4.b	Residential - Biomass	N2O	1.17	0.00	99.98
89	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	1.11	0.00	99.98
90	4.A.4	Enteric Fermentation - Goats	CH4	1.06	0.00	99.98
91	2.A.3	Limestone Use	CO2	1.04	0.00	99.98
92	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	1.01	0.00	99.99
93	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.86	0.00	99.99
94	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	0.84	0.00	99.99
95	2.A.7	Bricks & Ceramics	CO2	0.83	0.00	99.99
96	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.75	0.00	99.99
97	5.D.2	LULUCF - Land Converted to Wetlands	CO2	0.75	0.00	99.99
98	1.A.4.b	Residential - Gaseous Fuels	N2O	0.74	0.00	99.99
99	6.C	Waste - Waste Incineration	N2O	0.57	0.00	99.99
100	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.49	0.00	100.00
101	1.A.1	Energy Industries - Biomass	CH4	0.43	0.00	100.00
102	1.A.3.d	Navigation - Liquid Fuels	CH4	0.34	0.00	100.00
103	1.A.1	Energy Industries - Liquid Fuels	N2O	0.33	0.00	100.00
104	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.29	0.00	100.00
105	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.28	0.00	100.00
106	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.26	0.00	100.00
107	5.A.2	LULUCF - Land converted to Forest Land	N2O	0.17	0.00	100.00

108	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.15	0.00	100.00
109	4.B.7	Manure Management - Mules and Asses	CH4	0.14	0.00	100.00
110	1.A.1	Energy Industries - Liquid Fuels	CH4	0.12	0.00	100.00
111	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.11	0.00	100.00
112	2.A.4	Soda Ash Production and Use	CO2	0.07	0.00	100.00
113	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.04	0.00	100.00
114	4.B.4	Manure Management - Goats	CH4	0.03	0.00	100.00
115	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.01	0.00	100.00
116	6.C	Waste - Waste Incineration	CH4	0.00	0.00	100.00
117	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	0.00	0.00	100.00
118	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.00	0.00	100.00
119	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.00	0.00	100.00
120	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	100.00
121	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	100.00
122	2.A.7	Glass Production	CO2	0.00	0.00	100.00
123	2.B	Chemical Industry	N2O	0.00	0.00	100.00
124	2.B	Chemical Industry	CO2	0.00	0.00	100.00

**Table B.3 2011 Key Category Analysis Trend Assessment excluding LULUCF**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO <sub>2</sub> eq)	2011 Emissions (Gg CO <sub>2</sub> eq)	2011 Level assessment (%)	2011 Trend assessment (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO <sub>2</sub>	4690.42	10696.23	18.60	20.73	20.73
2	1.A.4.b	Residential - Solid Fuels	CO <sub>2</sub>	5606.94	1966.41	3.42	13.80	34.53
3	1.A.1	Energy Industries - Gaseous Fuels	CO <sub>2</sub>	1880.66	5403.02	9.39	12.28	46.81
4	1.A.1	Energy Industries - Solid Fuels	CO <sub>2</sub>	8009.44	5950.18	10.35	8.51	55.33
5	1.A.4.b	Residential - Liquid Fuels	CO <sub>2</sub>	1175.35	3106.47	5.40	6.71	62.04
6	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO <sub>2</sub>	873.02	2042.55	3.55	4.04	66.08
7	1.A.4.b	Residential - Gaseous Fuels	CO <sub>2</sub>	269.73	1359.20	2.36	3.85	69.93
8	1.A.1	Energy Industries - Liquid Fuels	CO <sub>2</sub>	1268.51	428.70	0.75	3.18	73.11
9	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO <sub>2</sub>	1957.00	1183.33	2.06	3.04	76.15
10	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO <sub>2</sub>	223.49	906.22	1.58	2.40	78.55
11	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH <sub>4</sub>	5630.17	5221.02	9.08	2.28	80.84
12	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO <sub>2</sub>	2198.38	1725.04	3.00	2.01	82.85
13	2.F	Consumption of Halocarbons & SF <sub>6</sub>	HFC	1.31	538.61	0.94	1.92	84.76
14	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO <sub>2</sub>	871.24	377.76	0.66	1.89	86.65
15	4.A.3	Enteric Fermentation - Sheep	CH <sub>4</sub>	1032.48	571.08	0.99	1.80	88.44
16	4.A.1	Enteric Fermentation - Dairy Cattle	CH <sub>4</sub>	2854.99	2572.06	4.47	1.43	89.87
17	6.A	Waste - Solid Waste Disposal on land	CH <sub>4</sub>	1173.05	830.85	1.44	1.39	91.26
18	4.D.1	Agricultural Soils - Direct Soil Emissions	N <sub>2</sub> O	3021.86	2762.22	4.80	1.37	92.63
19	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N <sub>2</sub> O	2868.35	2611.47	4.54	1.34	93.97
20	1.A.4.b	Residential - Solid Fuels	CH <sub>4</sub>	356.29	124.88	0.22	0.88	94.84
21	4.B.1	Manure Management - Non-Dairy Cattle	CH <sub>4</sub>	1279.75	1106.56	1.92	0.80	95.65
22	4.B.1	Manure Management - Dairy Cattle	CH <sub>4</sub>	608.23	474.76	0.83	0.56	96.21
23	4.D.3	Agricultural Soils - Indirect Emissions	N <sub>2</sub> O	1380.91	1308.50	2.28	0.46	96.67
24	1.B.2.b	Fugitive emissions - Natural gas	CH <sub>4</sub>	131.08	27.50	0.05	0.39	97.06
25	1.A.3.e	Other Transport - Gaseous Fuels	CO <sub>2</sub>	62.04	153.31	0.27	0.32	97.38
26	1.A.3.d	Navigation - Liquid Fuels	CO <sub>2</sub>	84.90	171.78	0.30	0.30	97.67
27	1.A.1	Energy Industries - Gaseous Fuels	N <sub>2</sub> O	10.62	84.08	0.15	0.26	97.93
28	4.B.8	Manure Management - Pigs	CH <sub>4</sub>	332.33	414.29	0.72	0.24	98.18
29	2.A.1	Cement Production	CO <sub>2</sub>	884.00	966.27	1.68	0.16	98.34
30	1.A.3.b	Road Transport - Liquid Fuels	N <sub>2</sub> O	44.38	91.96	0.16	0.16	98.51
31	1.A.3.a	Civil Aviation - Liquid Fuels	CO <sub>2</sub>	51.13	19.06	0.03	0.12	98.63
32	6.C	Waste - Waste Incineration	CO <sub>2</sub>	82.97	53.49	0.09	0.12	98.74
33	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO <sub>2</sub>	0.00	29.88	0.05	0.11	98.85
34	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO <sub>2</sub>	660.30	713.79	1.24	0.09	98.95
35	6.B	Waste - Waste Water Handling	N <sub>2</sub> O	111.71	141.35	0.25	0.09	99.03
36	2.A.2	Lime Production	CO <sub>2</sub>	214.08	199.06	0.35	0.08	99.12
37	1.A.3.b	Road Transport - Liquid Fuels	CH <sub>4</sub>	36.82	17.12	0.03	0.08	99.20

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2011 Emissions (Gg CO2eq)	2011 Level assessment (%)	2011 Trend assessment (%)	Cumulative Total (%)
38	1.A.4.b	Residential - Solid Fuels	N2O	25.36	8.90	0.02	0.06	99.26
39	1.A.3.c	Rail Transport - Liquid Fuels	CO2	133.19	121.91	0.21	0.06	99.32
40	1.A.1	Energy Industries - Other Fuels	CO2	0.00	16.39	0.03	0.06	99.38
41	1.A.1	Energy Industries - Solid Fuels	N2O	62.22	49.53	0.09	0.05	99.43
42	2.F	Consumption of Halocarbons & SF6	PFC	0.09	13.20	0.02	0.05	99.48
43	4.A.6	Enteric Fermentation - Horses	CH4	23.28	37.08	0.06	0.05	99.52
44	4.B.3	Manure Management - Sheep	CH4	26.13	14.45	0.03	0.05	99.57
45	4.B.13	Manure Management - Solid Storage	N2O	371.24	374.69	0.65	0.04	99.61
46	2.F	Consumption of Halocarbons & SF6	SF6	35.51	48.29	0.08	0.04	99.65
47	3	Solvent and Other Product Use	CO2	80.03	72.49	0.13	0.04	99.69
48	4.B.9	Manure Management - Poultry	CH4	105.20	119.41	0.21	0.04	99.72
49	1.A.4.b	Residential - Biomass	CH4	11.83	5.95	0.01	0.02	99.75
50	1.A.4.b	Residential - Liquid Fuels	CH4	3.12	8.95	0.02	0.02	99.77
51	1.A.4.b	Residential - Liquid Fuels	N2O	2.58	7.84	0.01	0.02	99.79
52	1.A.4.a	Commercial/Institutional - Biomass	CH4	0.00	4.62	0.01	0.02	99.80
53	2.A.7	Bricks & Ceramics	CO2	5.07	0.83	0.00	0.02	99.82
54	1.A.1	Energy Industries - Biomass	N2O	0.00	4.41	0.01	0.02	99.83
55	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	3.16	7.51	0.01	0.02	99.85
56	4.A.8	Enteric Fermentation - Pigs	CH4	29.61	34.77	0.06	0.01	99.86
57	4.B.12	Manure Management - Liquid Systems	N2O	63.87	62.84	0.11	0.01	99.88
58	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	71.60	0.12	0.01	99.89
59	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	4.28	1.86	0.00	0.01	99.90
60	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	5.53	3.36	0.01	0.01	99.91
61	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	1.61	3.81	0.01	0.01	99.91
62	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	4.87	2.96	0.01	0.01	99.92
63	1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.50	0.00	0.01	99.93
64	1.A.3.c	Rail Transport - Liquid Fuels	N2O	16.11	14.90	0.03	0.01	99.93
65	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	5.02	3.70	0.01	0.01	99.94
66	1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	0.00	0.00	99.94
67	1.A.4.b	Residential - Biomass	N2O	2.32	1.17	0.00	0.00	99.95
68	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	0.43	1.67	0.00	0.00	99.95
69	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	1.93	0.84	0.00	0.00	99.96
70	4.B.6	Manure Management - Horses	CH4	1.81	2.88	0.01	0.00	99.96
71	6.B	Waste - Waste Water Handling	CH4	14.73	16.32	0.03	0.00	99.96
72	1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.67	0.00	0.00	99.97
73	2.A.3	Limestone Use	CO2	0.15	1.04	0.00	0.00	99.97
74	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.00	0.86	0.00	0.00	99.97
75	4.A.4	Enteric Fermentation - Goats	CH4	1.83	1.06	0.00	0.00	99.98

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2011 Emissions (Gg CO2eq)	2011 Level assessment (%)	2011 Trend assessment (%)	Cumulative Total (%)
76	1.A.3.d	Navigation - Liquid Fuels	N2O	0.70	1.45	0.00	0.00	99.98
77	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	2.36	0.00	0.00	99.98
78	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	0.49	1.11	0.00	0.00	99.98
79	1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.74	0.00	0.00	99.99
80	1.A.1	Energy Industries - Solid Fuels	CH4	2.36	1.93	0.00	0.00	99.99
81	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.73	1.30	0.00	0.00	99.99
82	1.A.1	Energy Industries - Biomass	CH4	0.00	0.43	0.00	0.00	99.99
83	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.33	0.75	0.00	0.00	99.99
84	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.13	0.49	0.00	0.00	99.99
85	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.58	0.26	0.00	0.00	100.00
86	6.C	Waste - Waste Incineration	N2O	0.86	0.57	0.00	0.00	100.00
87	1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.12	0.00	0.00	100.00
88	1.A.3.d	Navigation - Liquid Fuels	CH4	0.17	0.34	0.00	0.00	100.00
89	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.28	0.00	0.00	100.00
90	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.00	0.11	0.00	0.00	100.00
91	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.18	0.29	0.00	0.00	100.00
92	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	1.01	0.00	0.00	100.00
93	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.00	0.04	0.00	0.00	100.00
94	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.74	1.85	0.00	0.00	100.00
95	2.A.4	Soda Ash Production and Use	CO2	0.10	0.07	0.00	0.00	100.00
96	4.B.4	Manure Management - Goats	CH4	0.04	0.03	0.00	0.00	100.00
97	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.16	0.15	0.00	0.00	100.00
98	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.02	0.01	0.00	0.00	100.00
99	6.C	Waste - Waste Incineration	CH4	0.01	0.00	0.00	0.00	100.00
100	4.B.7	Manure Management - Mules and Asses	CH4	0.13	0.14	0.00	0.00	100.00
101	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	138.29	0.00	0.00	0.00	100.00
102	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.29	0.00	0.00	0.00	100.00
103	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.59	0.00	0.00	0.00	100.00
104	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	0.00	0.00	100.00
105	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	0.00	0.00	100.00
106	2.A.7	Glass Production	CO2	13.33	0.00	0.00	0.00	100.00
107	2.B	Chemical Industry	N2O	1035.40	0.00	0.00	0.00	100.00
108	2.B	Chemical Industry	CO2	990.23	0.00	0.00	0.00	100.00

**Table B.4 2011 Key Category Analysis Trend Assessment including LULUCF**

Ranking	IPCC Sub-category	Emission Source / Activity	Direct GHG	1990 Emissions (Gg CO2eq)	2011 Emissions (Gg CO2eq)	2011 Level assessment (%)	2011 Trend assessment (%)	Cumulative Total (%)
1	1.A.3.b	Road Transport - Liquid Fuels	CO2	4690.42	10696.23	16.91	14.67	14.67
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	1966.41	3.11	10.34	25.01
3	5.A.2	LULUCF - Land converted to Forest Land	CO2	17.90	3821.95	6.04	9.80	34.81
4	1.A.1	Energy Industries - Gaseous Fuels	CO2	1880.66	5403.02	8.54	8.75	43.57
5	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2	3287.59	430.99	0.68	7.92	51.49
6	1.A.1	Energy Industries - Solid Fuels	CO2	8009.44	5950.18	9.41	6.68	58.17
7	1.A.4.b	Residential - Liquid Fuels	CO2	1175.35	3106.47	4.91	4.77	62.95
8	5.E.2	LULUCF - Land converted to Settlements	CO2	1173.05	9.56	0.02	3.20	66.15
9	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.02	2042.55	3.23	2.86	69.01
10	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1359.20	2.15	2.76	71.77
11	1.A.1	Energy Industries - Liquid Fuels	CO2	1268.51	428.70	0.68	2.38	74.15
12	1.A.4.a	Commercial/Institutional - Liquid Fuels	CO2	1957.00	1183.33	1.87	2.33	76.48
13	6.A	Waste - Solid Waste Disposal on land	CH4	14.73	830.85	1.31	2.10	78.58
14	4.A.1	Enteric Fermentation - Non-Dairy Cattle	CH4	5630.17	5221.02	8.26	2.02	80.60
15	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CO2	223.49	906.22	1.43	1.72	82.32
16	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.38	1725.04	2.73	1.60	83.92
17	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	377.76	0.60	1.42	85.34
18	2.F	Consumption of Halocarbons & SF6	HFC	1.31	538.61	0.85	1.38	86.73
19	4.A.3	Enteric Fermentation - Sheep	CH4	1032.48	571.08	0.90	1.37	88.09
20	5.C.1	LULUCF - Grassland Remaining Grassland	CO2	47.10	542.95	0.86	1.27	89.36
21	4.A.1	Enteric Fermentation - Dairy Cattle	CH4	2854.99	2572.06	4.07	1.22	90.58
22	4.D.1	Agricultural Soils - Direct Soil Emissions	N2O	3021.86	2762.22	4.37	1.19	91.77
23	4.D.2	Agricultural Soils - Pasture, Range & Paddock	N2O	2868.35	2611.47	4.13	1.15	92.92
24	5.C.2	LULUCF - Land converted to Grassland	CO2	0.00	322.79	0.51	0.83	93.75
25	5.B.2	LULUCF - Land converted to Cropland	CO2	602.37	329.34	0.52	0.81	94.56
26	4.B.1	Manure Management - Non-Dairy Cattle	CH4	1279.75	1106.56	1.75	0.67	95.22
27	1.A.4.b	Residential - Solid Fuels	CH4	356.29	124.88	0.20	0.66	95.88
28	4.B.1	Manure Management - Dairy Cattle	CH4	608.23	474.76	0.75	0.45	96.33
29	4.D.3	Agricultural Soils - Indirect Emissions	N2O	1380.91	1308.50	2.07	0.42	96.75
30	6.B	Waste - Waste Water Handling	N2O	0.00	141.35	0.22	0.36	97.12
31	1.B.2.b	Fugitive emissions - Natural gas	CH4	131.08	27.50	0.04	0.29	97.41
32	1.A.3.e	Other Transport - Gaseous Fuels	CO2	62.04	153.31	0.24	0.22	97.63
33	5.B.2	LULUCF - Land converted to Cropland	N2O	108.80	31.37	0.05	0.22	97.85
34	1.A.3.d	Navigation - Liquid Fuels	CO2	84.90	171.78	0.27	0.21	98.06

35	1.A.1	Energy Industries - Gaseous Fuels	N2O	10.62	84.08	0.13	0.19	98.25
36	4.B.8	Manure Management - Pigs	CH4	332.33	414.29	0.66	0.15	98.40
37	6.C	Waste - Waste Incineration	CO2	0.00	53.49	0.08	0.14	98.54
38	1.A.3.b	Road Transport - Liquid Fuels	N2O	44.38	91.96	0.15	0.12	98.65
39	1.A.3.a	Civil Aviation - Liquid Fuels	CO2	51.13	19.06	0.03	0.09	98.74
40	5.D.1	LULUCF - Wetlands remaining Wetlands	CO2	3.59	33.94	0.05	0.08	98.82
41	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CO2	0.00	29.88	0.05	0.08	98.90
42	2.A.2	Lime Production	CO2	214.08	199.06	0.31	0.08	98.97
43	2.A.1	Cement Production	CO2	884.00	966.27	1.53	0.06	99.04
44	1.A.3.b	Road Transport - Liquid Fuels	CH4	36.82	17.12	0.03	0.06	99.09
45	4.B.13	Manure Management - Solid Storage	N2O	371.24	374.69	0.59	0.05	99.15
46	1.A.3.c	Rail Transport - Liquid Fuels	CO2	133.19	121.91	0.19	0.05	99.20
47	5.A.2	LULUCF - Land converted to Forest Land	CH4	20.00	1.93	0.00	0.05	99.30
48	5.F.2	LULUCF - Land Converted to Other Land	CO2	111.71	138.19	0.22	0.05	99.25
49	1.A.4.b	Residential - Solid Fuels	N2O	25.36	8.90	0.01	0.05	99.34
50	5.B.1	LULUCF - Cropland remaining Cropland	CO2	0.00	16.95	0.03	0.04	99.39
51	1.A.1	Energy Industries - Solid Fuels	N2O	62.22	49.53	0.08	0.04	99.43
52	1.A.1	Energy Industries - Other Fuels	CO2	0.00	16.39	0.03	0.04	99.47
53	6.B	Waste - Waste Water Handling	CH4	0.00	16.32	0.03	0.04	99.52
54	4.B.3	Manure Management - Sheep	CH4	26.13	14.45	0.02	0.03	99.55
55	2.F	Consumption of Halocarbons & SF6	PFC	0.09	13.20	0.02	0.03	99.58
56	3	Solvent and Other Product Use	CO2	80.03	72.49	0.11	0.03	99.62
57	4.A.6	Enteric Fermentation - Horses	CH4	23.28	37.08	0.06	0.03	99.65
58	5.A.1	LULUCF - Forest land Remaining Forest Land	N2O	24.78	38.63	0.06	0.03	99.68
59	2.F	Consumption of Halocarbons & SF6	SF6	35.51	48.29	0.08	0.03	99.71
60	5.D.2	LULUCF - Land Converted to Wetlands	CO2	10.29	0.75	0.00	0.03	99.73
61	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30	713.79	1.13	0.02	99.76
62	4.B.9	Manure Management - Poultry	CH4	105.20	119.41	0.19	0.02	99.78
63	1.A.4.b	Residential - Biomass	CH4	11.83	5.95	0.01	0.02	99.79
64	1.A.4.b	Residential - Liquid Fuels	CH4	3.12	8.95	0.01	0.01	99.81
65	4.B.12	Manure Management - Liquid Systems	N2O	63.87	62.84	0.10	0.01	99.82
66	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	N2O	72.05	71.60	0.11	0.01	99.84
67	1.A.4.b	Residential - Liquid Fuels	N2O	2.58	7.84	0.01	0.01	99.85
68	1.A.4.a	Commercial/Institutional - Biomass	CH4	0.00	4.62	0.01	0.01	99.86
69	2.A.7	Bricks & Ceramics	CO2	5.07	0.83	0.00	0.01	99.87
70	1.A.1	Energy Industries - Biomass	N2O	0.00	4.41	0.01	0.01	99.88

71	5.A.1	LULUCF - Forest land Remaining Forest Land	CH4	9.29	5.65	0.01	0.01	99.90
72	1.A.2	Manufacturing Industries & Construction - Biomass	N2O	3.16	7.51	0.01	0.01	99.91
73	4.A.8	Enteric Fermentation - Pigs	CH4	29.61	34.77	0.05	0.01	99.91
74	1.A.2	Manufacturing Industries & Construction - Solid Fuels	N2O	4.28	1.86	0.00	0.01	99.92
75	1.A.4.a	Commercial/Institutional - Liquid Fuels	CH4	5.53	3.36	0.01	0.01	99.93
76	1.A.3.c	Rail Transport - Liquid Fuels	N2O	16.11	14.90	0.02	0.01	99.93
77	1.A.4.a	Commercial/Institutional - Liquid Fuels	N2O	4.87	2.96	0.00	0.01	99.94
78	1.A.2	Manufacturing Industries & Construction - Biomass	CH4	1.61	3.81	0.01	0.01	99.94
79	1.A.4.b	Residential - Gaseous Fuels	CH4	0.52	2.50	0.00	0.01	99.95
80	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	N2O	5.02	3.70	0.01	0.00	99.95
81	5.D.2	LULUCF - Land Converted to Wetlands	N2O	1.06	2.57	0.00	0.00	99.96
82	1.A.4.b	Residential - Biomass	N2O	2.32	1.17	0.00	0.00	99.96
83	1.A.1	Energy Industries - Liquid Fuels	N2O	1.52	0.33	0.00	0.00	99.96
84	1.A.2	Manufacturing Industries & Construction - Solid Fuels	CH4	1.93	0.84	0.00	0.00	99.97
85	1.A.4.a	Commercial/Institutional - Gaseous Fuels	CH4	0.43	1.67	0.00	0.00	99.97
86	4.B.6	Manure Management - Horses	CH4	1.81	2.88	0.00	0.00	99.97
87	1.A.3.e	Other Transport - Gaseous Fuels	N2O	0.70	1.67	0.00	0.00	99.98
88	4.A.4	Enteric Fermentation - Goats	CH4	1.83	1.06	0.00	0.00	99.98
89	2.A.3	Limestone Use	CO2	0.15	1.04	0.00	0.00	99.98
90	1.A.4.a	Commercial/Institutional - Biomass	N2O	0.00	0.86	0.00	0.00	99.98
91	1.A.1	Energy Industries - Gaseous Fuels	CH4	2.88	2.36	0.00	0.00	99.98
92	1.A.3.d	Navigation - Liquid Fuels	N2O	0.70	1.45	0.00	0.00	99.99
93	1.A.1	Energy Industries - Solid Fuels	CH4	2.36	1.93	0.00	0.00	99.99
94	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	N2O	0.49	1.11	0.00	0.00	99.99
95	1.A.4.b	Residential - Gaseous Fuels	N2O	0.15	0.74	0.00	0.00	99.99
96	6.C	Waste - Waste Incineration	N2O	0.00	0.57	0.00	0.00	99.99
97	1.A.2	Manufacturing Industries & Construction - Liquid Fuels	CH4	1.73	1.30	0.00	0.00	99.99
98	1.A.1	Energy Industries - Biomass	CH4	0.00	0.43	0.00	0.00	99.99
99	1.A.2	Manufacturing Industries & Construction - Gaseous Fuels	CH4	0.33	0.75	0.00	0.00	100.00
100	1.A.4.a	Commercial/Institutional - Gaseous Fuels	N2O	0.13	0.49	0.00	0.00	100.00
101	1.A.3.a	Civil Aviation - Liquid Fuels	N2O	0.58	0.26	0.00	0.00	100.00
102	1.A.1	Energy Industries - Liquid Fuels	CH4	0.33	0.12	0.00	0.00	100.00
103	1.A.3.d	Navigation - Liquid Fuels	CH4	0.17	0.34	0.00	0.00	100.00
104	5.A.2	LULUCF - Land converted to Forest Land	N2O	0.00	0.17	0.00	0.00	100.00
105	1.A.3.e	Other Transport - Gaseous Fuels	CH4	0.12	0.28	0.00	0.00	100.00
106	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	N2O	0.00	0.11	0.00	0.00	100.00

107	1.B.2.a	Fugitive Emissions - Oil Refining/Storage	CH4	0.18	0.29	0.00	0.00	100.00
108	1.A.4.c	Agriculture/Forestry/Fisheries - Liquid Fuels	CH4	0.90	1.01	0.00	0.00	100.00
109	1.A.2	Manufacturing Industries & Construction - Non-Renewable waste	CH4	0.00	0.04	0.00	0.00	100.00
110	2.A.4	Soda Ash Production and Use	CO2	0.10	0.07	0.00	0.00	100.00
111	1.A.3.c	Rail Transport - Liquid Fuels	CH4	0.16	0.15	0.00	0.00	100.00
112	4.B.4	Manure Management - Goats	CH4	0.04	0.03	0.00	0.00	100.00
113	1.A.3.a	Civil Aviation - Liquid Fuels	CH4	0.02	0.01	0.00	0.00	100.00
114	4.A.7	Enteric Fermentation - Mules & Asses	CH4	1.74	1.85	0.00	0.00	100.00
115	4.B.7	Manure Management - Mules and Asses	CH4	0.13	0.14	0.00	0.00	100.00
116	6.C	Waste - Waste Incineration	CH4	0.00	0.00	0.00	0.00	100.00
117	1.A.4.a	Commercial/Institutional - Solid Fuels	CO2	138.29	0.00	0.00	0.00	100.00
118	1.A.4.a	Commercial/Institutional - Solid Fuels	CH4	0.29	0.00	0.00	0.00	100.00
119	1.A.4.a	Commercial/Institutional - Solid Fuels	N2O	0.59	0.00	0.00	0.00	100.00
120	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	N2O	0.00	0.00	0.00	0.00	100.00
121	1.A.4.c	Agriculture/Forestry/Fisheries - Biomass	CH4	0.00	0.00	0.00	0.00	100.00
122	2.A.7	Glass Production	CO2	13.33	0.00	0.00	0.00	100.00
123	2.B	Chemical Industry	N2O	1035.40	0.00	0.00	0.00	100.00
124	2.B	Chemical Industry	CO2	990.23	0.00	0.00	0.00	100.00



## Annex C

### Expanded Energy Balance Sheets for 2011

Table C.1 Expanded Energy Balance Sheet 2011

2011	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	Naphta	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	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	0	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.1 Expanded Energy Balance Sheet 2011 (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	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.1 Expanded Energy Balance Sheet 2011 (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

## Annex D

### Energy (IPCC Sector 1)

D.1 – D.2 Calculation Sheets for Energy 2011

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 2011 (continued on following pages)**

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
	Sector/Fuel	kTOE	TJ	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
				kg/TJ	kg/TJ	kg/TJ	Gg	Mg	Mg
	<b>1A1a Public Electricity</b>								
1	Coal	913.07	38228.46	93688	0.7	0.5	3581.53	26.76	19.11
2	Peat	472.91	19799.83	114940	3.0	7.0	2275.79	59.40	138.60
3	Fuel Oil and Gas Oil	48.15	2015.95	78493	0.8	0.3	158.24	1.61	0.60
4	Natural Gas	2253.74	94359.40	57104	1.2	2.9	5388.31	112.16	271.21
5	Biomass (LFG, Wood & MSW)	75.66	3167.86	76207	6.5	4.5	241.41	20.45	14.23
6	MSW	2.91	121.74	134651	30.0	4.0	16.39	3.65	0.49
	<b>Public Electricity Total</b>	<b>3766.44</b>	<b>157693.23</b>				<b>11420.26</b>	<b>224.04</b>	<b>444.25</b>
	<b>1A1b Refinery Fuel</b>								
7	Refinery Gas	88.55	3707.43	71510	1.0	0.1	265.12	3.71	0.37
8	Natural Gas	6.17	258.28	56954	1.0	0.1	14.71	0.26	0.03
9	LPG	11.42	478.15	8638	1.0	0.1	4.13	0.48	0.05
10	Gasoil/Diesel/DERV	1.19	49.65	24440	3.0	0.6	1.21	0.15	0.03
	<b>Refinery Total</b>	<b>107.33</b>	<b>4493.50</b>				<b>285.17</b>	<b>4.59</b>	<b>0.47</b>
	<b>1A1c Manufacture of Briquettes</b>								
11	Peat	<b>25.09</b>	<b>1050.59</b>	88386	2.0	1.5	<b>92.86</b>	<b>2.10</b>	<b>1.58</b>
	<b>1A2a-1A2f Industry Fuel</b>								
12	Bituminous Coals	95.38	3993.19	94600	10.0	1.5	377.76	39.93	5.99
13	Briquettes	0.00	0.00	98860	2.0	1.5	0.00	0.00	0.00
14	Kerosene	88.74	3715.25	71400	3.0	0.6	265.27	11.15	2.23
15	Fuel Oil	170.59	7142.16	76000	3.0	0.6	542.80	21.43	4.29
16	LPG	99.34	4159.30	63700	1.0	0.1	264.95	4.16	0.42
17	Gasoil/Diesel/DERV	150.06	6282.69	73300	3.0	0.6	460.52	18.85	3.77
18	Pet Coke	49.05	2053.79	93242	3.0	0.6	191.50	6.16	1.23
19	Naphta	0.00	0.00	73330	3.0	0.6	0.00	0.00	0.00
20	Natural Gas	855.49	35817.51	57027	1.0	0.1	2042.55	35.82	3.58
21	Biomass (solid)	144.44	6047.36	110000	30.0	4.0	665.21	181.42	24.19
22	Biomass (gas)	5.26	220.42	54600	1.0	0.1	12.03	0.22	0.02
23	Non Renewable wastes	14.18	593.70	50332	3.0	0.6	29.88	1.78	0.36
	<b>Industry Total</b>	<b>1672.53</b>	<b>70025.35</b>				<b>4175.23</b>	<b>320.91</b>	<b>46.07</b>

**Table D.1 Calculation Sheet for Emissions from Fuel Combustion 2011 (continued from previous page)**

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
	Sector/Fuel	kTOE	TJ	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
				kg/TJ	kg/TJ	kg/TJ	Gg	Mg	Mg
24	<b>1A3a Aviation</b> Civil Aviation Kerosene	6.39	267.73	71206	1.8	3.2	19.06	0.47	0.85
25	<b>1A3b Road Transport Fuel</b> Gasoline	1424.03	59621.32	69960	11.9	1.75	4171.11	709.88	101.99
26	Gasoil/Diesel/DERV	2125.71	88999.36	73300	1.0	2.16	6523.65	87.58	186.54
27	LPG	0.55	23.02	63700	10.56	2.41	1.47	0.24	0.06
28	Liquid Biofuels	97.28	4072.71	70531	4.25	1.98	287.25	17.31	8.07
	<b>Road Transport Total</b>	<b>3647.57</b>	<b>152716.42</b>				<b>10696.23</b>	<b>815.01</b>	<b>296.66</b>
29	<b>1A3c-1A3e Other Transport Fuel</b> Railway Diesel	39.72	1663.20	73300	4.2	28.6	121.91	6.90	47.57
30	Navigation Fuel Oil	0.00	0.00	76000	7.0	2.0	0.00	0.00	0.00
31	Navigation Gasoil	55.97	2343.46	73300	7.0	2.0	171.78	16.40	4.69
32	Gas Distribution Use (Natural Gas)	64.21	2688.46	57027	5.0	2.0	153.31	13.44	5.38
33	Railway Biofuel	0.41	17.19	70800	4.2	28.6	1.22	0.07	0.49
	<b>Other Transport Total</b>	<b>160.32</b>	<b>6712.30</b>				<b>447.00</b>	<b>36.82</b>	<b>58.12</b>
34	<b>1A4a Commercial/Institutional Fuel</b> Bituminous Coal	0.00	0.00	94600	10.0	1.5	0.00	0.00	0.00
35	Anthracite + Manufactured Ovoids	0.00	0.00	98260	10.0	1.5	0.00	0.00	0.00
36	Lignite	0.00	0.00	101200	10.0	1.5	0.00	0.00	0.00
37	Briquettes	0.00	0.00	98860	10.0	1.4	0.00	0.00	0.00
38	Fuel Oil	9.85	412.36	76000	10.0	0.6	31.34	4.12	0.25
39	LPG	7.40	309.92	63700	5.0	0.1	19.74	1.55	0.03
40	Gasoil / Diesel/ DERV	368.94	15446.77	73300	10.0	0.6	1132.25	154.47	9.27
41	Pet Coke	0.00	0.01	93242	10.0	0.6	0.00	0.00	0.00
42	Natural Gas	379.56	15891.22	57027	5.0	0.1	906.22	79.46	1.59
43	Biomass	15.76	659.75	110000	300.0	4.0	72.57	197.93	2.64
44	Biogas	4.22	176.80	54600	5.0	0.1	9.65	0.88	0.02
	<b>Commercial/Institutional Total</b>	<b>785.73</b>	<b>32896.83</b>				<b>2089.55</b>	<b>438.41</b>	<b>13.79</b>

**Table D.1 Calculation Sheet for Emissions from Fuel Combustion 2011**

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
	Sector/Fuel	kTOE	TJ	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
				kg/TJ	kg/TJ	kg/TJ	Gg	Mg	Mg
	<b>1A4b Residential Fuel</b>								
45	Bituminous Coal	154.27	6458.83	94600	300.0	1.5	611.01	1937.65	9.69
46	Anthracite + Manufactured Ovoids	67.40	2821.69	98260	300.0	1.5	277.26	846.51	4.23
47	Lignite	10.50	439.81	101200	300.0	1.5	44.51	131.94	0.66
48	Sod Peat	162.66	6810.40	104000	300.0	1.4	708.28	2043.12	9.53
49	Briquettes	78.60	3291.02	98860	300.0	1.4	325.35	987.31	4.61
50	Kerosene	798.63	33437.21	71400	10.0	0.6	2387.42	334.37	20.06
51	LPG	34.28	1435.04	63700	5.0	0.1	91.41	7.18	0.14
52	Gasoil / Diesel/ DERV	193.50	8101.36	73300	10.0	0.6	593.83	81.01	4.86
53	Petroleum Coke	8.66	362.58	93242	10.0	0.6	33.81	3.63	0.22
54	Natural Gas	569.27	23834.38	57027	5.0	0.1	1359.20	119.17	2.38
55	Biomass	25.06	1049.01	110184	290.0	3.7	115.58	304.20	3.88
	<b>Residential Total</b>	<b>2102.83</b>	<b>88041.34</b>				<b>6432.07</b>	<b>6796.09</b>	<b>60.27</b>
	<b>1A4c Agriculture/Forestry/Fishing Fuel</b>								
56	Gasoil	232.59	9737.87	73300	4.9	23.7	713.79	48.04	230.98
57	Biomass	0.00	0.00	110000	300.0	4.0	0.00	0.00	0.00
	<b>Agriculture Total</b>	<b>232.59</b>	<b>9737.87</b>				<b>713.79</b>	<b>48.04</b>	<b>230.98</b>
	<b>Total Energy</b>	<b>12506.81</b>	<b>523635.17</b>				<b>36371.22</b>	<b>8686.47</b>	<b>1153.04</b>

**Table D.2 Emissions from Fuel Combustion Allocated by IPCC Source Category 2011**

	GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA Consumption (TJ)	IMPLIED EMISSION FACTORS			EMISSIONS		
			CO <sub>2</sub> (t/TJ)	CH <sub>4</sub> (kg/TJ)	N <sub>2</sub> O (kg/TJ)	CO <sub>2</sub> (Gg)	CH <sub>4</sub>	N <sub>2</sub> O
<b>A</b>	<b>1.A.1. Energy Industries</b>	<b>163,237.3254</b>				<b>11,798.2858</b>	<b>0.2307</b>	<b>0.4463</b>
B	Solid Fuels	59,078.8784	100.7158	1.4939	2.6962	5,950.1770	0.0883	0.1593
C	Liquid Fuels	6,251.1759	68.5793	0.9514	0.1685	428.7012	0.0059	0.0011
D	Gaseous Fuels	94,617.6727	57.1037	1.1881	2.8667	5,403.0151	0.1124	0.2712
E	Biomass	3,167.8570	76.2072	6.4568	4.4919	241.4135	0.0205	0.0142
F	Other Fuels	121.7414	134.6509	30.0000	4.0000	16.3926	0.0037	0.0005
<b>G</b>	<b>1.A.2 Manufacturing Industries and Construction</b>	<b>70,025.3483</b>				<b>4,175.2330</b>	<b>0.3209</b>	<b>0.0461</b>
H	Solid Fuels	3,993.1864	94.6000	10.0000	1.5000	377.7554	0.0399	0.0060
I	Liquid Fuels	23,353.1818	73.8675	2.6438	0.5109	1,725.0407	0.0617	0.0119
J	Gaseous Fuels	35,817.5064	57.0267	1.0000	0.1000	2,042.5549	0.0358	0.0036
K	Biomass	6,267.7776	108.0518	28.9802	3.8628	677.2444	0.1816	0.0242
L	Other Fuels	593.6960	50.3321	3.0000	0.6000	29.8820	0.0018	0.0004
<b>M</b>	<b>1.A.3 Transport</b>	<b>159,696.4525</b>				<b>11,162.2936</b>	<b>0.8523</b>	<b>0.3556</b>
N	Solid Fuels	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
O	Liquid Fuels	152,918.0966	71.9927	5.3720	2.2345	11,008.9796	0.8215	0.3417
P	Gaseous Fuels	2,688.4576	57.0267	5.0000	2.0000	153.3139	0.0134	0.0054
Q	Biomass	4,089.8982	70.5321	4.2488	2.0927	288.4691	0.0174	0.0086
<b>R</b>	<b>1.A.4 Other Sectors</b>	<b>130,676.0300</b>				<b>9,235.4083</b>	<b>7.2825</b>	<b>0.3050</b>
S	Solid Fuels	19,821.7572	99.2044	300.0000	1.4490	1,966.4059	5.9465	0.0287
T	Liquid Fuels	69,243.1144	72.2611	9.1614	3.8388	5,003.5818	0.6344	0.2658
U	Gaseous Fuels	39,725.5996	57.0267	5.0000	0.1000	2,265.4206	0.1986	0.0040
V	Biomass	1,885.5589	104.9076	266.7702	3.4672	197.8095	0.5030	0.0065
<b>W</b>	<b>1.A.5 Other (Not specified elsewhere)<sup>(6)</sup></b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>X</b>	<b>1.A. Fuel Combustion</b>	<b>523,635.1562</b>				<b>36,371.2207</b>	<b>8.6865</b>	<b>1.1530</b>
	<b>Memo Items</b>							
Y	Aviation Bunkers	29,051.0729	71.4000	0.2934	2.3375	2,074.2466	0.0085	0.0679
Z	Marine Bunkers	4,518.4140	73.8555	7.0000	2.0000	333.7096	0.0316	0.0090
AA	CO <sub>2</sub> from Biomass	15,411.0917	91.1640			1,404.9365	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
<b>A</b>	<b>1.A.1 Energy Industries (A = B+C+D+E+F)</b>	
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
<b>G</b>	<b>1.A.2 Manufacturing Industries (G = H+I+J+K+L)</b>	
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
<b>M</b>	<b>1.A.3 Transport (M = N+O+P+Q)</b>	
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
<b>R</b>	<b>1.A.4 Other Sectors (R = S+T+U+V)</b>	
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
<b>W</b>	<b>1.A.5 Other</b>	<b>NO</b>
<b>X</b>	<b>1.A Fuel Combustion (X = A+G+M+R+W)</b>	

Table D.4 Emissions of CO<sub>2</sub> from the Reference Approach in 2011 [CRF 2011 Table 1.A(b)]

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor	NCV/ GCV <sup>(1)</sup>	Apparent consumption	Carbon emission factor	Carbon content	Carbon stored	Net carbon emissions	Fraction of carbon oxidized	Actual CO <sub>2</sub> emissions	
										(TJ/Unit)		(TJ)	(t C/TJ)	(Gg C)	(Gg C)	(Gg C)		(Gg CO <sub>2</sub> )	
Liquid Fossil	Primary Fuels	Crude Oil	kt	NO	2,888.87	NO		-34.82	2,923.68	42.81	NCV	125,175.15	20.00	2,503.50	NA	2,503.50	1.00	9,179.51	
		Orimulsion		NO	NO	NO		NO	NO	41.87	NCV	NO	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
	Secondary Fuels	Gasoline	kt		1,162.83	254.21	NO	-4.32	912.93	44.59	NCV	40,707.09	19.08	776.69	NA	776.69	1.00	2,847.87	
		Jet Kerosene	kt		869.60	NO	658.76	15.25	195.59	44.10	NCV	8,625.46	19.47	167.96	NA	167.96	1.00	615.87	
		Other Kerosene	kt		596.41	1.46	NO	-8.35	603.30	44.20	NCV	26,663.43	19.47	519.21	NA	519.21	1.00	1,903.77	
		Shale Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO
		Gas / Diesel Oil	kt		2,177.67	195.12	82.87	6.36	1,893.32	43.31	NCV	81,996.45	19.99	1,639.18	NA	1,639.18	1.00	6,010.34	
		Residual Fuel Oil	kt		264.68	1,081.34	22.54	-3.77	-835.43	41.24	NCV	-34,449.56	20.73	-714.04	NA	-714.04	1.00	-2,618.16	
		Liquefied Petroleum Gas (LPG)	kt		97.45	30.45		1.49	65.51	47.16	NCV	3,089.28	17.37	53.67	NA	53.67	1.00	196.79	
		Ethane			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA	NO	NO	NA
		Naphtha	kt		NO	19.79		-3.74	-16.05	44.00	NCV	-706.34	20.00	-14.13	NO	-14.13	1.00	-51.80	
		Bitumen	kt		278.81	1.00		NO	277.81	37.70	NCV	10,472.67	22.00	230.40	230.40	0.00	1.00	0.00	
		Lubricants	kt		36.41	5.76	NO	NO	30.65	42.29	NCV	1,296.00	20.00	25.92	12.96	12.96	1.00	47.52	
		Petroleum Coke	kt		97.05	0.49		-3.86	100.41	32.09	NCV	3,222.11	25.52	82.23	NO	82.23	1.00	301.50	
Refinery Feedstocks	kt		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO		
Other Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO		
Other Liquid Fossil												93.95		1.88	NA	1.88		6.89	
Aviation Gasoline			kt	NO	NO	NO	NO	NO	NO	44.59	NCV	NO	19.08	NO	NO	NO	1.00	NO	
Other non-specified			kt	NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NA	NA	
White Spirit			kt	NO	1.14	-1.00	NO	NO	2.14	44.00	NCV	93.95	20.00	1.88	NA	1.88	1.00	6.89	
Liquid Fossil Totals												266,185.69		5,272.47	243.36	5,029.12		18,440.09	
Solid Fossil	Primary Fuels	Anthracite <sup>(2)</sup>	kt	NO	49.31	0.19		2.28	46.84	27.84	NCV	1,304.10	26.80	34.95	NO	34.95	1.00	128.14	
		Coking Coal	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA	NO	NA	
		Other Bituminous Coal	kt	NO	2,239.25	9.18	NO	232.02	1,998.06	25.65	NCV	51,251.92	25.00	1,281.30	NA	1,281.30	1.00	4,698.09	
		Sub-bituminous Coal		NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO
		Lignite	kt	NO	22.40	0.74		-0.56	22.22	19.82	NCV	440.25	27.60	12.15	NO	12.15	1.00	44.55	
		Oil Shale		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO
		Peat	kt	3,194.15	NO	NO		-101.03	3,295.18	7.79	NCV	25,660.85	29.86	766.31	NA	766.31	1.00	2,809.80	
	Secondary Fuels	BKB <sup>(3)</sup> and Patent Fuel	kt		NO	21.10		16.20	-37.29	18.55	NCV	-691.65	26.96	-18.65	NA	-18.65	1.00	-68.38	
Coke Oven/Gas Coke				NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	NO	
Other Solid Fossil												6,821.33		193.19	NO	193.19		708.35	
Manufactured Ovoids			kt	NO	10.00	9.25	NO	-5.08	5.82	32.00	NCV	186.32	26.80	4.99	NO	4.99	1.00	18.31	
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	
Sod Peat			kt	513.00	NO	NO	NO	6.69	506.31	13.10	NCV	6,635.01	28.36	188.19	NO	188.19	1.00	690.04	
Solid Fossil Totals												84,786.80		2,269.24	NA	2,269.24		8,320.56	
Gaseous Fossil		Natural Gas (Dry)	TJ	11,919.93	160,785.11	NO		-38.79	172,743.82	1.00	NCV	172,743.82	15.55	2,686.64	NO	2,686.64	1.00	9,851.01	
Other Gaseous Fossil												NO		NO	NO	NO		NO	
Other non-specified					NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO	
Gaseous Fossil Totals												172,743.82		2,686.64	NO	2,686.64		9,851.01	
Total												523,716.31		10,228.36	243.36	9,985.00		36,611.67	
Biomass total												14,009.60		303.82	NO	303.82		1,114.02	
		Solid Biomass	TJ	6,126.21	540.03	24.80		-14.10	6,655.54	1.00	NCV	6,655.54	30.00	199.67	NO	199.67	1.00	732.11	
		Liquid Biomass	TJ	996.36	3,706.97	NO		-240.76	4,944.09	1.00	NCV	4,944.09	13.77	68.10	NO	68.10	1.00	249.70	
		Gas Biomass	TJ	2,409.97	NO	NO		NO	2,409.97	1.00	NCV	2,409.97	14.96	36.06	NO	36.06	1.00	132.21	

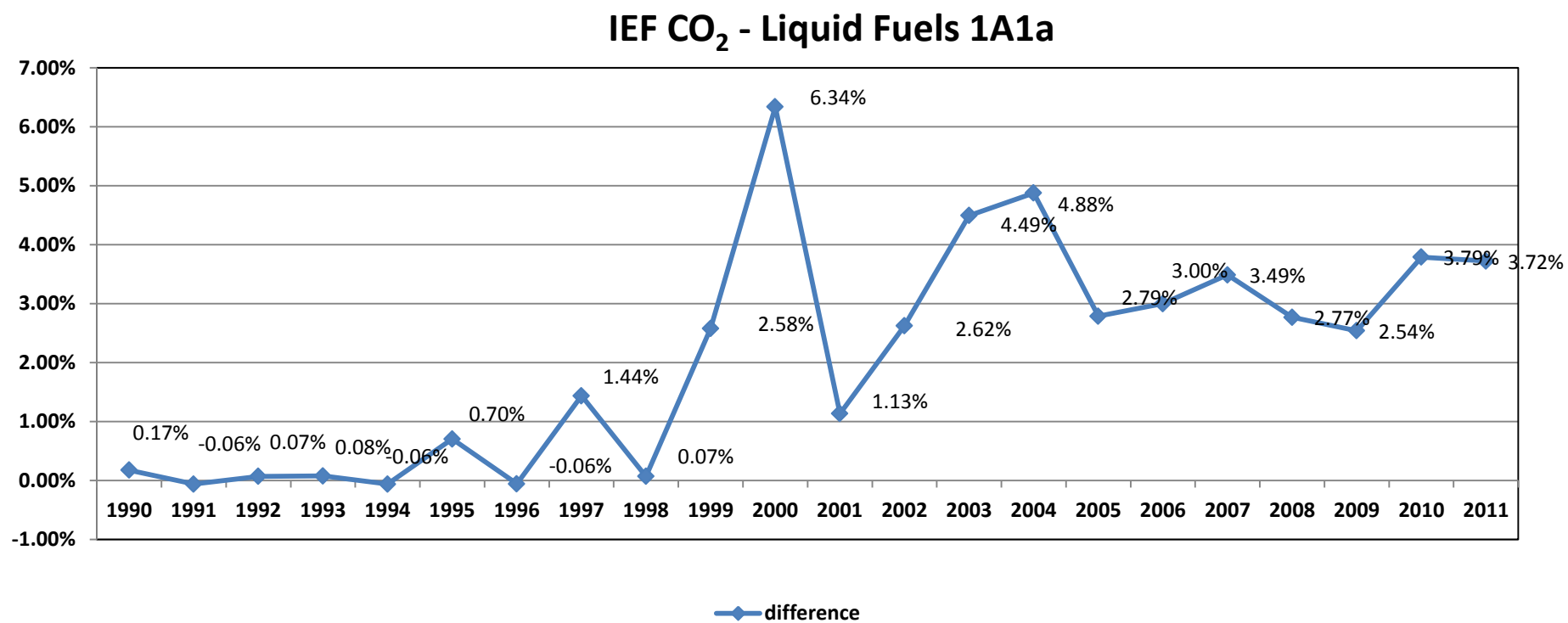
**Table D.5 Comparison of Results from Sectoral Approach and Reference Approach for 2011 (CRF 2011 Table 1.A(c))**

FUEL TYPES	REFERENCE APPROACH			SECTORAL APPROACH <sup>(1)</sup>		DIFFERENCE <sup>(2)</sup>	
	Apparent energy consumption <sup>(3)</sup> (PJ)	Apparent energy consumption (excluding non-energy use and feedstocks) <sup>(4)</sup> (PJ)	CO <sub>2</sub> emissions (Gg)	Energy consumption (PJ)	CO <sub>2</sub> emissions (Gg)	Energy consumption (%)	CO <sub>2</sub> emissions (%)
Liquid Fuels (excluding international bunkers)	266.19	254.97	18,440.09	251.77	18,166.30	1.27	1.51
Solid Fuels (excluding international bunkers) <sup>(5)</sup>	84.79	84.79	8,320.56	82.89	8,294.34	2.28	0.32
Gaseous Fuels	172.74	172.74	9,851.01	172.85	9,864.30	-0.06	-0.13
Other <sup>(5)</sup>	0.72	0.72	46.28	0.72	46.27	0.02	0.01
<b>Total <sup>(5)</sup></b>	<b>524.43</b>	<b>513.22</b>	<b>36,657.95</b>	<b>508.22</b>	<b>36,371.22</b>	<b>0.98</b>	<b>0.79</b>

**Table D.6 (a) Implied emission factors (IEFs) for CO<sub>2</sub> – Liquid Fuels in Sector I.A.I.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	
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	36436.44	23912.76	30201.29	30040.79	26180.99	15749.12	14187.59	8382.58	4308.13	1695.56	Energy balance data
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	822.86	1169.32	1645.71	2841.39	2259.13	580.00	457.38	355.46	1095.69	320.39	Energy balance data
<b>total</b>	<b>14282.09</b>	<b>23558.07</b>	<b>24139.52</b>	<b>23720.94</b>	<b>27252.93</b>	<b>25968.40</b>	<b>26162.15</b>	<b>33959.85</b>	<b>46295.57</b>	<b>58153.04</b>	<b>42984.49</b>	<b>51101.72</b>	<b>37259.30</b>	<b>25082.08</b>	<b>31847.00</b>	<b>32882.18</b>	<b>28440.12</b>	<b>16329.13</b>	<b>14644.96</b>	<b>8738.04</b>	<b>5403.82</b>	<b>2015.95</b>	<b>Liquid Fuels CRFReporter</b>
<b>Emission Factors (t CO<sub>2</sub>/TJ)</b>																							
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	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	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	73.30	
<b>CO<sub>2</sub> Emissions National Approach Tier 1)</b>																							
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	2769.17	1817.37	2295.30	2283.10	1989.76	1196.93	1078.26	637.08	327.42	128.86	
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	60.32	85.71	120.63	208.27	165.59	42.51	33.53	26.06	80.31	23.48	
<b>total</b>	<b>1084.62</b>	<b>1789.71</b>	<b>1833.67</b>	<b>1802.21</b>	<b>2069.12</b>	<b>1971.84</b>	<b>1987.27</b>	<b>2579.66</b>	<b>3516.83</b>	<b>4416.71</b>	<b>3263.55</b>	<b>3880.81</b>	<b>2829.48</b>	<b>1903.08</b>	<b>2415.93</b>	<b>2491.37</b>	<b>2155.35</b>	<b>1239.45</b>	<b>1111.78</b>	<b>663.13</b>	<b>407.73</b>	<b>152.35</b>	
<b>IEF calculated</b>	<b>75.94</b>	<b>75.97</b>	<b>75.96</b>	<b>75.98</b>	<b>75.92</b>	<b>75.93</b>	<b>75.96</b>	<b>75.96</b>	<b>75.96</b>	<b>75.95</b>	<b>75.92</b>	<b>75.94</b>	<b>75.94</b>	<b>75.87</b>	<b>75.86</b>	<b>75.77</b>	<b>75.79</b>	<b>75.90</b>	<b>75.92</b>	<b>75.89</b>	<b>75.45</b>	<b>75.57</b>	<b>IEF National Approach</b>
<b>CO<sub>2</sub> emissions from ETS (Tier 3 bottom up)</b>	<b>1086.52</b>	<b>1788.62</b>	<b>1834.97</b>	<b>1803.59</b>	<b>2067.85</b>	<b>1985.81</b>	<b>1986.13</b>	<b>2617.23</b>	<b>3519.32</b>	<b>4533.60</b>	<b>3484.39</b>	<b>3925.34</b>	<b>2905.74</b>	<b>1992.62</b>	<b>2539.76</b>	<b>2562.77</b>	<b>2222.00</b>	<b>1284.23</b>	<b>1143.44</b>	<b>680.41</b>	<b>423.79</b>	<b>158.24</b>	<b>Gg CO<sub>2</sub> CRFReporter</b>
<b>difference</b>	<b>0.17%</b>	<b>-0.06%</b>	<b>0.07%</b>	<b>0.08%</b>	<b>-0.06%</b>	<b>0.70%</b>	<b>-0.06%</b>	<b>1.44%</b>	<b>0.07%</b>	<b>2.58%</b>	<b>6.34%</b>	<b>1.13%</b>	<b>2.62%</b>	<b>4.49%</b>	<b>4.88%</b>	<b>2.79%</b>	<b>3.00%</b>	<b>3.49%</b>	<b>2.77%</b>	<b>2.54%</b>	<b>3.79%</b>	<b>3.72%</b>	
<b>IEF reported</b>	<b>76.08</b>	<b>75.92</b>	<b>76.02</b>	<b>76.03</b>	<b>75.88</b>	<b>76.47</b>	<b>75.92</b>	<b>77.07</b>	<b>76.02</b>	<b>77.96</b>	<b>81.06</b>	<b>76.81</b>	<b>77.99</b>	<b>79.44</b>	<b>79.75</b>	<b>77.94</b>	<b>78.13</b>	<b>78.65</b>	<b>78.08</b>	<b>77.87</b>	<b>78.42</b>	<b>78.49</b>	<b>IEF CRFReporter</b>

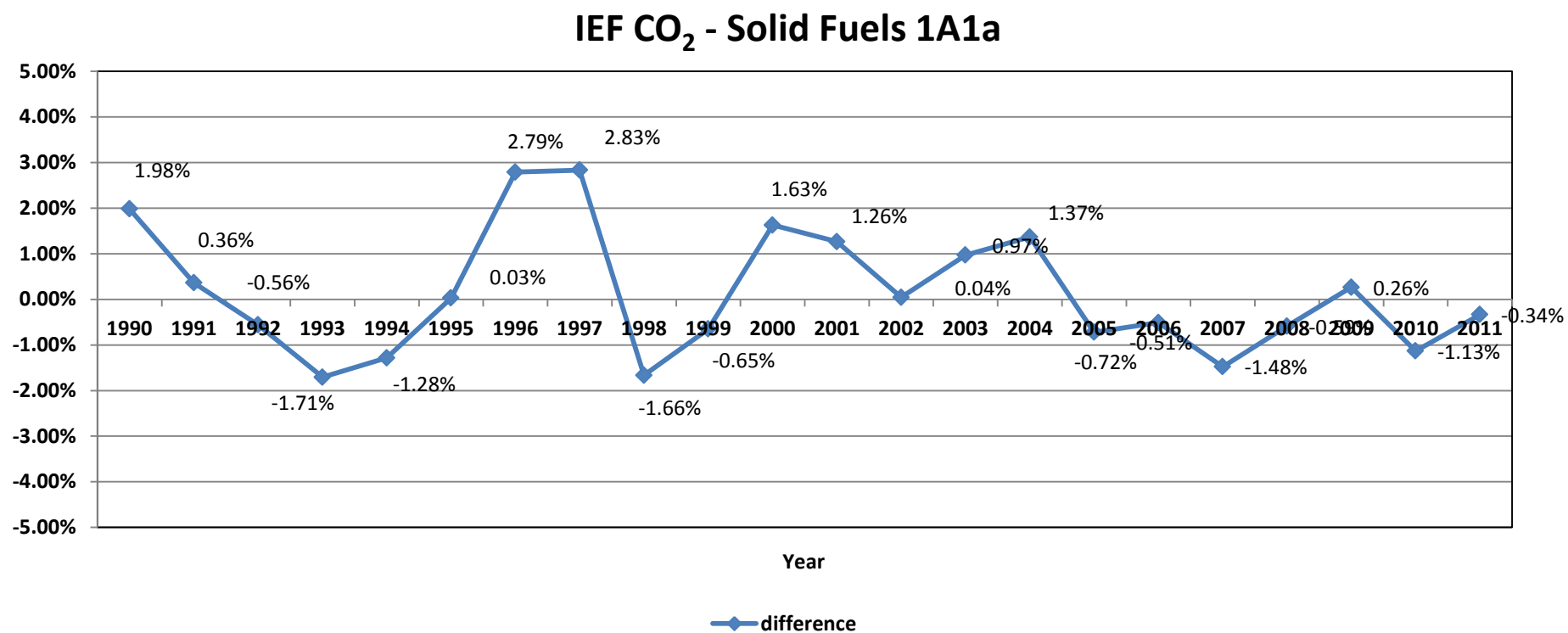
Table D.6 (b) Implied emission factors (IEFs) for CO<sub>2</sub> – Liquid Fuels in Sector 1.A.1.a



**Table D.7 (a) Implied emission factors (IEFs) for CO<sub>2</sub> – 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	
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	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	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	Energy balance data
<b>total</b>	<b>76759.23</b>	<b>76731.10</b>	<b>84555.44</b>	<b>80477.79</b>	<b>82681.22</b>	<b>86285.00</b>	<b>85993.17</b>	<b>83428.49</b>	<b>82874.94</b>	<b>74651.99</b>	<b>79750.03</b>	<b>85842.71</b>	<b>83872.41</b>	<b>76405.67</b>	<b>70820.42</b>	<b>79795.64</b>	<b>69923.01</b>	<b>67856.14</b>	<b>65362.59</b>	<b>55758.40</b>	<b>56464.72</b>	<b>58028.29</b>	<b>Solid Fuels CRFReporter</b>
<b>Emission Factors (t CO<sub>2</sub>/TJ)</b>																							
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	
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	
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	
<b>CO<sub>2</sub> Emissions National Approach (Tier 1)</b>																							
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	
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	
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	
<b>total</b>	<b>7752.52</b>	<b>7767.46</b>	<b>8524.86</b>	<b>8091.12</b>	<b>8310.56</b>	<b>8642.59</b>	<b>8609.98</b>	<b>8362.24</b>	<b>8280.63</b>	<b>7502.74</b>	<b>7952.79</b>	<b>8579.04</b>	<b>8393.92</b>	<b>7656.59</b>	<b>6981.48</b>	<b>7966.62</b>	<b>7001.71</b>	<b>6802.85</b>	<b>6669.98</b>	<b>5750.36</b>	<b>5752.50</b>	<b>5893.39</b>	
<b>IEF calculated</b>	<b>101.00</b>	<b>101.23</b>	<b>100.82</b>	<b>100.54</b>	<b>100.51</b>	<b>100.16</b>	<b>100.12</b>	<b>100.23</b>	<b>99.92</b>	<b>100.50</b>	<b>99.72</b>	<b>99.94</b>	<b>100.08</b>	<b>100.21</b>	<b>98.58</b>	<b>99.84</b>	<b>100.13</b>	<b>100.25</b>	<b>102.05</b>	<b>103.13</b>	<b>101.88</b>	<b>101.56</b>	<b>IEF National Approach</b>
<b>CO<sub>2</sub> emissions from ETS (Tier 3 bottom up)</b>	<b>7909.31</b>	<b>7795.76</b>	<b>8477.38</b>	<b>7955.29</b>	<b>8205.33</b>	<b>8645.06</b>	<b>8857.12</b>	<b>8606.14</b>	<b>8145.16</b>	<b>7454.31</b>	<b>8084.48</b>	<b>8688.84</b>	<b>8397.65</b>	<b>7731.52</b>	<b>7078.28</b>	<b>7909.68</b>	<b>6966.22</b>	<b>6703.73</b>	<b>6630.99</b>	<b>5765.58</b>	<b>5688.15</b>	<b>5873.71</b>	<b>Gg CO<sub>2</sub> CRFReporter</b>
<b>difference</b>	<b>1.98%</b>	<b>0.36%</b>	<b>-0.56%</b>	<b>-1.71%</b>	<b>-1.28%</b>	<b>0.03%</b>	<b>2.79%</b>	<b>2.83%</b>	<b>-1.66%</b>	<b>-0.65%</b>	<b>1.63%</b>	<b>1.26%</b>	<b>0.04%</b>	<b>0.97%</b>	<b>1.37%</b>	<b>-0.72%</b>	<b>-0.51%</b>	<b>-1.48%</b>	<b>-0.59%</b>	<b>0.26%</b>	<b>-1.13%</b>	<b>-0.34%</b>	
<b>IEF reported</b>	<b>103.04</b>	<b>101.60</b>	<b>100.26</b>	<b>98.85</b>	<b>99.24</b>	<b>100.19</b>	<b>103.00</b>	<b>103.16</b>	<b>98.28</b>	<b>99.85</b>	<b>101.37</b>	<b>101.22</b>	<b>100.12</b>	<b>101.19</b>	<b>99.95</b>	<b>99.12</b>	<b>99.63</b>	<b>98.79</b>	<b>101.45</b>	<b>103.40</b>	<b>100.74</b>	<b>101.22</b>	<b>IEF CRFReporter</b>

Table D.7 (b) Implied emission factors (IEFs) for CO<sub>2</sub> – Solid Fuels in Sector 1.A.1.a



**Table D.8 Implied emission factors (IEFs) for CO<sub>2</sub> – 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	
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	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	287.44	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	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	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	7598.42	9083.54	9484.38	8950.54	10928.27	9164.12	4202.91	3426.32	2053.79	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	Energy balance data
<b>total</b>	<b>10809.78</b>	<b>9898.20</b>	<b>9810.62</b>	<b>9728.91</b>	<b>11906.77</b>	<b>12640.08</b>	<b>10072.17</b>	<b>12303.07</b>	<b>12205.22</b>	<b>13110.97</b>	<b>15613.80</b>	<b>15746.06</b>	<b>16236.14</b>	<b>18216.57</b>	<b>19626.81</b>	<b>22948.82</b>	<b>20923.83</b>	<b>22713.01</b>	<b>20791.43</b>	<b>14022.93</b>	<b>13031.82</b>	<b>10240.76</b>	<b>Energy balance data</b>
<b>Emission Factors (t CO<sub>2</sub>/TJ)</b>																							
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	
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	
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	
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	
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	
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	
<b>CO<sub>2</sub> Emissions National Approach (Tier 1)</b>																							
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	
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	21.85	
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	
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	
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	711.61	850.69	902.29	836.28	1018.58	851.64	393.20	320.69	191.50	
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	
<b>total</b>	<b>823.55</b>	<b>757.28</b>	<b>741.57</b>	<b>732.28</b>	<b>905.72</b>	<b>963.53</b>	<b>751.15</b>	<b>950.37</b>	<b>934.76</b>	<b>1004.65</b>	<b>1227.59</b>	<b>1250.02</b>	<b>1295.28</b>	<b>1466.99</b>	<b>1595.21</b>	<b>1862.79</b>	<b>1686.26</b>	<b>1851.26</b>	<b>1669.65</b>	<b>1093.08</b>	<b>998.88</b>	<b>765.01</b>	
<b>IEF calculated</b>	<b>76.19</b>	<b>76.51</b>	<b>75.59</b>	<b>75.27</b>	<b>76.07</b>	<b>76.23</b>	<b>74.58</b>	<b>77.25</b>	<b>76.59</b>	<b>76.63</b>	<b>78.62</b>	<b>79.39</b>	<b>79.78</b>	<b>80.53</b>	<b>81.28</b>	<b>81.17</b>	<b>80.59</b>	<b>81.51</b>	<b>80.30</b>	<b>77.95</b>	<b>76.65</b>	<b>74.70</b>	<b>IEF National Approach</b>
<b>CO<sub>2</sub> emissions</b>	<b>823.55</b>	<b>757.28</b>	<b>741.57</b>	<b>732.28</b>	<b>905.72</b>	<b>963.53</b>	<b>751.15</b>	<b>950.37</b>	<b>934.76</b>	<b>1004.65</b>	<b>1227.59</b>	<b>1250.02</b>	<b>1295.28</b>	<b>1466.99</b>	<b>1595.21</b>	<b>1862.79</b>	<b>1686.26</b>	<b>1851.26</b>	<b>1669.65</b>	<b>1093.08</b>	<b>998.88</b>	<b>765.01</b>	<b>Gg CO<sub>2</sub> CRFReporter</b>
<b>difference</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	<b>0.00%</b>	
<b>IEF reported</b>	<b>76.19</b>	<b>76.51</b>	<b>75.59</b>	<b>75.27</b>	<b>76.07</b>	<b>76.23</b>	<b>74.58</b>	<b>77.25</b>	<b>76.59</b>	<b>76.63</b>	<b>78.62</b>	<b>79.39</b>	<b>79.78</b>	<b>80.53</b>	<b>81.28</b>	<b>81.17</b>	<b>80.59</b>	<b>81.51</b>	<b>80.30</b>	<b>77.95</b>	<b>76.65</b>	<b>74.70</b>	<b>IEF CRFReporter</b>
<b>% Share of Fuels</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	
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%	10.14%	8.10%	6.12%	7.57%	11.22%	9.46%	9.51%	
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%	10.71%	9.26%	10.31%	8.08%	6.76%	6.55%	9.61%	8.04%	2.81%	
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%	15.59%	17.17%	12.90%	14.44%	14.97%	17.52%	15.28%	21.09%	25.96%	
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%	29.03%	24.75%	25.13%	26.39%	23.84%	24.07%	33.60%	34.78%	41.67%	
<b>Petroleum Coke</b>	<b>18.24%</b>	<b>20.15%</b>	<b>14.91%</b>	<b>13.66%</b>	<b>16.56%</b>	<b>17.35%</b>	<b>10.12%</b>	<b>22.33%</b>	<b>19.79%</b>	<b>19.94%</b>	<b>29.52%</b>	<b>33.52%</b>	<b>36.66%</b>	<b>41.71%</b>	<b>46.28%</b>	<b>41.33%</b>	<b>42.78%</b>	<b>48.11%</b>	<b>44.08%</b>	<b>29.97%</b>	<b>26.29%</b>	<b>20.06%</b>	
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%	0.21%	0.19%	0.21%	0.31%	0.34%	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%	



## Annex E

### Energy - Transport (IPCC Sector 1.A.3)

#### E.1 – E.4 Civil aviation data 1990-2011

#### E.5 Vehicle population and kilometre data 1990-2011

*Table E.1 Number of Domestic LTOs by departure airport 1990-2011*

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
ex Dublin	7657	6944	6885	5921	6153	7235	7742	8134	8991	10183	11018	10947	10849	11261	12143	9976	10392	10803	9611	7844	6074	3331
ex Cork	2872	2604	2582	2221	2307	2713	2903	3050	3372	3819	4132	4106	4069	4223	4438	3649	3721	4608	3919	2872	1861	809
ex Shannon	1737	1576	1562	1343	1396	1641	1757	1845	2040	2310	2500	2484	2462	2555	2865	2809	2892	2277	1897	1349	1077	834
ex Galway	1425	1293	1282	1102	1145	1347	1441	1514	1674	1895	2051	2038	2019	2096	2224	1631	1615	1815	1848	1563	1746	1252
ex Sligo	620	562	557	479	498	586	627	658	728	824	892	886	878	912	946	759	748	754	785	741	678	381
ex Donegal	581	527	523	449	467	549	588	617	682	773	836	831	824	855	717	684	747	736	754	739	697	721
ex Knock	445	404	400	344	358	421	450	473	523	592	641	637	631	655	753	565	557	568	481	510	454	253
ex Kerry	1133	1027	1019	876	910	1070	1145	1203	1330	1506	1630	1620	1605	1666	1755	1477	1515	1506	1418	1170	1048	460
ex Waterford	236	214	213	183	190	223	239	251	278	314	340	338	335	348	254	181	191	279	456	231	472	707
ex Other	347	314	312	268	279	328	350	368	407	461	499	496	491	510	539	495	518	411	476	305	282	277
<b>Total</b>	<b>17053</b>	<b>15465</b>	<b>15334</b>	<b>13187</b>	<b>13703</b>	<b>16113</b>	<b>17242</b>	<b>18115</b>	<b>20024</b>	<b>22679</b>	<b>24538</b>	<b>24381</b>	<b>24164</b>	<b>25080</b>	<b>26634</b>	<b>22226</b>	<b>22896</b>	<b>23757</b>	<b>21645</b>	<b>17324</b>	<b>14389</b>	<b>9025</b>
Domestic LTOs (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ex Dublin	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%	46%	45%	45%	45%	44%	45%	42%	37%
ex Cork	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	17%	16%	16%	19%	18%	17%	13%	9%
ex Shannon	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	11%	13%	13%	10%	9%	8%	7%	9%
ex Galway	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	7%	7%	8%	9%	9%	12%	14%
ex Sligo	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	4%	4%	5%	4%
ex Donegal	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%	5%	8%
ex Knock	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	3%	3%	3%
ex Kerry	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	6%	7%	7%	7%	5%
ex Waterford	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	1%	3%	8%
ex Other	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%
<b>Total</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

*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 <sub>4</sub> kg/ LTO	N <sub>2</sub> O 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 1990-2011*

kg Fuel	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
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
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
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	989.6	938.6	826.5	625.6
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
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
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
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
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
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
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
<b>Total</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>454.5</b>	<b>402.0</b>	<b>433.5</b>	<b>492.9</b>	<b>451.1</b>	<b>467.0</b>	<b>485.6</b>	<b>440.6</b>	<b>334.9</b>

**Table E.5 Vehicle numbers, by technology class 1990, 2000-2011**

Sector	Subsector	Technology	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Pass. Cars	Gasoline <1,4 l	PRE ECE	12753	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/00-01	107124	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/02	280562	8600	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/03	38258	5332	4285	2063	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/04	71416	271727	192288	157760	115198	87750	60785	44162	30208	21293	14731	7424	5200
Pass. Cars	Gasoline <1,4 l	Open Loop	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	PC Euro 1	0	296111	291726	277565	271198	252511	234058	201949	175166	139275	113592	133343	113480
Pass. Cars	Gasoline <1,4 l	PC Euro 2	0	177840	305296	387716	380373	375274	368217	354676	340548	320459	312717	308269	306322
Pass. Cars	Gasoline <1,4 l	PC Euro 3	0	0	0	0	81521	157601	236126	233047	230927	228512	213481	214849	197364
Pass. Cars	Gasoline <1,4 l	PC Euro 4	0	0	0	0	0	0	0	86208	173076	258324	276615	214128	235867
Pass. Cars	Gasoline <1,4 l	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PRE ECE	4175	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	35071	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	91854	3634	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	12526	2251	1809	883	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	23381	115040	81171	67563	51553	39906	28597	21643	15689	11320	8970	4757	3368
Pass. Cars	Gasoline 1,4 - 2,0 l	Open Loop	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 1	0	125364	123147	118872	121366	114834	110113	98971	90979	74046	69163	85441	49813
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 2	0	75322	128876	166046	170224	170663	173229	173820	176876	170373	190406	197526	154230
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 3	0	0	0	0	36482	71672	111086	114211	119940	121490	129983	137606	146920
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 4	0	0	0	0	0	0	0	42249	89894	137339	168424	137204	149920
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	PRE ECE	291	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/00-01	2446	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/02	6406	222	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/03	874	137	122	85	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/04	1631	7011	5493	6505	4895	4302	3304	2667	2114	1642	770	418	438
Pass. Cars	Gasoline >2,0 l	PC Euro 1	0	7640	8333	11445	11525	12378	12723	12195	12259	10743	5940	7504	4973
Pass. Cars	Gasoline >2,0 l	PC Euro 2	0	4590	8722	15987	16164	18396	20016	21417	23834	24719	16354	17347	11832
Pass. Cars	Gasoline >2,0 l	PC Euro 3	0	0	0	0	3465	7726	12835	14072	16162	17627	11164	12090	12058
Pass. Cars	Gasoline >2,0 l	PC Euro 4	0	0	0	0	0	0	0	5206	12113	19927	14466	12050	11176
Pass. Cars	Gasoline >2,0 l	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel <2,0 l	Conventional	45976	60051	39587	31809	23614	18276	13201	10384	8432	6832	3105	1043	1184

Pass. Cars	Diesel <2,0 l	PC Euro 1	0	62255	58749	55242	55591	52592	50833	47487	48898	44687	23104	26595	19091
Pass. Cars	Diesel <2,0 l	PC Euro 2	0	37403	61483	77165	77970	78161	79970	83399	95064	102819	58346	70583	71530
<b>Sector</b>	<b>Subsector</b>	<b>Technology</b>	<b>1990</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
Pass. Cars	Diesel <2,0 l	PC Euro 3	0	0	0	0	16711	32825	51284	54799	64463	73318	79799	97469	100005
Pass. Cars	Diesel <2,0 l	PC Euro 4	0	0	0	0	0	0	0	20271	48314	82883	155636	157793	221345
Pass. Cars	Diesel <2,0 l	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel <2,0 l	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel >2,0 l	Conventional	3207	8189	5398	4753	3844	3225	2515	1978	1210	922	771	3257	321
Pass. Cars	Diesel >2,0 l	PC Euro 1	0	8489	8011	8255	9050	9281	9683	9045	7015	6030	5738	6550	4598
Pass. Cars	Diesel >2,0 l	PC Euro 2	0	5101	8385	11530	12693	13793	15233	15886	13638	13875	14490	17384	11947
Pass. Cars	Diesel >2,0 l	PC Euro 3	0	0	0	0	2720	5793	9767	10438	9248	9894	19818	24006	24124
Pass. Cars	Diesel >2,0 l	PC Euro 4	0	0	0	0	0	0	0	3861	6932	11185	38652	38864	42171
Pass. Cars	Diesel >2,0 l	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel >2,0 l	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	LPG	Conventional	3986	220	220	220	150	153	153	0	0	0	0	0	0
Pass. Cars	LPG	PC Euro 1	0	280	280	280	169	153	153	70	75	75	70	70	70
Pass. Cars	LPG	PC Euro 2	0	216	216	216	169	153	153	85	80	80	85	85	85
Pass. Cars	LPG	PC Euro 3	0	0	0	0	0	0	0	90	90	90	85	85	85
Pass. Cars	LPG	PC Euro 4	0	0	0	0	0	0	0	90	90	90	90	90	85
Pass. Cars	LPG	PC Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	LPG	PC Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Hybrid Gasoline <1,4 l	PC Euro 4	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Hybrid Gasoline 1,4-2,0 l	PC Euro 4	0	0	0	0	0	0	0	0	0	0	0	0	0
Pass. Cars	Hybrid Gasoline >2,0 l	PC Euro 4	0	0	0	0	0	0	0	0	0	0	0	0	0
LDV	Gasoline <3,5t	Conventional	33943	5329	1821	1271	850	588	394	224	122	69	48	37	27
LDV	Gasoline <3,5t	LD Euro 1	0	2845	3097	917	727	585	453	299	185	116	84	67	49
LDV	Gasoline <3,5t	LD Euro 2	0	0	0	2123	1668	1374	1125	802	554	384	308	263	206
LDV	Gasoline <3,5t	LD Euro 3	0	0	0	0	408	692	874	637	468	354	312	295	256
LDV	Gasoline <3,5t	LD Euro 4	0	0	0	0	0	0	0	284	421	485	535	548	528
LDV	Gasoline <3,5t	LD Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
LDV	Gasoline <3,5t	LD Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
LDV	Diesel <3,5 t	Conventional	57449	70983	62672	53848	53361	38845	31914	24683	19306	14838	11634	9485	7417
LDV	Diesel <3,5 t	LD Euro 1	0	81275	106574	38870	45653	38652	36684	33059	29333	24912	20424	17205	13765
LDV	Diesel <3,5 t	LD Euro 2	0	0	0	89942	104772	90837	91112	88497	87861	82717	74707	67526	57316
LDV	Diesel <3,5 t	LD Euro 3	0	0	0	0	25626	45804	70719	70282	74250	76253	75757	75665	71230
LDV	Diesel <3,5 t	LD Euro 4	0	0	0	0	0	0	0	31300	67027	104716	129528	140423	146941
LDV	Diesel <3,5 t	LD Euro 5	0	0	0	0	0	0	0	0	0	0	0	0	0
LDV	Diesel <3,5 t	LD Euro 6	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Gasoline >3,5 t	Conventional	651	193	167	140	119	102	87	71	54	44	42	38	30

HDT	Rigid <=7,5 t	Conventional	10195	3388	2608	2024	1503	1130	841	580	412	301	216	115	75
HDT	Rigid <=7,5 t	HD Euro I	0	3833	3467	3222	2955	2671	2353	1913	1579	1274	984	817	629
HDT	Rigid <=7,5 t	HD Euro III	0	2738	4034	5080	4717	4455	4243	3821	3597	3277	2795	2357	1906
HDT	Rigid <=7,5 t	HD Euro III	0	0	0	0	1154	2247	3293	3034	3039	3021	2834	2641	2368
<b>Sector</b>	<b>Subsector</b>	<b>Technology</b>	<b>1990</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
HDT	Rigid <=7,5 t	HD Euro IV	0	0	0	0	0	0	0	1351	2744	4148	4845	4902	4885
HDT	Rigid <=7,5 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid <=7,5 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 7,5 - 12 t	Conventional	7681	5326	3946	3048	2258	1687	1234	870	608	424	280	133	85
HDT	Rigid 7,5 - 12 t	HD Euro I	0	6031	5247	4852	4423	3968	3465	2884	2333	1796	1278	942	718
HDT	Rigid 7,5 - 12 t	HD Euro III	0	4308	6103	7651	7067	6471	6249	5753	5314	4619	3632	2719	2173
HDT	Rigid 7,5 - 12 t	HD Euro III	0	0	0	0	1716	3266	4873	4560	4490	4258	3683	3047	2700
HDT	Rigid 7,5 - 12 t	HD Euro IV	0	0	0	0	0	0	0	2046	4054	5847	6298	5654	5571
HDT	Rigid 7,5 - 12 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 7,5 - 12 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 12 - 14 t	Conventional	990	1741	1405	1178	920	726	564	453	348	205	132	60	38
HDT	Rigid 12 - 14 t	HD Euro I	0	1972	1868	1876	1803	1708	1585	1501	1337	867	603	429	317
HDT	Rigid 12 - 14 t	HD Euro III	0	1409	2174	2958	2880	2851	2859	2994	3044	2230	1713	1237	961
HDT	Rigid 12 - 14 t	HD Euro III	0	0	0	0	700	1439	2229	2374	2572	2056	1737	1386	1194
HDT	Rigid 12 - 14 t	HD Euro IV	0	0	0	0	0	0	0	1065	2323	2824	2970	2573	2464
HDT	Rigid 12 - 14 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 12 - 14 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 14 - 20 t	Conventional	91	162	143	126	100	90	74	64	52	94	70	34	24
HDT	Rigid 14 - 20 t	HD Euro I	0	184	190	201	196	214	208	211	200	397	320	244	200
HDT	Rigid 14 - 20 t	HD Euro III	0	131	220	316	313	356	374	422	456	1020	910	705	604
HDT	Rigid 14 - 20 t	HD Euro III	0	0	0	0	77	180	291	335	385	940	923	790	751
HDT	Rigid 14 - 20 t	HD Euro IV	0	0	0	0	0	0	0	149	346	1291	1578	1466	1549
HDT	Rigid 14 - 20 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 14 - 20 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 20 - 26 t	Conventional	0	0	0	0	5	5	4	4	3	3	2	1	1
HDT	Rigid 20 - 26 t	HD Euro I	0	0	0	0	11	12	12	14	13	11	11	9	6
HDT	Rigid 20 - 26 t	HD Euro III	0	0	0	0	17	20	21	29	29	29	30	26	19
HDT	Rigid 20 - 26 t	HD Euro III	0	0	0	0	4	10	16	23	25	27	31	29	23
HDT	Rigid 20 - 26 t	HD Euro IV	0	0	0	0	0	0	0	10	22	37	53	53	48
HDT	Rigid 20 - 26 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 20 - 26 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 26 - 28 t	Conventional	0	0	0	0	1	0	0	1	0	0	0	0	0
HDT	Rigid 26 - 28 t	HD Euro I	0	0	0	0	1	2	1	2	1	2	2	1	1
HDT	Rigid 26 - 28 t	HD Euro III	0	0	0	0	2	2	2	2	3	4	4	3	2

HDT	Rigid 26 - 28 t	HD Euro III	0	0	0	0	1	1	2	2	2	4	4	3	3
HDT	Rigid 26 - 28 t	HD Euro IV	0	0	0	0	0	0	0	0	2	5	8	6	5
HDT	Rigid 26 - 28 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 26 - 28 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 28 - 32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 28 - 32 t	HD Euro I	0	0	0	0	1	1	1	1	0	1	1	1	0
<b>Sector</b>	<b>Subsector</b>	<b>Technology</b>	<b>1990</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
HDT	Rigid 28 - 32 t	HD Euro III	0	0	0	0	1	1	1	1	1	2	4	3	1
HDT	Rigid 28 - 32 t	HD Euro III	0	0	0	0	0	0	1	0	1	2	4	3	1
HDT	Rigid 28 - 32 t	HD Euro IV	0	0	0	0	0	0	0	0	0	0	6	6	3
HDT	Rigid 28 - 32 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid 28 - 32 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid >32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid >32 t	HD Euro I	0	0	0	0	1	1	1	2	0	0	0	0	0
HDT	Rigid >32 t	HD Euro III	0	0	0	0	2	2	2	2	0	2	1	1	1
HDT	Rigid >32 t	HD Euro III	0	0	0	0	1	2	2	2	2	2	1	1	2
HDT	Rigid >32 t	HD Euro IV	0	0	0	0	0	0	0	0	2	2	2	2	3
HDT	Rigid >32 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Rigid >32 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 40 - 50 t	Conventional	0	0	0	0	0	0	1	0	0	0	0	0	0
HDT	Articulated 40 - 50 t	HD Euro I	0	0	0	0	1	1	1	0	0	0	0	0	0
HDT	Articulated 40 - 50 t	HD Euro III	0	0	0	0	0	0	0	1	0	0	0	0	0
HDT	Articulated 40 - 50 t	HD Euro III	0	0	0	0	0	0	0	0	0	1	0	0	1
HDT	Articulated 40 - 50 t	HD Euro IV	0	0	0	0	0	0	0	0	1	1	1	1	1
HDT	Articulated 40 - 50 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 40 - 50 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 50 - 60 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 50 - 60 t	HD Euro I	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 50 - 60 t	HD Euro III	0	0	0	0	0	0	0	0	0	0	0	1	0
HDT	Articulated 50 - 60 t	HD Euro III	0	0	0	0	0	0	0	1	0	0	0	1	0
HDT	Articulated 50 - 60 t	HD Euro IV	0	0	0	0	0	0	0	0	0	0	1	1	1
HDT	Articulated 50 - 60 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
HDT	Articulated 50 - 60 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
Buses	Urban Buses 15-18 t	Conventional	1679	1239	1034	812	611	468	348	247	173	126	98	55	38
Buses	Urban Buses 15-18 t	HD Euro I	0	1521	1373	1294	1202	1106	974	814	663	533	445	388	316
Buses	Urban Buses 15-18 t	HD Euro III	0	997	1593	2044	1918	1845	1756	1625	1511	1371	1264	1121	957
Buses	Urban Buses 15-18 t	HD Euro III	0	0	0	0	469	931	1364	1290	1277	1264	1282	1256	1189
Buses	Urban Buses 15-18 t	HD Euro IV	0	0	0	0	0	0	0	575	1152	1736	2192	2331	2452
Buses	Urban Buses 15-18 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0

Buses	Urban Buses 15-18 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
Buses	Coaches <=18 t	Conventional	1678	1342	1050	813	605	467	348	247	173	126	98	55	38
Buses	Coaches <=18 t	HD Euro I	0	1521	1395	1296	1189	1103	974	814	663	533	445	388	316
Buses	Coaches <=18 t	HD Euro III	0	1081	1620	2047	1898	1841	1756	1625	1511	1371	1264	1121	957
Buses	Coaches <=18 t	HD Euro III	0	0	0	0	463	930	1364	1290	1277	1264	1282	1256	1189
Buses	Coaches <=18 t	HD Euro IV	0	0	0	0	0	0	0	576	1152	1737	2192	2331	2452
Buses	Coaches <=18 t	HD Euro V	0	0	0	0	0	0	0	0	0	0	0	0	0
Buses	Coaches <=18 t	HD Euro VI	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Sector</b>	<b>Subsector</b>	<b>Technology</b>	<b>1990</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
Mopeds	<50 cm³	Conventional	0	7471	8716	9301	8530	8444	7395	4451	3443	2527	1987	1684	1429
Mopeds	<50 cm³	Mop - Euro I	0	0	0	0	0	0	0	1500	1475	1684	1988	1684	1430
Mopeds	<50 cm³	Mop - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	0
Mopeds	<50 cm³	Mop - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	2-stroke >50 cm³	Conventional	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke <250 cm³	Conventional	19371	9447	10036	10292	9638	9535	8817	6605	5885	5561	4937	4397	3738
M.cycles	4-stroke <250 cm³	Mot - Euro I	0	0	0	0	0	0	0	1500	1962	2383	3291	3598	3737
M.cycles	4-stroke <250 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke <250 cm³	Mot - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke 250 - 750 cm³	Conventional	6457	8759	10736	11988	13481	15404	16778	14220	14959	15765	14691	13954	12515
M.cycles	4-stroke 250 - 750 cm³	Mot - Euro I	0	0	0	0	0	0	0	3000	4986	6756	9794	11416	12515
M.cycles	4-stroke 250 - 750 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke 250 - 750 cm³	Mot - Euro III	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke >750 cm³	Conventional	0	1000	1150	1332	1498	1711	1864	1274	1662	1751	1633	1550	1391
M.cycles	4-stroke >750 cm³	Mot - Euro I	0	0	0	0	0	0	0	750	554	751	1088	1269	1390
M.cycles	4-stroke >750 cm³	Mot - Euro II	0	0	0	0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke >750 cm³	Mot - Euro III	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 1990-2011**

**Activity data and emission factors**

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
<b>Clinker production (kilotonnes)</b>																						
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
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
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
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
<b>Total</b>	<b>1,599</b>	<b>1,424</b>	<b>1,371</b>	<b>1,328</b>	<b>1,565</b>	<b>1,601</b>	<b>1,792</b>	<b>2,087</b>	<b>1,930</b>	<b>2,125</b>	<b>3,109</b>	<b>3,386</b>	<b>3,413</b>	<b>3,967</b>	<b>4,283</b>	<b>4,400</b>	<b>4,400</b>	<b>4,441</b>	<b>3,893</b>	<b>2,438</b>	<b>2,053</b>	<b>1,805</b>
<b>Emission Factor t CO<sub>2</sub>/t Clinker Produced</b>																						
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
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
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
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
<b>IEF t CO<sub>2</sub>/t Clinker</b>	<b>0.553</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.549</b>	<b>0.547</b>	<b>0.547</b>	<b>0.545</b>	<b>0.536</b>	<b>0.536</b>	<b>0.536</b>	<b>0.534</b>	<b>0.535</b>	<b>0.541</b>	<b>0.544</b>	<b>0.538</b>	<b>0.535</b>
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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
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
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
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
<b>Total</b>	<b>884</b>	<b>782</b>	<b>753</b>	<b>729</b>	<b>859</b>	<b>879</b>	<b>983</b>	<b>1,145</b>	<b>1,059</b>	<b>1,166</b>	<b>1,701</b>	<b>1,851</b>	<b>1,860</b>	<b>2,127</b>	<b>2,295</b>	<b>2,357</b>	<b>2,348</b>	<b>2,374</b>	<b>2,107</b>	<b>1,327</b>	<b>1,105</b>	<b>966</b>

**Table F.2 Lime Production 1990-2011**

**Activity data and emission factors**

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
<b>Lime production (kilotonnes)</b>																						
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
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
<b>Total</b>	<b>255.2</b>	<b>231.5</b>	<b>215.7</b>	<b>243.0</b>	<b>247.0</b>	<b>223.5</b>	<b>240.1</b>	<b>253.0</b>	<b>256.1</b>	<b>206.6</b>	<b>248.3</b>	<b>243.5</b>	<b>242.4</b>	<b>239.7</b>	<b>246.1</b>	<b>236.2</b>	<b>230.8</b>	<b>251.9</b>	<b>245.6</b>	<b>204.9</b>	<b>251.7</b>	<b>261.2</b>
<b>Emission Factor t CO<sub>2</sub>/t Lime Produced</b>																						
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
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
<b>IEF t CO<sub>2</sub>/t Lime</b>	<b>0.839</b>	<b>0.830</b>	<b>0.753</b>	<b>0.843</b>	<b>0.832</b>	<b>0.839</b>	<b>0.826</b>	<b>0.877</b>	<b>0.826</b>	<b>0.823</b>	<b>0.767</b>	<b>0.778</b>	<b>0.785</b>	<b>0.861</b>	<b>0.819</b>	<b>0.777</b>	<b>0.781</b>	<b>0.781</b>	<b>0.765</b>	<b>0.763</b>	<b>0.765</b>	<b>0.762</b>
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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
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
<b>Total</b>	<b>214.1</b>	<b>192.2</b>	<b>162.4</b>	<b>204.9</b>	<b>205.4</b>	<b>187.5</b>	<b>198.2</b>	<b>221.9</b>	<b>211.7</b>	<b>170.1</b>	<b>190.4</b>	<b>189.4</b>	<b>190.3</b>	<b>206.3</b>	<b>201.5</b>	<b>183.5</b>	<b>180.3</b>	<b>196.7</b>	<b>187.8</b>	<b>156.4</b>	<b>192.4</b>	<b>199.1</b>

**Table F.3 Limestone and Dolomite Use 1990-2011**

**Activity data and emission factors**

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
<b>Limestone use (kilotonnes)</b>																						
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
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
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
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
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
<b>Total</b>	<b>0.343</b>	<b>0.309</b>	<b>0.292</b>	<b>0.240</b>	<b>0.292</b>	<b>0.412</b>	<b>0.377</b>	<b>0.549</b>	<b>0.523</b>	<b>0.575</b>	<b>0.406</b>	<b>10.319</b>	<b>4.976</b>	<b>5.449</b>	<b>8.042</b>	<b>9.828</b>	<b>6.046</b>	<b>5.318</b>	<b>6.196</b>	<b>3.550</b>	<b>2.398</b>	<b>2.409</b>
<b>Emission Factor t CO<sub>2</sub>/t Limestone Use</b>																						
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
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
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
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
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
<b>IEF t CO<sub>2</sub>/t Limestone Use</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.440</b>	<b>0.436</b>	<b>0.436</b>	<b>0.436</b>	<b>0.441</b>	<b>0.437</b>	<b>0.437</b>	<b>0.436</b>	<b>0.437</b>	<b>0.434</b>	<b>0.430</b>	<b>0.433</b>
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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
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
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
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
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
<b>Total</b>	<b>0.151</b>	<b>0.136</b>	<b>0.128</b>	<b>0.106</b>	<b>0.128</b>	<b>0.181</b>	<b>0.166</b>	<b>0.242</b>	<b>0.230</b>	<b>0.253</b>	<b>0.179</b>	<b>4.502</b>	<b>2.171</b>	<b>2.378</b>	<b>3.549</b>	<b>4.292</b>	<b>2.640</b>	<b>2.321</b>	<b>2.707</b>	<b>1.540</b>	<b>1.032</b>	<b>1.042</b>

**Table F.4 Soda ash use 1990-2011**

**Activity data and emission factors**

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
<b>Soda ash used (kilotonnes)</b>																						
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
<b>Emission Factor t CO<sub>2</sub>/t Soda ash used</b>																						
IEF t CO <sub>2</sub> /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
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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

**Table F.5 Glass production 1990-2011**

**Activity data and emission factors**

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
<b>Carbonate use (kilotonnes)</b>																						
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
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
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
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
<b>Total</b>	<b>63.878</b>	<b>63.852</b>	<b>63.260</b>	<b>63.812</b>	<b>63.994</b>	<b>63.707</b>	<b>63.423</b>	<b>63.794</b>	<b>63.360</b>	<b>63.781</b>	<b>63.742</b>	<b>62.758</b>	<b>31.964</b>	<b>1.612</b>	<b>1.727</b>	<b>1.428</b>	<b>1.409</b>	<b>1.299</b>	<b>0.882</b>	<b>0.063</b>	<b>NO</b>	<b>NO</b>
<b>Emission Factor t CO<sub>2</sub>/t Carbonate Use</b>																						
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
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
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
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
<b>IEF t CO<sub>2</sub>/t Carbonate Use</b>	<b>0.209</b>	<b>0.204</b>	<b>0.199</b>	<b>0.196</b>	<b>0.192</b>	<b>0.188</b>	<b>0.183</b>	<b>0.180</b>	<b>0.174</b>	<b>0.172</b>	<b>0.168</b>	<b>0.162</b>	<b>0.161</b>	<b>0.343</b>	<b>0.336</b>	<b>0.337</b>	<b>0.345</b>	<b>0.350</b>	<b>0.348</b>	<b>0.275</b>	<b>NA</b>	<b>NA</b>
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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
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
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
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
<b>Total</b>	<b>13.325</b>	<b>13.056</b>	<b>12.587</b>	<b>12.520</b>	<b>12.307</b>	<b>11.966</b>	<b>11.625</b>	<b>11.465</b>	<b>11.049</b>	<b>10.957</b>	<b>10.714</b>	<b>10.136</b>	<b>5.131</b>	<b>0.553</b>	<b>0.580</b>	<b>0.481</b>	<b>0.487</b>	<b>0.455</b>	<b>0.307</b>	<b>0.017</b>	<b>NO</b>	<b>NO</b>

**Table F.6 Bricks and tiles 1990-2011**

**Activity data and emission factors**

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
<b>Raw material use (clays, shale, bricks and flues) (kilotonnes)</b>																						
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
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
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
<b>Total</b>	<b>110.39</b>	<b>106.43</b>	<b>104.44</b>	<b>98.50</b>	<b>104.44</b>	<b>118.32</b>	<b>114.35</b>	<b>134.17</b>	<b>131.20</b>	<b>137.15</b>	<b>139.79</b>	<b>138.45</b>	<b>127.77</b>	<b>133.07</b>	<b>133.21</b>	<b>158.31</b>	<b>151.55</b>	<b>136.97</b>	<b>82.78</b>	<b>16.35</b>	<b>15.83</b>	<b>22.54</b>
<b>Emission Factor t CO<sub>2</sub>/t Raw Material Use</b>																						
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
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
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
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
<b>IEF t CO<sub>2</sub>/t Raw Material Use</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.046</b>	<b>0.044</b>	<b>0.046</b>	<b>0.046</b>	<b>0.047</b>	<b>0.047</b>	<b>0.049</b>	<b>0.050</b>	<b>0.048</b>	<b>0.033</b>	<b>0.027</b>	<b>0.037</b>
<b>Emissions CO<sub>2</sub> (kilotonnes)</b>																						
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
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
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
<b>Total</b>	<b>5.07</b>	<b>4.88</b>	<b>4.79</b>	<b>4.50</b>	<b>4.79</b>	<b>5.46</b>	<b>5.27</b>	<b>6.23</b>	<b>6.08</b>	<b>6.37</b>	<b>6.49</b>	<b>6.12</b>	<b>5.91</b>	<b>6.12</b>	<b>6.23</b>	<b>7.41</b>	<b>7.40</b>	<b>6.83</b>	<b>4.00</b>	<b>0.53</b>	<b>0.42</b>	<b>0.83</b>



## 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 1990-2011

#### G.6 Input Parameters for the calculation of N<sub>2</sub>O Emissions from Agricultural Soils

#### G.7 Nitrogen application to agricultural soils from sewage sludge (4.D.1.6) 1990-2011

#### G.8 Activity data, parameters and emission factors for N-Fixing Crops (4.D.1.3) 1990-2011

#### G.9 Activity data, parameters and emission factors for Crop Residue (4.D.1.4) 1990-2011

**Table G.1 Animal Populations 1990-2011**

1000 head	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
<b>Total Cattle</b>	<b>6822</b>	<b>6921</b>	<b>6973</b>	<b>6959</b>	<b>6965</b>	<b>7009</b>	<b>7282</b>	<b>7491</b>	<b>7592</b>	<b>7348</b>	<b>7012</b>	<b>7022</b>	<b>6961</b>	<b>6971</b>	<b>6973</b>	<b>6951</b>	<b>6925</b>	<b>6827</b>	<b>6828</b>	<b>6813</b>	<b>6543</b>	<b>6409</b>
<b>Dairy Cows</b>	1341	1309	1262	1256	1247	1239	1241	1227	1216	1187	1165	1165	1146	1146	1139	1025	1054	1054	1060	1060	1049	1086
<b>All Other Cattle</b>	5481	5612	5711	5703	5718	5770	6041	6264	6376	6160	5847	5857	5814	5826	5834	5926	5872	5773	5768	5753	5494	5323
Other Cows	730	801	903	958	990	1022	1098	1183	1222	1192	1171	1178	1153	1166	1179	1121	1171	1185	1198	1169	1115	1093
Dairy Heifers	172	156	187	191	207	230	238	244	226	212	205	202	223	221	234	214	204	197	195	196	234	247
Other Heifers	80	71	106	116	104	123	134	149	128	121	133	140	142	139	142	191	193	212	180	156	170	189
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
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
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
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
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
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
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
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
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
Bulls	27	29	32	36	38	40	44	48	50	51	53	56	59	60	63	61	63	57	54	52	47	38
<b>Total Sheep</b>	<b>8021</b>	<b>8484</b>	<b>8736</b>	<b>8977</b>	<b>8559</b>	<b>8364</b>	<b>8329</b>	<b>8051</b>	<b>8572</b>	<b>8547</b>	<b>7957</b>	<b>7455</b>	<b>6682</b>	<b>6481</b>	<b>6703</b>	<b>6431</b>	<b>6187</b>	<b>5656</b>	<b>5105</b>	<b>4727</b>	<b>4336</b>	<b>4430</b>
Ewes Lowland	2397	2543	2622	2576	2511	2427	2369	2390	3056	2936	2814	2704	2637	2552	2464	2627	2414	2207	2057	1928	1920	1954
Ewes Upland	1961	2080	2145	2108	2055	1986	1938	1955	1310	1258	1206	1159	1130	1094	1056	657	604	552	514	482	480	489
Rams lowland	64	67	70	69	67	66	62	64	81	79	77	75	73	72	70	77	74	69	63	58	59	59
Rams upland	53	55	57	56	55	54	51	52	35	34	33	32	31	31	30	19	19	17	16	14	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	103	103
Other Sheep>1 - upland	134	79	73	81	88	92	86	97	74	66	61	55	55	62	60	31	31	27	28	26	26	26
Lambs - lowland	1787	1960	2024	2194	2022	1994	2044	1856	2692	2815	2535	2312	1838	1768	2019	2317	2339	2140	1853	1693	1387	1428
Lambs - upland	1462	1604	1656	1795	1654	1632	1672	1519	1154	1206	1086	991	788	758	865	579	585	535	463	423	347	357
<b>Total Pigs</b>	<b>1222</b>	<b>1325</b>	<b>1404</b>	<b>1504</b>	<b>1514</b>	<b>1546</b>	<b>1643</b>	<b>1708</b>	<b>1810</b>	<b>1775</b>	<b>1727</b>	<b>1760</b>	<b>1791</b>	<b>1729</b>	<b>1704</b>	<b>1679</b>	<b>1632</b>	<b>1544</b>	<b>1486</b>	<b>1444</b>	<b>1509</b>	<b>1551</b>
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
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
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
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
Boars	6	7	7	6	6	5	5	5	5	4	4	4	3	3	3	2	2	2	2	2	2	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
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
<b>Total Poultry</b>	<b>11413</b>	<b>12338</b>	<b>12913</b>	<b>12712</b>	<b>13675</b>	<b>14078</b>	<b>15016</b>	<b>15189</b>	<b>15327</b>	<b>15130</b>	<b>15321</b>	<b>15663</b>	<b>15183</b>	<b>15788</b>	<b>16743</b>	<b>16042</b>	<b>15426</b>	<b>12839</b>	<b>12839</b>	<b>14923</b>	<b>14923</b>	<b>14658</b>
Layer	1868	1800	2231	1832	1730	1371	1701	1580	1559	1537	1572	1676	1613	1907	1906	1950	1970	1813	1813	2145	2145	2060
Broiler	8035	8905	9067	9522	10393	11092	11730	12096	12287	12200	12426	12629	12322	12672	13375	12818	12360	9696	9696	11904	11904	11520
Turkey	1509	1633	1615	1358	1552	1616	1585	1513	1482	1393	1322	1358	1248	1209	1461	1274	1097	1330	1330	874	874	1078
<b>Horses</b>	<b>62</b>	<b>63</b>	<b>65</b>	<b>66</b>	<b>67</b>	<b>68</b>	<b>70</b>	<b>72</b>	<b>73</b>	<b>76</b>	<b>70</b>	<b>71</b>	<b>73</b>	<b>70</b>	<b>73</b>	<b>80</b>	<b>87</b>	<b>89</b>	<b>99</b>	<b>98</b>	<b>98</b>	<b>98</b>
<b>Mules</b>	<b>8</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>8</b>	<b>7</b>	<b>8</b>	<b>7</b>	<b>8</b>	<b>7</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>7</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>9</b>	<b>9</b>
<b>Goats</b>	<b>17</b>	<b>17</b>	<b>18</b>	<b>18</b>	<b>16</b>	<b>16</b>	<b>15</b>	<b>15</b>	<b>15</b>	<b>14</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>7</b>	<b>7</b>	<b>7</b>	<b>9</b>	<b>10</b>	<b>10</b>	<b>10</b>
<b>Fertiliser (1000's kg/N)</b>	<b>37931</b>	<b>37012</b>	<b>35830</b>	<b>37798</b>	<b>40481</b>	<b>42882</b>	<b>41691</b>	<b>38035</b>	<b>43199</b>	<b>44291</b>	<b>40759</b>	<b>36866</b>	<b>36351</b>	<b>38808</b>	<b>36252</b>	<b>35216</b>	<b>34213</b>	<b>32155</b>	<b>30896</b>	<b>30680</b>	<b>36239</b>	<b>34538</b>
	1	1	2	5	1	6	8	0	9	6	8	7	3	0	5	5	7	3	0	6	5	9

**Table G.2 CH<sub>4</sub> 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
<b>Cattle</b>																							
Dairy cows	535.00	101.38	101.93	102.47	103.02	103.56	104.10	104.65	105.19	105.74	106.28	106.82	107.37	107.91	108.45	108.36	107.84	109.44	109.81	109.99	108.54	112.59	112.77
Beef cows(Suckler Cows)	500.00	74.03	74.04	74.05	74.07	74.08	74.09	74.11	74.12	74.13	74.15	74.16	74.17	74.19	74.20	74.47	74.15	74.28	73.87	74.92	72.78	73.14	74.27
Dairy heifers	388.00	51.82	51.70	51.57	51.44	51.31	51.18	51.06	50.93	50.80	50.67	50.55	50.42	50.29	50.16	50.16	50.16	50.16	50.16	50.16	50.16	50.16	50.16
Beef heifers	450.00	55.42	55.29	55.15	55.02	54.88	54.75	54.62	54.48	54.35	54.22	54.08	53.95	53.82	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68	53.68
Bulls for breeding	500.00	86.38	86.01	85.64	85.27	84.90	84.52	84.15	83.78	83.41	83.03	82.66	82.29	81.92	81.55	81.55	81.55	81.55	81.55	81.55	81.55	81.55	81.55
Male cattle																							
< 1 year	140.00	30.46	30.39	30.31	30.24	30.17	30.09	30.02	29.95	29.88	29.80	29.73	29.66	29.58	29.51	29.70	29.74	29.61	29.69	29.71	29.77	29.11	29.82
1 - 2 years	388.00	62.22	62.09	61.95	61.82	61.69	61.55	61.42	61.29	61.15	61.02	60.89	60.75	60.62	60.49	59.27	58.94	59.88	59.19	59.07	58.57	59.96	58.01
> 2 years*	500.00	55.08	53.47	51.86	50.24	48.63	47.01	45.40	43.79	42.17	40.56	38.95	37.33	35.72	34.10	35.24	37.67	37.78	38.58	36.98	38.84	39.79	38.29
Female cattle																							
< 1 year	140.00	27.05	27.11	27.16	27.22	27.28	27.34	27.40	27.45	27.51	27.57	27.63	27.68	27.74	27.80	27.88	27.86	27.76	27.77	27.59	27.58	26.99	27.61
1 - 2 years	388.00	53.54	52.85	52.17	51.48	50.79	50.10	49.42	48.73	48.04	47.35	46.67	45.98	45.29	44.60	44.49	45.61	46.39	46.60	47.00	47.71	48.62	47.93
> 2 years*	500.00	21.65	21.72	21.78	21.84	21.90	21.96	22.03	22.09	22.15	22.21	22.27	22.33	22.40	22.46	22.46	22.43	22.38	22.42	22.55	22.63	22.63	22.72
<b>Sheep</b>																							
Lowland Ewes		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Upland Ewes		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Rams		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Sheep > 1 yrs		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Lambs		3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
<b>Horses</b>		18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
<b>Mules</b>		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
<b>Goats</b>		5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
<b>Pigs</b>	<b>58.36</b>																						
Gilts in Pig	160.00	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
Gilts not yet Served	120.00	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Sows in Pig	200.00	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
Other Sows for Breeding	210.00	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84	3.84
Boars	225.00	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12	4.12
Pigs > 20 Kg	58.00	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Pigs < 20 Kg	13.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
<b>Poultry</b>	<b>2.37</b>	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<sub>4</sub> 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
<b>Cattle</b>																						
Dairy cows	21.60	21.52	21.43	21.35	21.27	21.18	21.10	21.02	20.93	20.85	20.77	20.68	20.60	20.51	20.49	20.44	20.58	20.58	20.61	20.42	20.80	20.82
Beef cows(Suckler Cows)	14.25	14.23	14.22	14.21	14.20	14.18	14.17	14.16	14.15	14.13	14.12	14.11	14.10	14.08	14.12	14.09	14.11	14.08	14.30	13.83	13.92	14.17
Dairy heifers	13.40	13.21	13.02	12.83	12.64	12.45	12.26	12.07	11.88	11.69	11.50	11.31	11.12	10.93	10.93	10.93	10.93	10.93	10.93	10.93	10.93	10.93
Beef heifers	15.61	15.40	15.19	14.98	14.77	14.56	14.35	14.14	13.93	13.72	13.50	13.29	13.08	12.87	12.87	12.87	12.87	12.87	12.87	12.87	12.87	12.87
Bulls for breeding	23.79	23.42	23.04	22.67	22.30	21.93	21.56	21.18	20.81	20.44	20.07	19.70	19.32	18.95	18.95	18.95	18.95	18.95	18.95	18.95	18.95	18.95
Male cattle																						
< 1 year	9.30	9.21	9.12	9.03	8.94	8.85	8.76	8.67	8.58	8.49	8.40	8.31	8.22	8.13	8.20	8.22	8.55	8.21	8.25	8.30	8.49	8.38
1 - 2 years	16.89	16.69	16.49	16.30	16.10	15.90	15.71	15.51	15.31	15.12	14.92	14.72	14.53	14.33	13.92	13.99	14.08	14.02	13.95	13.88	14.25	13.53
> 2 years*	5.16	4.89	4.61	4.34	4.07	3.79	3.52	3.24	2.97	2.70	2.42	2.15	1.88	1.60	1.77	2.12	1.92	2.25	2.02	2.28	2.38	2.20
Female cattle																						
< 1 year	8.41	8.37	8.33	8.30	8.26	8.22	8.18	8.15	8.11	8.07	8.03	8.00	7.96	7.92	7.93	7.92	7.91	7.91	7.92	7.90	7.88	7.91
1 - 2 years	14.93	14.51	14.09	13.66	13.24	12.82	12.40	11.98	11.56	11.14	10.72	10.30	9.88	9.46	9.22	9.74	9.87	9.91	10.08	10.44	10.76	10.38
> 2 years*	0.33	0.33	0.33	0.33	0.33	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	0.35	0.35	0.35
<b>Sheep</b>																						
Lowland Sheep	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	0.19	0.19	0.19	0.19	0.19	0.19
Upland Sheep	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	0.19	0.19	0.19	0.19	0.19	0.19
Rams	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	0.19	0.19	0.19	0.19	0.19	0.19
Sheep >1 yrs	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	0.19	0.19	0.19	0.19	0.19	0.19
Lambs	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
<b>Horses</b>	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
<b>Mules</b>	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
<b>Goats</b>	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
<b>Pigs</b>																						
Gilts in Pig	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68
Gilts not yet Served	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68
Sows in Pig	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68
Other Sows for Breeding	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92	31.92
Boars	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96
Pigs > 20 Kg	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68	13.68
Pigs < 20 Kg	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
<b>Poultry</b>																						
Layers	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Broilers	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Turkeys	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08

\* 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**

<b>Cattle</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>
<b>Number of days housed</b>																						
Dairy Cows	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	118	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
Dairy Heifer	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
Under1yr	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	222	223	223	230	224
Oneto2yrs	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	155	157	157	154
Over2yrs	23	23	23	23	23	23	23	23	23	23	23	23	23	23	25	29	28	31	29	31	32	28
Bulls	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	155	157	157	154
<b>Number of days grazing</b>																						
Dairy Cows	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	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
Dairy Heifer	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
Under1yr	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	143	142	142	135	141
Oneto2yrs	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	210	208	208	211
Over2yrs	342	342	342	342	342	342	342	342	342	342	342	342	342	342	340	336	337	334	336	334	333	337
Bulls	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	210	208	208	211
<b>Proportion to each AWMS</b>																						
<b>Liquid</b>																						
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
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
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
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
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
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
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
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
<b>Solid</b>																						
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
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
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
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
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
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
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
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
<b>Pasture</b>																						
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
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
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
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
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
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	0.57	0.58	0.57	0.57	0.57	0.57	0.57	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
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

**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
<b>Sheep</b>								
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
<b>Pigs</b>								
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
<b>Poultry</b>								
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
<b>Horses</b>	143.00	100.00	0.00	0.00	100.00	0.00	0.39	0.61
<b>Mules and Asses</b>	143.00	100.00	0.00	0.00	100.00	0.00	0.39	0.61
<b>Goats</b>	0.00	0.00	100.00	0.00	0.00	0.00	0.00	1.00

**Table G.5 Nitrogen excretion values for Livestock 1990-2011**

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
	N excretion values																					
Dairy Cows	95.54	95.89	96.25	96.61	96.96	97.32	97.68	98.03	98.39	98.75	99.10	99.46	99.81	100.17	99.97	97.79	99.97	100.35	100.75	99.70	101.63	102.12
Suckler Cows	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	
Dairy Heifer	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	
Other Heifer	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	74.43	
Under1yr	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	27.61	
One to 2yrs	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	63.44	
Over 2yrs	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	37.22	
Bulls	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	73.78	
Ewes Lowland	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	12.31	
Ewes Upland	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	6.49	
Rams - lowland	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	
Rams - upland	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	
Other Sheep>1 - lowland	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	6.48	
Other Sheep>1 - upland	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	4.21	
Lambs - lowland	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	
Lambs - upland	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	
Gilts in pig	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	
Gilts not yet served	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	
Sows in pig	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	
Other breeding sows	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	
Boars	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	
Fatteners > 20 kg	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	
Fatteners < 20 kg	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
Laying hen per bird place	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	
Broiler per bird place	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	
Turkey per bird place	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	
Horses	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	
Mules	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	
Goats	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	12.93	

**Table G.6 Input Parameters for the calculation of N<sub>2</sub>O 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
<b>Frac<sub>GASF</sub></b>	0.028	0.029	0.034	0.029	0.027	0.024	0.025	0.025	0.025	0.026	0.026	0.026	0.026	0.024	0.023	0.022	0.023	0.021	0.025	0.031	0.029	0.036
<b>Frac<sub>GRAZ</sub></b>	0.635	0.634	0.637	0.635	0.634	0.632	0.629	0.626	0.628	0.631	0.632	0.628	0.625	0.627	0.627	0.615	0.618	0.616	0.614	0.613	0.614	0.615
<b>Frac<sub>GASM1</sub></b>	0.358	0.359	0.360	0.361	0.360	0.361	0.361	0.361	0.362	0.362	0.363	0.363	0.363	0.363	0.363	0.361	0.362	0.362	0.362	0.361	0.358	0.360
<b>Frac<sub>GASM2</sub></b>	0.056	0.055	0.054	0.054	0.054	0.054	0.054	0.054	0.053	0.053	0.054	0.054	0.054	0.054	0.054	0.053	0.054	0.055	0.055	0.055	0.056	0.056
<b>Frac<sub>GASM</sub></b>	0.166	0.166	0.165	0.166	0.167	0.167	0.168	0.169	0.168	0.167	0.167	0.169	0.170	0.170	0.169	0.172	0.172	0.173	0.173	0.173	0.172	0.173
<b>F<sub>BN</sub> (tonnes/year)</b>	512	443	443	887	853	648	733	662	1105	628	263	304	256	467	491	645	682	437	379	757	853	563
<b>Frac<sub>LEACH</sub></b>	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	0.100	0.100
<b>F<sub>SN</sub> (tonnes/year)</b>	368663	359336	346225	367122	393812	418564	406692	370788	421025	431229	397104	359131	354236	378766	354310	344517	334296	314906	301205	297394	351805	333048
<b>F<sub>AM</sub> (tonnes/year)</b>	107842	109769	110508	111048	111621	112893	117309	121605	123434	118830	113612	114759	115201	114627	114907	116025	114685	113162	113518	113045	110380	108401
<b>F<sub>S</sub> (tonnes/year)</b>	106	106	107	108	108	97	92	255	365	569	741	933	1104	1229	1688	1840	1913	1952	1990	2028	2065	2101
<b>F<sub>CR</sub> (tonnes/year)</b>	19692	19001	19335	16199	17934	19439	20849	19969	19917	21127	21683	19743	17757	19963	23569	17959	10551	10244	11741	10482	10792	12170

**Table G.7 Nitrogen application to agricultural soils from sewage sludge (4.D.1.6) 1990-2011**

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
<b>N applied (t/year)</b>	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

Table G.8 Activity data, parameters and emission factors for N-Fixing Crops (4.D.1.3) 1990-2011

	Pulses yield Crop <sub>BF</sub>	Residue/ Crop Product mass ratio (Res <sub>BF</sub> )	Residue/ Crop Product mass ratio (Res <sub>BF</sub> )	Fraction Dry matter (Frac <sub>DM</sub> )	Fraction of crop biomass that is nitrogen (Frac <sub>NCRBF</sub> )	Nitrogen Fixed by Crops F <sub>BN</sub>	EF <sub>1</sub>	Emissions
	tonnes		(1 + Res <sub>BF</sub> )			kg N <sub>2</sub> O-N/yr		Gg N <sub>2</sub> O
	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 
$$FBN = \sum i [CropBFi * \left(1 + \frac{ResBFi}{CropBFi}\right) * FracDMi * FracNCRBFi]$$

**Table G.9 Activity data, parameters and emission factors for Crop Residue (4.D.1.4) 1990-2011**

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Crop j	tonnes																					
Pulses	15,000	13,000	13,000	26,000	25,000	19,000	21,500	19,400	32,400	18,400	7,700	8,900	7,500	13,700	14,400	18,900	20,000	12,800	11,100	22,200	25,000	16,500
Potatoes	605,000	571,000	638,000	569,000	642,000	618,000	733,300	471,900	482,100	558,600	454,800	477,600	518,600	488,200	552,200	409,200	382,900	399,000	344,900	336,100	419,600	356,100
Sugarbeet	1,480,000	1,409,000	1,397,000	1,117,000	1,390,000	1,547,000	1,475,600	1,648,200	1,640,000	1,712,100	1,829,000	1,498,000	1,300,700	1,505,200	1,861,400	1,380,000	NO	NO	NO	NO	NO	NO
Barley	1,223,000	1,148,000	1,168,000	958,000	910,000	1,084,000	1,224,600	1,087,200	1,072,900	1,277,500	1,309,900	1,277,200	962,800	1,197,700	1,326,600	1,024,400	1,136,900	1,124,500	1,294,200	1,227,300	1,223,000	1,412,100
Oats	144,000	143,000	136,000	129,000	128,000	129,000	146,100	131,600	119,100	136,400	126,600	118,700	133,600	155,100	155,200	112,800	145,200	159,100	174,300	145,700	148,100	168,100
Wheat	598,000	673,600	714,000	539,000	572,000	583,000	771,200	724,500	673,000	597,400	737,400	769,200	867,200	794,100	1,019,200	802,700	801,000	713,400	992,900	690,100	669,200	929,300
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
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
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
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
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
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
Fraction Dry matter (Frac <sub>DM</sub> )																						
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
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
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
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
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
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
Fraction of crop biomass that is nitrogen (Frac <sub>NCRBF</sub> )																						
Pulses	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140	0.0140
Potatoes	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110	0.0110
Sugarbeet	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230
Barley	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043
Oats	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070
Wheat	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028	0.0028
Crop Residues (F <sub>CR</sub> )	kg N <sub>2</sub> O-N/yr																					
Pulses	328,860	285,012	285,012	570,024	548,100	416,556	471,366	425,326	710,338	403,402	168,815	195,124	164,430	300,359	315,706	414,364	438,480	280,627	243,356	486,713	548,100	361,746
Potatoes	2,262,700	2,135,540	2,386,120	2,128,060	2,401,080	2,311,320	2,742,542	1,764,906	1,803,054	2,089,164	1,700,952	1,786,224	1,939,564	1,825,868	2,065,228	1,530,408	1,432,046	1,492,260	1,289,926	1,257,014	1,569,304	1,331,814
Sugarbeet	8,680,200	8,263,785	8,193,405	6,551,205	8,152,350	9,073,155	8,654,394	9,666,693	9,618,600	10,041,467	10,727,085	8,785,770	7,628,606	8,827,998	10,917,111	8,093,700	NO	NO	NO	NO	NO	NO
Barley	5,364,078	5,035,128	5,122,848	4,201,788	3,991,260	4,754,424	5,371,096	4,768,459	4,705,739	5,603,115	5,745,221	5,601,799	4,222,841	5,253,112	5,818,468	4,493,018	4,986,443	4,932,057	5,676,361	5,382,938	5,364,078	6,193,471
Oats	1,205,568	1,197,196	1,138,592	1,079,988	1,071,616	1,079,988	1,223,149	1,101,755	997,105	1,141,941	1,059,895	993,756	1,118,499	1,298,497	1,299,334	944,362	1,215,614	1,331,985	1,459,240	1,219,800	1,239,893	1,407,333
Wheat	1,850,212	2,084,118	2,209,116	1,667,666	1,769,768	1,803,802	2,386,093	2,241,603	2,082,262	1,848,356	2,281,516	2,379,905	2,683,117	2,456,945	3,153,405	2,483,554	2,478,294	2,207,260	3,072,033	2,135,169	2,070,505	2,875,254
EF <sub>i</sub>	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
Emissions	Gg N <sub>2</sub> O																					
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
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
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
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
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
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
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

$$\text{IPCC Equation 4.29 Tier 1b } \text{FCR} = \sum j [\text{Crop } j * \left( \frac{\text{Res } j}{\text{Crop } j} \right) * \text{FracDM } j * \text{FracNCRO } j] + \sum j [\text{CropBF } j * \left( \frac{\text{ResBF } j}{\text{CropBF } j} \right) * \text{FracDM } j * \text{FracNCRBF } j]$$

## 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.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 ( $\pm 1$  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

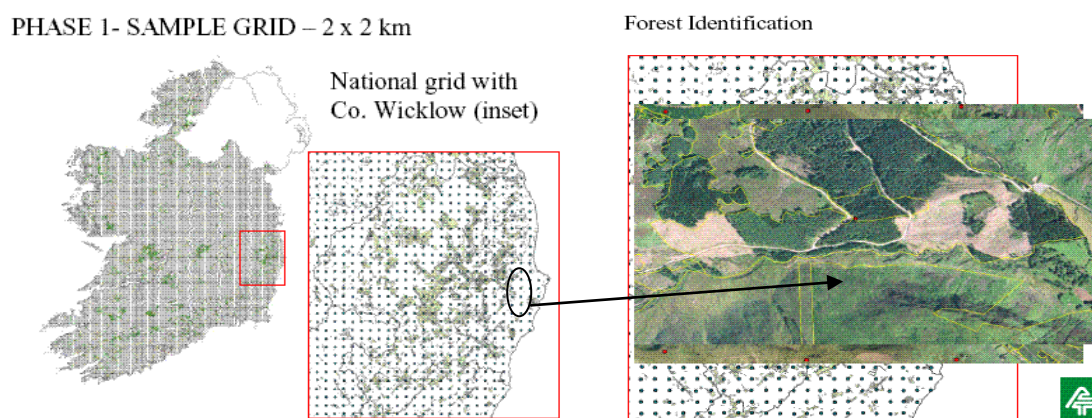
Despite the above mentioned inappropriateness of CLC for reporting areas under LULUCF in a consistent, representative and accurate manner, this methodology uses the only data currently available to track historic land use change (see chapter 7).

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 than 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)

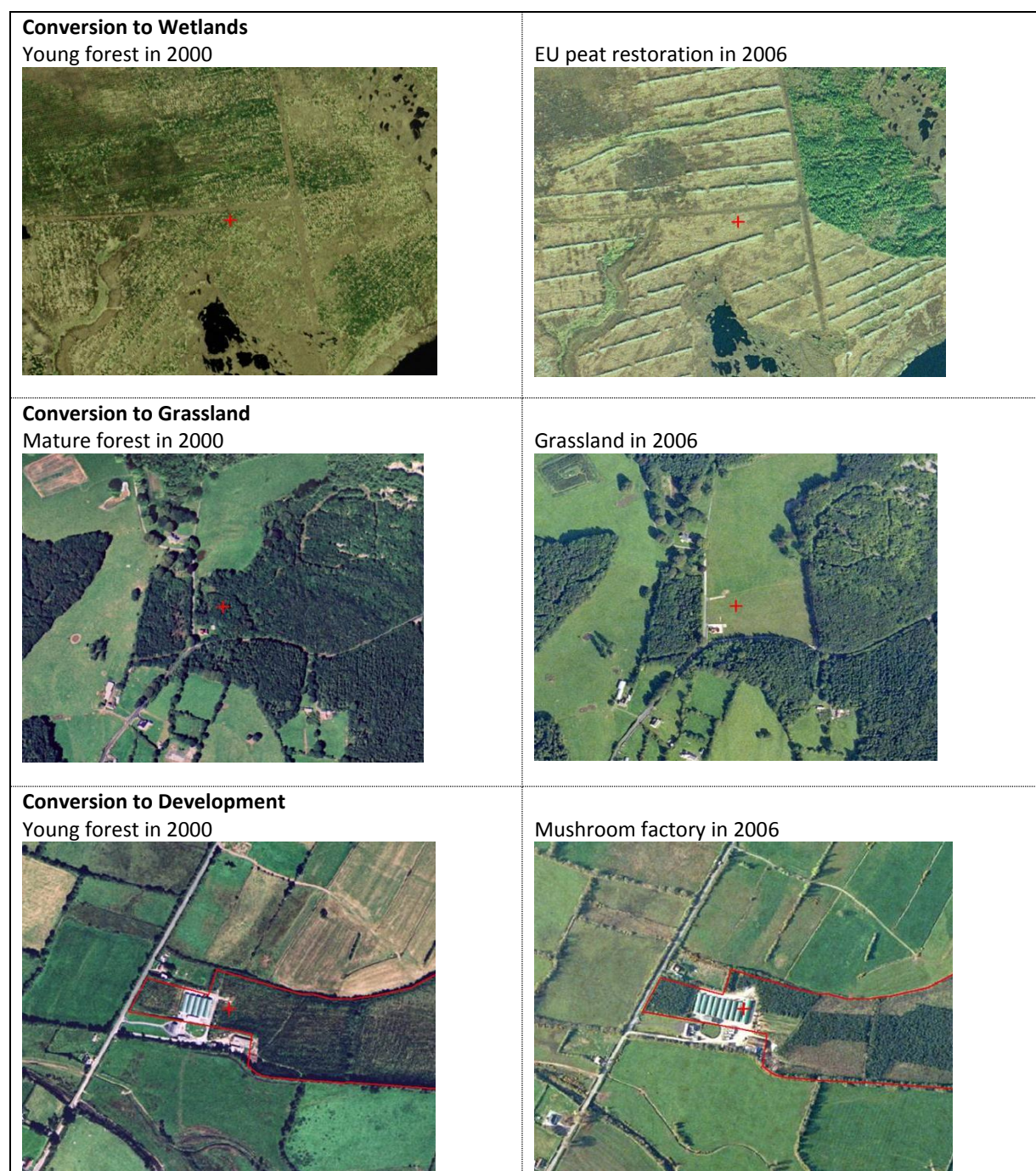
This sampling approach is a modification of approach 3, where the grids or centroids are sampled using a systematic sampling procedure adopted in the NFI. Note:

- 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.

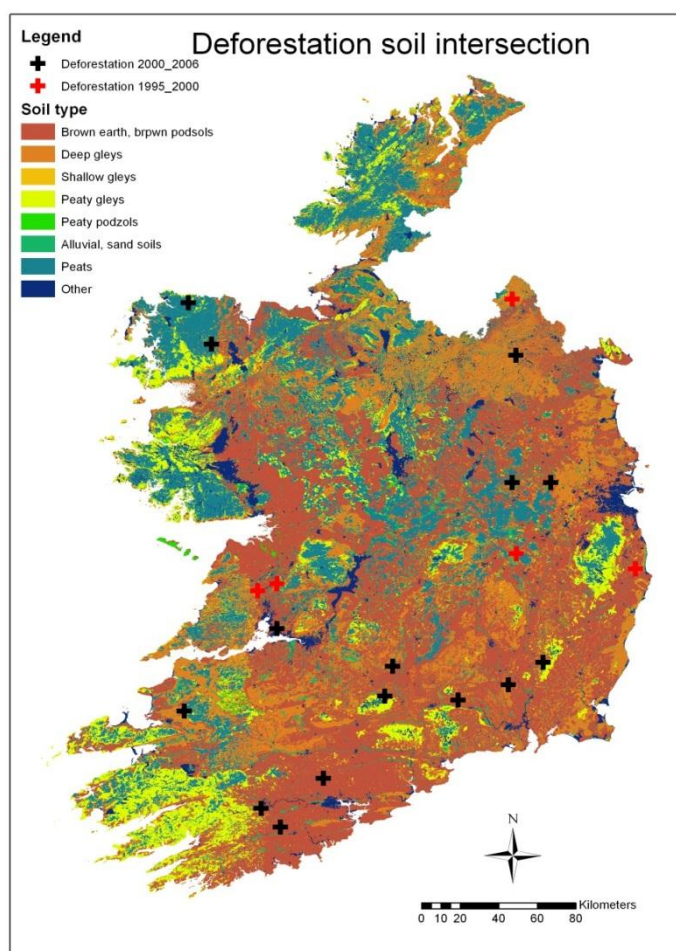


*Figure H.2: Examples of NFI PSP (as indicated by the red cross) which were classified forests in 2000 but have since been converted to other land uses in 2006*

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
<b>1990-1994</b>	<b>CLC1990-2000</b>			<b>20.6<sup>11</sup></b>	<b>100</b>
		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		
<b>1995-1999</b>	<b>NFI-FIPs 95</b>			<b>333.3<sup>12</sup></b>	<b>100</b>
		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
<b>2000-2005</b>	<b>NFI-2000-2006</b>			<b>857.1<sup>13</sup></b>	<b>100</b>

<sup>11</sup> The CLC 1990-1994 area was calculated using the values show in table 1a to be, where annual deforestation

$$\text{area 1990-1994} = \frac{\text{area1990} \rightarrow 2000}{10 \times 5} \times 5$$

<sup>12</sup> NFI 1995-1999 area was calculated using the values show in table 2a to be, where the annual deforested area

$$1995-1999 = \frac{\text{area1995} \rightarrow 2000}{6 \times 5} \times 5$$

<sup>13</sup> NFI 2000-2005 area was calculated using the values show in table 2b to be, where the annual deforested area

$$2000-2005 = \frac{\text{area2000} \rightarrow 2006}{7 \times 6} \times 6$$

		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
<b>2006</b>	<b>Felling licence and land taken out</b>			<b>376.44</b>	<b>100</b>
	242.34+134.1	Grassland	Mineral	5.3	1.4
	(LFL+LTO) <sup>14</sup>	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
<b>2007</b>	<b>Felling licence and land taken out</b>			<b>338.7</b>	<b>100</b>
	174.83+163.9	Grassland	Mineral	0.6	0.2
	(LFL+LTO) <sup>4</sup>	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		
<b>2008</b>	<b>Felling licence and land taken out</b>			<b>294.5</b>	<b>100</b>
	26.42+268	Grassland	Mineral	80.2	27.2
	(LFL+LTO) <sup>4</sup>	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

<sup>14</sup> 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
<b>2009</b>	<b>Felling licence and land taken out</b>			<b>196.9</b>	<b>100</b>
	49.9+147	Grassland	Mineral	5.1	2.6
	(LFL+LTO) <sup>4</sup>	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
<b>2010</b>	<b>Felling licence and land taken out</b>			<b>124</b>	<b>100</b>
	26+98	Grassland	Mineral	39.7	39.1
	(LFL+LTO) <sup>4</sup>	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

## 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 1990-2011

I.3 Parameters, EFs for Clinical Waste Incineration 1990-2011

I.4 Parameters, EFs for Solvent (Liquid/Vapour destruction) Waste Incineration 1990-2011

**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 2011	MSW Total (t)	MSW 2011 (t)	<sup>a</sup> DOC Fraction	DOC <sub>i</sub>	<sup>b</sup> Decay Rate k	<sup>c</sup> MCF
1	From 1969	13	1956-2011	Open	7,305,377	238,042	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	0.40-0.67, 1.0
2	From 1979	10	1972-2011	Open	6,977,068	194,421	0.15, 0.40, 0.43, 0.24	0.60	0.20, 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, 0.40, 0.43, 0.24	0.60	0.20, 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, 0.40, 0.43, 0.24	0.60	0.20, 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, 0.40, 0.43, 0.24	0.60	0.20, 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, 0.40, 0.43, 0.24	0.75	0.20, 0.07, 0.04, 0.07, 0.10	1.0
7	W0127	1	1976-2001	Closed	4,812,569	NO	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	0.8,1.0
8	W0009	1	1971-2011	Open	3,583,860	46,051	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	0.8,1.0
9	W0012	1	1965-2009	Closed	2,675,434	NO	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	0.8,1.0
10	W0081	1	1999-2011	Open	2,015,205	81,466	0.15, 0.40, 0.43, 0.24	0.75	0.20, 0.07, 0.04, 0.07, 0.10	1.0
12	W0047	1	1996-2010	Closed	2,123,265	NO	0.15, 0.40, 0.43, 0.24	0.60	0.2, 0.07, 0.04, 0.07, 0.10	0.6
11	New Sites	10	1995-2011	Open	7,537,540	758,857	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	1.0
13	Town Dumps	~250	1956-1998	Closed	15,372,064	NO	0.15, 0.40, 0.43, 0.24	0.60	0.20, 0.07, 0.04, 0.07, 0.10	0.4
14	Sewage Sludge	1	1990-2011	Open	314,302	2,159	0.05	0.60	0.20	0.8,1.0
15	Street Cleanings	1	1990-2011	Open	1,611,423	22,291	0.20	0.60	0.10	0.8,1.0

**a** The four values are for food, paper, wood and straw, textiles and disposable nappies

**b** The five values are for food, 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 1990-2011**

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 Organic %	MSW Paper %	MSW Wood %	MSW Textiles %	MSW Nappies %	MSW Other %	MSW Organic tonnes	MSW Paper tonnes	MSW Wood tonnes	MSW Textiles tonnes	MSW Nappies <sup>a</sup> tonnes	MSW Other tonnes
1990	3,505,800	1.4	2,037,978	0.92	1,878,358	46,959	16,365	39.3%	29.5%	5.2%	9.8%	0.0%	16.3%	756,805	567,893	99,436	187,836		313,348
1991	3,525,700	1.4	2,020,416	0.92	1,862,172	46,554	16,458	37.7%	29.6%	5.2%	8.0%	0.0%	19.5%	720,201	565,619	98,579	152,700		371,628
1992	3,554,500	1.4	2,000,684	0.92	1,843,986	46,100	16,592	36.2%	29.8%	5.2%	6.2%	0.0%	22.7%	683,379	562,688	97,616	118,019		428,384
1993	3,574,100	1.4	2,026,906	0.92	1,868,154	46,704	16,684	34.6%	29.9%	5.2%	4.5%	0.0%	25.9%	662,157	572,689	98,895	85,941		495,175
1994	3,585,900	1.4	2,136,712	0.92	1,969,360	49,234	16,739	33.0%	30.0%	5.2%	2.7%	0.0%	29.1%	666,215	606,484	104,253	55,151		586,491
1995	3,601,300	1.4	2,067,106	0.92	1,905,206	46,791	16,489	31.4%	30.2%	4.5%	1.0%	1.0%	31.9%	613,637	589,328	88,157	19,063	19,063	622,750
1996	3,626,100	1.4	2,716,562	0.92	2,493,238	58,194	16,798	28.9%	28.2%	3.9%	0.9%	0.9%	37.1%	738,510	719,521	99,249	23,990	22,451	947,710
1997	3,664,300	1.5	2,786,165	0.91	2,546,292	69,596	23,529	27.4%	28.7%	3.3%	1.0%	0.9%	38.7%	717,856	751,077	87,196	25,892	22,741	1,011,128
1998	3,703,100	1.5	2,572,473	0.91	2,341,001	80,999	24,213	25.8%	28.9%	2.8%	1.0%	0.8%	40.6%	625,701	699,309	68,358	24,822	20,514	983,296
1999	3,741,600	1.7	2,291,958	0.90	2,052,870	80,156	28,400	25.9%	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%	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%	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%	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%	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	33.0%	26.9%	0.9%	4.2%	3.5%	31.5%	645,648	526,192	18,107	82,845	68,759	617,110
2005	4,133,800	2.0	2,962,364	0.65	1,937,844	23,875	3,192	32.8%	26.8%	0.9%	4.2%	3.4%	31.8%	643,995	525,176	17,651	83,235	67,385	624,277
2006	4,232,900	2.2	3,304,329	0.64	2,110,955	30,366	1,962	33.5%	25.5%	0.9%	4.4%	3.7%	32.0%	716,385	547,100	19,510	93,751	78,400	686,175
2007	4,339,000	2.1	3,458,182	0.63	2,194,800	70,334	2,002	38.8%	20.6%	1.5%	6.6%	4.4%	28.1%	879,361	466,316	33,264	149,983	98,660	637,550
2008	4,422,100	2.0	3,314,128	0.62	2,070,075	24,969	2,041	33.1%	23.2%	1.5%	6.3%	4.8%	31.1%	694,156	486,831	30,588	131,127	100,014	652,329
2009	4,459,300	1.8	3,010,663	0.61	1,837,004	26,701	2,081	34.7%	20.8%	1.5%	6.2%	5.0%	31.8%	646,366	388,011	27,255	116,165	92,395	593,513
2010	4,470,700	1.7	2,554,463	0.58	1,480,512	18,713	2,120	35.4%	21.7%	0.9%	6.2%	4.7%	31.0%	531,183	325,051	13,982	92,794	70,898	465,318
2011	4,588,252	1.6	2,275,510	0.58	1,318,837	22,291	2,159	34.3%	23.0%	0.9%	6.2%	4.7%	30.9%	460,020	308,441	12,189	83,169	62,948	414,361

<sup>a</sup> 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 1990-2011

	Quantity of Clinical Waste (SW <sub>CW</sub> )	Dry Matter content of Clinical Waste (dm <sub>CW</sub> )	Fraction of Carbon in the dry matter as % (CF <sub>CW</sub> )	Fraction of fossil carbon in total carbon as % (FCF <sub>CW</sub> )	Oxidation Factor (OF <sub>CW</sub> )	Emissions CO <sub>2</sub> (Fossil)
	Gg					Gg CO <sub>2</sub>
	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

Equation 5.1, 2006 IPCC Guidelines:  $CO_2 \text{ emissions} = \sum i (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$

*i*, type of waste incinerated (CW: Clinical Waste)

**Table I.4 Parameters, EFs for Solvent (Liquid/Vapour destruction) Waste Incineration 1990-2011**

	Quantity of Fossil Liquid Waste (SW <sub>i</sub> )	Dry Matter content of Fossil Liquid Waste (dm <sub>i</sub> )	Fraction of Carbon in the dry matter as % (CF <sub>i</sub> )	Fraction of fossil carbon in total carbon as % (FCF <sub>i</sub> )	Oxidation Factor (OF <sub>i</sub> )	Emissions CO <sub>2</sub>
	Gg					Gg CO <sub>2</sub>
	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	21.378	NA	80.00	100.00	1.000	62.709
2010	18.237	NA	80.00	100.00	1.000	53.495
2011	18.237	NA	80.00	100.00	1.000	53.495

Equation 5.1, 2006 IPCC Guidelines: 
$$\text{CO}_2 \text{ emissions} = \sum i (SW_i * dm_i * CF_i * FCF_i * OF_i) * \frac{44}{12}$$



## Annex J

### Ireland's Response to the Recommendations in the UNFCCC Annual Review Reports

J.1 for Submission 2010

J.2 for Submission 2011

**Table J.1 Ireland's Response to the recommendations in the UNFCCC Annual Review Report for Submission 2010**

Sector	Issue	ARR Paragraph	Recommendation	Party response	NIR Section
General	Completeness	11	The ERT noted that Ireland had reported the emissions for some categories as not estimated (NE), including CO <sub>2</sub> , N <sub>2</sub> O and CH <sub>4</sub> emissions from the use of solid fuels in navigation and CO <sub>2</sub> emissions from refining/storage and distribution of oil products (the Party informed the ERT that emissions from these two categories are negligible. In accordance with the information provided by Ireland in the previous review report <sup>4</sup> , the ERT recommends that the Party revise the notation key used for these categories, and consider replacing "NE" to "NO" (not occurring) if appropriate justifications are provided in the NIR of its next annual submission. The Party also reported CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions from petrol distribution as "NE" (reported under other non-specified fugitive emissions from oil and natural gas). The Party did, however, provide explanations to the ERT during the centralized review that these emissions are included under production/processing (natural gas). Finally, Ireland did not estimate N <sub>2</sub> O emissions from industrial, domestic and commercial wastewater, and the ERT recommends that Ireland provide estimates of N <sub>2</sub> O emissions from the domestic fraction in its next annual submission (see paragraph 101 below) Generally, the ERT recommends that the Party revise the notation keys used and the explanations provided in the CRF tables for its next annual submission.	Notation keys have been corrected in the CRF Submission for 2011. Estimates for N <sub>2</sub> O from domestic wastewater are reported under "human sewage". Ireland will consider providing estimates for the industrial and commercial fraction of wastewater in its 2012 submission.	
General	Completeness	12	The ERT encourages the Party to continue its efforts to include emission estimates for other categories for which there are no methodologies 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 CO <sub>2</sub> emissions from asphalt roofing, road paving with asphalt, and food and drink, N <sub>2</sub> O emissions from the use of N <sub>2</sub> O from anaesthesia, and N <sub>2</sub> O from industrial and commercial wastewater.	This will be considered for the 2012 submission.	
General	Inventory preparation: Key Categories	20	The results of the key category analysis are discussed in the NIR and are used as a driving factor for the prioritization of improvements in the national inventory. The ERT encourages Ireland to consider undertaking a tier 2 key category analysis and to discuss the use of elements from a qualitative approach.	This will be considered for the 2012 submission.	

LULUCF	Inventory preparation: Uncertainties	21	Ireland performed and reported a tier 1 uncertainty analysis for the year 2008 and for the uncertainty of the trend in the period 1990-2008 in accordance with the IPCC good practice guidance. The ERT welcomes the information on the uncertainty of emission factors (EFs) and AD provided in table 1.9 of the NIR. The level of category disaggregation corresponds to the level used in the key category analysis, which the ERT finds appropriate except for the LULUCF sector. In fact, the ERT noted that, although the LULUCF sector is considered in the uncertainty analysis in line with the recommendations from the previous review report, overall emissions/removals for the LULUCF sector are disaggregated in only two categories: "liming" and "LULUCF excluding liming". The ERT encourages Ireland to further disaggregate the LULUCF categories for the purposes of the uncertainty analysis in its next annual submission. The ERT further noted that detailed uncertainty estimates for LULUCF activities under Article 3, paragraph 3, of the Kyoto Protocol were provided in chapter 11 of the NIR, also using a tier 1 approach.	This will be considered for the 2012 submission. The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011.	
General	Inventory preparation: Uncertainties	22	The overall uncertainty of the inventory in 2008 was estimated at 6.4 per cent, which corresponds closely to the uncertainty estimates reported in previous submissions (5.9 per cent in 2009 and 6.1 per cent in 2008). The uncertainty in the trend reported in the 2010 submission is slightly higher (4.7 per cent) in comparison with the corresponding estimates reported in the 2008 and 2009 submissions, which were 3.8 and 3.6 per cent, respectively. The ERT encourages the Party to analyse the reasons behind this increase in uncertainty.	Improved explanation of uncertainties and trend are provided in NIR 2011.	Chapter 1, section 1.7.
General	Inventory preparation: Uncertainties	23	The ERT noted that some emission estimates for 2008 reported in table 1.9 of the NIR and used in the uncertainty analysis do not correspond to the numbers provided in the CRF tables for the same categories: for example, emission estimates for liming are reported as 262.21 Gg CO <sub>2</sub> eq in CRF table 5(IV) but as 376.77 Gg CO <sub>2</sub> eq in the NIR. The ERT recommends that Ireland check and improve the consistency of data between the NIR and the CRF tables in its next annual submission.	These errors are corrected in the Uncertainty analysis for 2011.	Chapter 1, Table 1.9.
IP and LULUCF, Art 7.1 KP	Inventory preparation: Verification and QA/QC	28	Summary information on the QA/QC system and procedures is provided in section 1.6 of the NIR. Additional information on QA/QC activities in individual sectors is provided for the energy, agriculture and waste sectors. Reiterating the recommendations from the previous review report, the ERT recommends that the Party also include sector specific information for the industrial processes and LULUCF sectors in its next annual submission. The ERT noted an improvement in the level of detail of the information on QA/QC procedures relating to EU ETS data, but considers that the information provided in the NIR is still insufficient to fulfil the recommendations from the previous review report, (i.e. the NIR did not include information on which tier approach from the EU ETS guidelines was used) and encourages the Party to continue its efforts in that regard.	Sector specific QA/QC for the Industrial Processes sector is now documented in NIR 2011. Additional information on the use of EU ETS data is provided for the Power Generation sector of Energy Industries.	Chapter 4, section 4.6. Chapter 3, section 3.2.1.1.

General	Inventory preparation: Transparency	31, 32	<p>(31) The ERT noted some inconsistencies between the information in the NIR and the CRF tables, such as information on some categories reported as "NE" and the use of notation keys (see para. 11 above). Based on the information included in CRF summary table 3, the ERT noted that data is largely consistent, although inconsistencies were identified in relation to the methods used: e.g. CH<sub>4</sub> and N<sub>2</sub>O emissions from energy industries were reported as estimated using tier 2 (T2) and tier 3 (T3) in the NIR, but as using tier 1 (T1) and T2 in the CRF tables; CO<sub>2</sub> emissions from fugitive emissions from oil and natural gas were reported as estimated using country-specific ("CS") in the NIR but as not applicable ("NA") in the CRF tables; and CO<sub>2</sub> EFs in manufacturing industries and construction were reported as CORINAIR ("CR") in the NIR but as "CS" in the CRF tables.</p> <p>(32) The ERT recommends that Ireland make efforts to harmonize the reported information between the NIR and the CRF tables in its next annual submission.</p>	Inconsistencies between the use of Notation Keys and data reported in the NIR have been corrected in submission 2011.	Chapter 1, Tables 1.4 and 1.5. and CRF Submission 2011.
General	Inventory management	33	The ERT found that information provided in the NIR on the archiving system is not fully detailed and transparent. During the centralized review, Ireland explained to the ERT that all 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, which is the single national entity and has overall responsibility for inventory submissions and data archiving. All background data for recent years is available in electronic format. All data (emission estimates, AD, inventory submissions, references, QA/QC) on the data server are backed up daily. The ERT recommends that Ireland include this information in the NIR of its next annual submission.	Additional information is provided in NIR 2011.	Chapter 1, section 1.3.2.
Energy	Sector overview	42	Ireland's inventory for the energy sector is complete and generally transparent and has been prepared in accordance with the 1996 Revised IPCC Guidelines, the IPCC good practice guidance and the UNFCCC reporting guidelines. The ERT identified areas for improvement and recommends that the Party improve transparency in the energy sector by providing more information on methods that would enhance the understanding of the inventory and its estimates (see paras. 51, 56-58 below).	See below.	
Energy	Sector overview	44	Ireland reports having used EU ETS data to prepare emission estimates for the total CO <sub>2</sub> emissions from energy industries. Further, in the NIR, Ireland states that all plants included use high tier methods (defined as high tier in accordance with EU ETS rules. During the centralized review, the ERT enquired as to whether high tier methods were used for all fuels. Ireland responded that for minor fuels, lower-tier methods were in fact used. The ERT recommends that the Party clarify this issue in the next annual submission.	Additional information is provided in NIR 2011.	Chapter 3, section 3.2.1.1.
Energy	Sector overview	45	The ERT identified another problem: for peat briquettes production, only peat consumption is included in the category manufacture of solid fuels and other energy industries, while all other fuels are reported under other (manufacturing industries and construction). The ERT finds this approach inconsistent and recommends that Ireland report all fuel consumption and emissions from peat briquettes production in the category manufacture of solid fuels and other energy industries. Additionally, the ERT identified discrepancies between the energy consumption reported under the EU ETS and under the energy balance (see para. 48 below).	The inventory agency will work with the energy Balance provider to improve the allocation of fuels in the EB for peat briquette production for the fuel: Gasoil. The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011.	

Energy	Reference and sectoral approaches	47, 48	<p>(47) In 2008, CO<sub>2</sub> emissions calculated using the reference approach were 0.2 per cent lower than emissions estimated in accordance with the sectoral approach. The difference between energy consumption was 0.4 per cent. For all years of the period 1990–2008, the differences between both approaches in fuel consumption and CO<sub>2</sub> emissions are below 2 per cent.</p> <p>(48) However, as identified in previous review report, there are some discrepancies between International Energy Agency (IEA) data and the data reported in the CRF tables related to energy consumption. Since the differences between the sectoral and the reference approaches are very small, and in its 2010 submission Ireland has used data directly from the IEA/Eurostat questionnaire, the difference between the IEA data and the CRF data could be due to differences in the net calorific values used. The ERT recommends that Ireland verify what are the reasons for the difference and report on the outcome of the analysis in its next annual submission.</p>	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency will work with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	
Energy	Reference and sectoral approaches: International bunker fuels	51	The ERT considers that the Party has not yet improved the explanation of the method used to distinguish between emissions from domestic and international navigation bunkers, which was recommended in the previous review report. The ERT again recommends that Party explain in detail how emissions from domestic and international segments are disaggregated between the two sources in its next annual submission (see para. 55 below).	Information is provided in NIR 2011. Fuels are split by domestic and international in the National Energy Balance.	Chapter 3, sections 3.2.1.3 and 3.5.
Energy	Reference and sectoral approaches: Feedstocks and non-energy use of fuels	52	Ireland indicated that work was ongoing to analyse whether emissions from the non-energy use of fuels, such as lubricants and bitumen, could be estimated. During the centralized review, the ERT found that a small amount of white spirit included in the energy balance was not included in the inventory estimates. In response to questions raised by the ERT, Ireland explained that it would include the consumption of white spirit in the CRF tables in future submissions. Further, Ireland stated that emission estimates from the non-energy use of fuels would be reassessed and revised if necessary. The ERT recommends that Ireland report on the results of this work in its next annual submission.	White spirit is now included in the CRF Submission for 2011.	
Energy	Key categories: Stationary combustion: all fuels – CO <sub>2</sub>	53	Ireland uses CO <sub>2</sub> emissions reported under the EU ETS for the reporting of the energy industries category. However, the ERT noted that the fuel consumption data provided in the CRF tables are taken from the national energy balance. Because the fuel consumption data used to derive CO <sub>2</sub> emissions do not correspond to the energy balance, this results in implied emission factors (IEFs) that are not comparable to those of other reporting Parties. During the centralized review, Ireland confirmed that this was the case and also explained that the estimation of CH <sub>4</sub> and N <sub>2</sub> O emissions was based on the energy balance data presented in the CRF tables. This means that the data basis for estimating and reporting CO <sub>2</sub> and non-CO <sub>2</sub> emissions is not consistent. However, the ERT noted that fuel consumption is not consistently lower or higher in the EU ETS data compared to the energy balance for individual categories, but varies between fuels and categories, and that, overall, the fuel consumption data in the EU ETS are slightly higher than in the energy balance. Therefore, the ERT believes that emissions of CH <sub>4</sub> and N <sub>2</sub> O are not underestimated, while CO <sub>2</sub> emissions are accurately estimated. The ERT strongly recommends that Ireland uses consistent data for all GHG for the next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	

Energy	Non-key categories: Civil aviation: liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	55	Ireland has reported all fuel consumption and associated emissions for civil aviation under jet fuel. The ERT noted that the energy balance contains information on the use of both aviation gasoline and jet fuel. During the centralized review, Ireland informed the ERT that the fuel consumption used for civil aviation is calculated by the EPA, and that this is the source of the split in the energy balance. The ERT recommends that Ireland, in its next annual submission, report the consumption of aviation gasoline and the associated emissions separately to increase transparency.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has plans to improve reporting of domestic aviation in Submission 2012.	Chapter 3, section 3.2.1.3 and 3.8.
Energy	Non-key categories: Road transportation: all fuels – CH <sub>4</sub> and N <sub>2</sub> O	56	The ERT noted that Ireland has improved the transparency of its reporting for this category by discussing the time-series trends for the transport sector. However, the ERT considers that some of the important parameters used in the tier 3 estimation of emissions from road transportation have not yet been provided in the NIR. In response to a question raised by the ERT during the centralized review, Ireland provided information on vehicle distribution, annual distance travelled by vehicle type, trip speed and distribution between road types. To enhance the transparency of the emission estimates from road transportation and to allow for a proper review of the model, the ERT recommends that Ireland include this information in an annex to the NIR in its next annual submission. Additionally, the ERT recommends that Ireland include in the NIR a comparison between the fuel consumption estimated by the bottom-up model and statistical data on fuel sales.	Additional information is provided in NIR 2011.	Chapter 3, section 3.2.1.3., Annex C Table C.1 and Annex D Tables D.1 and D.2
Energy	Non-key categories: Navigation: liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	57	The ERT noted that the energy balance contains data on marine bunkers, but no information on the use of fuels in national navigation. However, Ireland has reported a consumption of 57.95 TJ of gas/diesel oil in 2008 under navigation, although no explanations are provided in the NIR on how this figure was derived from the energy balance. The ERT recommends that the Party provides clear explanations on how activity data for navigation is established, in the NIR for the next annual submission.	Additional information is provided in NIR 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	Chapter 3, sections 3.2.1.3 and 3.5.
Energy	Non-key categories: Navigation: liquid fuels – CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O	58	The ERT also found that the trend of total liquid fuel consumption displays a drop of 52.1 per cent between 2001 (1,662.08 TJ) and 2002 (795.33 TJ) and by 93.4 per cent between 2005 (792.24 TJ) and 2006 (52.65 TJ). The consumption of residual oil in 2005 is 742.24 TJ, and is reported as "NO" for the following years (2006–2008). During the centralized review, Ireland explained to the ERT that the consumption of residual oil had been incorrectly allocated for the period 1990–2005. The ERT recommends that Ireland improve the reporting of data for national navigation and provide explanations in the NIR for the fluctuations in the time series in the next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	
IP and Solvent and other product use	Sector overview	61	The Party has reported a number of categories as "NE", such as: CO <sub>2</sub> emissions from asphalt roofing, road paving with asphalt, and food and drink; and N <sub>2</sub> O emissions from the use of N <sub>2</sub> O for anaesthesia. Although there are no methodologies available in the Revised 1996 IPCC Guidelines or the IPCC good practice guidance, the ERT encourages the Party to investigate ways to estimate emissions from these categories wherever possible.	This will be considered for the 2012 submission.	
IP and Solvent and other product use	Sector overview	62	The ERT also noted that potential SF <sub>6</sub> emissions from sporting goods (consumption of halocarbons and SF <sub>6</sub> ) are reported as "NE". Actual emissions are reported for 2008, while the Party stated in the NIR that the use of SF <sub>6</sub> in sporting goods was discontinued in 2007. Ireland also reported potential emissions of HFCs from other (2.G) as "NA" and "NE", while actual emissions are reported as "NO". The ERT encourages the Party to clarify its use of these notation keys in its next annual submission and to verify the reporting of potential	Notation keys have been corrected in the CRF Submission for 2011.	

			emissions.		
IP and Solvent and other product use	Sector overview	63, 64	<p>(63) The ERT considers that estimation approaches, data availability and the relevant documentation have, in general, been reported in a transparent manner. However, the ERT considers that Ireland could considerably enhance the transparency and completeness of its inventory by providing an analysis of the observed changes in the emissions level and/or trend of AD and IEF.</p> <p>(64) The ERT noted that Ireland is not presenting transparent separated information on time series of activity data and EF for each category as appropriate. The ERT considers that the aggregating approach adopted by Ireland impairs the transparency, and recommends that the Party increases the level of disaggregation of the information in its next annual submission.</p>	Additional information on AD and Efs for Industrial Processes sector is provided in Annex E of NIR 2011.	Annex E, Tables E.1 to E.4.
IP and Solvent and other product use	Sector overview	65	The NIR includes only a very short section on the uncertainty analysis (and mostly with qualitative information) and QA/QC procedures for the whole sector. The ERT reiterates the recommendation from previous review report that the Party provide more detailed information on the uncertainty analysis separately in its next annual submission, at least for the key categories.	This will be considered for the 2012 submission.	
IP and Solvent and other product use	Key categories: Cement production – CO2	67	CO2 emissions from cement production are the largest source of GHG emissions in the Party's industrial processes sector, accounting for 70.5 per cent of total sectoral emissions. Ireland uses plant-specific data and EFs reported under the EU ETS to estimate emissions. Emissions include the consideration of the clinker kiln dust (CKD) factor. However, the Party does not report information on the content of calcium oxide (CaO) and magnesium oxide (MgO) in the clinker that are used to derive the country-specific estimates. The ERT therefore recommends, in accordance with the IPCC good practice guidance, that Ireland include information on the CaO and MgO content of clinker in its next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. Additional information on AD and EFs for the Industrial Processes sector is provide in an Annex in NIR 2011. The inventory agency will provide additional information on CaO and MgO content in clinker for reporting in Submission 2012.	Chapter 4, section 4.7. Annex E, Tables E.1 to E.4.
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6 – HFCs	68	The ERT noted that in CRF table 2(II).F the Party appears to have inconsistently used the notation keys "IE" (included elsewhere) and "NA" to report AD and the corresponding emissions of HFCs from refrigeration and air conditioning equipment: emissions from manufacturing and from disposal for commercial refrigeration are reported as "IE" and included under "stock", and AD are reported as "NA". The Party explained during the centralized review to the ERT that the use of a bottom-up approach is not appropriate for estimating actual emissions from stationary refrigeration and air conditioning in Ireland due to the lack of data available on equipment types and sales of HFCs for each equipment subcategory. Emissions are therefore estimated using a top-down approach based on reported sales data and information on market shares. These are used to allocate the estimates of total HFC sales into stationary refrigeration and air-conditioning. Therefore, Ireland is not in a position to provide AD but only actual emissions from stocks. The ERT recommends that Ireland investigate this matter further for its next annual submission and improve the transparency of its reporting by reviewing its use of notation keys for this category. The ERT also recommends that the Party provide more information on the contribution of emissions from mobile air conditioners from new vehicle registries to the emissions in this category.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011.	

IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6 – HFCs	69	The ERT noted that in semiconductor manufacture, the amount of HFC emissions has been increasing over time. However, at the same time, the amount of PFC emissions has been decreasing since 2000, while SF6 emissions show an oscillating trend. In response to a question raised by the ERT during the centralized review, the Party replied that the installations involved in this activity have been subjected to several optimization programmes and corporate targets to reduce their overall impact on the environment. The Party also provided information to justify why the emissions of HFCs, PFCs and SF6 are somehow unrelated: HFCs are primarily used as refrigerants in enclosed systems which occasionally need some replenishment following maintenance work; PFCs are used as “chamber clean” gases; while SF6 is used in chemical vapour deposition tools and “dry etching”. The ERT suggests that Ireland include these explanations in the NIR of its next annual submission.	Additional information is provided in NIR 2011.	Chapter 4, sections 4.1, 4.4.1 and 4.4.2.5.
IP and Solvent and other product use	Key categories: Consumption of halocarbons and SF6 – HFCs	70	Although the NIR states that data on the use of HFCs for fire extinguishers have been provided by the industry and it is assumed that 97.5 per cent of the total product is HFC-227ea and the remainder is HFC-23, this information was not reflected in the CRF background table 2(II).Fs2 which only contains data on HFC-227ea. The ERT recommends that Ireland include data on HFC-23 in CRF table 2(II)Fs2 in its next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency will examine whether it is feasible to include data on HFC-23 in CRF table 2(II)Fs2 for reporting in Submission 2012.	Chapter 4, section 4.7.
IP and Solvent and other product use	Non-key categories: Soda ash use – CO2	71	The NIR states that, for reporting years prior to 2005, CO2 emissions from soda ash use were estimated using an EF based on 2005–2008 EU ETS data. However, from detailed data provided by the Party during the centralized review, the ERT concluded that plant-specific data were used and not EU ETS-derived data. The ERT recommends that Ireland revise the description in the NIR of its next annual submission in order to correctly reflect the applied methodology for the complete time-series.	Additional information is provided in NIR 2011.	Chapter 4, section 4.2.4.
Agriculture		76	The ERT considers that the Party has generally prepared accurate and relevant estimates on the basis of a very good model for enteric fermentation and manure management. However, during the review, the ERT recommended that Ireland increase the consistency of the calculations within the sector by incorporating the results of the model on N excretion in manure in the calculation of estimated N2O emissions from manure management and agricultural soils.		
Agriculture	Key categories: Enteric Fermentation	77	Emissions from enteric fermentation accounted for 13.3 per cent of the total GHG emissions and have decreased by 7.3 per cent since 1990. Since the 2006 submission, a tier 2 method has been used to estimate emissions from cattle. This country-specific methodology results in values that are close to the ones resulting from the use of the default tier2 methodology proposed in the IPCC good practice guidance, although it is based on animal feeding requirements, while the IPCC default methodology is based on the digestibility of rations. The ERT finds that this country-specific method is appropriate, considering that the Irish system of rearing livestock is rather different from other systems observed in Western Europe. The ERT also noted that estimates calculated using this approach are based on very accurate data collected from three different geographical regions and taking into account several animal subcategories. The ERT recommends that the Party report this method as country-specific (“CS”).	Notation Key changed in CRF Submission 2011 and in NIR 2011.	

Agriculture	Key categories: Enteric Fermentation	79	Ireland has used a tier 1 approach to estimate emissions for other livestock categories (e.g. swine and sheep), departing from the IPCC default EFs for these species and adjusting it for subcategory classes on the basis of the animals' weight. As a result, the aggregated IEFs for sheep (5.90 kg/head/year) and swine (0.45 kg/head/year) are lower than the IPCC default EFs (8.00 kg/head/year and 1.50 kg/head/year, for sheep and swine, respectively). During the centralized review, the Party provided supplementary information on animal weights for each subcategory. It is unclear to the ERT how Ireland's modification of the default EFs by subcategory constitutes an improvement from the use of the IPCC default EFs. The ERT strongly recommends that Ireland provide information to support the use of these adjusted default EFs but strongly encourages the development and implementation of a tier 2 approach for sheep, which is a key category, for the next annual submission.	Ireland has revised estimates for Swine for IPCC categories 4.A.8 and 4.B.8 in this submission. Additional information is provided in NIR 2011.	Chapter 6, sections 6.2.6 and 6.9 and Annex F, Table F.2(a).
Agriculture	Key categories: Manure management – CH <sub>4</sub> and N <sub>2</sub> O (80, 81,82)	80, 81, 82	<p>(80) During the centralized review, the ERT identified potential problems with the CH<sub>4</sub> IEF for dairy cattle: (a) the value reported in CRF table 4.B(a) is 20.7 kg CH<sub>4</sub>/head/year, but the ERT estimated it to be equal to 27 kg CH<sub>4</sub>/head/year using the values provided by Ireland for the following parameters: CH<sub>4</sub> production potential (Bo), volatile solids daily excretion (VS), methane conversion factor (MCF), and animal waste management system (AWMS); and (b) the allocation of AWMS used by Ireland to estimate CH<sub>4</sub> emissions (liquid (29.2 per cent), solid storage (1.9 per cent) and pasture range and paddock (68.9 per cent)) is different from the allocation scheme used to report N<sub>2</sub>O emissions from manure management (liquid (40.6 per cent), solid storage (2.7 per cent) and pasture range and paddock (56.7 per cent)).</p> <p>(81) After the centralized review, responding to the list of potential problems and further questions raised by the ERT, Ireland recognized the existence of problems in the emission estimates and clarified that the correct allocation should be the following for both CH<sub>4</sub> and N<sub>2</sub>O emissions from dairy cattle: liquid (29.2 per cent), solid storage (1.9 per cent) and pasture range and paddock (68.9 per cent). This AWMS allocation is based on expert assumptions on the housing period and on a farm facilities survey conducted in 2003 (Hyde et al., 2008) to distinguish liquid and solid systems. In its efforts to respond to the ERT questions, the Party made the following additional changes to the inventory: (a) using information from the farm facilities survey, the AWMS allocation for other cattle was revised from liquid (23.2 per cent), solid storage (11.5 per cent) and pasture range and paddock (65.2 per cent), to liquid (30.0 per cent), solid storage (10.7 per cent) and pasture range and paddock (59.3 per cent); and (b) FracGASM was revised from 0.189 to 0.175. The ERT agreed with the revision of estimates submitted by the Party.</p> <p>(82) Following the recognition of transcription errors in the tier 2 model, the Party revised the emission estimates of all categories directly and indirectly affected: CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management; N<sub>2</sub>O emissions from pasture range and paddock; and N<sub>2</sub>O indirect emissions from agricultural soils. The ERT considers that the revised estimates conducted by Ireland have corrected the identified problem. The ERT recommends that the Party improve the QA/QC for this category for the next annual submission.</p>	Additional QA/QC was undertaken for Submission 2011.	Chapter 6, section 6.7.

Agriculture	Key categories: Direct soil emissions – N <sub>2</sub> O	84	AD and emissions from sewage sludge spreading applied to soils are currently aggregated together with the N input to soils as animal manure. This reporting procedure impairs comparability with the reports of other reporting Parties and creates difficulties for the ERT when comparing this information with the information concerning the other categories related to animal activity. The ERT encourages the Party to report this category separately to improve the transparency of its reporting.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency will consider separate reporting of sewage sludge in Submission 2012.	
Agriculture	Key categories: Indirect soil emissions – N <sub>2</sub> O	85	Indirect soil emissions from leaching and runoff accounted for 1.2 per cent of the total GHG emissions and have decreased by 11.6 per cent since 1990. Ireland estimates emissions from leaching and runoff using a fraction of losses by leaching and runoff (Frac <sub>LEACH</sub> ) that is 0.1, instead of the IPCC default fraction (0.3). This country-specific parameter leads to lower overall emissions than if the IPCC default values had been used. During the centralized review, the Party clarified that references to the country-specific value are provided in the NIR. The ERT considers the documentation valid but recommends that the Party provide more detailed information for the justification of the choice of value for this parameter in the NIR for the next annual submission.	Additional references for these country specific fractions are provided in NIR 2011.	Chapter 6, section 6.5.3.
Agriculture	Key categories: Indirect soil emissions – N <sub>2</sub> O	86	Indirect soil emissions from the deposition of N added accounted for 0.6 per cent of the total GHG emissions and have decreased by 7.4 per cent since the base year. Ireland does not estimate the volatilization of ammonia (NH <sub>3</sub> ) and nitrogen oxide (NO <sub>x</sub> ) after sludge spreading, but the ERT encourages the Party to estimate the volatilization for this activity and to estimate the associated emissions from deposition.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. Ireland will consider this recommendation for reporting in Submission 2012.	
LULUCF	Sector overview	88	The ERT commends Ireland for the detailed information provided in the NIR on the LULUCF sector, including the transparent descriptions of methodological issues and assumptions. However, the ERT found that the information on methodologies is split between chapters 7 (LULUCF) and 11 (Emissions and Removals from LULUCF activities under Article 3.3 of the Kyoto Protocol) of the NIR. The reason for this is that some methods are used for LULUCF estimates under both the Convention and under Kyoto Protocol activities, while others seem to be applied to Kyoto Protocol activities only. The ERT recommends that Ireland streamline the common methodological information on this sector in a single location in the NIR, and that it clearly explain in chapter 11 the instances where methods differ between the Convention and Kyoto Protocol activities.	The inventory agency has made significant changes to the relevant chapters for Convention and KP reporting of LULUCF in NIR 2011.	Chapters 7 and 11.
LULUCF	Sector overview	89	The inventory is mostly complete, but Ireland still reports as "NE" for some categories and pools for which there are methodologies available in the IPCC good practice guidance for LULUCF, including net carbon stock changes (CSC) in soils for forest land remaining forest land, net CSC in dead organic matter (DOM) under wetlands converted to grasslands, all CSC from forest lands converted to wetlands, and CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O emissions from wildfires in land converted to forest land, cropland and wetlands. The ERT recommends that the Party improve completeness of the inventory by providing estimates for the missing categories and pools. The ERT noted several instances of inappropriate use of notation keys in the sectoral background 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 notation keys in its next annual submission in order to increase the transparency of its reporting	Notation Keys have been revised in CRF Submission 2011.	Chapters 7 and 11.

LULUCF	Sector overview	90	In the forest land category, Ireland uses higher-tier methods for estimating net removals in biomass and emissions from the litter component of the dead organic matter (DOM) pool. Tier 1 methods are applied for all remaining categories and pools. Ireland has provided detailed land-use change information (land-use matrices) in its NIR. The dominant land-use category is grassland, which accounts for 58.0 per cent of the total national territory. Although accounting for 8.7 per cent of the total national area, the forest land area has increased by 67.0 per cent since 1990 and is the key driver for the rise in removals in the sector. The ERT believes that the use of tier 1 methods in all but the forest land category may contribute to obscuring the real contribution of land management and land-use change to LULUCF emissions and removals. The ERT, in line with the recommendations in the previous review report, recommends that Ireland develop an improvement plan for other key categories (e.g. grassland remaining grassland was identified as a key category in 2010 submission) in the LULUCF sector and report thereon in its next annual submission.	Additional information on Grassland is provided in NIR 2011.	Chapter 7 section 7.5.1
LULUCF	Sector overview	91	The ERT commends Ireland for having devoted significant resources to the development of improved forest-related information, notably post-disturbance decay rates for DOM in land converted to forest land. During the centralized review, the ERT learned that this improvement was motivated by the need to quantify the effect of thinning disturbance and other losses during first forest rotations. However, these improvements have not been applied to the emission estimates for the conversion of forest land to other land uses, where it is assumed that all above-ground living biomass is emitted at once. Hence, the Party appears to be using different and inconsistent assumptions and tiers to estimate disturbance emissions on forest land and forest land converted to other land. To improve consistency and transparency, the ERT recommends that Ireland, in its next annual submission, simultaneously implement methodological improvements to all applicable land uses under the Convention and Kyoto Protocol activities.	Significant improvements have been made in submission 2011 for Convention and KP LULUCF reporting.	Chapter 7, section 7.11 and Chapter 11, section 11.1.5.
LULUCF	Sector overview	92	The ERT also noted inconsistencies between estimates reported under the Convention and corresponding activities under the Kyoto Protocol, and also between the NIR and the CRF tables. For example, CRF table 5.D shows that forest land converted to wetlands is reported as "NE" in 2006, 2007 and 2008, due to a lack of AD. However, CRF table 5(KP-I)A.2, reporting information on LULUCF activities under the Kyoto Protocol, indicates that 366 ha of forest land were converted to wetlands in 2006–2007 and 4 ha of forest land were converted to wetlands in 2008; further, table 7.7 of the NIR indicates that 217.82 ha and 153.40 ha of forest land were converted to wetlands in 2006 and 2007, respectively. Likewise, Ireland has reported non-CO2 emissions from wildfires on afforested land in CRF table 5(KP-II)5, but it has used the notation key "NE" to report emissions from wildfires in areas of land converted to forest land in CRF table 5(V) under the Convention. The ERT recommends that Ireland correct these inconsistencies in its next annual submission by enhancing QC procedures.	Notation Keys have been amended in CRF Submission 2011.	

LULUCF	Key categories: Forest land remaining forest land – CO2	93	This category accounts for significant net carbon sinks. The ERT noted that Ireland relies on higher-tier methods for the living biomass and DOM pools, but carbon stock changes in soils are not estimated and are assumed to be zero as Ireland uses the tier 1 method. In light of the importance of the forest land remaining forest land category in the Irish GHG inventory, the ERT encourages Ireland to further pursue its methodological improvements in this pool.	Country specific research suggests mineral soils under forestry are typically a sink for carbon, however there is insufficient data to accurately represent the national forest area. Therefore a conservative estimate of carbon loss it to assume that it not occurring.	
LULUCF	Key categories: Land converted to forest land – CO2	94	In accordance with the explanations on inter-annual variability provided by Ireland during the centralized review, the ERT understands that Ireland estimates carbon stock changes in the category land converted to forest land in a given year by subtracting the total carbon stocks from the previous year to the total carbon stocks in the current year, regardless of whether these stock changes occur on the same land units. The ERT considers that this practice confuses two processes: the movement of land between the forest land remaining forest land and land converted to forest land categories (showing as a carbon loss in forest land converted to other land and a carbon gain in forest land remaining forest land), and the carbon gains and losses on land units that have remained in the land converted to forest land category during the entire year. The ERT recommends that Ireland re-examine the method used to calculate carbon stock changes for each year, and also recommends that the Party base its estimates on consistently defined land areas (e.g. land converted to forest land on 1 January each year). The ERT considers that this will reduce spurious variations that do not reflect actual carbon gains or losses in managed forests and will improve comparability between the LULUCF sector and KP-LULUCF activities.	There is no case for areas or emission/reductions from forest land converted to forest land in convention reporting to be the same as KP LULUCF since they reflect different time series. To our knowledge this is not required according to GPG. However, we understand that differences between convention and KP reporting need to be explained better. See Chapters 7 and 11 of NIR 2011.	Chapter 7 and 11.
LULUCF	Key categories: Land converted to forest land – CO2	95	The ERT found that a shorter transition period (four years) is applied to land converted to forest land on organic soils, compared to the 20-year default period used for land converted to forest land on mineral soils. The ERT believes that this is the underlying reason why land converted to forest land on organic soils accounts for only 3 per cent of the area in this category. However, the implied rate of soil carbon stock change is one order of magnitude higher on organic soils (infertile, acidic peat) than on mineral soils, and, as a result, carbon sequestration on afforested organic soils in lands converted to forest land accounts for 45 per cent of the total soil carbon sequestration. A single scientific paper provided by Ireland during the centralized review (Hargreaves et al., 2003), is the basis for the approach used by the Party. The ERT recommends that Ireland examine options to validate the use of this approach and the estimates submitted in its next annual submission.	Recent research findings have indicated that afforestation on organic soils can lead to carbon loss over the first forest rotation, up to 50 years. The methodology and NIR 2011 have been revised according.	Chapter 7 Section 7.3.3
LULUCF	Key categories: Land converted to cropland – CO2	96	Generally, net emissions from land converted to cropland have increased significantly over the period (1990–2008), from “NO” in 1990–1991 and 7.91 Gg CO2 in 1992 to 359.57 Gg CO2 eq in 2008. The Party has not provided explanations in the NIR for this trend. The ERT recommends that Ireland provide such explanations in its next annual submission.	Additional information on Cropland is provided in NIR 2011.	Chapter 7 Section 7.4.1

LULUCF	Non key categories: Grassland remaining grassland – CO <sub>2</sub>	97	Grassland is the dominant land use in Ireland. Information in the NIR suggests that this category plays an important role in the national land-use dynamics with seemingly ongoing losses to forest land and other land, and gains from cropland. The cause of the ongoing emissions from this category (ranging from 480.36 to 718.45 Gg CO <sub>2</sub> according to years) is unclear to the ERT. The ERT recommends that Ireland re-examine its calculations of carbon stock changes in light of the suggestions made in paragraph 93 above in relation to land converted to forest land. The ERT reiterates recommendations of the previous review report that the Party prioritize methodological improvements in this category.	Research is on-going to improve methodology in tracking land use change and estimating associated change in carbon stocks in grasslands and croplands. Necessary revision of the methodology will be undertaken in light of the findings for this research. More details on this research will be provided as it matures in NIR 2012.	Chapter 7 Section 7.11
Waste	Sector overview	100	Ireland's waste inventory is generally complete for 2008. Ireland reported "NO" for waste incineration as this activity did not occur during the period 1998–2008. However, during the centralized review, the Party clarified that for the period 1990–1997, the Party informed the ERT that emissions from clinical incineration did indeed occur but have not been estimated. The ERT recommends that the Party improve its reporting of the waste incineration category. The ERT noted that emissions from some categories have not yet been estimated (e.g. N <sub>2</sub> O emissions from industrial, domestic and commercial wastewater), and recommends that the Party provide estimates when methodologies are available in the Revised 1996 IPCC Guidelines or the IPCC good practice guidance (e.g. N <sub>2</sub> O emissions from human sewage).	Emissions from "human sewage" are reported in Submission 2011 and were also reported in Submission 2010. Ireland will consider providing estimates for clinical waste incineration for 1990–2007 in Submission 2012.	Chapter 8, section 8.3.2.
Waste	Key categories: Solid waste disposal on land – CH <sub>4</sub>	103	In the NIR, Ireland provides detailed information on the calculations and parameters applied to estimate CH <sub>4</sub> emissions from food, paper, wood and straw textiles, and disposable nappies. The ERT recommends that Ireland expand the information in its next annual submission to illustrate how all other waste streams are accounted for in the estimates.	Additional information is provided in NIR 2011.	Chapter 8, section 8.2.2. and Annex H, Tables H.1 and H.2.
Waste	Key categories: Solid waste disposal on land – CH <sub>4</sub>	104	Ireland has recalculated the CH <sub>4</sub> recovery estimates from solid waste disposal on land based on a detailed study prepared by Fehily Timony Consultants. This study quantified the CH <sub>4</sub> recovered through landfill gas flaring for all years since the practice was introduced and validated the CH <sub>4</sub> utilization in the annual energy balance. During the centralized review, Ireland provided the ERT with information demonstrating that the efficiencies for flaring are based on international good practice standards. The ERT recommends that Ireland include the information provided during the centralized review in its next annual submission to improve the transparency of the inventory.	Additional information is provided in NIR 2011.	Chapter 8, section 8.2.3
Waste	Non-key categories: Wastewater handling – CH <sub>4</sub>	106	Ireland has reported CH <sub>4</sub> emissions from domestic septic tanks as "NO". In response to a question raised by the ERT during the centralized review, the Party explained that this decision was based on expert judgement: in Ireland, the temperature of the surrounding soil is constantly below 15 °C throughout the year, except for short periods and only in certain areas of country. These climatic conditions therefore prevent the process of methanogenesis. During the centralized review, the Party provided the ERT with sufficient information and documentation to support this claim. The ERT encourages Ireland to include the information provided to the ERT during the review in its next annual submission.	Additional information is provided in NIR 2011.	Chapter 8, section 8.3.1.

Waste	Non-key categories: Waste incineration – CO <sub>2</sub> and N <sub>2</sub> O	107	Ireland has reported emissions from waste incineration for the period 1998–2008 as “NO”. However, during the review, Ireland provided clarification that there was indeed a small amount of clinical waste incineration up to 2007. The ERT also noted that, in accordance with the information in Ireland’s inventory submitted to the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution, hazardous waste was incinerated in Ireland For 2007]. The ERT recommends that Ireland reflect this information in its next annual submission to improve the completeness of its reporting. The ERT further recommends that Ireland provide an explanation of how the clinical waste not incinerated is treated of in its next inventory submission.	Additional information is provided in NIR 2011.	Chapter 8, section 8.4.
Art 7.1 KP	Overview (109), Activities under Article 3, paragraph 3, of the Kyoto Protocol: Afforestation and reforestation – CO <sub>2</sub> (110) and Deforestation – CO <sub>2</sub> (112)	109, 110, 112	<p>(109) The ERT considers that chapter 11 of the NIR and the CRF tables that refer to KP-LULUCF activities contain all the necessary information as required by decision 5/CMP.1. The ERT also considers that sufficient information is provided on definitions, institutional arrangements and land areas. However, the ERT considers that time-trends of data on afforestation/reforestation and deforestation may be inconsistent before and after 2006 (see paras. 110 and 112 below), and there is lack of full consistency between the methodology and parameters used to report to the Convention and to the Kyoto Protocol. The Party also presented the corresponding AD under the Convention, and the underlying causes of the differences between both reporting under the Kyoto Protocol and Convention are explained.</p> <p>(110) Ireland has provided estimates of emissions and removals in afforested areas of land for the year 2008. Ireland states, in chapter 11 of the NIR, that reforestation does not occur in Ireland. High-quality AD after 2006 have been assembled from a variety of sources, notably maps of indicative forest soils and global information systems (GIS) map layers from the database of the Forest Service Grant and Premiums Scheme, but no information is provided for the years before 2006. The ERT recommends that Ireland clarify in the NIR of its next annual submission how it monitors afforested land prior to 2006.</p> <p>(112) During the centralized review, the ERT learned that detailed deforestation data is only available from 2006 onwards, and for previous inventory years, AD were derived from large-scale data sets. According to the literature cited in the NIR, this would provide biased estimates of land-use change in Ireland (Black et al., 2008). The ERT recommends that Ireland continue its efforts to improve historical deforestation data and correct the problems of bias in its next annual submission.</p>	Additional information is provided in NIR 2011.	Chapter 11, sections 11.1.5, 11.2.2.1, 11.2.2.2, 11.2.3.1 and 11.2.3.4.
Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Deforestation – CO <sub>2</sub>	113	In CRF table 5(KP-1)A.2, Ireland reports carbon stock changes in the litter, dead wood and soil pools on 1,354.08 ha of deforested land over the period 1990–2007 as “NO”. However, table 7.7 of the NIR presents data indicating that the conversion of forest land to grassland did occur in 2006 and 2007. Further, Ireland made the assumption that all pre- 2006 deforested land was converted to settlements, although transparent and verifiable information has not been provided that there was no deforestation to grassland prior to 2006. Noting that methodologies are provided in the IPCC good practice guidance for LULUCF to estimate soil residual emissions on forest land converted to grassland during the 20 years following the conversion, the ERT believes that emissions from this pool are in fact “NE”. The Party recognized during the centralized review that it has no data to estimate forest areas converted to grassland before 2006, but it will estimate it assuming the same rate as the conversion of forest land to	Additional information is provided in NIR 2011.	Chapter 11, sections

			settlements.		
Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Deforestation – CO3	114	Responding to the list of potential problems and further questions raised by the ERT after the centralized review, the Party provided further information clarifying the issue described in paragraph 113 above and submitted a revised set of KP-LULUCF CRF tables, with revised values in table 5(KP-1)A.2. Ireland explained that emissions from the dead fractions are assumed to be immediately oxidized in the year during which deforestation occurs. For mineral soils, the Party provided documentation showing that there is no significant change in soil carbon stocks for up to 30 years following transitions between grassland and forest land. However, Ireland resubmitted new estimates for emissions from organic soils (0.029 Gg C) using the tier 1 methodology and an EF of 0.25 t C/year. The ERT recommends that Ireland provide these justifications in the NIR for its next annual submission.	Additional information is provided in NIR 2011.	Chapter 11, sections
Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Deforestation – CO4	115	The ERT noted inconsistencies between the selection of values for the biomass expansion factor (BEF) used to report emissions/removals from the LULUCF sector under the Convention and emissions/removals under the Kyoto Protocol: for example, Ireland uses a BEF of 1.64 to estimate emissions from living biomass from forest land converted to other land, but it uses a BEF of 1.4 for deforestation under the Kyoto Protocol. The ERT also noted that the estimates for the Convention and KP-LULUCF are not always consistent. For example, it is not clear if below-ground biomass is included in the estimation of emissions from deforestation both under the Convention and under Kyoto Protocol activities. The ERT notes that BEF values strongly influence the estimates of carbon stock changes in the biomass and DOM pools in all forest-related categories. The ERT recommends that Ireland examine the appropriateness of the BEF values used and equations for all forest-related estimates and indicate in its next annual submission whether any corrections were implemented as a result.	Additional information is provided in NIR 2011.	Chapter 11, sections
Art 7.1 KP	Information on Kyoto Protocol units: National Registry	120	The SIAR identified the following problem: the national registry did not fulfil the requirements regarding the public availability of information in accordance with section II.E of the annex to decisions 13/CMP.1. In particular, the SIAR recommends that the Party include the information required by paragraph 47(a), (d), (f), and (l) of the annex to decision 13/CMP.1. The ERT reiterates this recommendation that should be implemented in Ireland's next annual submission.	Additional information is provided in NIR 2011.	Chapter 14, sections 14.3 and 14.4.

Conclusions and recommendations		141	<p>In the course of the review, the ERT formulated a number of recommendations relating to the transparency and the consistency of the information presented in Ireland's annual submission. The key recommendations are that Ireland:</p> <p>(a) Provide more precise and transparent descriptions of the methodologies for some categories in the energy, industrial processes and waste sectors (see paras. 51 , 56, 57, 58, 66 and 103 above);</p> <p>(b) Improve the transparency of the reporting on the national system by including more detailed information on the archiving system;</p> <p>(c) Improve transparency of the inventory by including more information on implemented QA/QC activities for all sectors, particularly the industrial processes and LULUCF sectors;</p> <p>(d) Improve the uncertainty analysis with the consideration of a higher level of disaggregation for the LULUCF sector;</p> <p>(e) Improve completeness of the inventory, in particular by estimating the remaining emissions reported as "NE" (see paragraph 13 above);</p> <p>(f) Reconcile the activity data used to estimate emissions for the energy sector, which is coming from the energy balance, with the EU ETS data;</p> <p>(g) Improve the methodological tier level used for categories in the LULUCF sector other than forest land, in particular grassland in accordance with the recommendations of the IPCC good practice guidance for LULUCF;</p> <p>(h) Improve the consistency of the information reported for the LULUCF sector under the Convention and KP-LULUCF activities, and the provision of more detailed information on forest-related land-use changes that occurred prior to 2006.(see paras. 92 and 115 above).</p>	See above.	
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**Table J.2 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 CO <sub>2</sub> emissions from asphalt roofing, road paving with asphalt, and food and drink, potential emissions of SF <sub>6</sub> from consumption in sporting goods, N <sub>2</sub> O emissions from the use of N <sub>2</sub> O 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.	<p>The uncertainty analysis has been significantly improved in this submission 2013, in particular, for LULUCF.</p> <p>Additional information on uncertainty for LULUCF and KP-LULUCF is also provided in Chapters 7 and 11 of NIR 2013.</p>	<p>Chapter 1, section 1.7 and Table 1.13</p> <p>Chapter 7 and 11 Sections 7.3.4.7, 7.3.5.7 and 7.9 Section 11.6.</p>

General	Inventory preparation: Recalculations and time-series consistency	24, 25	<p>(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 CO<sub>2</sub> emissions from fuel combustion activities and from manufacturing industries and construction, and to the recalculation of estimates of CH<sub>4</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> eq excluding LULUCF. The rationale for these recalculations is provided in the NIR and in CRF table 8(b).</p> <p>(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.</p>	Every effort is made to report recalculations consistently between the National Inventory Report and the CRF Submission.	<p>Chapter 10, section 10.3 and Tables 10.2 and 10.3</p> <p>See also CRF Tables 8(a)s1 and 8 s(a)s2</p>
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.	<p>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.</p> <p>Additional extensive information on QA\QC for LULUCF has been provided in this submission 2013.</p>	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.	<p>Chapter 3, section 3.2.1.3.3</p> <p>See also CRF Table 1.A(a)s3</p>
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 N <sub>2</sub> O and CH <sub>4</sub> emissions from road transportation. In 2008, these recalculations represented a downward revision of 23.0 per cent in N <sub>2</sub> O emissions (38.15 Gg CO <sub>2</sub> eq) and of 15.1 per cent in CH <sub>4</sub> emissions (4.07 Gg CO <sub>2</sub> 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 CH <sub>4</sub> and N <sub>2</sub> O 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 N <sub>2</sub> O 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 CO <sub>2</sub> 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 CO <sub>2</sub> emissions from EU ETS combustion installations using coal compared with CO <sub>2</sub> 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 CO <sub>2</sub> 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 CH <sub>4</sub> and N <sub>2</sub> O 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 CH <sub>4</sub> and N <sub>2</sub> O 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 CH <sub>4</sub> and N <sub>2</sub> O for reporting emissions from international shipping in its future annual submissions.	Emissions of CH <sub>4</sub> and N <sub>2</sub> O have been estimated for all years from 1990-2011 in this submission 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 CO <sub>2</sub> . 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 – CO <sub>2</sub>	46	The previous review report concluded that the implied EFs to derive CO <sub>2</sub> emissions from energy industries are not comparable with those of other Parties. CO <sub>2</sub> 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 CO <sub>2</sub> 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 CO <sub>2</sub> 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.	<p>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.</p> <p>The notation key for disposal emissions has been changed from “NO” to “IE” in this submission 2013.</p> <p>The notation key for industrial refrigeration is now “IE” in this and the previous submission.</p>	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	CO2 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.  <a href="http://www.eeca.eu/data/File/ESIA%20Perfluoro%20Brochure%20LR%20Final.pdf">http://www.eeca.eu/data/File/ESIA%20Perfluoro%20Brochure%20LR%20Final.pdf</a>	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 CO <sub>2</sub>	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 CH <sub>4</sub>	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 CH <sub>4</sub>	74	The ERT noted that the data on the fraction of gross energy that is converted to CH <sub>4</sub> 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 CH <sub>4</sub> 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 CH <sub>4</sub>	76	The Party applied a tier 1 approach to estimate CH <sub>4</sub> emissions from sheep. For lowland ewes, upland ewes and rams, the default EF for enteric fermentation of 8 kg CH <sub>4</sub> /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 CH <sub>4</sub> . 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 CH <sub>4</sub> 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 CH <sub>4</sub>	77	According to CRF table 4.B(a), the CH <sub>4</sub> producing potential for non-dairy cattle amounts to 0.24 m <sup>3</sup> CH <sub>4</sub> /kg organic matter excretion as volatile solids (VS), while according to table B-1 of the Revised 1996 IPCC Guidelines, the maximum CH <sub>4</sub> producing capacity of manure (Bo) for non-dairy cattle for all regions (except for Latin America) is 0.17 m <sup>3</sup> CH <sub>4</sub> /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 m <sup>3</sup> /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.  <a href="http://www.agriculture.gov.ie/farmers/chemespayments/crosscompliance/">http://www.agriculture.gov.ie/farmers/chemespayments/crosscompliance/</a>	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 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	<p>(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.</p> <p>(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.</p> <p>(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.</p>		
Art 7.1 KP	Activities under Article 3, paragraph 3, of the Kyoto Protocol: Deforestation – CO2	110	<p>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 <math>(1-R)</math> and <math>R</math>, respectively, where <math>R</math> 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 <math>(1+R)</math> or the belowground biomass multiplied by <math>(1/R + 1)</math>. Therefore, the ERT recommends the Party to correct the equation 11.10 by substituting the term <math>(1-R)</math> with <math>1/(1+R)</math> and equation 11.11 by substituting the term <math>R</math> with <math>1/(1/R + 1)</math>; 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.</p>		

Conclusions and recommendations		134, 135	<p>(134) The ERT identifies the following cross-cutting issues for improvement:</p> <ul style="list-style-type: none"> <li>(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;</li> <li>(b) The implementation of a tier 2 key category analysis;</li> <li>(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;</li> <li>(d) The further improvement of the use of notation keys in the CRF;</li> <li>(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.</li> </ul> <p>(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:</p> <ul style="list-style-type: none"> <li>(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;</li> <li>(b) Provide a clear indication about the methodological tiers used in the estimation of emissions in the industrial processes sector;</li> <li>(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 SF<sub>6</sub>;</li> <li>(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;</li> <li>(e) Further harmonize the methods used for estimating emissions and removals for the LULUCF sector reported under the Convention and its Kyoto Protocol.</li> </ul>	See above.	
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## 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<sup>-1</sup>)**

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<sub>HR</sub>= lop and top from harvest residues, DBH diameter at breast height (1.3 m) in cm, H –height in m.

Eg	Function	Range	Equation	Coefficients				r <sup>2</sup>	RMSE	Slope	Source
				a	b	c	d				
<b>Spruce</b>											
1	AB	H>4.5m	$a \times DBH^b + c \times H^d$	0.23	2.12	$5 \times 10^{-7}$	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 <sub>HR</sub>		AB-SB								
<b>Pines</b>											
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 <sub>HR</sub>		AB-SB								
<b>Larch</b>											
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 <sub>HR</sub>		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 <sub>HR</sub>		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 <sub>HR</sub>		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 <sub>HR</sub>		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, it 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***

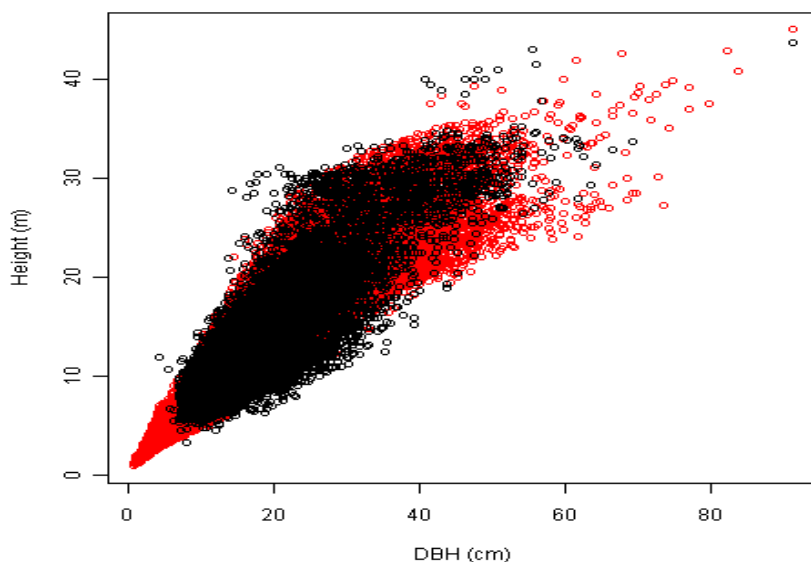
Data used were obtained from Coillte Teoranta's (the Irish Forestry Board state commercial forestry company) permanent sample plot record system. The dataset contains records from many silvicultural and thinning trials established during the period 1963 to 2001. The trials were initially established 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<sup>2</sup> ha<sup>-1</sup>), basal area in larger trees (BAL, m<sup>2</sup> ha<sup>-1</sup>) 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<sup>-1</sup>). 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	$H = (a_1 + a_2BAL + a_3BA)(1 - \exp(b.DBH^{(c_1 - c_2BAL)}))$	58341	58417
3	$H = (Ui + a_1 + a_2BAL + a_3DENS + a_4BA)(1 - \exp(b.DBH^{(c_1 - c_2BAL)}))$	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<sup>2</sup> 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:

$$CR = \frac{\exp(ICR)}{1 + \exp(ICR)}$$

where *ICR* is derived from the non-linear equations, which may vary for different cohorts.

Cohort	Model ( <i>ICR</i> variations)	a1	a2	a3	a4	a5	b	c
Spruce	$ICR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + a_5 \left[ \frac{H}{BAL} \right] + bDBH^c$	4.8705	-0.017	-0.397	-0.119	-0.296	0.0003	2
Pine	$ICR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + bDBH^c$	3.8478	-0.024	-0.213	-0.137		0.0002	2
Larch	$ICR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H$	5.8306	-0.018	-0.794	-0.039			

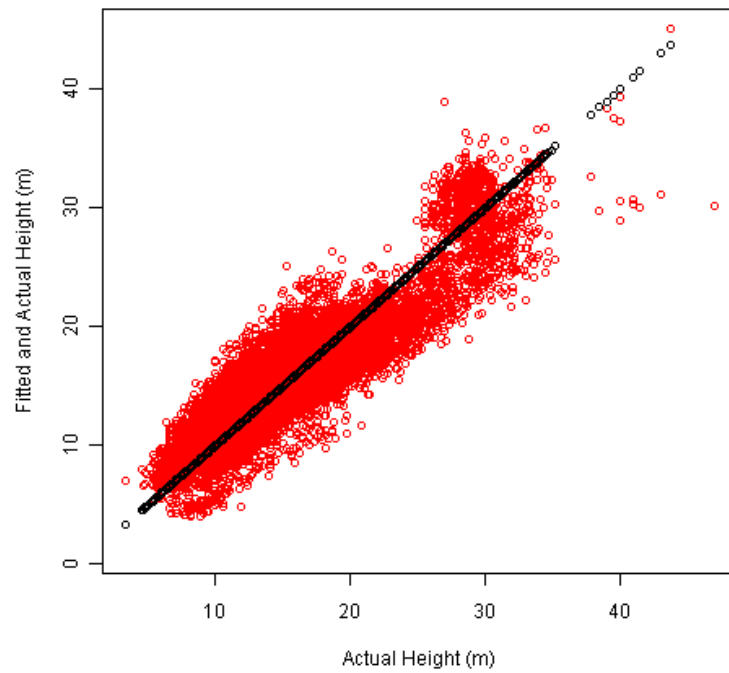
Conifers	$ICR = (a_1 + a_2BAL + a_3Ln(CCF) + a_4H + bDBH^c$	4.1759	-0.019	-0.394	-0.965		0.0004	2
FGB	$ICR = (a_1 + a_2BAL + a_3Ln(CCF) + a_4H + a_5\left[\frac{H}{DBH}\right] + bDBH^c$	2.4539	-0.009	-0.145	-0.045	-0.591	0.0001	2
SGB	$ICR = (a_1 + a_2BAL + a_3H + a_5\left[\frac{H}{BAL}\right]$	1.477	-0.005	-0.017	-0.578			

**BAL** is the sum of the basal area of all individual trees larger than the subject tree (m<sup>2</sup> per ha)

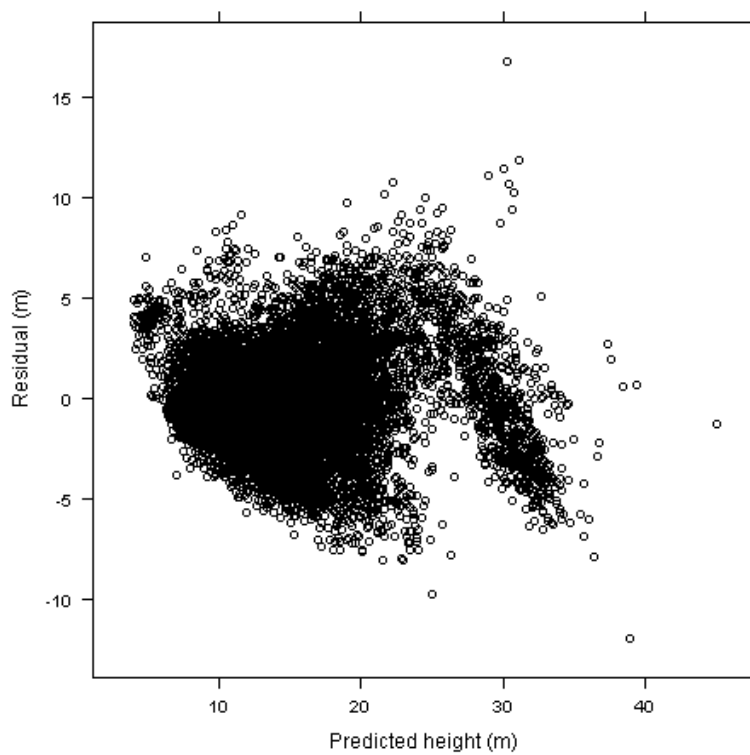
**CCF** is the crown competition factor, which is a measure of the crown areas of the subject tree relative to a open grown tree that would not be subjected to crown competition (taken from Hassenhaur, see section B of this appendix)

**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.

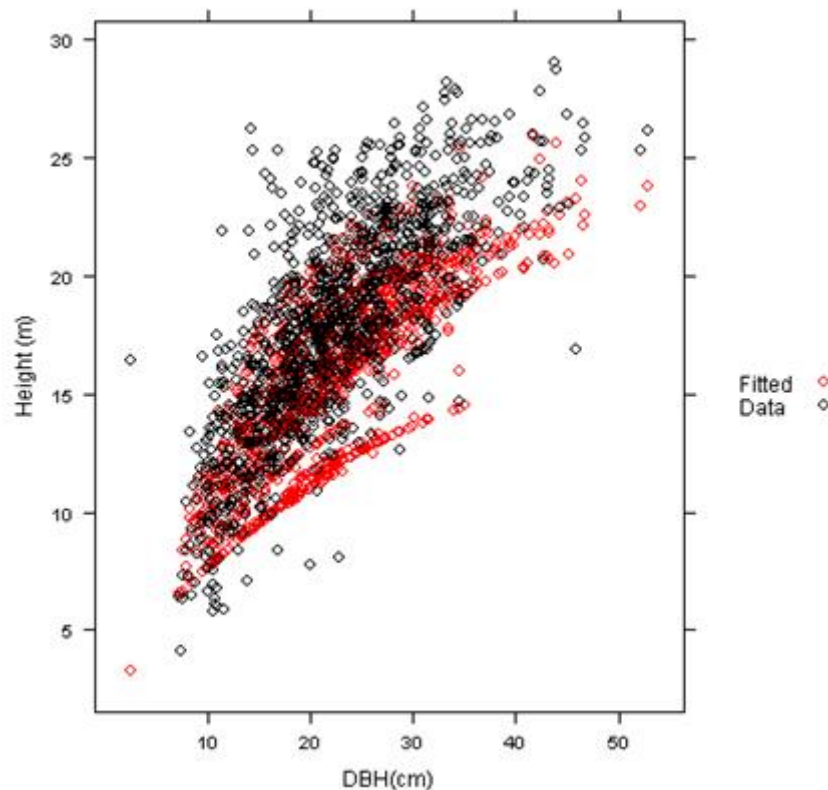
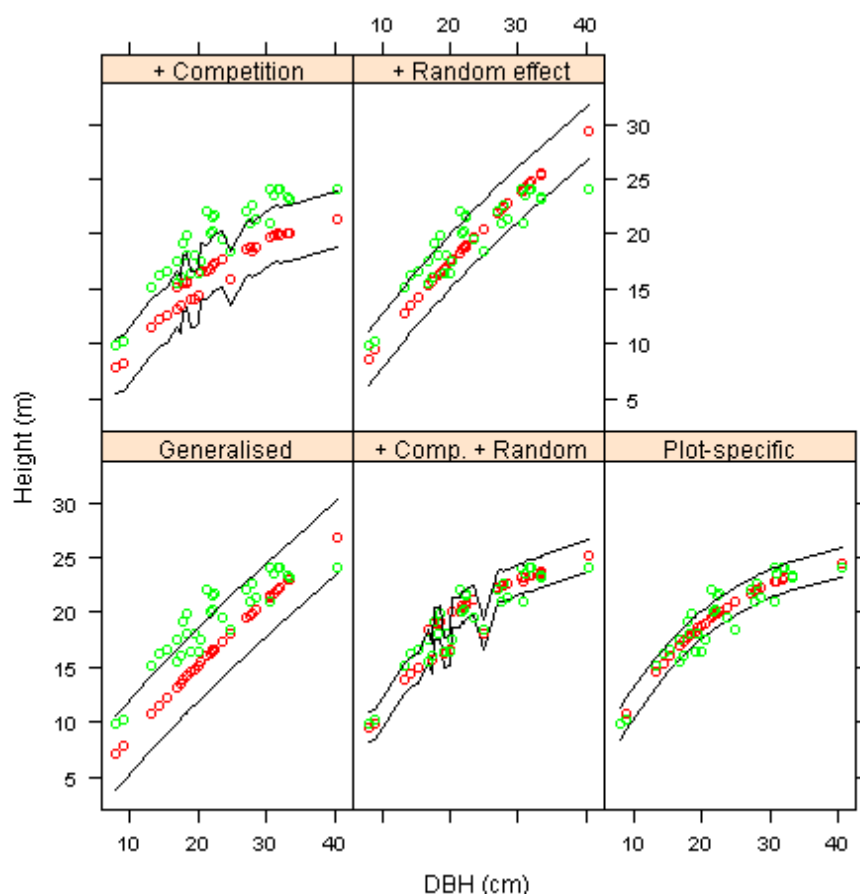


Figure K.1-A.4. Estimated and observed validation heights versus DBH

### 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 function (cf. Table K.1-A.1)**

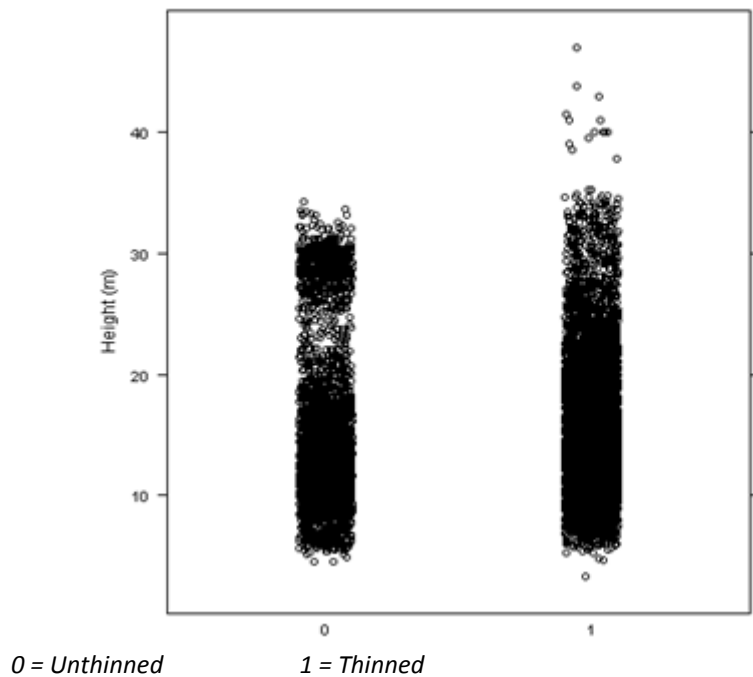
Green, red and black are data, estimates, and single standard error of prediction, respectively. Competition denotes a generalised model with competition covariates (cf. Model 2, Table K.1-A.1), Random denotes a plot-specific random asymptote (cf. Model 3, Table K.1-A.1), Generalised denotes parameters 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. :

$$H = (U_i + a + a_1BAL + a_2DENS + a_3BA + a_4I(Thinned))(1 - \exp(b.DBH^{(c_1 - c_2BAL)}))$$

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).



*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 than 5cm. This model is a distance independent individual tree growth model parameterised on Coillte permanent plot data recorded every 4 to 6 years 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 variables, 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:

$$\text{Dinc(cm)} = \exp(a_0 + a_1 \ln \text{DBH} + a_2 \text{DBH}^2 + a_3 \ln \text{CR} + a_4 \ln \text{CCF} + a_5 \cdot \text{BAL})$$

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**

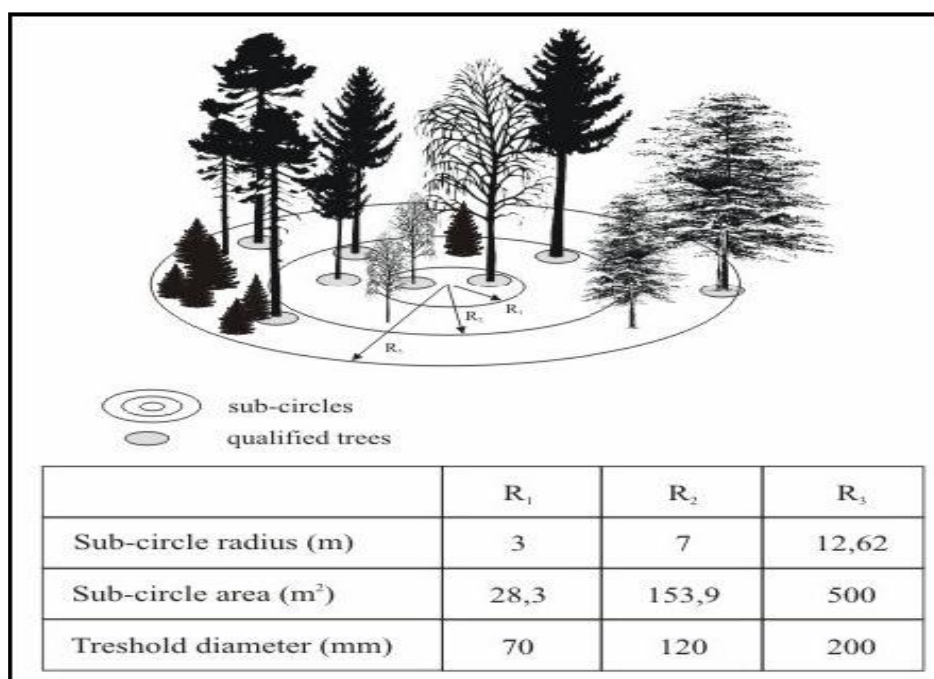
Variable	Formula	Scale of measurement
CR	Crown length/height	Range (0,1)
DBH	Diameter at 1.3 m	Cm
Crown competition factor (CCF)	The “open-grown” (e.g. if every tree had zero competitors) crown area of all trees in a plot expressed as a percentage of plot area.	Percent
BAL	A function for each plot that 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 <sup>2</sup> ha <sup>-1</sup>
BA	Plot basal area	M <sup>2</sup> ha <sup>-1</sup>
Annualised diameter increment (Dinc)	$(DBH(t+1)-DBH(t))/([t+1] - [t])$ . DBH(t) stands for “DBH on the occasion of the t <sup>th</sup> measurement”. Since measurement 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** :  $cw = \exp(-0.3232) * ((DBH)^{0.6441})$   
**Other conifers** :  $cw = \exp(0.092) * ((DBH)^{0.538})$   
**Pine** :  $cw = \exp(-0.1797) * ((DBH)^{0.6267})$   
**Larch** :  $cw = \exp(-0.3396) * ((DBH)^{0.6823})$   
**Slow-growing broadleaves** :  $cw = \exp(-0.3973) * ((DBH)^{0.7328})$   
**Fast-growing broadleaves** :  $cw = \exp(0.1366) * ((DBH)^{0.6183})$   
 (where a circumflex denotes exponentiation.)

Open grown crown area (m<sup>2</sup>) =  $(0.25) * (3.141593 * cw^2)$

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.



**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.

$$Dinc = \exp(a_0 + a_1 \ln DBH + a_2 DBH^2 + a_3 \ln CR + a_4 \ln CCF + a_5 \cdot BAL) + e$$

Where  $a_i$ ,  $i = 1 \dots 5$  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**

$$E(Dinc) = \exp(-2.8528 + \ln(DBH) \cdot 1.1729 - 0.00012 \cdot DBH^2 + \ln(CR) \cdot 0.8241 - 0.000015 \cdot CCF)$$

#### **Larch**

$$E(Dinc) = \exp(-2.2969 + \ln(DBH) \cdot 0.6338 - 0.00096 \cdot CCF)$$

#### **OC**

$$E(Dinc) = \exp(-1.4191 + \ln(DBH) \cdot 0.554 - 0.00025 \cdot DBH^2 + \ln(CR) \cdot 0.5549 - 0.00052 \cdot CCF - 0.00646 \cdot BAL)$$

### Pine

$$E(\text{Dinc}) = \text{EXP}(-1.3466 + \text{LN}(\text{DBH}) \cdot 0.741 - 0.001 \cdot \text{DBH}^2 + \text{LN}(\text{CR}) \cdot 0.998 - 0.00066 \cdot \text{CCF} - 0.00417 \cdot \text{BAL})$$

### SGB

$$E(\text{Dinc}) = \text{EXP}(-2.5897 + \text{LN}(\text{DBH}) \cdot 0.7534 - 0.00068 \cdot \text{DBH}^2 - 0.0006 \cdot \text{CCF} - 0.00979 \cdot \text{BAL})$$

### Spruce

$$E(\text{Dinc}) = \text{EXP}(-1.8628 + \text{LN}(\text{DBH}) \cdot 0.9456 - 0.0005 \cdot \text{DBH}^2 + \text{LN}(\text{CR}) \cdot 1.1639 - 0.000638 \cdot \text{CCF} - 0.00273 \cdot \text{BAL})$$

### 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** :  $((\sum(\text{predicted}-\text{observed})/n) \cdot 100)/m$ . Where  $m$  is  $E(\text{obs})$ , and  $n$  is the number of observations.

**Precision** :  $\text{SD}(\text{pred}-\text{obs})$

**Empirical Excess error (%)** :  $((1-\text{Sec})/\text{Sei}) \cdot 100$ . Where  $\text{Sec}$  is the *precision* of the calibration data, and  $\text{Sei}$  the *precision* of the independent data.

**Theoretical Excess error** :  $(1/n)[\sum(\text{pred}_{(-1)}-\text{obs})^2 - \sum(\text{pred}-\text{obs})^2]$ . Where  $\text{pred}_{(-1)}$  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.

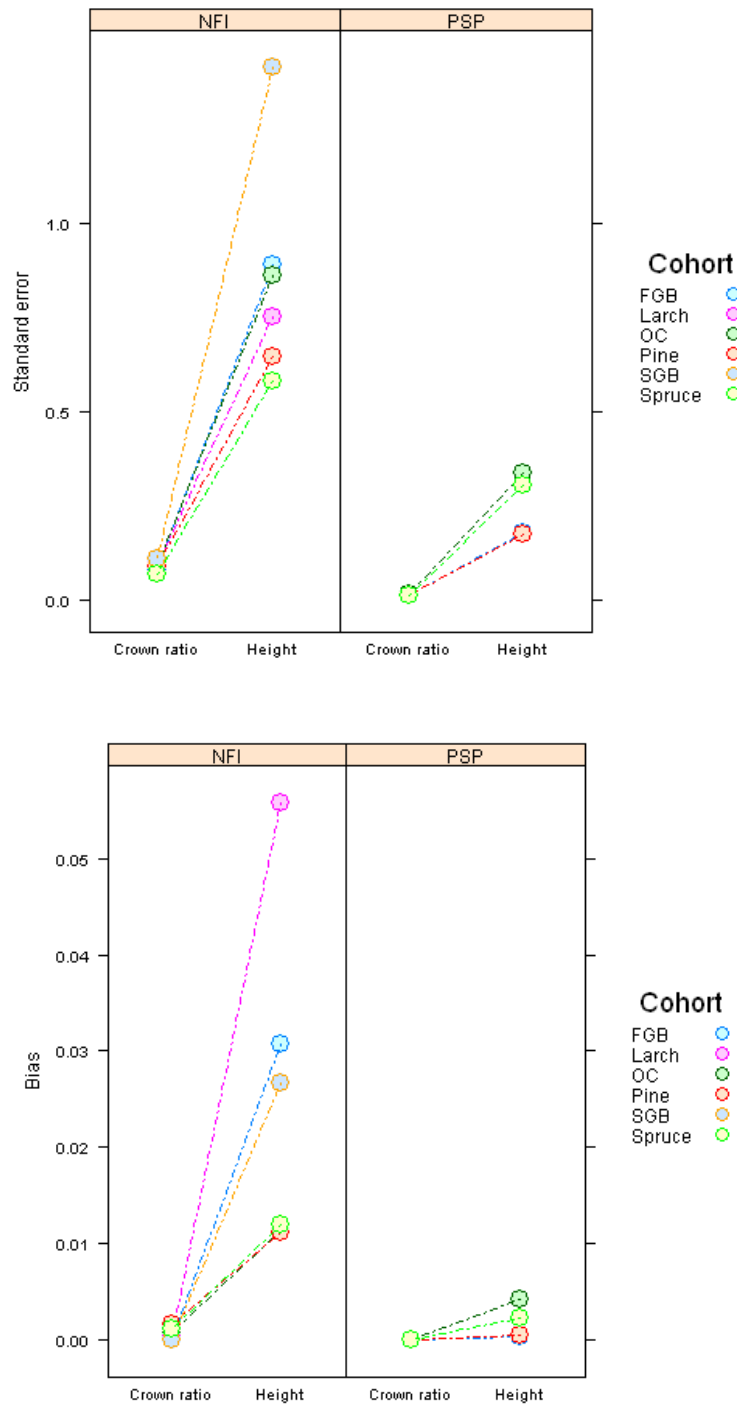
**Bias** :  $(\sum(\text{pred}-\text{obs})/n)$

**RMSE** :  $\sqrt{(\sum(\text{pred}-\text{obs})^2/n-p)}$ . Where  $p$  is the number of parameters in the model.

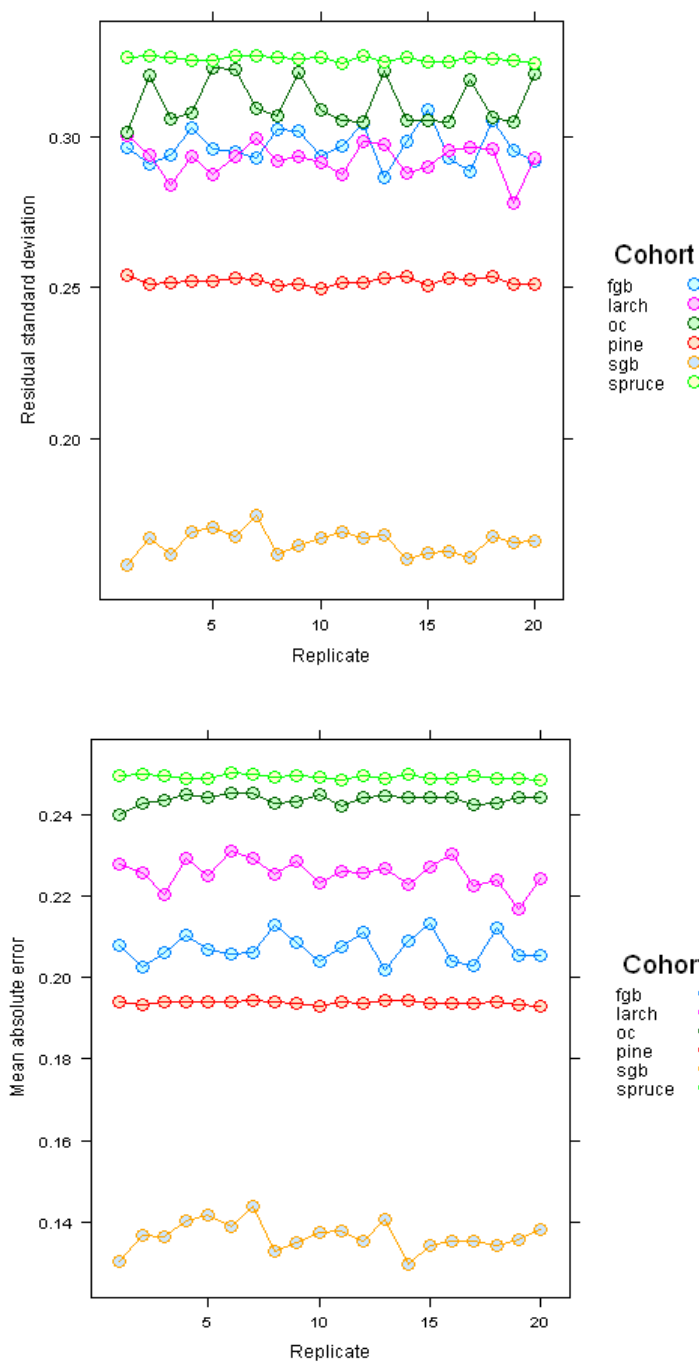
Another measure is *mean absolute error* (MAE).

**MAE** :  $\sum |\text{pred}-\text{obs}|/n$

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).

$$xHinc_{i,j}^{n+1} = \frac{a_1}{1 + \exp(-1 \times \left[ \frac{age^n - a_2}{a_3} \right])} \dots \dots \dots (1)$$

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:

$$H_{n+1} = \frac{H_n}{xH_n} \times H_n \dots \dots \dots (2)$$

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  $\bar{x}H_n$  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 (YCe<sub>q</sub>) 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.

$$YCe_q = HI = \min, \{YCH_{ij} - \bar{x}H_{ij}\}^2$$

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 ( $\bar{x}H$  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 in 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 Thuring et al (2005), for example, are *accuracy*, *precision*, and *excess error*, calculated as follows.

**Accuracy** :  $((\sum(\text{predicted-observed})/n)*100)/m$ . 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 (Thuring et al., 2005).

**Bias** :  $(\sum(\text{pred-obs})/n)$

**RMSE** :  $\sqrt{(\sum(\text{pred-obs})^2/n-p)}$ . 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	YCe <sub>q</sub>				Precision	RMSE	Bias
		<b>a<sub>1</sub></b>	<b>a<sub>2</sub></b>	<b>a<sub>3</sub></b>			
>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 logistica<sup>1</sup> 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 differs 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 probability 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 misclassification 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 *i*th diameter class is:

$$\frac{R_3^2}{R_i^2} \dots\dots\dots(1)$$

where *R<sub>i</sub>* 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, we estimate the number of trees of the *i*th diameter class that were not included in the sample by  $\frac{R_3^2}{R_i^2} \cdot n_i$ , where *n<sub>i</sub>* is the number of trees of the *i*th class

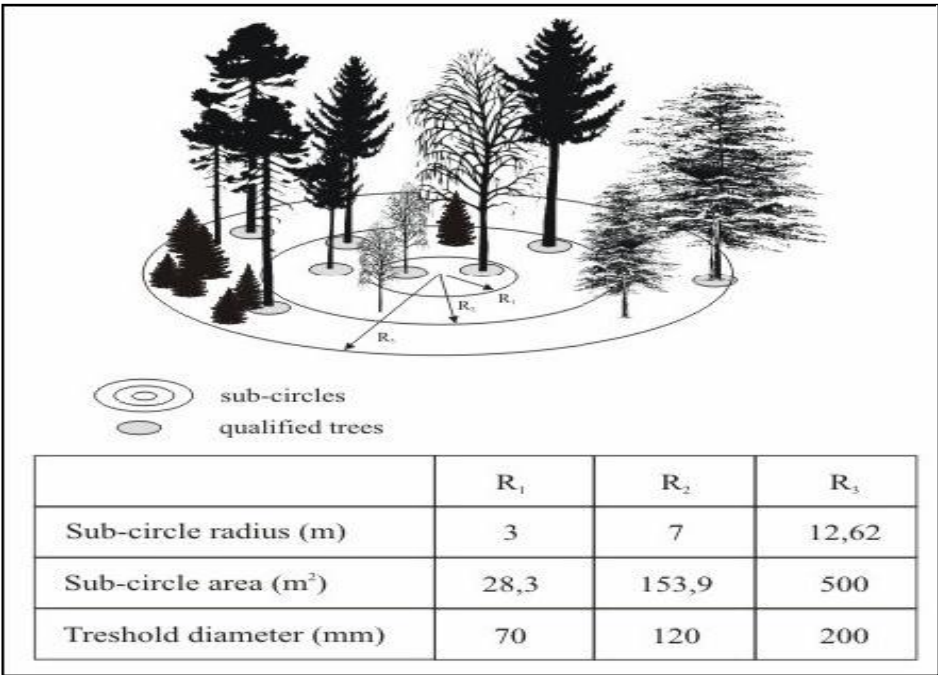


Figure K.2-A.1. The NFI concentric-plot sampling schema

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).

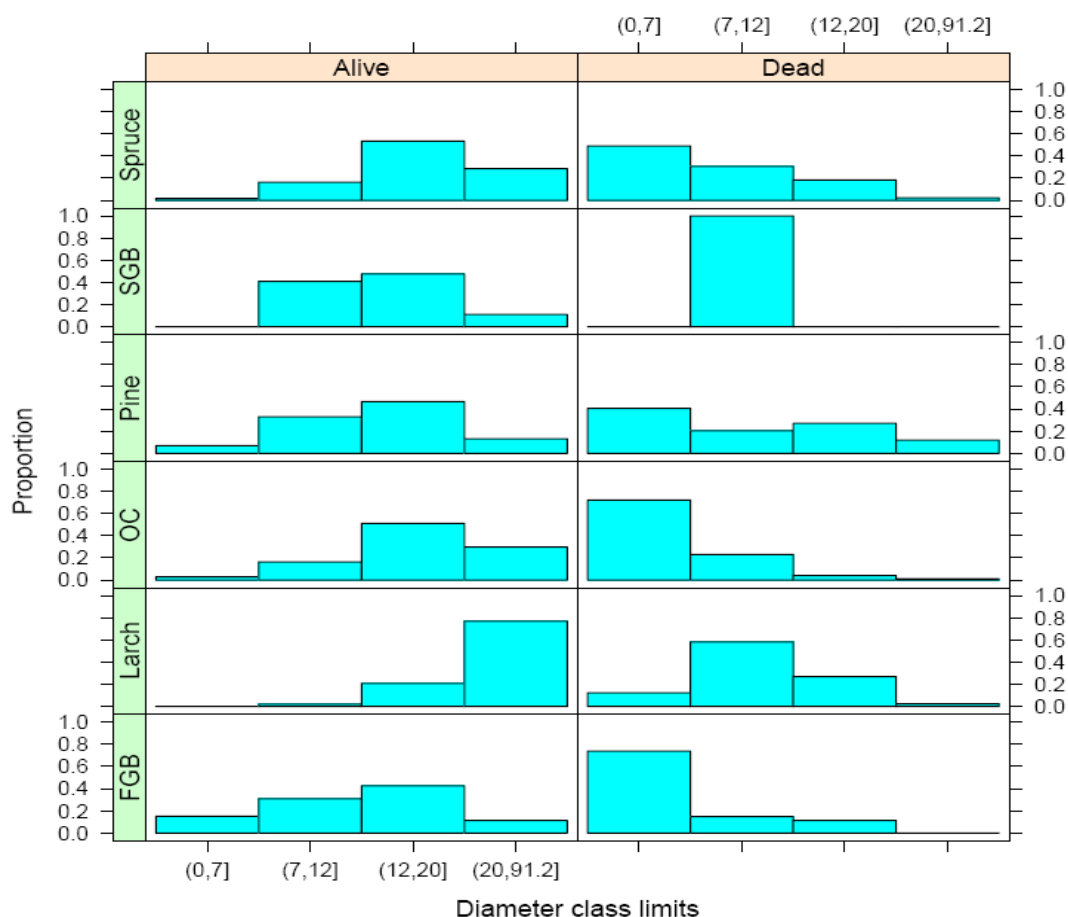
$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \dots\dots\dots(2)$$

where  $n_{ij} \sim EF_{ij}$  is the product of the expansion factor for the  $j$ th tree in the  $i$ th class, and  $\hat{N}_{ij}$  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 high 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

$$\text{RelDiamInc} \left( \frac{\text{growth}(t - t - 1)}{\text{DBH}(t)} \right)$$

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*

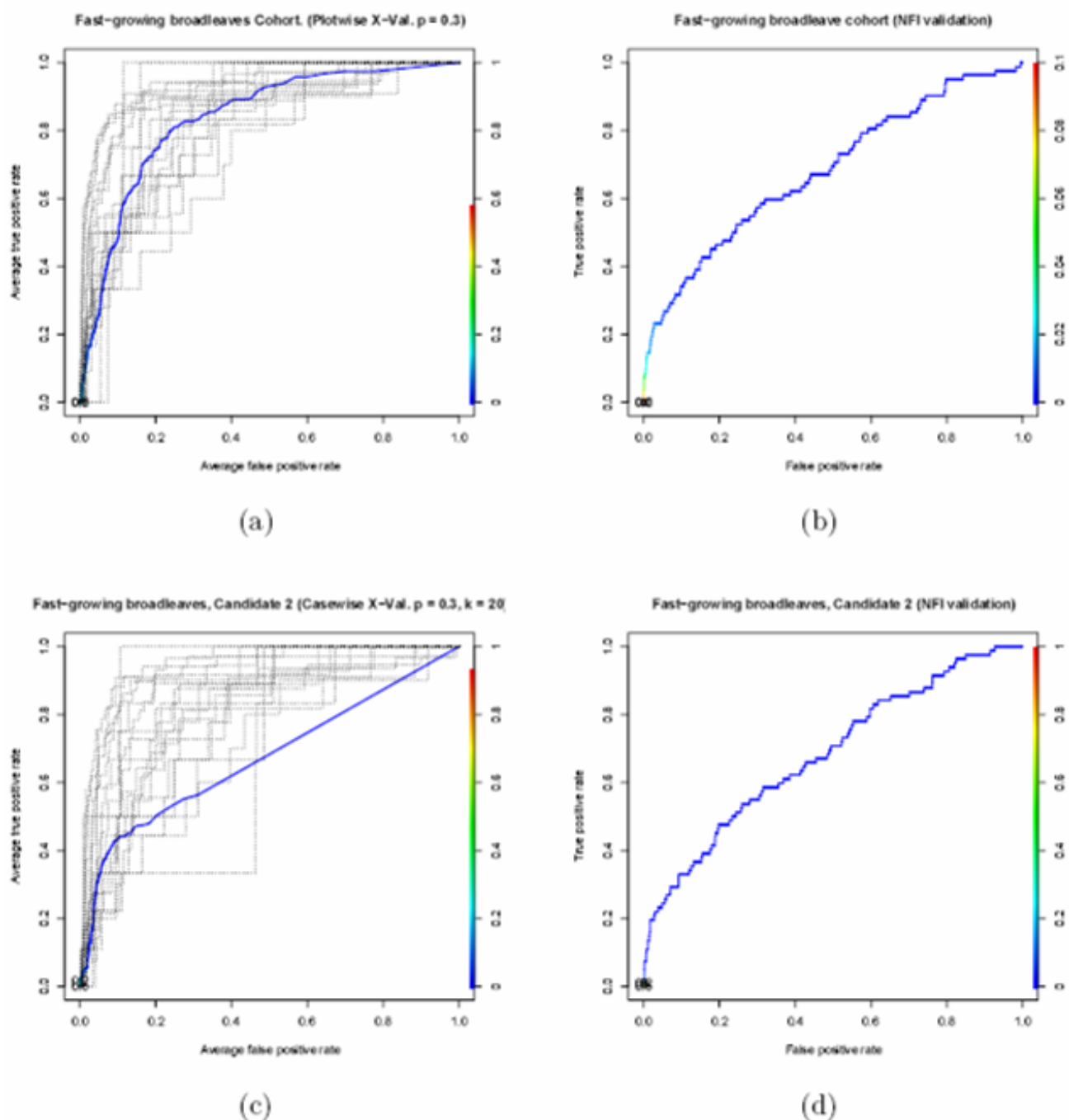
Parameter	Estimate	s.e.	df	Wald statistic	Wald p-value
Intercept	1.2286	0.02747	298E3	44.72	0.0001
DBH	-0.6640	0.003840	298E3	-172.93	0.0001
BAL	0.05051	0.000529	298E3	95.57	0.0001
RelDiamInc	-13.0524	0.2544	298E3	-51.30	0.0001

### ***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 cases 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.

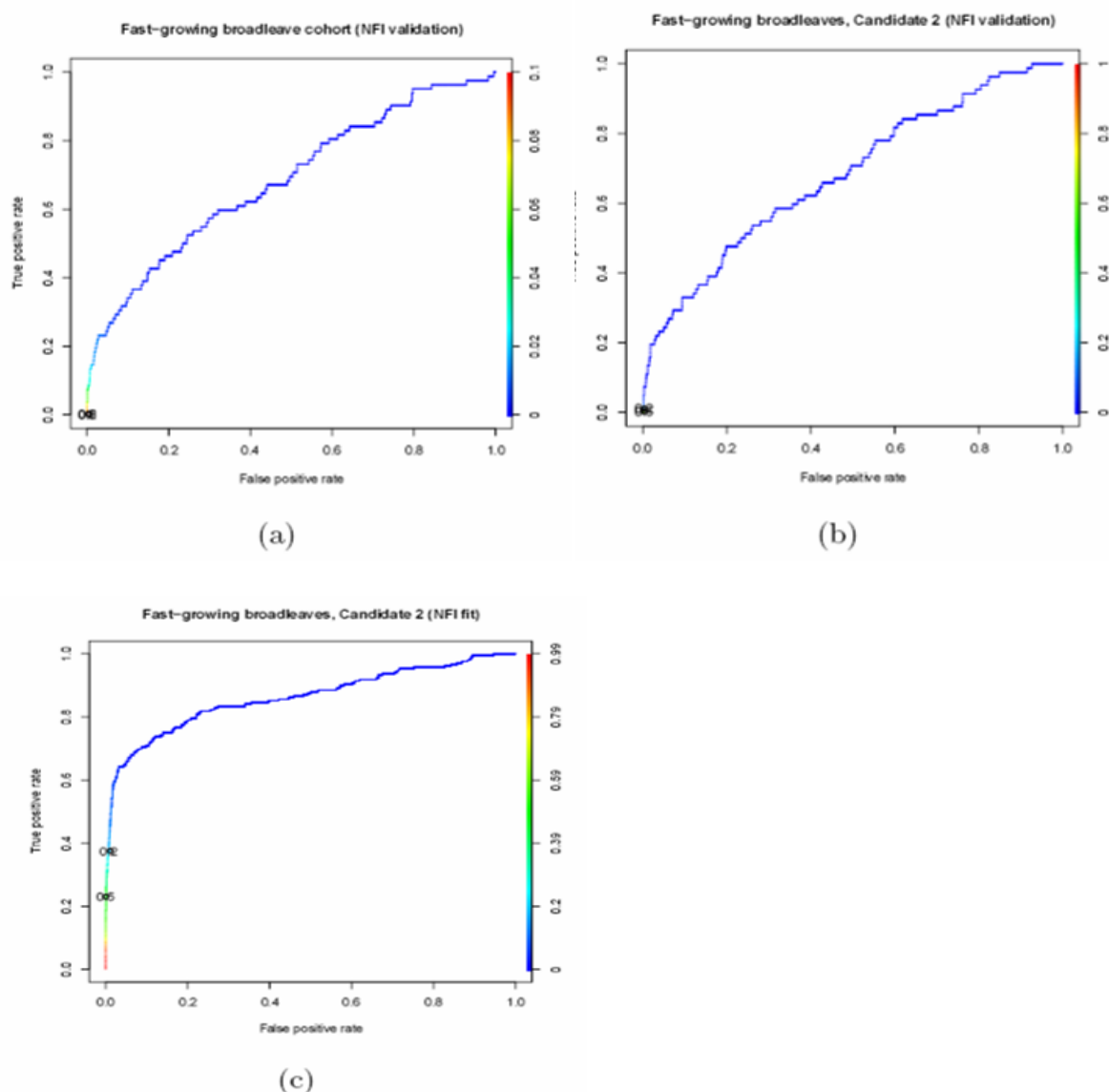


Figure K.2-A.4. The Receiver operating characteristic curve for Fast-growing broadleaves cohort Candidate models 1 and 2 fitted on PSP, and for the NFI-fitted model.

## The selected CARBWARE models based on NFI data fits

### Fast-growing broadleaves cohort

$$P_{mort} = IL(12.93 + 0.068 \times BAL - 2.868 \times CR - 0.962 \times DBH - 72.28 \times \frac{1}{DBH} + 0.009 \times DBH^2)$$

### Larch cohort

$$P_{mort} = IL(-4.9266 + 0.04273 \times DBH)$$

## Other conifers

$P_{mort} = IL(-4.5226 + 0.067 \times BAL - 6.05 \times CR + 0.066 \times DBH)$  **Pine cohort**

$$P_{mort} = IL(2.395 + 0.0408 \times BAL - 3.0036 \times CR - 0.2263 \times DBH - 24.21 \times \frac{1}{DBH})$$

## Slow growing broadleaves

$$P_{mort} = IL(15.78 + 0.0109 \times BAL - 2.2807 \times CR - 0.771 \times DBH - 94.002 \times \frac{1}{DBH} + 0.00449 \times DBH^2)$$

## Spruce cohort

$$P_{mort} = IL(6.8976 + 0.0912 \times BAL - 21.3795 \times CR - 0.8287 \times DBH - 49.15 \times \frac{1}{DBH} + 0.008 \times DBH^2)$$

Where ( $0 < P_{mort} < 1$ ) is the probability the tree is dead. We map then this estimated probability 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.

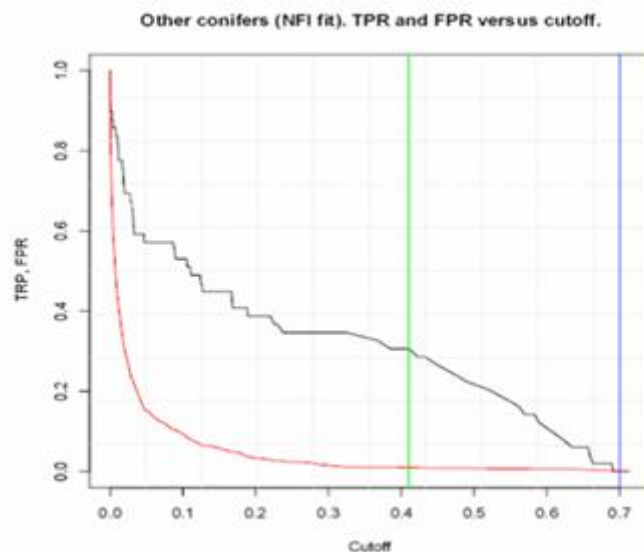
**Table K.2-A.2 Formulae for some standard performance measures used in the text**

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].



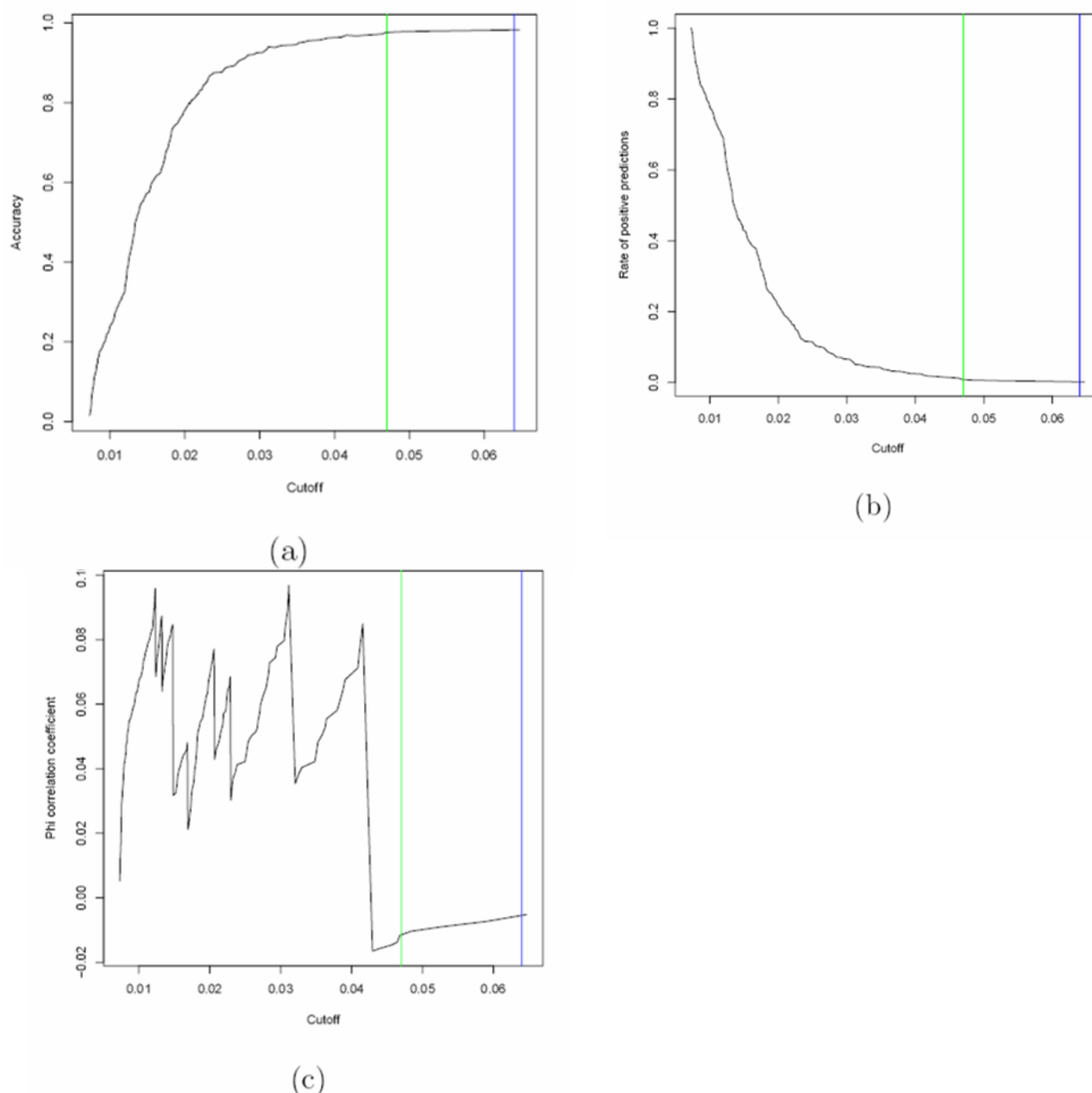
**Figure K.2-A.5 TPR (Black) and FPR (Red) versus cut-off for Fast-growing broadleaves**  
The vertical green line shows the cut-off where  $FPR < 0.01$ , the blue vertical line shows the cut-off where  $FPR < 0.001$

## 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 by 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 removed 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 not 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 felling with re-establishment (NIR section 11.4.2)



## Annex L

### Standard Electronic Format (SEF) 2012

# UNFCCC SEF application

Version 1.2

## Workflow

Unlock file

Completeness Check

Consistency Check

Lock file

## Functions

Mandatory data

Import XML

Reset SEF

Export XML

## Settings

Party: Ireland  
ISO: IE  
Submission year: 2013  
Reported year: 2012  
Commitment period: 1

Completeness check: YES  
Consistency check: YES  
File locked: YES

Lock timestamp: 09/04/2013 11:01  
Submission version number: 1  
Submission type: Official

Party Ireland  
 Submission year 2013  
 Reported year 2012  
 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	ICERs
Party holding accounts	231132084	NO	NO	NO	NO	NO
Entity holding accounts	14568785	129852	NO	9138714	NO	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	52890867	394883	NO	1667332	NO	NO
tCER replacement account for expiry	NO	NO	NO	NO	NO	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
<b>Total</b>	298592471	524735	NO	10808105	NO	NO

Party Ireland  
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**Table 2 (a). Annual internal transactions**

Transaction type	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Article 6 issuance and conversion</b>												
Party-verified projects		NO					NO		NO			
Independently verified projects		NO					NO		NO			
<b>Article 3.3 and 3.4 issuance or cancellation</b>												
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		
<b>Article 12 afforestation and reforestation</b>												
Replacement of expired tCERs							NO	NO	NO	NO	NO	
Replacement of expired ICERs							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
<b>Other cancellation</b>							NO	NO	NO	NO	NO	NO
<b>Sub-total</b>		NO	NO				NO	NO	NO	NO	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Retirement</b>	13828869	844000	NO	1113662	NO	NO

Party Ireland  
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Add registry

Delete registry

**Table 2 (b). Annual external transactions**

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Transfers and acquisitions</b>												
AT	65800	NO	NO	NO	NO	NO	NO	NO	NO	113228	NO	NO
NL	131200	9931	NO	184742	NO	NO	NO	NO	NO	232700	NO	NO
GB	351989	944625	NO	4504746	NO	NO	4150253	NO	NO	1428835	NO	NO
SK	264024	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
FR	61500	NO	NO	6615	NO	NO	161000	NO	NO	28500	NO	NO
DE	585200	335770	NO	NO	NO	NO	365574	NO	NO	551700	NO	NO
CH	NO	NO	NO	1406195	NO	NO	NO	NO	NO	1633071	NO	NO
ES	595000	NO	NO	NO	NO	NO	NO	NO	NO	1220000	NO	NO
IT	18500	NO	NO	NO	NO	NO	4000	NO	NO	68500	NO	NO
SE	94500	NO	NO	134753	NO	NO	NO	NO	NO	22000	NO	NO
CZ	8200	NO	NO	NO	NO	NO	NO	NO	NO	7700	NO	NO
JP	NO	NO	NO	NO	NO	NO	NO	NO	NO	2141049	NO	NO
EU	NO	NO	NO	NO	NO	NO	NO	NO	NO	1343136	NO	NO
CDM	NO	NO	NO	NO	503489	NO	NO	NO	NO	NO	NO	NO
<b>Sub-total</b>	2175913	1290326	NO	6237051	503489	NO	4680827	NO	NO	8790419	NO	NO

**Additional information**

Independently verified ERUs								NO				
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**Table 2 (c). Total annual transactions**

<b>Total (Sum of tables 2a and 2b)</b>	2175913	1290326	NO	6237051	503489	NO	4680827	NO	NO	8790419	NO	NO
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Party Ireland  
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**Table 3. Expiry, cancellation and replacement**

Transaction or event type	Expiry, cancellation and requirement to replace		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Temporary CERs (tCERs)</b>								
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							
<b>Long-term CERs (ICERs)</b>								
Expired in retirement and replacement accounts		NO						
Replacement of expired ICERs			NO	NO	NO	NO		
Expired in holding accounts		NO						
Cancellation of ICERs 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
<b>Total</b>			NO	NO	NO	NO	NO	NO

Party Ireland  
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**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	ICERs
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	
ICER replacement account for expiry	NO	NO	NO	NO		
ICER replacement account for reversal of storage	NO	NO	NO	NO		NO
ICER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
<b>Total</b>	296087557	1815061	NO	8254737	503489	NO

Party Ireland  
 Submission year 2013  
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**Table 5 (a). Summary information on additions and subtractions**

	Additions						Subtractions					
	Unit type						Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Starting values</b>												
Issuance pursuant to Article 3.7 and 3.8	314184272											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
<b>Sub-total</b>	314184272	NO		NO			NO	NO	NO	NO		
<b>Annual transactions</b>												
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	NO	NO	NO	NO	NO	NO	NO	NO	NO	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
<b>Sub-total</b>	18442610	2250061	NO	42490021	503489	NO	36540060	435000	NO	34237343	NO	NO
<b>Total</b>	332626882	2250061	NO	42490021	503489	NO	36540060	435000	NO	34237343	NO	NO

**Table 5 (b). Summary information on replacement**

	Requirement for replacement		Replacement					
	Unit type		Unit type					
	tCERs	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
<b>Previous CPs</b>			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
<b>Total</b>	NO	NO	NO	NO	NO	NO	NO	NO

**Table 5 (c). Summary information on retirement**

Year	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	ICERs
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
<b>Total</b>	66719736	1238883	NO	2780994	NO	NO

Party Ireland  
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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	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

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	ICERs	AAUs	ERUs	RMUs	CERs	tCERs	ICERs

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	ICERs



Appendix 1  
Standard Independent Assessment Report  
(Electronic Appendix)