# IRELAND

# NATIONAL INVENTORY REPORT 2012

## GREENHOUSE GAS EMISSIONS 1990 - 2010
## REPORTED TO THE UNITED NATIONS
## FRAMEWORK CONVENTION
## ON CLIMATE CHANGE

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CONTENTS

***Acknowledgements***

*The authors wish to express their appreciation to the various Government Departments, Sustainable Energy Authority of Ireland, the Central Statistics Office, the Forest Service, COFORD, Teagasc, the Electricity Supply Board and the many other data suppliers and individuals who have contributed to the subject matter of this national inventory report.*

**List of Tables**

## List of Figures

# EXECUTIVE SUMMARY

## ES.1 Background

The present report constitutes Irelands NIR for 2012 and refers to the inventory time-series for the years 1990-2010.

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 2012 is also its submission under the Kyoto Protocol, with 2010 being the third 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 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 2012 NIR is intended to inform Irish Government departments and institutions involved in the national system, as well as other relevant stakeholders in Ireland, of the level of emissions and the state-of-the-art of Irish greenhouse gas inventories. The in-depth analysis of key categories and the up-to-date data on emissions trends provides essential information for the implementation of the National Climate Change Strategy and the development of emissions projections. The detailed NIR, together with activities provided for in the national system, allows data suppliers to become fully aware of the importance of their contributions to the inventory process and it serves to identify areas where improvements in input data can be achieved.

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

## ES.2 Emissions Trends and Key Categories

In 2010, total emissions of greenhouse gases (excluding the *LULUCF* sector) in Ireland were 61,313.92 Gigagrams (Gg) $CO_2$ equivalent, which is 11.2 per cent higher than emissions in 1990. The total for 2010 is 12.5 per cent lower than the peak of 70,064.81 Gg $CO_2$ equivalent in 2001 when emissions reached a maximum following a period of unprecedented economic growth. The *Energy* sector accounted for 66.1 per cent of total emissions in 2010, *Agriculture* contributed 29.2 per cent while a further 3.2 per cent emanated from *Industrial Processes* and 1.4 per cent was due to *Waste*. Emissions of $CO_2$ accounted for 67.3 per cent of the national total in 2010, with $CH_4$ and $N_2O$ contributing 18.9 per cent and 12.7 per cent, respectively. The combined emissions of HFC, PFC and $SF_6$ accounted for 1.0 per cent of total emissions in 2010.

Tier 1 level assessment of emission source categories (ranking on the basis of their contribution to total emissions) identified 24 key categories in 2010 (excluding the *LULUCF* sector). There were 14 key categories of $CO_2$, accounting for 66.0 per cent of total emissions. There were six key categories of $CH_4$, three key categories of $N_2O$ and 1 key category of HFC in level assessment, which accounted for 17.5 per cent, 11.2 per cent and 0.9 per cent of total emissions, respectively. The results of the Tier 1 key category analysis clearly show the impact of $CO_2$ emissions from energy consumption on total emissions in Ireland. These combustion sources of $CO_2$ emissions accounted for 13 out of 24 key categories identified by level assessment in 2010 and for two-thirds (64.2) per cent of total emissions. The top ten key categories contributed 73.6 per cent of total emissions in 2010 with emissions of $CO_2$ from the combustion of petrol and diesel by road traffic being the single largest source, accounting for 17.9 per cent of the total national emissions.

The application of uncertainty analysis for Irish greenhouse gas inventories using the IPCC approach indicates an overall level uncertainty of 6.8 per cent in the 2010 inventory (excluding the LULUCF sector) and a trend uncertainty of 2.6 per cent for the period 1990 to 2010. These values are determined largely by the low uncertainty in the estimates of $CO_2$ emissions from the energy sector, which is the major source category in Ireland and for which the input data and methodologies are most reliable. The 67 per cent of emissions contributed by $CO_2$ are estimated to have an uncertainty of 1.2 per cent. Emissions of $N_2O$ from the agriculture sector account for over 95 per cent of the level uncertainty in the 2010 inventory. The impact of HFC, PFC and $SF_6$ on inventory uncertainty in the year 2010 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 8,589.64 Gg $CO_2$ eq. for 2008, 2009 and 2010 under Article 3.3 of the Kyoto Protocol in respect of 271.60 kha of lands subject to afforestation since 1990 while there were net emissions of 80.53 Gg $CO_2$ for a deforested area of 8.24 kha for the same 3 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 2010. 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 2012 submission and the latest inventories for the years 1990-2010 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 2010. 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 2010. As the emissions from energy increased, the contribution of agriculture to total national emissions decreased from 35.6 per cent in 1990 to 29.2 per cent in 2010. This is primarily as a result of falling livestock numbers since 1998 due to reform of the Common Agricultural Policy (CAP).

## ES.4 Indirect Greenhouse Gases

The inventory reporting process requires the inclusion of a number of gases whose indirect effects are also relevant to the assessment of human-induced impacts on climate. They include sulphur dioxide ($SO_2$), nitrogen oxides ($NO_X$), carbon monoxide (CO) and volatile organic compounds (VOC). Emissions of $SO_2$ contribute to the formation of aerosols, which may offset the effects of greenhouse gases, while CO, $NO_X$ and VOC are precursors of ozone, another naturally occurring greenhouse gas. This NIR does not describe the methods used to estimate emissions of $SO_2$, $NO_X$, CO and VOC but the annual emissions estimates over the period 1990-2010 are included in the submission.

The emissions of most of the indirect gases have decreased substantially in the period 1990-2010 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 2010 in Ireland are of the order of 85.8 per cent in the case of $SO_2$, 66.9 per cent for CO and 51.9 per cent for NMVOC and 37.6 per cent for $NO_{X.}$

# PART I

## ANNUAL INVENTORY SUBMISSION 2012

# Chapter One

# Introduction

## 1.1 Background and Context

This report constitutes Ireland's National Inventory Report (NIR), for the years 1990-2010, as required under the United Nations Framework Convention on Climate Change. Ireland's submission under the UNFCCC in 2012 is also its submission under the Kyoto Protocol, with 2010 being the third 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://coe.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 2012 is also its submission under the Kyoto Protocol.

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

### 1.1.2 Scope of Greenhouse Gas Inventories

#### 1.1.2.1 Greenhouse Gases and Global Warming Potential

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

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

#### 1.1.2.2 IPCC Reporting Format

Greenhouse gas emissions are reported under the Convention in a multi-level reporting format adopted by the Intergovernmental Panel on Climate Change (IPCC). This is a standard table format that forms the basis of the Common Reporting Format (CRF) which assigns all potential sources of emission 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, Research and Resource Use (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 Change and Environmental Research Unit, 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 Change and Environmental Research Unit 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 Change and Environmental Research Unit 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 | Use of nitrogen fertilizer, cattle populations from CMMS (Cattle Movement and Monitoring Scheme) | 30 September | Agriculture |
| Central Statistics Office | Annual population, livestock populations, crop statistics, housing survey data | 30 September | Agriculture, Industrial Processes, Waste |
| Department of Agriculture, Food and Marine | Estimates of $CO_2$ emissions and removals and other GHG emissions for forest land; Statistical data on afforestation, reforestation and harvesting; Estimates of $CO_2$ emissions and removals and other GHG emissions for Article 3.3 activities | 30 September | LULUCF |
| 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 $CO_2$ estimates and related fuel and production data for installations covered by the EU ETS[1] | 30 April | Energy, Industrial Processes |
| *Department of Communications, Energy and Natural Resources | National Oil Balance (as a component of the energy balance) | 30 September | Energy |
| *Road Safety Authority | Road transport statistics from the National Car Test (NCT) | 30 April | Energy |
| **Forest Service | (i) GIS data base on premiums and grants afforestation areas (iFORIS) with associated attributes<br>(II) NFI database | 30 September<br><br>2007, 2012 | LULUCF and Article 3.3 activities |
| **Coillte | GIS data base of intersected of NFI permanent sample plot points (Coillte-NFI plots) with sub-compartment and management unit data. | 30 September | LULUCF and Article 3.3 activities |

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

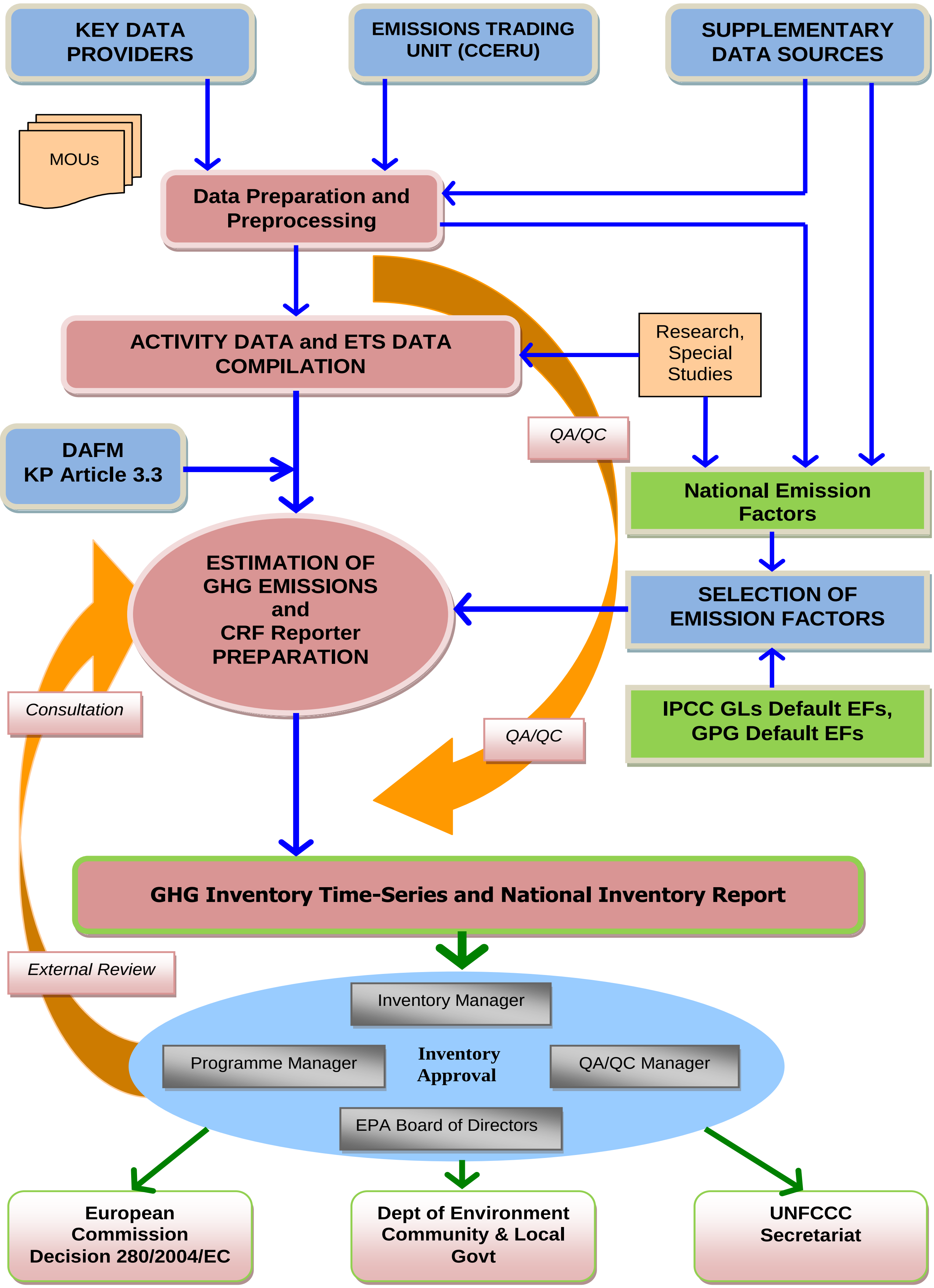


*Figure 1.1. National Inventory System Overview*

### 1.2.2 Inventory Planning

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

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

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

### 1.2.3 Overview of Inventory Preparation and Management

The first version of the latest annual inventory, produced in autumn of the following year, is 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, land areas), emission factors and the associated emission estimates for a specified list of source categories. In practice, very few measured data are available for greenhouse gases and, consequently, the emissions from most activities are estimated by applying emission factors for each source/gas combination to appropriate activity data for the activity concerned. Virtually all emissions and removals estimates may be ultimately derived on the basis of such simple product of activity data and emission factor. However, a certain amount of data analysis and preparatory calculations are generally needed in order to make available suitable combinations of activity data and emission factors at the level of disaggregation that gives the best estimates of emissions and removals. In the case of some source/gas combinations, such as methane emissions from solid waste landfills and $CO_2$ sequestration by forest biomass, it may be necessary to apply sophisticated models to generate the activity data, the emission factors or the emissions. The methods recommended by the Revised 1996 IPCC Guidelines (IPCC, 1997), IPCC Good Practice Guidance (IPCC, 2000) and IPCC Good Practice Guidance on LULUCF (IPCC, 2000) 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 spreadsheet system where activity data stored in *Source Data* files are linked to calculation sheets in *Data Processing* files that produce the emissions estimates at the lowest possible level of disaggregation. These are combined and allocated according to IPCC requirements for direct transmission into the CRF Reporter utility for the generation of the CRF tables. These results are stored in *Outputs* files while supporting QA/QC sheets, extracted from *Data Processing* files, are held in summary *QA/QC* record files. The *Data Processing* files hold the emission factors and they are structured on a time-series basis, which facilitates efficient recalculation and output to the CRF Reporter. This procedure applies to all IPCC sectors of the GHG inventory for which the calculations are made by the inventory team and the full set of files applicable to each year under the four headings is stored using appropriate version control on the OCLR servers.

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

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

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

The annual ETS compilation serves as an important source of activity-specific and company-specific data on $CO_2$ emissions, fuel use and emission factors for major combustion sources and industrial processes. The emissions trading scheme covers approximately 100 installations in Ireland with combined $CO_2$ emissions of 17,356 Gg in 2010, accounting for 28.3 per cent of total greenhouse gas emissions (61,313.92 Gg $CO_2$ equivalent). Guidance provided under the associated Decision 2004/156/EC (EP and CEU, 2004) on methodologies for estimating and reporting greenhouse gas emissions to support Directive 2003/87/EC, together with monitoring and verification mechanisms administered by the ETU, consolidates and improves the information in relation to a substantial proportion of $CO_2$ emissions for the purposes of reporting national GHG inventories under the Convention and the Protocol.

All of the data used in the compilation of the national GHG inventory submission is stored on an EPA data server located in the Monaghan Regional Inspectorate of the EPA where key staff involved in inventory compilation are located. All background data for recent years is 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 1990-2010. More than 80 per cent of the total emissions (excluding LULUCF) are covered by Tier 2 methods or higher in Ireland’s GHG inventory under the Convention and a Tier 3 model is applied for carbon stock changes for Article 3.3 activities under the Kyoto Protocol.

#### Carbon dioxide ($CO_2$)

Tier 2 or Tier 3 methods are used for the majority of $CO_2$ combustion source categories and country-specific emission factors are used for all fuels. Even for those combustion categories where data limitations dictate the use of Tier 1 methods, such as 1.A.2 (Manufacturing Industries and Construction) and 1.A.4 (Other Sectors), the $CO_2$ emissions obtained using the energy balance fuel data and country-specific emission factors are reliable.

Tier 2 methods also apply to important process sources of $CO_2$ emissions, such as cement and lime production, where country-specific circumstances are again taken fully into account.

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

#### Methane ($CH_4$)

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

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

#### Nitrous oxide ($N_2O$)

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

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

## 1.5 Overview of Key Categories

The IPCC good practice guidance defines a key category as one that is prioritised within the national inventory system because its emission estimate has a significant influence on the Party's total inventory in terms of the absolute level of emissions, the trend in emissions or both. Information about key categories is considered to be crucial to the choice of methodology for individual sources and to the management and reduction of overall inventory uncertainty. The identification of such categories is recommended in order that inventory agencies can give them priority in the preparation of annual inventories, especially in cases where resources may be limited. Information on key categories is clearly also vital for the development of policies and measures for emissions reduction. The IPCC good practice guidance provides several methods for undertaking the analysis of key categories that can be applied at any appropriate level of source aggregation, depending on the information available. The simplest Tier 1 approach is again used for 2010 to further highlight which sources of emissions are the most important in Ireland.

### 1.5.1 Key Categories at IPCC Level 2

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

The results at the IPCC Level 2 source category classification may be readily drawn from the CRF Summary 2. Those for 1990 and 2010 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 1990-2010 trend.

They are the $CO_2$ 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 $CH_4$ emissions from category *4.A Enteric Fermentation* and $N_2O$ emissions from *4.D Agricultural Soils*. These six categories accounted for 85.2 per cent and 90.1 per cent of total emissions in 1990 and 2010, respectively. In the case of 2010 emissions, two 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 CH4 emissions and *2.A.1 Cement Production* with $CO_2$ emissions. The increase in the contribution of $CO_2$ emissions from category *1.A.3 Transport* from 9.1 per cent in 1990 to 18.7 per cent in 2010 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, $CO_2$ emissions in *2.A.1 Cement production* become a key category in 1990 and $CO_2$ emissions in *6.A. Solid Waste disposal on land* become a key category in 2010.

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

| | IPCC Level 2 Source Category | GHG | Emissions in 1990 Gg $CO_2$ eq | 1990 Level Assessment % | Cumulative Total of Level % |
|---|---|---|---|---|---|
| 1.A.1. | Energy Industries | CO2 | 11,158.61 | 20.23 | 20.23 |
| 1.A.4 | Other Sectors(Comm/Resid/Agric) | CO2 | 10,030.97 | 18.18 | 38.41 |
| 4.A | Enteric Fermentation | CH4 | 9,574.12 | 17.36 | 55.77 |
| 4.D. | Agricultural Soils | N2O | 7,272.21 | 13.18 | 68.95 |
| 1.A.3 | Transport | CO2 | 5,022.04 | 9.10 | 78.06 |
| 1.A.2. | Manufacturing Industries and Construction | CO2 | 3,942.64 | 7.15 | 85.20 |
| 4.B | Manure Management | CH4 | 2,353.63 | 4.27 | 89.47 |
| 6.A | Solid Waste Disposal on land | CH4 | 1,173.05 | 2.13 | 91.60 |
| 2.B.2 | Nitric Acid Production | N2O | 1,035.40 | 1.88 | 93.47 |
| 2.B.1 | Ammonia Production | CO2 | 990.23 | 1.80 | 95.27 |

* nitric acid and ammonia plants ceased operation in 2002 and 2001, respectively

*Table 1.3. Key Categories at IPCC Level 2 in 2010*

| | IPCC Level 2 Source Category | GHG | Emissions in 2010 Gg $CO_2$ eq | 2010 Level Assessment % | Cumulative Total of Level % |
|---|---|---|---|---|---|
| 1.A.1. | Energy Industries | CO2 | 13,170.78 | 21.48 | 21.48 |
| 1.A.3 | Transport | CO2 | 11,475.61 | 18.72 | 40.20 |
| 1.A.4 | Other Sectors(Comm/Resid/Agric) | CO2 | 10,725.20 | 17.49 | 57.69 |
| 4.A | Enteric Fermentation | CH4 | 8,496.26 | 13.86 | 71.55 |
| 4.D. | Agricultural Soils | N2O | 6,837.61 | 11.15 | 82.70 |
| 1.A.2. | Manufacturing Industries and Construction | CO2 | 4,525.74 | 7.38 | 90.08 |
| 4.B | Manure Management | CH4 | 2,133.78 | 3.48 | 93.56 |
| 2.A.1 | Cement Production | CO2 | 1,105.11 | 1.80 | 95.36 |

*Table 1.4. Summary of Methods*

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

T1: IPCC Tier 1 or equivalent
T2: IPCC Tier 2 or equivalent
T3: IPCC Tier 3 or equivalent
CS: Country specific
CR: CORINAIR
D: IPCC Default

*Table 1.5. Summary of Emission Factors*

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

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

### 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 in both 1990 and 2010 are presented in Table 1.6 and Table 1.7, respectively. 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 2010 are shown in Table 1.8.

The results of the level assessment for 2010 including LULUCF categories may be summarised as follows:

(i) level assessment identifies 28 key categories, all of which but four (liquid fuels $CO_2$ emissions in both 1.A.2. and 1.A.4.c. plus $CO_2$ emissions in 2.A.1 and $N_2O$ emissions in 4.D.3.) are key categories for 2010 trend assessment;

(ii) there are 17 key categories of $CO_2$ in level assessment, accounting for 66.7 per cent of total emissions;

(iii) there are 7 key categories of $CH_4$, three key categories of $N_2O$ and one category of HFC in level assessment, which account for 17.9 per cent, 10.5 per cent and 0.9 per cent, respectively, of total emissions;

(iv) *Energy* accounts for 13 key categories, *Agriculture* for 9, *LULUCF* for 3 while *Industrial Processes* contributes two and *Waste* contributes one;

(v) trend assessment identifies 21 key categories, all of which but one (solid fuels $CH_4$ emissions in 1.A.4.b.) are key categories for 2010 level assessment;

(vi) there are 11 key categories of $CO_2$ in trend assessment, accounting for 79.2 per cent of the total trend;

(vii) there are 7 key categories of $CH_4$, two key categories of $N_2O$ and one key category of HFC in trend assessment, which account for 11.0 per cent, 3.3 per cent and 1.8 per cent, respectively, of the total trend.

The list of key categories given by level assessment in 2010 is very similar to that for 1990. However, the higher ranking of the main $CO_2$ sources in *Energy,* at the expense of $CH_4$ and $N_2O$ sources in *Agriculture*, is notable in 2010. The top ten key categories (excluding LULUCF) were in a different order but identical apart from one (1.A.4.a with $CO_2$ emissions from liquid fuels in 1990 was replaced by 1.A.4.b. with $CO_2$ emissions from liquid fuels) and contributed 67.7 and 68.9 per cent, of total emissions in 1990 and 2010, respectively. The emissions of $CO_2$ 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 2010, accounting for 16.7 and 19.0 per cent of the total, respectively.

The $CO_2$ removals in category *5.A.1 Forest Land Remaining Forest Land*, $CO_2$ emissions in *5.C.1 Grassland Remaining Grassland* and $CO_2$ emissions in *5.A.2 Land Converted to Forest Land* are key categories in level assessment when the LULUCF sector is included in the detailed analysis. Similarly, $CO_2$ removals in category KP *A.1 Afforestation (*which are determined largely by *5.A.1 Forest Land Remaining Forest Land* under LULUCF) is a key category in 2010 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 1.7. The results including LULUCF indicate that 17 of the 28 key categories in 2010 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 clearly show the impact of $CO_2$ emissions from energy consumption on total emissions in Ireland. These emissions account for 13 of the key categories listed in Table 1.7 and for 60.1 per cent of total emissions in 2010. While key categories determined by $CO_2$ emissions from energy consumption have a major bearing on total emissions in Ireland, the remaining potential for significant reduction in the uncertainties associated with these sources is rather limited. The activity data and $CO_2$ emission factors for *Energy* source categories in general are among the most reliable items of input data in the inventory and there is consequently little scope for improving the accuracy of the emission estimates. The application of a robust Tier 2 methodology for emissions of $CH_4$ from enteric fermentation in cattle (dairy and non-dairy) and the use of verified estimates for $CO_2$ emissions from cement production means that the contributions from three additional key categories (ranked 4, 8 and 17 in Table 1.7), making up a further 13.7 per cent of the total, are also known with probably the highest certainty now achievable. The $N_2O$ emissions from *4.D Agricultural Soils* and $CH_4$ 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 2010. 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 2012 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 $CO_2$ estimates in a number of sub-categories under 1.A.1 (Energy Industries) and 2.A. (Mineral Products). When the allocation to these categories from the ETS raw data is completed, the output is returned to the ETS administrator in OCLR for final checking against the source data. This ensures the efficient and consistent transfer of the verified ETS emissions estimates into the national inventory. Inventory development continues to benefit from the internal review procedures that are on-going with regard to the EU and its Member States. The 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 2010. 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 for 2010 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 2010 is presented in Table 1.9, 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 1.9. 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 $CO_2$ emissions sources in Industrial Processes, for which bottom-up data are applied in most cases and the major sources of emissions are covered by ETS. Country-specific $CO_2$ emission factors are used for all combustion sources, which gives a basis for assigning the uncertainties for emission factors while again taking into account the applicable tiers. Uncertainties in the emission factors for $CH_4$ and $N_2O$ released from combustion sources are high and not well established quantitatively. For the 2010 submission, Ireland updated the $CH_4$ and $N_2O$ emission factors for combustion categories in general to those given by the most up-to-date IPCC publications and has used an indicative uncertainty of 50 per cent for both gases.

The *Agriculture* sector is the second most important sector in Ireland's GHG inventory and has a major influence on overall uncertainty due to its large contribution in terms of $CH_4$ and $N_2O$ emissions. Ireland has long-established and robust statistical data collection procedures in place for agriculture in general, which guides the selection of 1 per cent as the activity data uncertainty for all agriculture sub-categories. The IPCC good practice guidance indicates that the emission factor estimates for the Tier 2 approach to determine $CH_4$ emissions from enteric fermentation in cattle are likely to have an uncertainty of 20 per cent. Following the opinion of national agriculture experts, a value of 15 per cent has been adopted for these emissions which takes 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 1.9 show how some of these uncertainty inputs are obtained.

Category 6.A Solid Waste is the principal source of $CH_4$ emissions outside *Agriculture*. Under the revised methodology used for category 6.A in this submission, the component uncertainties for both activity data and emission factor for $CH_4$ generation are derived using equation 6.4 of the IPCC good practice guidance and as shown in the footnotes to Table 1.9. 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.

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 (including LULUCF) for Ireland's 2010 inventory under the Convention (Table 1.9) gives an overall uncertainty of 7.15 per cent in total emissions and a trend uncertainty of 2.72 per cent for the period 1990 to 2010 These relatively low estimates are determined largely by the low uncertainties in the estimate of $CO_2$ emissions, which accounts for 67 per cent of total Irish emissions in 2010 and which are estimated to have a level uncertainty of 2.0 per cent. When $CH_4$ is included, bringing the proportion of total emissions up to 86 per cent, the total uncertainty estimate is 2.6 per cent, even though there are large uncertainties assigned to the $CH_4$ emission factors in some source categories. However, it is the influence of $N_2O$ that leads to a substantial uncertainty in total emissions. This influence is not as large in the case of the trend, due to the modest change in emissions of $N_2O$ from 1990 to 2010 and the relatively small share of this gas in total emissions. The impact of HFC, PFC and $SF_6$ on inventory uncertainty remains negligible because these gases account for only 1 per cent of total emissions in Ireland.

The overall uncertainly of the inventory in 2010 is estimated at 7.15 per cent which is showing a decrease since the last submission. The corresponding value in 2009 was 7.84 per cent. The reason for the decrease from 2009 to 2010 is due to applying a higher level of disaggregation within the uncertainty analysis for $CO_2$ emissions from LULUCF. The overall trend uncertainty increased in 2010 when compared to 2009 to a value of 4.45 per cent compared to 4.44 per cent.

The overall uncertainty estimate for Article 3.3 activities in 2010 is 20.46 per cent, which is determined largely by an uncertainty of 19.79 per cent calculated for $CO_2$ removals in the category 5(KP-I)A.1.1

## 1.8 Completeness and Time-Series Consistency

Table 1.10 gives an overview of the level of completeness of the 2010 GHG inventories 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 1990-2009 to bring them fully into line with that for 2010, which features important methodological changes in the Agriculture and Waste sectors. 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 Level Assessment 1990*

| 1990 Rank | IPCC Sub-Category | Emission Source/Activity | Direct GHG | 1990 Estimate Emission exclud. LULUCF Gg CO2 eq | 1990 Estimate LULUCF Gg CO2 eq | 1990 Estimate Absolute Value Gg CO2 eq | 1990 Level Assessment with LULUCF % | Cumulative Total % |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.A.1. | Energy Industries - Solid Fuels | CO2 | 8009.44 | | 8009.44 | 14.00 | 14.00 |
| 2 | 4.A.1. | Enteric Fermentation - Non-Dairy Cattle | CH4 | 5630.17 | | 5630.17 | 9.84 | 23.85 |
| 3 | 1.A.4.b | Residential - Solid Fuels | CO2 | 5606.94 | | 5606.94 | 9.80 | 33.65 |
| 4 | 1.A.3.b. | Road Transport - Liquid Fuels | CO2 | 4690.77 | | 4690.77 | 8.20 | 41.86 |
| 5 | 4.D.1. | Agricultural Soils - Direct Soil Emissions | N2O | 3024.59 | | 3024.59 | 5.29 | 47.14 |
| 6 | 4.D.2. | Agricultural Soils - Pasture, Range & Paddock | N2O | 2868.35 | | 2868.35 | 5.02 | 52.16 |
| 7 | 4.A.1. | Enteric Fermentation - Dairy Cattle | CH4 | 2854.99 | | 2854.99 | 4.99 | 57.15 |
| 8 | 1.A.2. | Manufacturing Industries & Construction - Liquid Fuels | CO2 | 2198.38 | | 2198.38 | 3.84 | 61.00 |
| 9 | 1.A.4.a. | Commercial/Institutional - Liquid Fuels | CO2 | 1957.00 | | 1957.00 | 3.42 | 64.42 |
| 10 | 1.A.1. | Energy Industries - Gaseous Fuels | CO2 | 1880.66 | | 1880.66 | 3.29 | 67.71 |
| 11 | 4.D.3. | Agricultural Soils - Indirect Emissions | N2O | 1379.27 | | 1379.27 | 2.41 | 70.12 |
| 12 | 4.B.1. | Manure Management - Non-Dairy cattle | CH4 | 1279.75 | | 1279.75 | 2.24 | 72.36 |
| 13 | 1.A.1. | Energy Industries - Liquid Fuels | CO2 | 1268.51 | | 1268.51 | 2.22 | 74.57 |
| 14 | 1.A.4.b | Residential - Liquid Fuels | CO2 | 1175.35 | | 1175.35 | 2.06 | 76.63 |
| 15 | 6.A. | Waste - Solid Waste Disposal on land | CH4 | 1173.05 | | 1173.05 | 2.05 | 78.68 |
| 16 | 2.B. | Chemical Industry | N2O | 1035.40 | | 1035.40 | 1.81 | 80.49 |
| 17 | 4.A.3. | Enteric Fermentation - Sheep | CH4 | 1032.48 | | 1032.48 | 1.81 | 82.30 |
| 18 | 2.B. | Chemical Industry | CO2 | 990.23 | | 990.23 | 1.73 | 84.03 |
| 19 | 2.A.1. | Cement Production | CO2 | 884.00 | | 884.00 | 1.55 | 85.57 |
| 20 | 1.A.2. | Manufacturing Industries & Construction - Gaseous Fuels | CO2 | 873.02 | | 873.02 | 1.53 | 87.10 |
| 21 | 1.A.2. | Manufacturing Industries & Construction - Solid Fuels | CO2 | 871.24 | | 871.24 | 1.52 | 88.62 |
| 22 | 5.A.1 | LULUCF - Forest land Remaining Forest Land | CO2 | | -803.41 | 803.41 | 1.40 | 90.03 |
| 23 | 1.A.4.c. | Agriculture/Forestry/Fisheries - Liquid Fuels | CO2 | 660.30 | | 660.30 | 1.15 | 91.18 |
| 24 | 4.B.1. | Manure Management - Dairy Cattle | CH4 | 608.23 | | 608.23 | 1.06 | 92.25 |
| 25 | 5.C.1 | LULUCF - Grassland Remaining Grassland | CO2 | | 602.37 | 602.37 | 1.05 | 93.30 |
| 26 | 4.B.13. | Manure Management - Solid Storage | N2O | 371.24 | | 371.24 | 0.65 | 93.95 |
| 27 | 5.A.2. | LULUCF - Land Converted to Forest Land | CO2 | | 412.72 | 412.72 | 0.72 | 94.67 |
| 28 | 1.A.4.b | Residential - Solid Fuels | CH4 | 356.29 | | 356.29 | 0.62 | 95.29 |

*Table 1.7. Key Category Level Assessment 2010*

| 2010 Rank | IPCC Sub-Category | Emission Source/Activity | Direct GHG | 2010 Estimate Emission exclud. LULUCF Gg CO2 eq | 2010 Estimate LULUCF Gg CO2 eq | 2010 Estimate Absolute Value Gg CO2 eq | 2010 Level Assessment with LULUCF % | Cumulative Total % |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.A.3.b. | Road Transport - Liquid Fuels | CO2 | 10950.80 | | 10950.80 | 16.73 | 16.73 |
| 2 | 1.A.1. | Energy Industries - Gaseous Fuels | CO2 | 6633.19 | | 6633.19 | 10.13 | 26.86 |
| 3 | 1.A.1. | Energy Industries - Solid Fuels | CO2 | 5808.95 | | 5808.95 | 8.87 | 35.74 |
| 4 | 4.A.1. | Enteric Fermentation - Non-Dairy Cattle | CH4 | 5370.20 | | 5370.20 | 8.20 | 43.94 |
| 5 | 1.A.4.b | Residential - Liquid Fuels | CO2 | 3802.95 | | 3802.95 | 5.81 | 49.75 |
| 6 | 4.D.1. | Agricultural Soils - Direct Soil Emissions | N2O | 2878.33 | | 2878.33 | 4.40 | 54.15 |
| 7 | 4.D.2. | Agricultural Soils - Pasture, Range & Paddock | N2O | 2635.77 | | 2635.77 | 4.03 | 58.18 |
| 8 | 4.A.1. | Enteric Fermentation - Dairy Cattle | CH4 | 2494.61 | | 2494.61 | 3.81 | 61.99 |
| 9 | 1.A.2. | Manufacturing Industries & Construction - Liquid Fuels | CO2 | 2413.71 | | 2413.71 | 3.69 | 65.68 |
| 10 | 5.A.1 | LULUCF - Forest land Remaining Forest Land | CO2 | | -2010.25 | 2010.25 | 3.07 | 68.75 |
| 11 | 1.A.4.b | Residential - Solid Fuels | CO2 | 2135.30 | | 2135.30 | 3.26 | 72.01 |
| 12 | 1.A.4.b | Residential - Gaseous Fuels | CO2 | 1696.65 | | 1696.65 | 2.59 | 74.60 |
| 13 | 1.A.2. | Manufacturing Industries & Construction - Gaseous Fuels | CO2 | 1686.15 | | 1686.15 | 2.58 | 77.18 |
| 14 | 1.A.4.a. | Commercial/Institutional - Liquid Fuels | CO2 | 1230.31 | | 1230.31 | 1.88 | 79.06 |
| 15 | 4.D.3. | Agricultural Soils - Indirect Emissions | N2O | 1323.51 | | 1323.51 | 2.02 | 81.08 |
| 16 | 4.B.1. | Manure Management - Non-Dairy Cattle | CH4 | 1129.48 | | 1129.48 | 1.73 | 82.81 |
| 17 | 2.A.1. | Cement Production | CO2 | 1105.11 | | 1105.11 | 1.69 | 84.49 |
| 18 | 1.A.4.a. | Commercial/Institutional - Gaseous Fuels | CO2 | 1092.74 | | 1092.74 | 1.67 | 86.16 |
| 19 | 1.A.4.c. | Agriculture/Forestry/Fisheries - Liquid Fuels | CO2 | 767.26 | | 767.26 | 1.17 | 87.34 |
| 20 | 1.A.1. | Energy Industries - Liquid Fuels | CO2 | 728.63 | | 728.63 | 1.11 | 88.45 |
| 21 | 6.A. | Waste - Solid Waste Disposal on land | CH4 | 727.46 | | 727.46 | 1.11 | 89.56 |
| 22 | 5.C.1 | LULUCF - Grassland Remaining Grassland | CO2 | | 570.61 | 570.61 | 0.87 | 90.43 |
| 23 | 2.F. | Consumption of F Gas & SF6 | HFC | 563.04 | | 563.04 | 0.86 | 91.29 |
| 24 | 4.A.3. | Enteric Fermentation - Sheep | CH4 | 556.76 | | 556.76 | 0.85 | 92.14 |
| 25 | 5.A.2. | LULUCF - Land converted to Forest Land | CO2 | | 594.77 | 594.77 | 0.91 | 93.05 |
| 26 | 4.B.1. | Manure Management - Dairy Cattle | CH4 | 461.77 | | 461.77 | 0.71 | 93.76 |
| 27 | 1.A.2. | Manufacturing Industries & Construction - Solid Fuels | CO2 | 409.18 | | 409.18 | 0.63 | 94.38 |
| 28 | 4.B.8. | Manure Management - Pigs | CH4 | 406.38 | | 406.38 | 0.62 | 95.00 |

*Table 1.8. Key Category Trend Assessment 2010 (excluding LULUCF)*

| Rank | IPCC Sub-Category | Emission Source/Activity | Direct GHG | 1990 Emissions exc LULUCF Gg CO2 eq | 2010 Emissions exc LULUCF Gg CO2 eq | 2010 Level Assessment % | 2010 Trend Assessment | Contribution to Trend % | Cumulative Total Contribution % |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.A.3.b. | Road Transport - Liquid Fuels | CO2 | 4690.77 | 10950.80 | 17.86 | 8.42 | 18.10 | 18.10 |
| 2 | 1.A.1. | Energy Industries - Gaseous Fuels | CO2 | 1880.66 | 6633.19 | 10.82 | 6.67 | 14.33 | 32.43 |
| 3 | 1.A.4.b | Residential - Solid Fuels | CO2 | 5606.94 | 2135.30 | 3.48 | 6.01 | 12.92 | 45.35 |
| 4 | 1.A.1. | Energy Industries - Solid Fuels | CO2 | 8009.44 | 5808.95 | 9.47 | 4.54 | 9.76 | 55.11 |
| 5 | 1.A.4.b | Residential - Liquid Fuels | CO2 | 1175.35 | 3802.95 | 6.20 | 3.66 | 7.88 | 62.99 |
| 6 | 1.A.4.b | Residential - Gaseous Fuels | CO2 | 269.73 | 1696.65 | 2.77 | 2.05 | 4.41 | 67.39 |
| 7 | 4.A.1. | Enteric Fermentation - Non-Dairy Cattle | CH4 | 5630.17 | 5370.20 | 8.76 | 1.30 | 2.80 | 70.19 |
| 8 | 1.A.4.a. | Commercial/Institutional - Gaseous Fuels | CO2 | 223.37 | 1092.74 | 1.78 | 1.24 | 2.66 | 72.86 |
| 9 | 1.A.4.a. | Commercial/Institutional - Liquid Fuels | CO2 | 1957.00 | 1230.31 | 2.01 | 1.39 | 2.98 | 75.84 |
| 10 | 1.A.2. | Manufacturing Industries & Construction - Gaseous Fuels | CO2 | 873.02 | 1686.15 | 2.75 | 1.05 | 2.26 | 78.10 |
| 11 | 1.A.1. | Energy Industries - Liquid Fuels | CO2 | 1268.51 | 728.63 | 1.19 | 1.00 | 2.15 | 80.25 |
| 12 | 4.A.1. | Enteric Fermentation - Dairy Cattle | CH4 | 2854.99 | 2494.61 | 4.07 | 1.00 | 2.14 | 82.39 |
| 13 | 4.A.3. | Enteric Fermentation - Sheep | CH4 | 1032.48 | 556.76 | 0.91 | 0.87 | 1.86 | 84.25 |
| 14 | 6.A. | Waste - Solid Waste Disposal on land | CH4 | 1173.05 | 727.46 | 1.19 | 0.85 | 1.82 | 86.07 |
| 15 | 2.F. | Consumption of F Gas & SF6 | HFC | 1.31 | 563.04 | 0.92 | 0.82 | 1.77 | 87.84 |
| 16 | 1.A.2. | Manufacturing Industries & Construction - Solid Fuels | CO2 | 871.24 | 409.18 | 0.67 | 0.82 | 1.76 | 89.61 |
| 17 | 4.D.2. | Agricultural Soils - Pasture, Range & Paddock | N2O | 2868.35 | 2635.77 | 4.30 | 0.81 | 1.74 | 91.35 |
| 18 | 4.D.1. | Agricultural Soils - Direct Soil Emissions | N2O | 3024.59 | 2878.33 | 4.69 | 0.71 | 1.53 | 92.87 |
| 19 | 4.B.1. | Manure Management - Non-Dairy cattle | CH4 | 1279.75 | 1129.48 | 1.84 | 0.43 | 0.92 | 93.80 |
| 20 | 1.A.4.b | Residential - Solid Fuels | CH4 | 356.29 | 135.95 | 0.22 | 0.38 | 0.82 | 94.62 |
| 21 | 4.B.1. | Manure Management - Dairy Cattle | CH4 | 608.23 | 461.77 | 0.75 | 0.31 | 0.68 | 95.29 |

***Table 1.9 Tier 1 Uncertainty Estimates 2010 (continued on following pages)***

| IPCC Source Category | | Gas | Emissions in 1990 | Emissions in 2010 | Activity Data (AD) Uncertainty | Emission Factor (EF) Uncertainty | Combined Uncertainty | Combined Uncertainty as % of Emissions in 2010 | 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 $CO_2$eq** | **Gg $CO_2$eq** | **%** | **%** | **%** | **%** | | **%** | **%** | **%** | **%** | **%** | |
| 1A1 | Energy-Liquid | $CO_2$ | 1268.51 | 728.63 | 1.0 | 2.5 | 2.69 | 0.03 | 0.00 | -0.01 | 0.01 | 0.02 | -0.03 | 0.03 | 0.00 |
| 1A1 | Energy-Solid | $CO_2$ | 8009.44 | 5808.95 | 1.0 | 5.0 | 5.10 | 0.49 | 0.23 | -0.05 | 0.10 | 0.15 | -0.26 | 0.30 | 0.09 |
| 1A1 | Energy-Gas | $CO_2$ | 1880.66 | 6633.19 | 1.0 | 2.5 | 2.69 | 0.30 | 0.07 | 0.08 | 0.12 | 0.17 | 0.21 | 0.27 | 0.07 |
| 1A2 | Industry-Liquid exc Pet Coke | $CO_2$ | 2013.71 | 2093.01 | 10.0 | 2.5 | 10.31 | 0.36 | 0.14 | 0.00 | 0.04 | 0.53 | 0.00 | 0.53 | 0.29 |
| 1A2 | Industry-Coal | $CO_2$ | 871.24 | 409.18 | 2.0 | 5.0 | 5.39 | 0.04 | 0.00 | -0.01 | 0.01 | 0.02 | -0.05 | 0.05 | 0.00 |
| 1A2 | Industry-Pet Coke | $CO_2$ | 184.67 | 320.69 | 5.0 | 5.0 | 7.07 | 0.04 | 0.00 | 0.00 | 0.01 | 0.04 | 0.01 | 0.04 | 0.00 |
| 1A2 | Industry-Gas | $CO_2$ | 873.02 | 1686.15 | 2.5 | 2.5 | 3.54 | 0.10 | 0.01 | 0.01 | 0.03 | 0.11 | 0.03 | 0.11 | 0.01 |
| 1A3 | Transport-Oil | $CO_2$ | 4959.99 | 11311.01 | 1.0 | 2.5 | 2.69 | 0.51 | 0.31 | 0.11 | 0.20 | 0.29 | 0.27 | 0.39 | 0.15 |
| 1A3 | Transport-Gas | $CO_2$ | 62.04 | 164.60 | 1.0 | 2.5 | 2.69 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| 1A4 | Comm-Liquid | $CO_2$ | 1957.00 | 1230.31 | 10.0 | 5.0 | 11.18 | 0.23 | 0.06 | -0.02 | 0.02 | 0.31 | -0.08 | 0.32 | 0.11 |
| 1A4 | Comm-Coal | $CO_2$ | 2.56 | 0.00 | 5.0 | 10.0 | 11.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Peat | $CO_2$ | 135.73 | 0.00 | 10.0 | 20.0 | 22.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.05 | 0.05 | 0.00 |
| 1A4 | Comm-Gas | $CO_2$ | 223.37 | 1092.74 | 2.5 | 2.5 | 3.54 | 0.06 | 0.00 | 0.02 | 0.02 | 0.07 | 0.04 | 0.08 | 0.01 |
| 1A4 | Res-Liquid | $CO_2$ | 1099.66 | 3750.90 | 10.0 | 5.0 | 11.18 | 0.70 | 0.40 | 0.05 | 0.07 | 0.96 | 0.23 | 0.99 | 0.97 |
| 1A4 | Res-Coal | $CO_2$ | 2483.57 | 1050.28 | 5.0 | 10.0 | 11.18 | 0.19 | 0.03 | -0.03 | 0.02 | 0.13 | -0.30 | 0.33 | 0.11 |
| 1A4 | Res-Petcoke | $CO_2$ | 75.68 | 52.05 | 5.0 | 5.0 | 7.07 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| 1A4 | Res-Peat | $CO_2$ | 3123.37 | 1085.02 | 10.0 | 20.0 | 22.36 | 0.40 | 0.17 | -0.04 | 0.02 | 0.28 | -0.84 | 0.88 | 0.78 |
| 1A4 | Res-Gas | $CO_2$ | 269.73 | 1696.65 | 2.5 | 2.5 | 3.54 | 0.10 | 0.01 | 0.03 | 0.03 | 0.11 | 0.06 | 0.13 | 0.02 |
| 1A4 | Agric/Fishing Liquid | $CO_2$ | 660.30 | 767.26 | 10.0 | 5.0 | 11.18 | 0.14 | 0.01 | 0.00 | 0.01 | 0.20 | 0.00 | 0.20 | 0.04 |
| 2A1 | Cement Production | $CO_2$ | 884.00 | 1105.11 | 1.5 | 1.5 | 2.12 | 0.04 | 0.00 | 0.00 | 0.02 | 0.04 | 0.00 | 0.04 | 0.00 |
| 2A2 | Lime Production | $CO_2$ | 214.08 | 192.41 | 5.0 | 5.0 | 7.07 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 |
| 2A3 | Limestone and Dolomite Use | $CO_2$ | 0.15 | 1.03 | 5.0 | 2.5 | 5.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2A4 | Soda Ash Production and Use | $CO_2$ | 0.10 | 0.07 | 5.0 | 2.5 | 5.59 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2A7 | Glass Production | $CO_2$ | 13.33 | 0.00 | 5.0 | 5.0 | 7.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2A7 | Other Mineral Products | $CO_2$ | 5.07 | 0.42 | 5.0 | 5.0 | 7.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2B1 | Ammonia Production | $CO_2$ | 990.23 | 0.00 | 1.0 | 5.0 | 5.10 | 0.00 | 0.00 | -0.02 | 0.00 | 0.00 | -0.10 | 0.10 | 0.01 |
| 3 | Solvent and Other Product Use | $CO_2$ | 80.03 | 71.59 | 30.0 | 5.0 | 30.41 | 0.04 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.05 | 0.00 |
| 5A | LULUCF-Forest Land | $CO_2$ | -390.70 | -1415.48 | 15 | 50 | 52.20 | -1.23 | 1.50 | -0.02 | -0.03 | -0.54 | -0.89 | 1.05 | 1.09 |
| 5B | LULUCF-Cropland | $CO_2$ | 20.00 | 227.09 | | | 73.00 | 0.28 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5C1 | LULUCF-Grassland | $CO_2$ | 602.37 | 570.61 | | | 94.00 | 0.89 | 0.79 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5C2 | LULUCF-Grassland-Soils | $CO_2$ | -68.30 | -84.52 | | | 74.00 | -0.10 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5C2 | LULUCF-Grassland-Biomass | $CO_2$ | -40.50 | -277.58 | | | 80.00 | -0.37 | 0.14 | 0.00 | -0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5D | LULUCF-Wetlands | $CO_2$ | 47.07 | 37.22 | | | 93.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5E | LULUCF-Settlements | $CO_2$ | 9.22 | 23.33 | | | 85.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5F | LULUCF-Other Land | $CO_2$ | -1.06 | -183.26 | | | 86.00 | -0.26 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **Total $CO_2$** | | **32519.35** | **40148.65** | **0.67** | | | **2.01** | **4.05** | | | | | **1.94** | **3.75** |

| | IPCC Source Category | Gas | Emissions in 1990 | Emissions in 2010 | Activity Data (AD) Uncertainty | Emission Factor (EF) Uncertainty | Combined Uncertainty | Combined Uncertainty as % of Emissions in 2010 | 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 $CO_2$eq** | **Gg $CO_2$eq** | **%** | **%** | **%** | **%** | | **%** | **%** | **%** | **%** | **%** | |
| 1A1 | Energy-Liquid | $CH_4$ | 0.33 | 0.22 | 1.0 | 50.0 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A1 | Energy-Solid | $CH_4$ | 2.36 | 1.86 | 1.0 | 50.0 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A1 | Energy-Gas | $CH_4$ | 2.88 | 3.51 | 1.0 | 50.0 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Liquid exc Pet Coke | $CH_4$ | 1.60 | 1.63 | 10.0 | 50.0 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Coal | $CH_4$ | 1.93 | 0.91 | 2.0 | 50.0 | 50.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Pet Coke | $CH_4$ | 0.12 | 0.22 | 5.0 | 50.0 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Gas | $CH_4$ | 0.33 | 0.62 | 2.5 | 50.0 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A3 | Transport-Oil | $CH_4$ | 36.17 | 17.95 | 1.0 | 50.0 | 50.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | -0.02 | 0.02 | 0.00 |
| 1A3 | Transport-Gas | $CH_4$ | 0.12 | 0.30 | 1.0 | 50.0 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Liquid | $CH_4$ | 5.53 | 3.50 | 10.0 | 50.0 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Coal | $CH_4$ | 0.01 | 0.00 | 5.0 | 50.0 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Peat | $CH_4$ | 0.28 | 0.00 | 10.0 | 50.0 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Gas | $CH_4$ | 0.43 | 2.01 | 2.5 | 50.0 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Res-Liquid | $CH_4$ | 2.95 | 10.86 | 10.0 | 50.0 | 50.99 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| 1A4 | Res-Coal | $CH_4$ | 165.07 | 69.07 | 5.0 | 50.0 | 50.25 | 0.06 | 0.00 | 0.00 | 0.00 | 0.01 | -0.10 | 0.10 | 0.01 |
| 1A4 | Res-Petcoke | $CH_4$ | 0.17 | 0.12 | 5.0 | 50.0 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Res-Peat | $CH_4$ | 191.22 | 66.88 | 10.0 | 50.0 | 50.99 | 0.06 | 0.00 | 0.00 | 0.00 | 0.02 | -0.13 | 0.13 | 0.02 |
| 1A4 | Res-Gas | $CH_4$ | 0.52 | 3.12 | 2.5 | 50.0 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Agric/Fishing Liquid | $CH_4$ | 0.90 | 1.09 | 10.0 | 50.0 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Biomass | $CH_4$ | 13.39 | 15.90 | 10.0 | 50.0 | 50.99 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1B | Fugitive Emissions | $CH_4$ | 131.26 | 31.64 | 2.5 | 10.0 | 10.31 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | -0.02 | 0.02 | 0.00 |
| 4A | Ent Ferm Dairy Cattle | $CH_4$ | 2854.99 | 2494.61 | 1.0 | 15.0 | 15.03 | 0.62 | 0.39 | -0.01 | 0.05 | 0.06 | -0.17 | 0.18 | 0.03 |
| 4A | Ent Ferm Other Cattle | $CH_4$ | 5630.17 | 5370.20 | 1.0 | 15.0 | 15.03 | 1.34 | 1.79 | -0.01 | 0.10 | 0.14 | -0.21 | 0.25 | 0.06 |
| 4A | Ent Ferm Other Livestock | $CH_4$ | 1088.95 | 631.45 | 1.0 | 30.0 | 30.02 | 0.31 | 0.10 | -0.01 | 0.01 | 0.02 | -0.30 | 0.30 | 0.09 |
| 4B | Manure Mgt Dairy Cattle | $CH_4$ | 608.23 | 461.77 | 1.0 | 15.0 | 15.03 | 0.12 | 0.01 | 0.00 | 0.01 | 0.01 | -0.05 | 0.06 | 0.00 |
| 4B | Manure Mgt Other Cattle | $CH_4$ | 1279.75 | 1129.48 | 1.0 | 15.0 | 15.03 | 0.28 | 0.08 | 0.00 | 0.02 | 0.03 | -0.07 | 0.08 | 0.01 |
| 4B | Manure Mgt Other Livestock | $CH_4$ | 465.65 | 542.53 | 1.0 | 30.0 | 30.02 | 0.27 | 0.07 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.00 |
| 5A | LULUCF-Forest Land | $CH_4$ | 2.69 | 7.02 | 30 | 100 | 104.40 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 |
| 6A | Solid Waste[abc] | $CH_4$ | 1173.05 | 727.46 | 34.6 | 34.6 | 48.99 | 0.59 | 0.35 | -0.01 | 0.01 | 0.64 | -0.34 | 0.73 | 0.53 |
| 6B | Wastewater Handling | $CH_4$ | 14.73 | 16.03 | 10.0 | 30.0 | 31.62 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **Total $CH_4$** | | **13675.79** | **11611.93** | | | | **1.67** | **2.80** | | | | | **0.87** | **0.75** |
| | | | | | | | | | | | | | | | |
| | **Cumulative $CO_2$ and $CH_4$** | | **46195.14** | **51760.59** | **0.86** | | | **2.62** | **6.85** | | | | | **2.12** | **4.50** |

| | IPCC Source Category | Gas | Emissions in 1990 | Emissions in 2010 | Activity Data (AD) Uncertainty | Emission Factor (EF) Uncertainty | Combined Uncertainty | Combined Uncertainty as % of Emissions in 2010 | 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 $CO_2$eq | Gg $CO_2$eq | % | % | % | % | | % | % | % | % | % | |
| 1A1 | Energy-Liquid | $N_2O$ | 1.52 | 0.73 | 1.00 | 50.00 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A1 | Energy-Solid | $N_2O$ | 62.22 | 49.97 | 1.00 | 50.00 | 50.01 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | -0.02 | 0.02 | 0.00 |
| 1A1 | Energy-Gas | $N_2O$ | 10.62 | 97.23 | 1.00 | 50.00 | 50.01 | 0.08 | 0.01 | 0.00 | 0.00 | 0.00 | 0.08 | 0.08 | 0.01 |
| 1A2 | Industry-Liquid exc Pet Coke | $N_2O$ | 4.65 | 4.68 | 10.00 | 50.00 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Coal | $N_2O$ | 4.28 | 2.01 | 2.00 | 50.00 | 50.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Pet Coke | $N_2O$ | 0.37 | 0.64 | 5.00 | 50.00 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A2 | Industry-Gas | $N_2O$ | 1.93 | 0.91 | 2.50 | 50.00 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A3 | Transport-Oil | $N_2O$ | 58.51 | 109.89 | 1.00 | 25.00 | 25.02 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.00 |
| 1A3 | Transport-Gas | $N_2O$ | 0.70 | 1.79 | 1.00 | 50.00 | 50.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Liquid | $N_2O$ | 4.87 | 3.08 | 10.00 | 50.00 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Comm-Coal | $N_2O$ | 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 |
| 1A4 | Comm-Peat | $N_2O$ | 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 |
| 1A4 | Comm-Gas | $N_2O$ | 0.13 | 0.59 | 2.50 | 50.00 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Res-Liquid | $N_2O$ | 2.43 | 9.52 | 10.00 | 50.00 | 50.99 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| 1A4 | Res-Coal | $N_2O$ | 12.18 | 5.10 | 5.00 | 50.00 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.01 | 0.01 | 0.00 |
| 1A4 | Res-Petcoke | $N_2O$ | 0.15 | 0.10 | 5.00 | 50.00 | 50.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Res-Peat | $N_2O$ | 13.17 | 4.61 | 10.00 | 50.00 | 50.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.01 | 0.01 | 0.00 |
| 1A4 | Res-Gas | $N_2O$ | 0.15 | 0.92 | 2.50 | 50.00 | 50.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1A4 | Agric/Fishing Liquid | $N_2O$ | 72.05 | 76.14 | 10.00 | 50.00 | 50.99 | 0.06 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 |
| | Biomass | $N_2O$ | 5.48 | 13.57 | 10.00 | 50.00 | 50.99 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| 2B | Nitric Acid | $N_2O$ | 1035.40 | 0.00 | 1.00 | 10.00 | 10.05 | 0.00 | 0.00 | -0.02 | 0.00 | 0.00 | -0.20 | 0.20 | 0.04 |
| 4B | Liquid System[d] | $N_2O$ | 63.87 | 63.15 | 11.22 | 100.00 | 100.63 | 0.11 | 0.01 | 0.00 | 0.00 | 0.02 | -0.01 | 0.02 | 0.00 |
| 4B | Solid Storage and Dry Lot[d] | $N_2O$ | 371.24 | 378.90 | 11.22 | 100.00 | 100.63 | 0.63 | 0.40 | 0.00 | 0.01 | 0.11 | -0.05 | 0.12 | 0.01 |
| 4D | Direct Soil Emissions[d] | $N_2O$ | 3024.59 | 2878.33 | 11.22 | 100.00 | 100.63 | 4.81 | 23.10 | -0.01 | 0.05 | 0.83 | -0.75 | 1.11 | 1.24 |
| 4D | Pasture Range and Paddock[d] | $N_2O$ | 2868.35 | 2635.77 | 11.22 | 100.00 | 100.63 | 4.40 | 19.37 | -0.01 | 0.05 | 0.76 | -0.88 | 1.16 | 1.34 |
| 4D | Indirect Emissions[d] | $N_2O$ | 1379.27 | 1323.51 | 11.22 | 50.00 | 51.24 | 1.13 | 1.27 | 0.00 | 0.02 | 0.38 | -0.16 | 0.41 | 0.17 |
| 5A | LULUCF-Forest Land | $N_2O$ | 16.977 | 37.237 | 30 | 100 | 104.40 | 0.06 | 0.00 | 0.00 | 0.00 | 0.03 | 0.03 | 0.04 | 0.00 |
| 5B | LULUCF-Cropland | $N_2O$ | | 25.357 | 30 | 100 | 104.40 | 0.04 | 0.00 | 0.00 | 0.00 | 0.02 | 0.05 | 0.05 | 0.00 |
| 5C1 | LULUCF-Grassland-Remaining | $N_2O$ | | | 91 | 100 | 135.21 | | | | | 0.00 | 0.00 | 0.00 | 0.00 |
| 5C2 | LULUCF-Grassland-Wetland | $N_2O$ | | | 86 | 100 | 131.89 | | | | | 0.00 | 0.00 | 0.00 | 0.00 |
| 5D | LULUCF-Wetlands | $N_2O$ | 3.593 | 2.593 | 93 | 100 | 136.56 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| 6B | Wastewater Handling | $N_2O$ | 114.00 | 145.25 | 10.00 | 10.00 | 14.14 | 0.03 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.04 | 0.00 |
| | **Total $N_2O$** | | **9133.31** | **7871.55** | | | | **6.65** | **44.17** | | | | | **1.68** | **2.82** |
| | **Cumulative $CO_2$, $CH_4$, $N_2O$** | | **55328.45** | **59632.14** | | | | **7.14** | **51.02** | | | | | **2.71** | **7.33** |
| 2F | Halocarbons & SF6 | HFC | 1.31 | 563.04 | 20.00 | 10.00 | 22.36 | 0.21 | 0.04 | 0.01 | 0.01 | 0.29 | 0.10 | 0.31 | 0.09 |
| 2F | Halocarbons & SF6 | PFC | 0.09 | 37.02 | 10.00 | 2.50 | 10.31 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| 2F | Halocarbons & SF6 | $SF_6$ | 35.51 | 34.51 | 15.00 | 5.00 | 15.81 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| | **Total HFC, PFC & $SF_6$** | | **36.91** | **634.57** | | | | **0.21** | **0.04** | | | | | **0.31** | **0.09** |
| | **Total all gases** | | **55365.37** | **60266.71** | | | | | **51.06** | | | | | | **7.42** |
| | | | | | **Overall Uncertainty in Emissions** | | | **7.15** | | | | **Trend Uncertainty** | | **2.72** | |

*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* 0.3464

*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* 0.3464

*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* 0.3113

*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 1.10. Summary of Completeness*

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

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

# Chapter Two

# Emission Trends

## 2.1 Trends in Total Emissions

The trends in emissions of the six greenhouse gases in Ireland over the period 1990-2010 are shown in Table 2.1. The estimates reported here show some changes on those reported in the 2011 submission, which reflect recalculations that are fully described in subsequent chapters. The trends in the principal emission components, shown as $CO_2$ equivalents. within the six IPCC sectors are shown on Figure 2.2 through Figure 2.10. Total emissions of the six greenhouse gases in Ireland (excluding net emissions from *Land Use Land Use Change and Forestry*) increased steadily from 55,162.55 Gg $CO_2$ eq in 1990 to 70,064.81 Gg $CO_2$ eq in 2001 and then decreased slightly to 68,064.16 Gg $CO_2$ eq in 2004. Total emissions increased again in 2005 to 69,315.38 Gg $CO_2$ eq and then decreased for five consecutive years. The largest annual change occurred from 2008 to 2009 when emissions decreased by 5,825.54 Gg $CO_2$ eq from 67,567.04 to 61,741.50 Gg $CO_2$ equivalent, a reduction of 8.6 per cent. Total emissions in 2010 were 11.2 per cent higher than in 1990 and 12.5 per cent lower than the peak level in 2001. The estimated total for 2010 is 61,313.92 Gg $CO_2$ eq, 427.58 Gg $CO_2$ eq or 0.7 per cent lower than that for 2009. Inter annual changes to national total emission estimates are shown in figure 2.1.

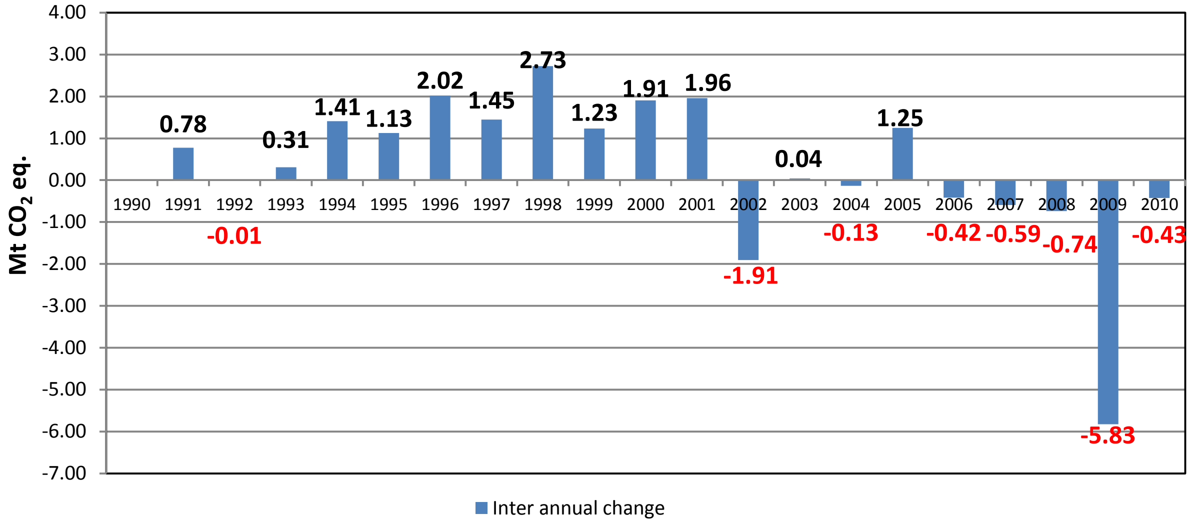


***Figure 2.1 Inter annual change in national total emissions 1990-2010***

In 2010, the total *Energy* sector accounted for 66.1 per cent of total emissions, *Agriculture* contributed 29.2 per cent while a further 3.2 per cent emanated from *Industrial Processes*, 1.4 per cent was due to *Waste* and 0.1 per cent was due to *Solvents and Other Product Use*.

The *Energy* and *Industrial Processes* sectors accounted for the bulk of the $CO_2$ emissions in 2010 (96.7 per cent and 3.2 per cent), $CH_4$ emissions are produced mainly in the *Agriculture* (91.6 per cent) and *Waste* (6.3 per cent) sectors and most of the $N_2O$ emissions are generated in *Agriculture* and *Energy* (93.3 per cent and 4.9 per cent, respectively).

The large increase in emissions during the period 1990-2001 was clearly driven by the growth in $CO_2$ emissions from energy use. $CO_2$ from energy use increased its share of national total emissions from 54.7 per cent in 1990 to 62.6 per cent share in 2001. The bulk of this increase occurred in the years between 1994 and 2001, during which Ireland experienced a period of unprecedented economic growth with energy $CO_2$ emissions increasing by an average of 2.8 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 to reach the level pre-2003.

*Table 2.1. Greenhouse Gas Emissions 1990, 1995, 2000-2010 (Gg $CO_2$ equivalent)*

(a) Emissions by Gas

| GREENHOUSE GAS EMISSIONS | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Change from base to latest reported year % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ emissions including net $CO_2$ from LULUCF | 32,519.355 | 35,584.592 | 44,978.569 | 47,279.227 | 45,638.510 | 44,959.576 | 45,968.096 | 47,404.851 | 46,942.857 | 46,704.208 | 45,786.733 | 40,548.311 | 40,165.359 | 23.512 |
| $CO_2$ emissions excluding net $CO_2$ from LULUCF | 32,341.247 | 35,148.597 | 44,627.075 | 47,037.839 | 45,611.873 | 45,060.257 | 45,945.326 | 47,673.097 | 47,295.875 | 47,465.103 | 46,960.776 | 41,649.260 | 41,267.968 | 27.602 |
| $CH_4$ emissions including $CH_4$ from LULUCF | 13,675.788 | 13,921.998 | 13,412.721 | 13,461.556 | 13,394.988 | 13,943.540 | 13,157.184 | 12,809.321 | 12,884.168 | 12,366.186 | 12,243.456 | 11,924.811 | 11,611.957 | -15.091 |
| $CH_4$ emissions excluding $CH_4$ from LULUCF | 13,673.094 | 13,918.479 | 13,410.408 | 13,456.943 | 13,393.928 | 13,937.002 | 13,153.375 | 12,807.936 | 12,882.783 | 12,364.629 | 12,241.561 | 11,923.741 | 11,604.941 | -15.126 |
| $N_2O$ emissions including $N_2O$ from LULUCF | 9,131.869 | 9,524.620 | 9,485.145 | 8,969.810 | 8,605.448 | 8,525.454 | 8,349.066 | 8,139.802 | 8,010.276 | 7,794.137 | 7,701.141 | 7,607.839 | 7,871.624 | -13.801 |
| $N_2O$ emissions excluding $N_2O$ from LULUCF | 9,111.299 | 9,491.334 | 9,446.934 | 8,927.106 | 8,560.367 | 8,476.097 | 8,299.525 | 8,089.927 | 7,959.923 | 7,742.966 | 7,637.162 | 7,543.626 | 7,806.437 | -14.321 |
| HFCs | 1.308 | 54.350 | 259.178 | 279.102 | 308.362 | 381.183 | 414.856 | 474.453 | 547.102 | 533.900 | 564.668 | 521.067 | 563.037 | 42,947.381 |
| PFCs | 0.093 | 75.382 | 305.406 | 295.984 | 212.403 | 228.795 | 182.427 | 168.340 | 148.320 | 130.579 | 106.197 | 65.570 | 37.022 | 39,666.273 |
| $SF_6$ | 35.514 | 82.931 | 54.349 | 67.839 | 67.732 | 115.428 | 68.654 | 101.629 | 62.896 | 65.520 | 56.676 | 38.236 | 34.511 | -2.824 |
| **Total (including LULUCF)** | **55,363.927** | **59,243.873** | **68,495.369** | **70,353.517** | **68,227.443** | **68,153.975** | **68,140.284** | **69,098.397** | **68,595.619** | **67,594.529** | **66,458.870** | **60,705.834** | **60,283.510** | **8.886** |
| **Total (excluding LULUCF)** | **55,162.555** | **58,771.075** | **68,103.349** | **70,064.813** | **68,154.665** | **68,198.761** | **68,064.164** | **69,315.381** | **68,896.899** | **68,302.697** | **67,567.040** | **61,741.499** | **61,313.916** | **11.151** |

***Table 2.1 contd. Greenhouse Gas Emissions 1990, 1995, 2000- 2010 (Gg $CO_2$ equivalent)***

## (b) Emissions by IPCC Source Category

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | 1990 | 1995 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Change from base to latest reported year % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy | 30,966.407 | 33,711.662 | 42,415.189 | 44,532.230 | 43,316.905 | 43,857.586 | 44,002.400 | 45,702.539 | 45,328.880 | 45,479.480 | 45,251.007 | 40,717.848 | 40,510.272 | 30.820 |
| 2. Industrial Processes | 3,179.274 | 3,082.730 | 4,222.465 | 4,329.896 | 3,754.952 | 3,068.021 | 3,173.000 | 3,297.217 | 3,297.061 | 3,310.433 | 3,029.124 | 2,110.195 | 1,933.619 | -39.180 |
| 3. Solvent and Other Product Use | 80.028 | 85.394 | 79.041 | 77.913 | 75.605 | 74.395 | 73.924 | 74.067 | 75.102 | 75.671 | 74.313 | 71.802 | 71.590 | -10.543 |
| 4. Agriculture | 19,635.070 | 20,315.699 | 19,970.914 | 19,595.320 | 19,378.964 | 19,510.702 | 19,314.939 | 18,857.164 | 18,723.236 | 18,295.215 | 18,162.315 | 17,926.090 | 17,909.692 | -8.787 |
| 5. Land Use, Land-Use Change and Forestry[5] | 201.372 | 472.799 | 392.019 | 288.704 | 72.778 | -44.786 | 76.120 | -216.985 | -301.280 | -708.168 | -1,108.170 | -1,035.665 | -1,030.406 | -611.691 |
| 6. Waste | 1,301.777 | 1,575.590 | 1,415.739 | 1,529.454 | 1,628.240 | 1,688.057 | 1,499.901 | 1,384.394 | 1,472.620 | 1,141.897 | 1,050.282 | 915.562 | 888.743 | -31.728 |
| 7. Other | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.000 |
| **Total (including LULUCF)[5]** | **55,363.927** | **59,243.873** | **68,495.369** | **70,353.517** | **68,227.443** | **68,153.975** | **68,140.284** | **69,098.397** | **68,595.619** | **67,594.529** | **66,458.870** | **60,705.834** | **60,283.510** | **8.886** |

## 2.2 Trends by Gas

Emissions of $CO_2$ accounted for 67.3 per cent of the total (excluding LULUCF) of 61,313.92 Gg $CO_2$ equivalent in 2010, with $CH_4$ and $N_2O$ contributing 18.9 per cent and 12.7 per cent, respectively. The combined emissions of HFC, PFC and $SF_6$ accounted for approximately 1.0 per cent of total emissions in 2010. In 1990 emissions of $CO_2$, $CH_4$, $N_2O$ and the combined emissions of HFCs, PFCs and $SF_6$ accounted for 58.6, 24.8, 16.5 and less than 0.1 per cent, respectively of total emissions of 55,162.55 Gg $CO_2$ equivalent.

$CO_2$ is the most significant contributor to the greenhouse gas emissions with *1.A.1 Energy Industries* responsible for 31.9 per cent of total $CO_2$ emissions in 2010. *1.A.3 Transport* represents a share of 27.8 per cent, *1.A.4 Other Sectors* has a share of 26.0 per cent, *1.A.2 Manufacturing Industries and Construction* has an 11.0 per cent share and the remainder of $CO_2$ emissions (3.3 per cent share) fall into other sectors. Emissions of $CO_2$ increased from 32,341.25 Gg in 1990 to 41,267.97 Gg in 2010, which equates to an increase of 27.6 per cent. The main driver behind this increase in emissions is primarily fuel combustion in Transport followed by Energy Industries. Over the period 1990-2010, emissions of $CO_2$ from transport, predominantly road traffic in Ireland, increased by 128.5 per cent. This trend is exaggerated somewhat in later years by so-called fuel-tourism. In 2010 it is estimated that approximately 8 per cent of automotive fuel sold in Ireland is used in vehicles in the UK and other countries. Over the time-series, emissions of $CO_2$ from 1.A.1 *Energy Industries* increased by 18.0 per cent, further adding to the increase in $CO_2$ emissions over the 1990-2010 period. In addition, even though Ireland has only a small number of energy intensive industries, $CO_2$ emissions from combustion in the industrial sector 1.A.2 *Manufacturing Industries and Construction* increased by 14.8 per cent between 1990 and 2010.

Methane is the second most significant contributor to greenhouse gas emissions in Ireland which is due to the large population of cattle. In 2010 emissions of $CH_4$ were 11,604.94 Gg $CO_2$ equivalent, indicating a decrease of 15.1 per cent on the 1990 level of 13,673.09 Gg $CO_2$ equivalent. Emissions of $CH_4$ increased progressively from 1990, reaching a peak in 1998 of 14,417.11 Gg $CO_2$ equivalent, which reflects an increase in livestock numbers and therefore increased emissions from source categories *4.A Enteric Fermentation and 4.B Manure Management*. Between 1998 and 2010 $CH_4$ emissions decreased as a result of falling livestock numbers due to reform of the Common Agricultural Policy (CAP). However, total $CH_4$ emissions in the period 2001-2010 fluctuated to some extent on a yearly basis. This trend is a direct result of fluctuating $CH_4$ emissions from *1.A.4 Other Sectors* and *1.B.Fugitive Emissions from Fuels.* The main contributor to the $CH_4$ trend has been Agriculture and in 2010 the sector accounted for 91.6 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 10.9 per cent between 1990 (11,927.75 Gg $CO_2$ equivalent) and 2010 (10,630.04 Gg $CO_2$ equivalent). Another significant source of methane emissions is Waste sector, especially from landfill gas in category *6.A Solid Waste Disposal on Land*. $CH_4$ emissions from Waste decreased from 8.6 per cent share of total methane emissions (1,173.05 Gg $CO_2$ equivalent) in 1990 to 6.3 per cent share (727.46 Gg $CO_2$ equivalent) in 2010. This decrease is a result of improved management of landfill facilities, including increased recovery of landfill gas utilised for electricity generation and flaring.

Emissions of $N_2O$ decreased by 14.3 per cent from their 1990 level of 9,111.30 Gg $CO_2$ equivalent in 1990 to 7,806.44 Gg $CO_2$ equivalent in 2010. Similar to $CH_4$, emissions of $N_2O$ increased during the 1990s to reach peak level of 9,961.06 Gg $CO_2$ equivalent in 1998 reflecting increased use of synthetic fertilisers and increased amounts of animal manures associated with increasing animal numbers over that period. Emissions of $N_2O$ subsequently show a clear downward trend following reductions in synthetic fertiliser use and organic nitrogen applications on land as a result of the effect of CAP reform on animal numbers as well the closure of Irelands only nitric acid plant in 2002. The biggest contributor to the trend is Agriculture sector with 93.3 per cent share of the total $N_2O$ emissions (7,279.65 Gg $CO_2$ equivalent) in 2010. This reflects an increase from 84.6 per cent share (7,707.32 Gg $CO_2$ 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 $N_2O$ emissions in 1990 and an average of 8.9 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 4.9 per cent and 1.9 per cent respectively to the rest of the $N_2O$ trend.

Emissions of the F-gases (HFCs, PFCs and $SF_6$) were 634.57 Gg $CO_2$ equivalent in 2010 compared to 36.91 Gg $CO_2$ 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 $CO_2$ equivalent in 1990 reaching a peak of 564.67 Gg $CO_2$ equivalent in 2008, decreased to 521.07 Gg $CO_2$ equivalent in 2009 and increased again to 563.04 Gg $CO_2$ equivalent in 2010.

Emissions of PFCs show an increasing trend from 0.09 Gg $CO_2$ equivalent in 1990 up to 130.82 Gg $CO_2$ equivalent in 1997 through their use in the semiconductor manufacturing process in *2.F.7 Semiconductor Manufacture.* Emissions subsequently decreased, only to significantly increase to reach 305.41 Gg $CO_2$ equivalent in 2000. Semiconductor manufacturers continue to investigate various reduction initiatives through gas substitution and new process technologies which is reflected in the downward trend in PFC emissions between 2000 and 2010 (37.02 Gg $CO_2$ equivalent in 2010).

$SF_6$ is used in a diverse number or products and processes and is therefore included in a number of IPCC source sub-categories including *2.F.7 Semiconductor Manufacture, 2.F.8 Electrical Equipment* and *2.F.9 Other*. Emissions of $SF_6$ were 35.40 Gg $CO_2$ equivalent and 34.51 Gg $CO_2$ equivalent in 1990 and 2010, respectively. However, emissions of $SF_6$ at peaked in 1997 at 132.20 Gg $CO_2$ 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 $SF_6$ through gas substitution and new process technologies. In *2.F.8 Electrical Equipment,* where $SF_6$ is used for electrical insulation, arc quenching and current interruption, a leak reduction programme has been in place since 1997.

## 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 2010 contributes 66.1 per cent of total greenhouse gas emissions (excluding *LULUCF*). The second largest sector is *Agriculture*, which accounted for 29.2 per cent of total greenhouse gas emissions in 2010. Emissions from *Industrial Processes, Waste* and *Solvent and Other Product Use* accounted for 3.2 per cent, 1.4 per cent and 0.1 per cent, respectively of total emissions in

2010. 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 30.8 per cent from 30,966.41 Gg $CO_2$ equivalent in 1990 to 40,510.27 Gg $CO_2$ equivalent in 2010. 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 45,702.54 Gg $CO_2$ equivalent. A major decrease occurred between 2008 and 2009 when the sectoral emissions fell by 10.0 per cent and continued decreasing in 2010 by further 0.5 per cent.

*1.A.1 Energy Industries* accounted for 20.4 per cent and 21.7 per cent of total national greenhouse gas emissions in 1990 and 2010, respectively. Total greenhouse gas emissions from this sub-sector increased by 54.5 per cent from 11,238.54 $CO_2$ equivalent in 1990 to 17,364.19 $CO_2$ equivalent in 2001. Some reductions were achieved in 2002, 2003 and 2004 from improvements in energy efficiency and fuel switching as some new electricity producers entered the market with the result that emissions decreased to 15,368.72 Gg $CO_2$ equivalent in 2004. Emissions subsequently increased in 2005 to 15,770.30 Gg $CO_2$ equivalent as levels of peat use returned to former levels with the entry into service of two new peat fired power plants. Emissions in 2006 decreased to 15,028.57 Gg $CO_2$ equivalent due to a reduction in the use of Moneypoint coal-fired station during the installation of pollutant control measures, while further reductions in 2007 (14,535.37 Gg $CO_2$ equivalent) are largely a result of the displacement of oil by natural gas. In 2008, emissions increased by 0.8 per cent or 117.54 Gg $CO_2$ equivalent to 14,652.91 Gg $CO_2$ equivalent, then decreased in 2009 by 10.8 per cent to 13,077.67 Gg $CO_2$ equivalent reflecting the impact of the economic recession in Ireland. There was a slight increase in emissions (1.9 per cent) in 2010 to reach 13,328.09 Gg $CO_2$ equivalent which reflects a reduction in the share of renewables in gross electricity consumption from 14.3% 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.. Overall drivers and trends in emissions from the *Energy* sector are presented in Figure 2.2 and Figure 2.3.

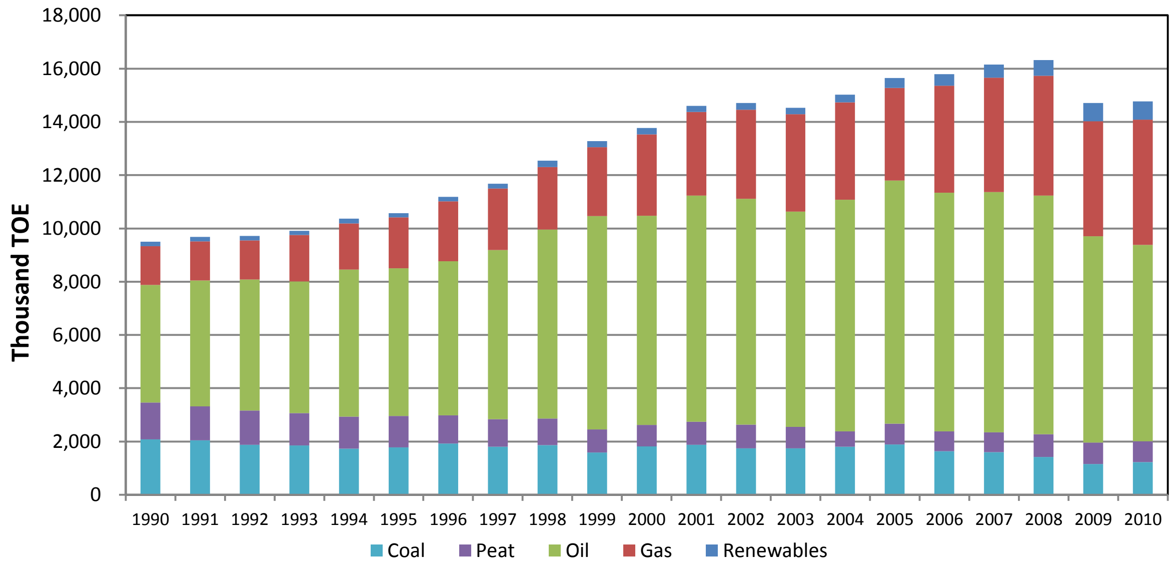


***Figure 2.2 Total Primary Energy Requirement (TPER) 1990-2010***

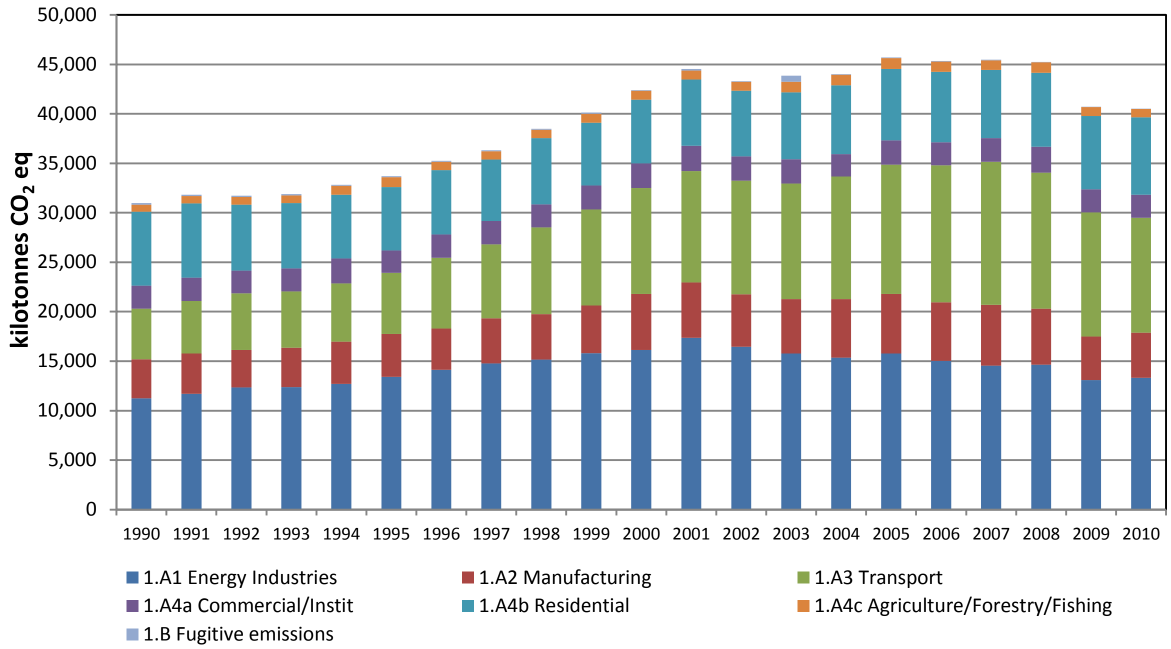


***Figure 2.3 Trend in Emissions from Energy 1990-2010***

There are only a small number of energy intensive industries in Ireland under sub-category *1.A.2 Manufacturing Industries and Construction*. This sub-category accounted for 7.2 per cent (3,961.19 Gg $CO_2$ equivalent) and 7.4 per cent (4,549.04 Gg $CO_2$ equivalent) of total national greenhouse gas emissions in 1990 and 2010, respectively. However, the trend shows an increase of 14.8 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 18.9 per cent of total national greenhouse gas emissions in 1990 and 2010, respectively. The overall sectors emissions increased by 126.8 per cent from 5,117.54 Gg $CO_2$ equivalent in 1990 to 11,605.54 Gg $CO_2$ equivalent in 2010. This is largely accounted for by a 132.0 per cent increase in road transport emissions over the same period, due to sustained growth in the use of passenger cars and goods vehicles. The trend is however, somewhat exaggerated by so-called fuel tourism whereby a proportion of the automotive fuel sold in the Republic of Ireland is used in vehicles in the UK and other countries. Fuel tourism is estimated to account for 8 per cent of automotive fuels in 2010. 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 0.92 million tonnes lower in 2010 than in 2009. This represents a decrease of 7.3%, 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 20.8 per cent between 1990 (51.73 Gg $CO_2$ equivalent) and 2010 (40.98 Gg $CO_2$ equivalent), having peaked in 2006 at 77.31 Gg $CO_2$ equivalent. However, their overall effect on transport emission trends is negligible.

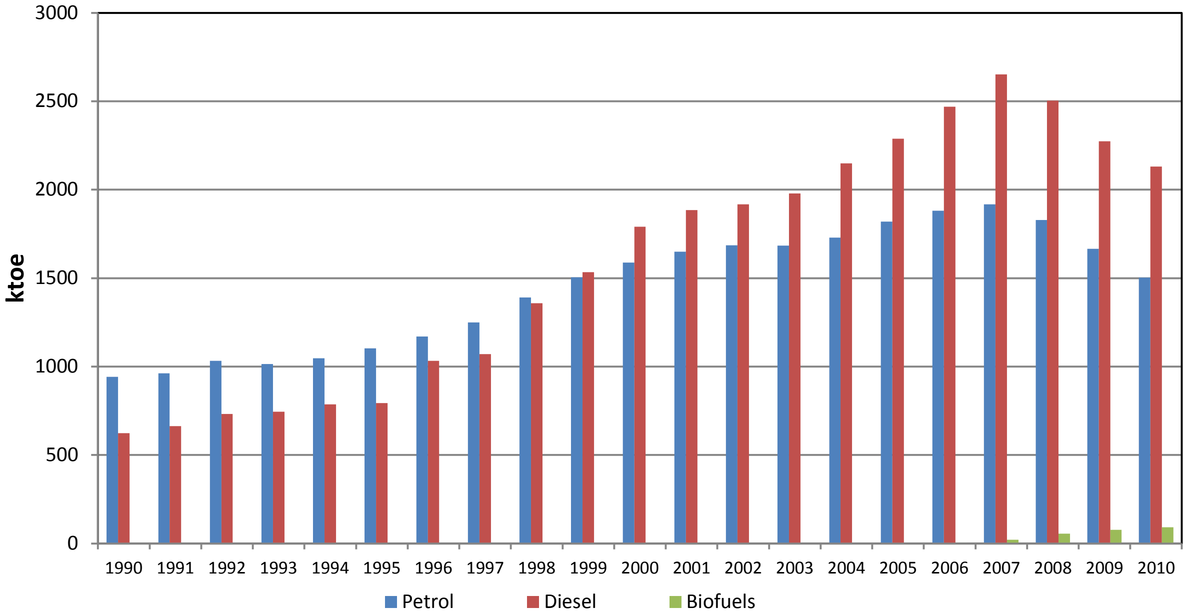


*Figure 2.4 Fuel use in Road Transport 1990-2010*

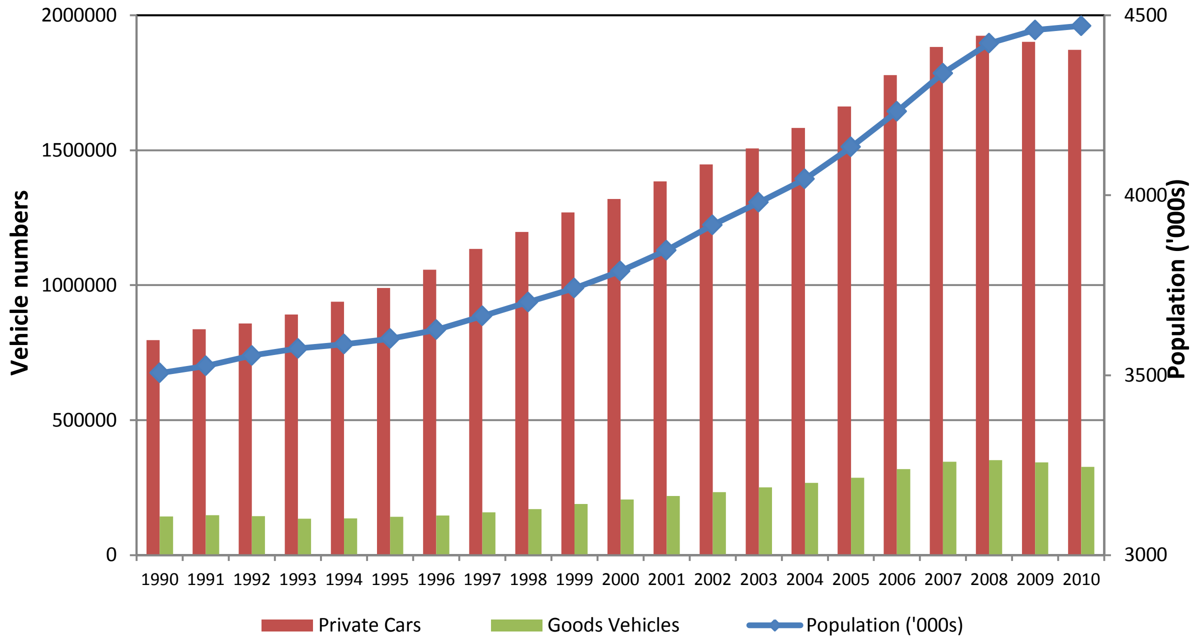


*Figure 2.5 Vehicle numbers and Census of Population 1990-2010*

Emissions from category *1.A.4 Other Sectors* increased by 4.5 per cent from 10,517.87 Gg $CO_2$ equivalent in 1990 to 10,995.97 Gg $CO_2$ equivalent in 2010. Emissions from the Commercial (1.A.4 a), Residential (1.A.4 b) and Agriculture/Forestry/Fishing (1.A.4 c) sub-categories increased by 0.2, 4.8 and 15.2 per cent respectively. Although residential fossil fuel consumption increased by 34.2 per cent from 1990 to 2010 there has been a decline in the use of carbon-intensive fuels, such as peat and coal, and greater use of oil and natural gas. The emissions of $CO_2$ from coal and peat use in the residential sector decreased by

61.8 per cent between 1990 and 2010 while those from oil and natural gas almost quadrupled (increased by 290.1 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 3.2 per cent in 2010. Total emissions from the sector were 3,179.27 Gg $CO_2$ equivalent in 1990 and 1,933.62 Gg $CO_2$ equivalent in 2010. This is a decrease of 39.2 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 $CO_2$ equivalent, however by 2000 they had reduced by 16.3 per cent to 1,694.57 Gg $CO_2$ 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 $CO_2$ in 1990 to 1,700.90 Gg $CO_2$ in 2000. Economic growth was sustained into the early years of the new millennium with associated increases in emissions from the sector, during which two new cement production plants were commissioned, with one opening in 2000 and the other in 2003. This resulted in even further growth in emissions from cement sector to reach peak of 2,374.06 Gg $CO_2$ in 2007 (an increase of 168.6 per cent from 1990). Due to the economic recession, emissions from sector 2.A.1 decreased by 53.5 per cent between 2007 and 2010 to reach 1,105.11 Gg $CO_2$, bringing the level of emissions in 2010 similar to those pre-1999.

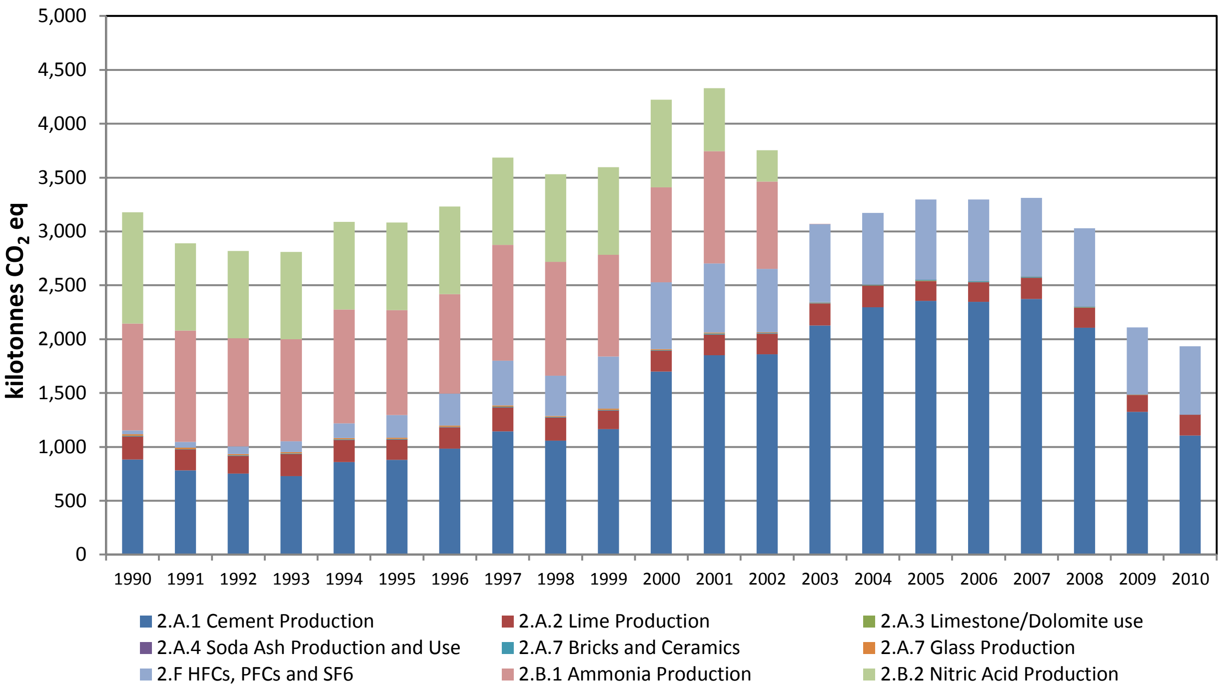


***Figure 2.6 Trend in Emissions from Industrial Processes 1990-2010***

The closure of Ireland's ammonia and nitric acid plants in 2003 and 2002 significantly changed the level of process emissions in Ireland. As a result $CO_2$ emissions from cement production (2.A.1) became the single major component of sector emissions and these emissions increased steadily during the period of economic growth up to 2007, the year when they reached a peak at 71.7 per cent share of total sector emissions. Emissions from cement manufacture decreased in line with the economic downturn since 2007, accounting for 69.5, 62.9 and 57.2 per cent of total emissions from *Industrial Processes* in 2008, 2009 and 2010, 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 10.0 per cent of total sector emissions in 2010. The emissions from these sub-categories are small and their effect on overall trends is negligible.

Emissions from *2.F Consumption of Halocarbons and* $SF_6$ were estimated to be 634.57 Gg $CO_2$ equivalent in 2010, compared to 36.91 Gg $CO_2$ 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 32.8 per cent in 2010 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 just over 0.1 per cent share of total national greenhouse gas emissions in 2010 do not affect the overall trend in greenhouse gases in Ireland. The $CO_2$ emissions from this source were estimated to be 80.03 Gg $CO_2$ equivalent in 1990 and 71.59 Gg $CO_2$ equivalent in 2010, a decrease of 10.5 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 57.0 per cent of total sectoral emissions in 1990 and 2010, respectively. The contribution of sub-category, *3.A Paint Application,* to overall emissions from the sector grew from 26.6 per cent in 1990 to 35.1 per cent share due to increasing paint sales in this period. However, the market share of water-based paints, which have a lower VOC content, is increasing 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 11.0 per cent, respectively of total overall emissions in the sector in 2010. The emissions from both sub-categories show a downward trend over the time-series 1990-2010; 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.

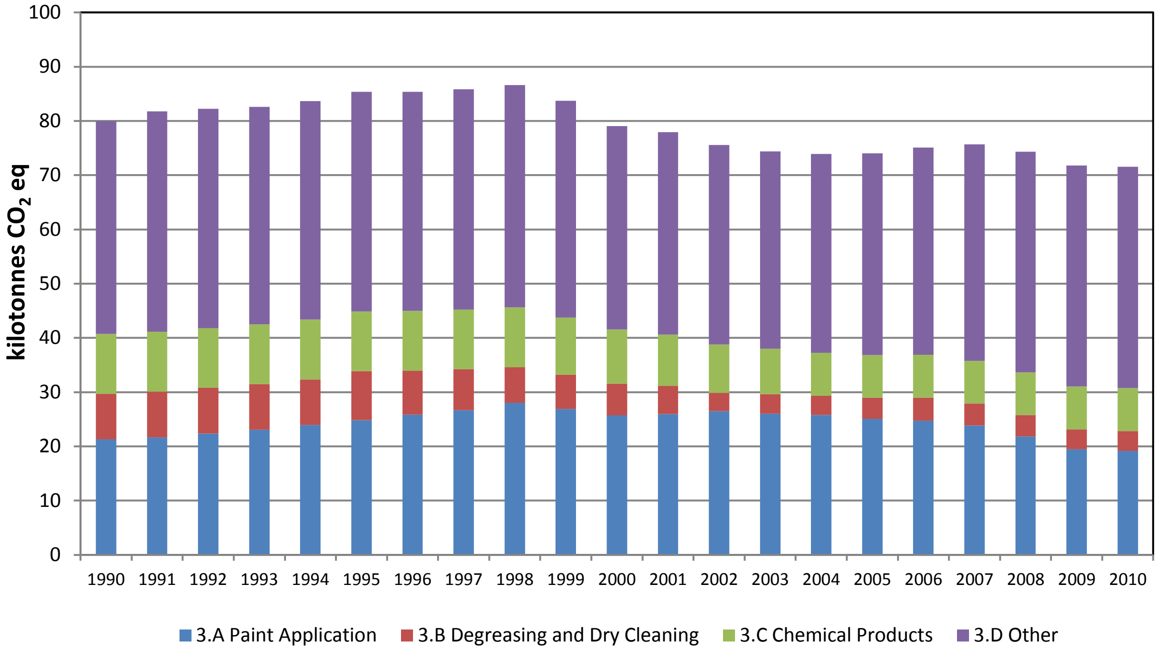


***Figure 2.7 Trend in Emissions from Solvents and Other Product Use 1990-2010***

### 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 19,635.07 Gg $CO_2$ equivalent in 1990 and 17,909.69 Gg $CO_2$ equivalent in 2010, a reduction of 8.8 per cent. The emissions from *Agriculture* decreased by 0.02 million tonnes (0.1 per cent) in 2010. 2010 saw a substantial increase in nitrous oxide emissions due to increased fertiliser sales (up 18 per cent on 2009). This increase in nitrous oxide emissions was offset by the continuing decline in total cattle and sheep numbers in 2010 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 21,514.29 Gg $CO_2$ equivalent in 1998, emissions from the sector decreased by 16.8 per cent to 17,909.69 Gg $CO_2$ equivalent in 2010, 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 $CH_4$ from enteric fermentation and manure management expressed in $CO_2$ equivalents was 12,362.86 Gg in 1990. This increased by 7.8 per cent to reach 13,321.23 Gg $CO_2$ equivalent in 1998 and subsequently decreased by 16.9 per cent to 11,072.08 Gg $CO_2$ equivalent in 2010. Cattle account for 89.0 per cent of $CH_4$ emissions in Irish agriculture in 2010.

The emissions of $N_2O$ from the Agriculture sector follow similar trends to those of $CH_4$ because cattle also largely determine the amount of nitrogen inputs to agricultural soils from synthetic fertiliser and animal manures, which produce the bulk of $N_2O$ emissions (93.9 per cent of the sector $N_2O$ emissions in 2010). Nitrous oxide emissions in the sector increased from 7,707.32 Gg $CO_2$ equivalent in 1990 by 13.0 per cent in the period 1990-1998 with emissions in 1998 totalling 8,707.79 Gg $CO_2$ equivalent. Nitrous oxide emissions totalling 7,279.65 $CO_2$ equivalent in 2010 represent a reduction of 16.4 per cent on the 1998 level and 5.5 per cent on the 1990 level. Crops contribute very little to $N_2O$ emissions in Ireland and the amount fluctuates annually in response to varying production of the relevant crops.

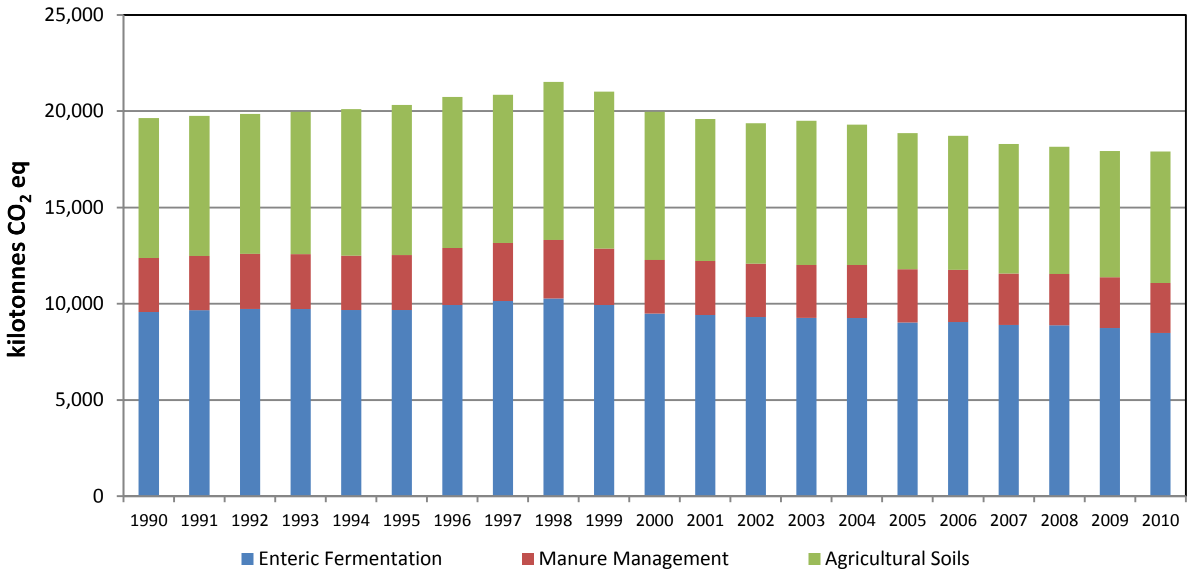


*Figure 2.8 Trend in Emissions from Agriculture 1990-2010*

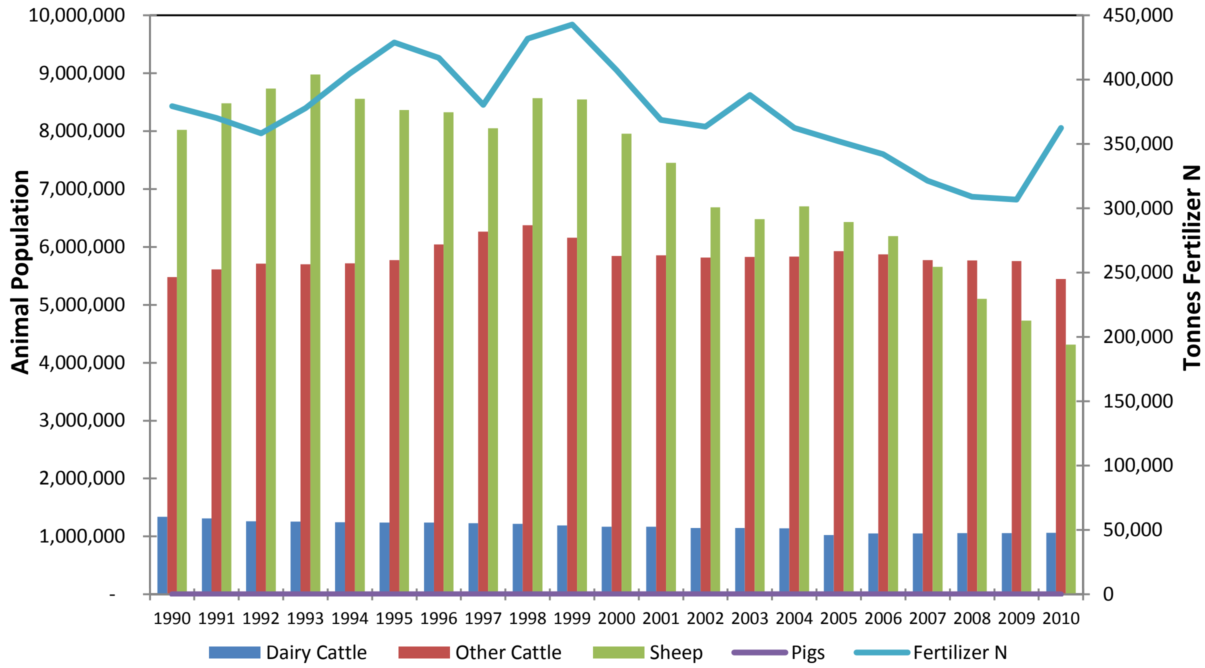


*Figure 2.9 Principal Drivers of Emissions from Agriculture 1990-2010*

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

The full assessment of emissions and removals in the LULUCF sector according to the reporting requirements of Decision 13/CP.9 has given a new understanding of the relative contributions of sub-categories in this sector. In addition, this assessment has identified a number of land-use categories that are important in terms of either emissions or removals of $CO_2$. This sector is a net source of emissions in some years and a net sink of carbon in other years (Table 2.1 and Figure 2.10). This result is determined largely by the balance between *5.A Forest Land*, which is a major carbon sink, and *5.C Grassland*, where soil disturbance and liming of agricultural lands generate relatively large emissions of $CO_2$, 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- 2010

The most important individual emission categories over the time-series are the carbon releases from soils in *5.A.2 Land Converted to Forest Land* and the $CO_2$ emissions from agricultural lime application on *Grassland* and *Cropland*. The increase in carbon stocks in living biomass in the category *5.A.1 Forest Land remaining Forest Land* is the dominant removal that offsets $CO_2$ emissions. The *Wetland, Settlements* and *Other Land* categories are comparatively less important in terms of emissions or removals but *Cropland* constituted a significant net source of carbon to the atmosphere towards the end of the time series with a sharp rise in 2008. This has decreased in 2009 and 2010, but remains high relative to earlier in the time series.

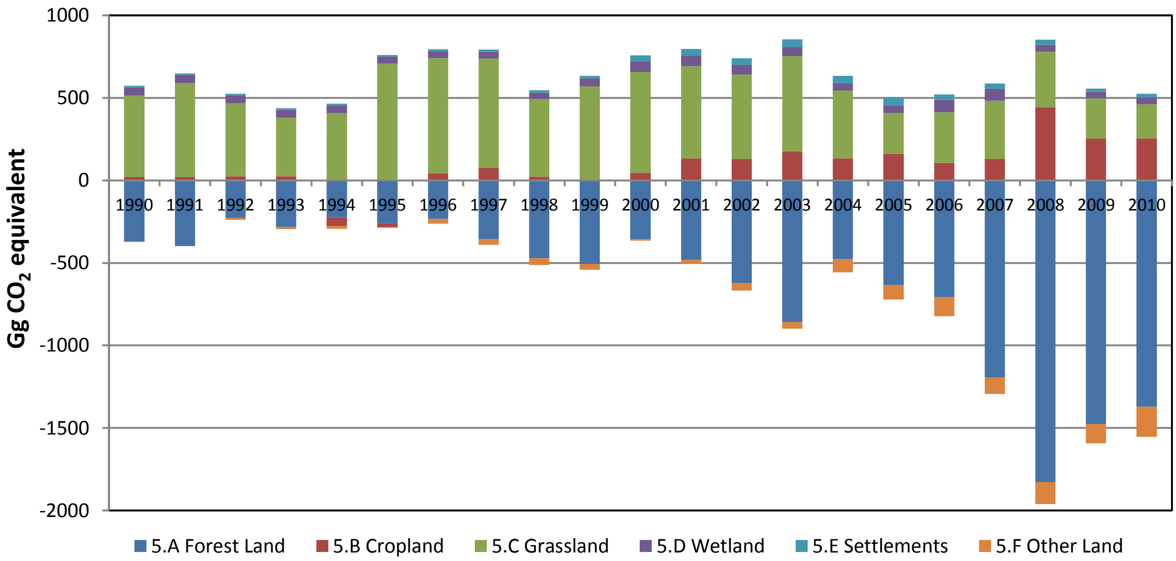


***Figure 2.10 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2010***

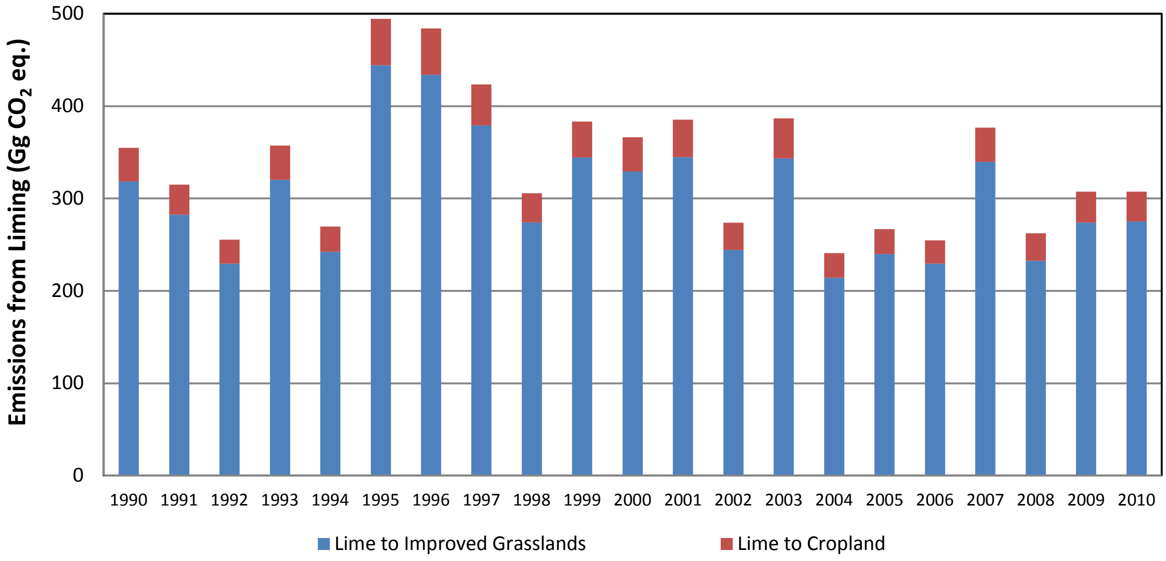


***Figure 2.11 Trend in Emissions from Liming on Grasslands and Cropland 1990-2010***

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

The *Waste* sector remains an important source of $CH_4$ emissions (Figure 2.12) due to the continued dominance of landfills as a means of solid waste disposal in Ireland. Emissions from the waste sector increased by 29.7 per cent from 1,301.78 Gg $CO_2$ equivalent in 1990 to 1,688.06 Gg $CO_2$ equivalent in 2003 (peak) and then decreased by 47.4 per cent to 888.74 Gg $CO_2$ equivalent in 2010. Overall, emissions in the *Waste* sector have decreased by 31.7 per cent from 1990 to 2010. The main contributor to trends in the *Waste* sector is the $CH_4$ emissions from municipal solid wastes (MSW) disposed of in solid waste landfills (*6.A Solid Waste Disposal on Land*). The decrease in emission levels reflects increasing recovery of landfill gas for energy production and particularly through flaring at landfill sites, without which emissions in this sector would be considerably larger.

Since 1990 the population of Ireland increased by 27.5 per cent by 2010, 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 11.1 per cent between 2008 and 2009 to 1.77 million tonnes and further by 16.4 per cent to 1.48 million tonnes in 2010. The proportion of organic materials in MSW has decreased from 39.3 per cent in 1990 to 34.7 per cent in 2010. The proportions of paper and textiles changed from 29.5 per cent and 9.8 per cent, respectively in 1990 to 21.1 per cent and 6.3 per cent, respectively in 2010, reflecting a significant diversion of paper products from landfills. This reduces $CH_4$ potential, as paper products are the main source of degradable organic carbon in landfills. A major increase in the use of flares as a means of odour control in landfills in recent years offsets a large proportion of the $CH_4$ generated. This offset from flares and utilisation was 71.8 per cent in 2010, hence there was 12.6 fold increase in flaring and utilisation since 1996 (9.1 per cent first year of methane recovery). Emissions of $CH_4$ and $N_2O$ from *6.B Wastewater Handling* accounted for 128.73 Gg $CO_2$ equivalent in 1990 and 161.28 Gg $CO_2$ equivalent in 2010 (25.3 per cent increase on 1990), which equates to 9.9

and 18.1 per cent of total emissions from the waste sector, respectively. The contribution of this sub-category to overall sectoral trends is negligible.

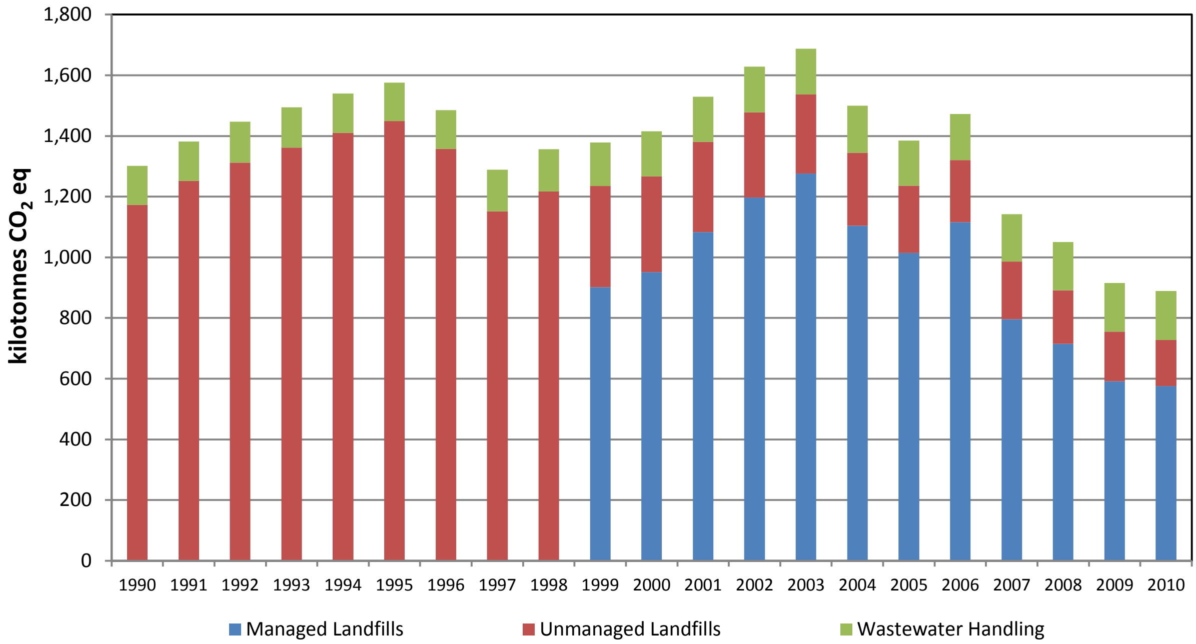


***Figure 2.12 Trend in Emissions from Waste 1990-2010***

## 2.4 Emissions of Indirect Greenhouse Gases

The total emissions of $SO_2$, $NO_X$, NMVOC and CO for the years 1990 to 2010 are summarised in Table 2.2 and Figure 2.13. As in the case of $CO_2$, the emissions of $SO_2$, $NO_X$ and CO in Ireland are dominated by those emanating from fuel combustion activities, while the bulk of NMVOC emissions are generated by road traffic and solvent use. Substantial decreases have occurred in the emissions of $SO_2$ (85.8 per cent) and CO (66.9 per cent). Significant reductions have also taken place in NMVOC emissions (51.9 per cent) and emissions of $NO_X$ in 2010 were 37.6 per cent lower than those in 1990.

Total $SO_2$ emissions decreased by 85.8 per cent, from 182,251 tonnes in 1990 to 25,815 tonnes in 2010. 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 $SO_2$ emissions up to 2009. In 2010 the principal source of $SO_2$ emissions was, the commercial/residential (1.A.4.a, 1.A.4.b) sectors, contributing 36.2 per cent of the total in 2010. In 2010, power stations accounted for 36.2 per cent of the total. Combustion sources in the industrial (1.A.2) sector largely account for the remainder of emissions, with a contribution of 21.5 per cent in 2010. In 1990, coal combustion accounted for 51.6 per cent of $SO_2$ emissions and fuel oil contributed 30.1 per cent. By 2009, the share of $SO_2$ emissions from coal had decreased to 49.5 per cent and that from fuel oil had decreased to 21.7 per cent.

Road transport is the principal source of $NO_X$ emissions, contributing approximately 48.2 per cent of the total in 2010. The power generation sector is the other main source of $NO_X$ emissions, accounting for 14.6 per cent of emissions in 2010. The reductions in $NO_X$ emissions delivered by catalytic converters in cars and heavy-duty vehicles have been offset by large increases in vehicle numbers and fuel use in the past 10 years. This effect is exaggerated in latter years by so-called fuel-tourism, whereby a significant proportion of the automotive fuel sold in Ireland is used by vehicles in the UK and possibly to some extent in other countries.

The emissions of NMVOC are determined mainly by road traffic and solvent use. These two sources combined produced 70.5 per cent of the 2010 total NMVOC emissions in Ireland. Coal burning in the residential sector is another important source. Technological controls for NMVOCs in motor vehicles have been more successful than in the case of $NO_X$, and have given a significant reduction in emissions from road transport over recent years.

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

***Table 2.2. Emissions of $SO_2$, $NO_X$, NMVOC and CO 1990-2010 (Tonnes)***

| | $SO_2$ | $NO_X$ | NMVOC | CO |
|---|---|---|---|---|
| **1990** | 182,251 | 119,988 | 92,988 | 416,528 |
| **1991** | 180,614 | 121,871 | 93,549 | 413,475 |
| **1992** | 169,115 | 130,878 | 94,095 | 401,233 |
| **1993** | 160,123 | 121,209 | 90,287 | 367,855 |
| **1994** | 174,951 | 119,670 | 88,439 | 344,166 |
| **1995** | 160,866 | 121,632 | 85,181 | 313,226 |
| **1996** | 148,645 | 125,910 | 90,053 | 319,297 |
| **1997** | 166,077 | 126,003 | 89,646 | 304,217 |
| **1998** | 177,311 | 130,561 | 90,207 | 313,901 |
| **1999** | 158,614 | 130,420 | 79,660 | 278,954 |
| **2000** | 139,453 | 134,001 | 72,680 | 251,848 |
| **2001** | 134,114 | 136,212 | 69,995 | 241,113 |
| **2002** | 101,217 | 127,113 | 64,651 | 222,041 |
| **2003** | 79,071 | 126,170 | 61,650 | 210,523 |
| **2004** | 71,687 | 126,833 | 58,326 | 200,744 |
| **2005** | 71,051 | 126,393 | 56,289 | 190,537 |
| **2006** | 61,140 | 121,748 | 54,915 | 181,801 |
| **2007** | 55,314 | 119,071 | 53,201 | 169,976 |
| **2008** | 45,408 | 108,728 | 50,714 | 157,849 |
| **2009** | 32,560 | 86,506 | 47,579 | 150,459 |
| **2010** | 25,815 | 74,833 | 44,725 | 137,741 |

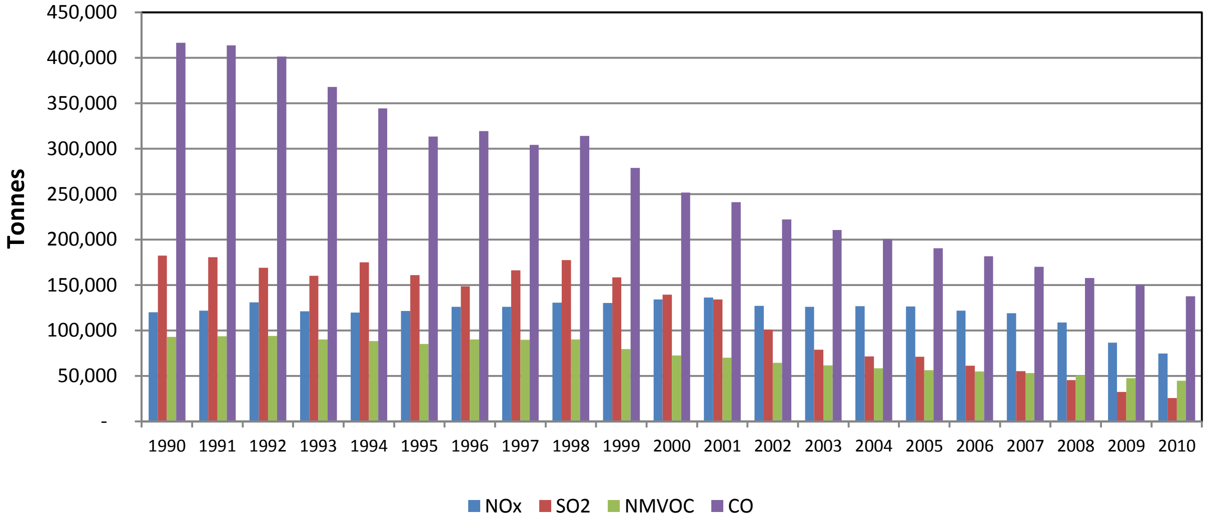


*Figure 2.13 Trend in Indirect Greenhouse Gases 1990-2010*

# Chapter Three

# Energy

## 3.1 Overview of Energy Sector

The *Energy* source category covers all combustion sources of $CO_2$, $CH_4$ and $N_2O$ emissions and the fugitive emissions of these gases associated with the production, transport and distribution of fossil fuels. Table 3.1 presents the CRF Level 3 classification of sources concerned and indicates their degree of coverage in Ireland. Estimates are included for all emission sources that occur in the country and the required level of disaggregation is achieved for detailed completion of the CRF tables. The overall approach and methodologies used to estimate emissions in the *Energy* sector for 2010 remain largely as described in the 2011 NIR except for the improvement in the methodology for civil aviation (1.A.3.a) and the inclusion of emission estimates from fishing (1.A.4.c) for the first time. As for all years since 2005, $CO_2$ estimates reported under the EU Emissions Trading Scheme (ETS) for 2010 are used to achieve complete bottom-up results in respect of some important sub-categories in this sector for the 2010 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 (66.1 per cent) of greenhouse gas emissions in Ireland in 2010, with $CO_2$ emissions making up 96.7 per cent of the total for the sector. The 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 32.9 per cent, 11.2 per cent, 28.6 per cent and 27.1 per cent respectively to the sector total in 2010. 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 B.1 of Annex B shows the national energy balance sheets for 2010, 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 2010 example indicates the same form of expanded balance sheet as previously used for all years from 1990 to 2009. 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 1990-2010 underlies the estimates of emissions for *Energy* in this submission. The energy balances provided for this submission include revisions made to improve the allocation of fuels used in national navigation (1.A.3.d) and include, for the first time, fuel used in national fishing (1.A.4.c) for the years 2003 to 2010. Data on marine diesel used in national fishing prior to 2003 is not available.

Following the methods decision tree of the IPCC good practice guidance for combustion sources, the information in Table B.1 of Annex B allows for the full application of the two available IPCC methods for emission sources in *Energy*, i.e. the Sectoral Approach and the Reference Approach. The Sectoral Approach uses the detailed sectoral breakdown of fuel consumption by all end users as the basis of the calculations for $CO_2$, $CH_4$ and $N_2O$. The relevant activity data are represented by the disaggregated entries below TPER (Total Primary Energy Requirement) in Table B.1 of Annex B. A combination of top-down and bottom-up methods is used in the sectoral application of the national statistics on fuel consumption to derive the emission estimates in the various sub-categories. The Reference Approach provides an estimate of aggregate $CO_2$ emissions only, based on the apparent consumption of fuels in the country. This estimate is not used in the compilation of total national emissions but rather for comparison purposes only. The apparent fuel consumption is determined from the energy balance items relating to primary and secondary fuels represented by those above TPER in Table B.1 of Annex B. The application of the Sectoral Approach and the Reference Approach is now described with reference to 2010 data and their results are then compared for $CO_2$, as required by the UNFCCC reporting guidelines. The Sectoral Approach is described according to the individual sub-categories listed in Table 3.1.

***Table 3.1. Level 3 Source Category Coverage for Energy***

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

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

## 3.2 Sectoral Approach for Emissions from Energy Use

### 3.2.1 Combustion Sources

The combustion of fossil fuels accounts for the bulk of $CO_2$ emissions in most countries. In Ireland, emissions of $CO_2$ from fuel combustion contributed two-thirds of total emissions in 2010. The $CO_2$ emissions are quantified with reasonable accuracy as the fuel amounts are detailed in the energy balance sheets and information on their carbon contents is well established. The total amount of $CO_2$ released on combustion can therefore be readily ascertained. Only small amounts of $CH_4$ and $N_2O$ are associated with fuel combustion activities. The emissions of these gases are generally not quantified with the same reliability as the emissions of $CO_2$ because the rates of $CH_4$ and $N_2O$ production depend on several factors, in addition to fuel type, and consequently there is considerable uncertainty in the available emission factors for these gases.

Ireland's energy data in the expanded energy balance sheets (Table B.1 of Annex B) 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 C.1 of Annex C shows how the emissions from combustion sources are computed for the year 2010 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 C.2 of Annex C. The correspondence between the national disaggregation of sources and IPCC combustion source categories is given in Table C.3 of Annex C.

All $CO_2$ emission factors for fuel combustion in the present submission, except in the case of biomass, are country-specific values, regardless of methodological tier used, which are determined directly from information on the carbon contents and net calorific values of the fuels used in stationary and mobile sources. The $CO_2$ emission factor for natural gas takes into account the increasing contribution of imported gas in the national total given by the energy balance. The importation of natural gas from the UK began around 1993 and imported gas accounted for 93.3 per cent of the total in 2010. The $CO_2$ emission factor appropriate to the split between domestic and imported natural gas, which is more carbon intensive, is now used for all years from 1993 to 2010.

The annual returns to the EPA's Climate Change Unit (CCU) by participants in the EU Emissions Trading Scheme under Directive 2003/87/EC (EP and CEU, 2003) comprise an important source of information on $CO_2$ emissions and emission factors that is now fully utilised for the national inventory compilation. The fuel combustion $CO_2$ emission factors for solid fuels used by participants under ETS take account of the fact that a very small fraction (typically less than 1 per cent) of fuel carbon may remain un-oxidised and IPCC oxidation factors appropriate to these fuels are applied when computing the emissions under the scheme. Complete oxidation of carbon is assumed in the case of liquid and gaseous fuels. For other stationary combustion sources, where activity data are in general top-down fuel use quantities taken from the energy balance, the inventory agency adopts the approach that no specific allowance is needed for un-oxidised carbon in the calculation of $CO_2$ emissions. Default $CO_2$ emission factors from IPCC are used only for biomass, which almost invariably refers to wood and wood wastes. For stationary sources and all mobile sources except road traffic, Ireland relied largely on the default emission factors for $CH_4$ and $N_2O$ available from the CORINAIR/EMEP Emission Factor Guidebook (McInnes, 1996 and Richardson, 1999) in preparing the submissions up to 2009. A comprehensive internal review of $CH_4$ and $N_2O$ emission factors was undertaken in 2009 (Annex C NIR 2010), which led to substantial revision of these emission factors across stationary combustion sources in general so that they now conform to the latest available IPCC values.

#### 3.2.1.1 Energy Industries (1.A.1)

The Annual Installation Emissions Reports (AIER) submitted by ETS participants in respect of their $CO_2$ emissions and fuel combustion in 2010 under Directive 2003/87/EC were used to report the complete inventory for category 1.A.1. The emissions data from a total of 24 individual installations – 21 electricity generating stations in 1.A.1 (a), one oil refinery in 1.A.1 (b) and two peat briquetting plants under 1.A.1(c) – are the basis for compiling the results in this important category. In each of the three sub-categories, the verified $CO_2$ estimates reported by the ETS participants were used directly and the corresponding fuel use as given in the national energy balance was used to estimate $CH_4$ and $N_2O$ emissions using the appropriate IPCC emission factors mentioned in the previous section.

The $CO_2$ emissions for sub-category 1.A.1 (a) obtained from 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 $CO_2$ emissions compiled in the ETS database according to fuel type for all installations that constituted sub-category 1.A.1 (a) in 2010 are aggregated to report the $CO_2$ emissions for this category.

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

The rigour of the monitoring and verification process for $CO_2$ emissions under the ETS results in estimates for sub-category 1.A.1 (a) that are more accurate and more reliable than previously reported plant-specific estimates for the same source activities. The ETS estimates are available only since 2005 and the detailed information that underlies these data cannot reasonably be acquired by the inventory agency for historical years of the relevant UNFCCC time-series. As such, the application of the improved methodology introduces a degree of inconsistency in the time-series that is unavoidable in this instance. However, given that the ETS results fully cover sub-category 1.A.1 (a) and that these estimates match those reported separately under parallel arrangements that have been in place for many years for the same plants, it is assumed that time-series consistency is not seriously affected and that there is no impact on the emission trend from using the ETS data.

The bottom-up $CO_2$ emission estimates received from the ETS participants, along with the emissions of $CH_4$ and $N_2O$ estimated by the inventory agency, are aggregated on the basis of four main fuel types (peat, coal, oil and natural gas) in the calculation sheets shown in Annex C and also by solid, liquid and gaseous 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 met with SEAI twice in 2011 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) and also includes improvements in the fuel allocated to national navigation 1.A.3(d) and fishing 1.A.4(c). Additional information on fluctuating IEFs for $CO_2$ in category 1.A.1 can be found for liquid and solid fuels in Tables C.6 and C.7 of Annex C, respectively. The application of the most up-to-date IPCC $CH_4$ and $N_2O$ emission factors in this category now also improves the robustness and comparability of the emissions estimates.

Figure 3.1 shows the trend in emissions from 1.A.1(a) Public Electricity and Heat Production over the period 1990-2010, which account for 96.8 per cent of the total for category 1.A.1. The emissions from this category in 2010 show a marginal increase (2.3 per cent) on the 2009 emissions, following a large decrease between 2008 and 2009 of 10.9 per cent reflecting the impact of the recent economic downturn in Ireland and the opening of new CCGT plant. In 2010 the increases are primarily from coal and gas, while peat and oil continue to decline.

One small oil refinery accounts for the emissions reported under 1.A.1(b) Petroleum Refining. The reported $CO_2$ emissions are those available from the ETS database. These emissions are estimated using tier 2 methodologies in accordance with the monitoring and verification guidelines for combustion activities set down in Decision 2004/156/EC. The emissions are estimated from the use of high-pressure gas, low-pressure gas, LPG and small amounts of other gases as well as gasoil and residual fuel oil using country-specific emission factors. The $CH_4$ and $N_2O$ 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 2010 values for $CO_2$ are also taken from ETS returns which are based on tier 2 methodologies in accordance with the monitoring and verification guidelines for combustion activities set down in Decision 2004/156/EC. The $CH_4$ and $N_2O$ estimates are computed 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 2010 submission.

The inventory experts continue to collaborate with colleagues managing annual ETS returns from all participants to fully consolidate and formalise data gathering in respect of categories

1.A.1(a), 1.A.1(b) and 1.A.1(c) using the prescribed monitoring and verification mechanisms to ensure full consistency with reporting of $CO_2$ estimates under ETS and under the Convention and Decision 280/2004/EC.

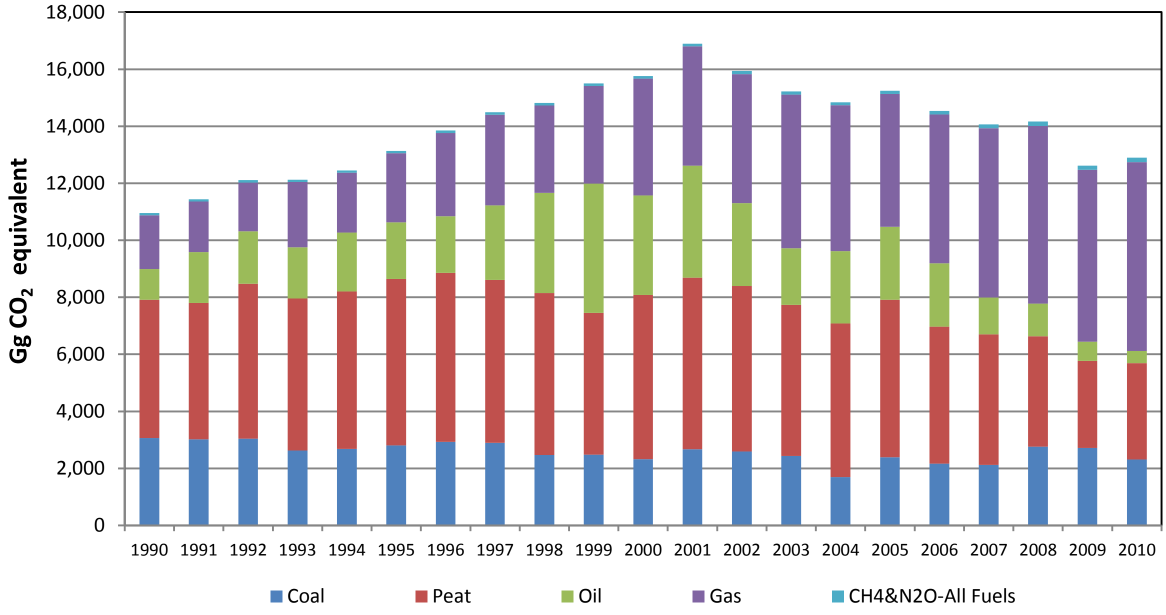


*Figure 3.1 Emissions from 1.A.1(a) Public Electricity and Heat 1990-2010*

### 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) through (f) under 1.A.2 Manufacturing Industries and Construction. This facilitates the complete disaggregation of emissions in this source category for completion of the CRF Table 1.A (a).s2.

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

Information provide from the ETS on fuel data have been used to develop an annual country-specific $CO_2$ emission factor for petroleum coke since 2005. Petroleum coke is used in sub-categories 1.A.2. (b), (e) and (f). The IPCC default emission factor of 97.5 t $CO_2$/TJ compares well with the year specific emission factors which vary from 92.93 to 95.13 $CO_2$/TJ. The average of the five years between 2005 and 2009 of yearly specific emission factors is applied to all years from 1990 to 2004, as ETS data is only available from 2005 onwards.

When the country-specific emission factor for petroleum coke is taken into account, the implied emission factors for liquid fuels in 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 $CO_2$/TJ in 2001. However the implied emission factor in 2010 is 71.94 t $CO_2$/TJ as no petroleum coke is consumed. In 1.A.2(f), the implied emission factor for liquid fuels increases from 76.19 t $CO_2$/TJ in 1990 to 81.53 t $CO_2$/TJ in 2007, but then decreases substantially to 76.65 t $CO_2$/TJ in 2010 reflecting the decline in petroleum coke use in cement production.

Figure 3.2 shows the trend in emissions from 1.A.2 Maufacturing Industries and Construction over the period 1990-2010. The emissions from this category in 2010 show a 2.7 per cent increase on the 2009 emissions, following 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. Increases in 2010 are primarily from sub-category 1.A.2(b), alumina production, with an annual increase of 20.2 per cent between 2009 and 2010.

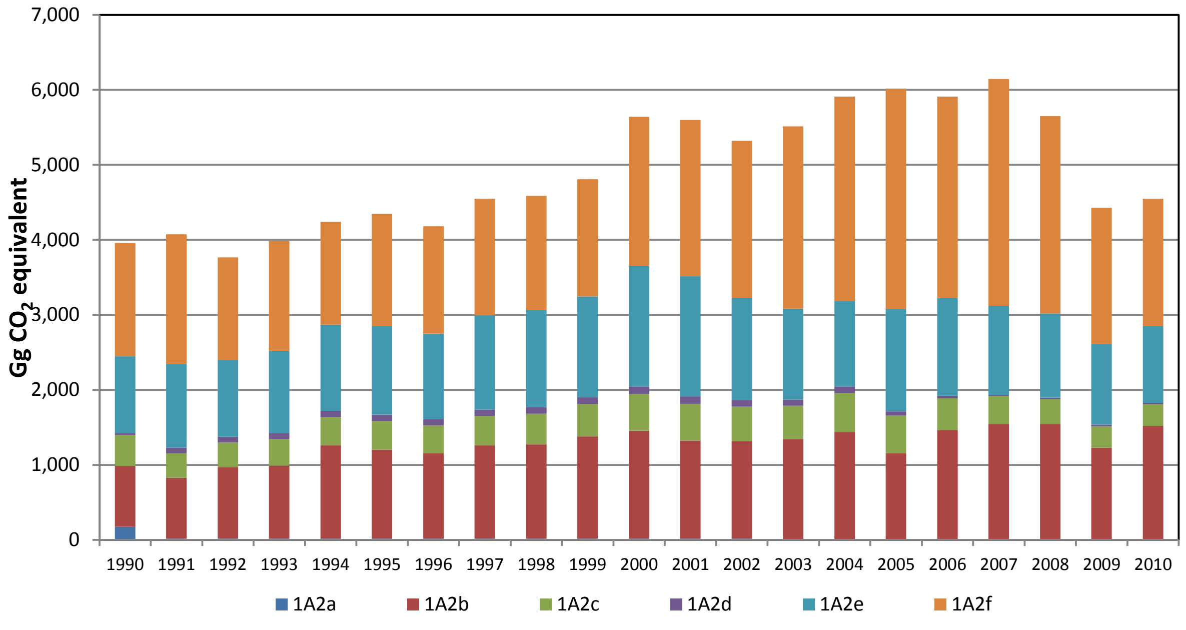


***Figure 3.2 Emissions from 1.A.2 Manufacturing Industries and Construction 1990-2010***

### 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 2010 where airport pair data is available. This is a major improvement in the method used to estimate fuel consumption from civil aviation, the previous method 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 new flight data for all Irish airports from the IAA in 2011 for the years 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 D.1 of Annex D shows the number of LTOs for each or these nine airports and all remaining airports together under "*other*". Table D.2 of Annex D outlines the distance between the airport pairs in nautical miles (nm) used in estimating fuel used in the cruise phase.

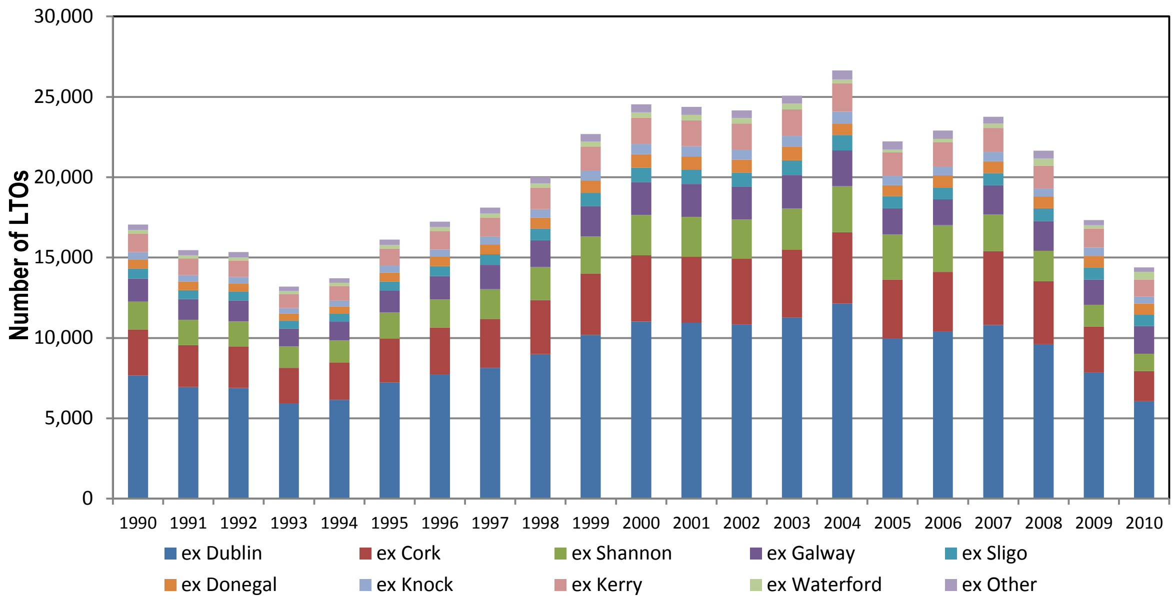


***Figure 3.3 Number of LTOs from Irish airports 1990-2010***

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 D.3 of Annex D outlines the emission factors used for LTO/cruise for fuel, $CH_4$ and $N_2O$ by aircraft type. $CH_4$ and $N_2O$ emissions factors by aircraft type are from Table 3.6.9 of the 2006 IPCC guidelines. Table D.4 of Annex D presents implied emission factors (IEF) for fuel consumption used in the cruise phase of flights weighted by number of flights per airport.

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

Emissions of $CO_2$ reported under 1.A.3(b) Road Transportation are computed from the amounts of petrol, diesel and biofuels given under road transport in the national energy balance and country-specific emission factors for these fuels as shown in Table C.1 of Annex C. Following the IPCC good practice guidance, the activity data are based on fuel sales within Ireland, even though a significant proportion of automotive fuels purchased in Ireland are used in the UK. The $CH_4$ and $N_2O$ emissions from road traffic are estimated in the COPERT 4v.8.0 model (Gkatzoflias et al., 2007), 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 second time, and gives rise to significant recalculations of $N_2O$ emissions for the years 1993 to 2006 primarily due to revising the sulphur content of leaded petrol to the same value as for unleaded petrol within the COPERT model. Tables 3.4 and 3.5 show the impact of recalculations for $N_2O$. However, because emissions of $CH_4$ and $N_2O$ are considerably smaller than $CO_2$, the impact on the total for 1.A.3(b) Road Transportation sector is small.

The COPERT 4v.8.0 model estimates emissions of $CH_4$ and $N_2O$ on the basis of distance travelled using a detailed bottom-up approach (Tier 3) that accounts for such factors as fuel type, fuel consumption, engine capacity, driving speed and a range of applicable technological emission controls that may be applied on the basis of the age of the vehicle. The model is applied annually in Ireland to derive $CH_4$ and $N_2O$ emissions estimates. The resultant 2010 emission factors have been converted to national average values per fuel type for the purpose of Table C.1 in Annex C. Detailed information on vehicle population by type and vehicle kilometre data is presented in Tables D.5 and D.6 of Annex D.

Road traffic is an important source of $N_2O$ from fuel combustion and from 1990-2007 emissions increased in line with the increasing share of catalyst-controlled vehicles in the national fleet. Over the last three years, 2008-2010, emissions of $N_2O$ decreased substantially. This is primarily due to a decrease in consumption of petrol and mileage driven and also due to significant reductions in the sulphur content of petrol since the introduction of the 10 ppm sulphur content limit under the Directive 2009/30/EC since the $1^{st}$ of January 2009. The impact of this legislation on sulphur content of petrol in Ireland has been to reduce sulphur content from over 100 ppm in 2006 to less than 5 ppm in 2010.

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

The $CO_2$ emissions under 1.A.3(c) Railways and 1.A.3(d) Navigation are calculated from the amounts of oil used by these activities, as recorded in the energy balance, and the country specific emission factors for oil. The emissions of $CH_4$ and $N_2O$ are estimated using the IPCC default emission factors adopted following the review of emission factors in 2009, referred to in 2010 National Inventory report. The previous national energy balance contained no activity data for Navigation 1.A.3(d) for 2009 and the inventory agency reported emissions from this category as “included elsewhere (IE)” in the previous submission. The inventory agency with SEAI worked together to resolve this issue during the meetings referred to in Section 3.2.1.1 above and revised the time series accordingly in this submission. Emissions factors used in these two sub-categories are presented in Table 3.2.

***Table 3.2. Emission factors for Rail and Navigation***

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

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

Figure 3.4 shows the trend in emissions from 1.A.3 Transport over the period 1990-2010. Road transport accounts for 95.3 per cent of the sectoral emissions in 2010. Overall Transport emissions increased by 182.9 per cent between 1990 (5,117.54 Gg $CO_2$ equivalent) and 2007 (14,478.47 Gg $CO_2$ equivalent) and since declined by 19.8 per cent by 2010 (11,605.54 Gg $CO_2$ equivalent), reflecting the impact of the recent economic downturn in Ireland.

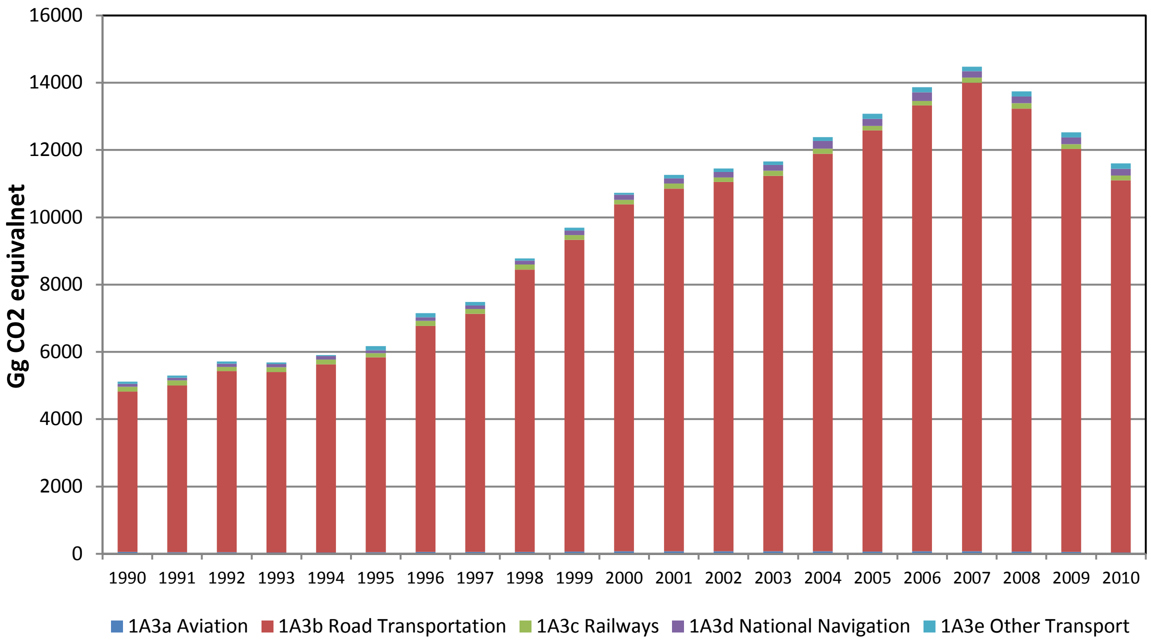


*Figure 3.4 Emissions from 1.A.3 Transport 1990-2010*

### 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 and agriculture/fishing/forestry sectors. The residential sub-category 1.A.4(b) with 71.1 per cent share of the sector emissions remains the most important source of emissions in this sub-category in Ireland. This is evident from Figure 3.4, which shows the trend in the principal components of emissions in 1.A.4 Other Sectors over the period 1990-2010. 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 the residential sub-category increased by 8.7 per cent in 2008, which is attributed to colder than normal winter months. In 2009 decreases in emissions from all subsectors by 4.5 per cent from 2008 reflect the impact of the economic downturn. Emissions increased in 2010 by 3.3 per cent and were mainly driven by increases in emissions from 1.A.4(a).

Table C.2 of Annex C shows the calculation of emissions for sub-category 1.A.4 Other Sectors, using the fuel quantities as given by the energy balance (Table B.1 of Annex B). The inventory agency uses country-specific emission factors for $CO_2$, including that for petroleum coke referred to in section 3.2.1.2, and IPCC default values for $CH_4$ and $N_2O$. The energy balance provides no indication on the specific end-use of gasoil in the agricultural sector 1.A.4 (c). Consequently, a split based on information from agricultural experts (10 per cent stationary sources and 90 per cent mobile sources) is used by the inventory agency to distinguish between the use of this fuel in stationary and mobile combustion sources. This split has little bearing on emissions of $CO_2$, but it is important in relation to $CH_4$ or $N_2O$ and the indirect greenhouse gases. This submission also includes fuel used in national fishing for the first time for the years 2003 to 2010. Emissions factors used for stationary and mobile sources in sub-category 1.A.4(c), agriculture/forestry/fishing, are presented in Table 3.3.

***Table 3.3. Emission factors for Agriculture/Forestry/Fishing***

| IPCC category | Fuel | CO2 t/TJ | Reference | $CH_4$ kg/TJ | $N_2O$ kg/TJ | Reference |
|---|---|---|---|---|---|---|
| Agriculture Stationary | Gasoil | 73.30 | CS | 10.00 | 0.60 | 2006 IPCC Guidelines Table 3.4.1 Default |
| Agriculture Mobile | Gasoil | 73.30 | CS | 4.15 | 28.60 | 2006 IPCC Guidelines Table 3.3.1 Default |
| Fishing | Gasoil | 73.30 | CS | 7.00 | 2.00 | 1996 IPCC Guidelines Table 1-48<br>2006 IPCC Guidelines Table 3.5.3 |

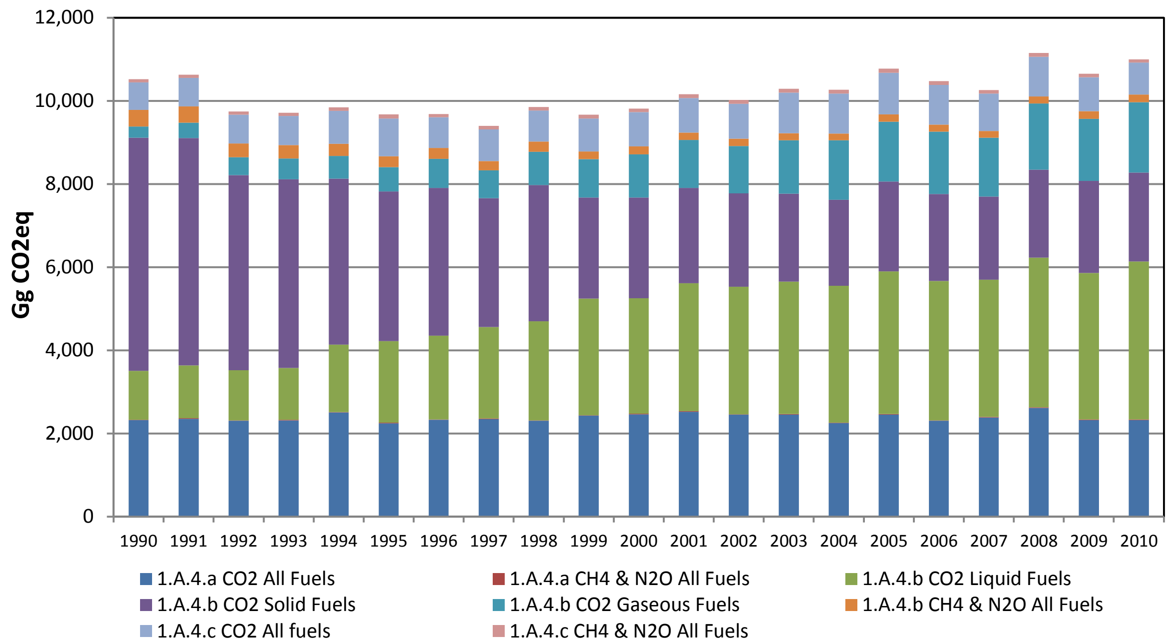


***Figure 3.5 Trend in Emissions from 1.A.4 Other Sectors 1990-2010***

## 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 being 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 1990-2010 time series and are currently covered by MOU with the inventory agency. The available data, which relate largely to gas extraction but which also account for a small amount of flaring in some years, indicate a close relationship between emissions and the amount of gas produced. This relationship has been applied in terms of the indicative emission rates of $CO_2$ and $CH_4$ per unit of gas extracted to estimate the emissions for those years for which no reports were received. A report on emissions was supplied to the inventory agency for 2010.

## 3.3 IPCC Reference Approach for $CO_2$ Emissions from Energy Use

The IPCC Reference Approach is a top-down methodology for $CO_2$ that estimates emissions by accounting for the overall production of primary fuels, the external trade in primary and secondary fuels, stock changes and for the carbon that may enter long-term storage in non-energy products and feedstocks. It can be used to report national emissions in cases where the detailed activity data required for the Sectoral Approach are not available but it is more usually applied for verification of the results of the latter for those countries that have the information to apply both methods. The Reference Approach is used in Ireland as a verification procedure for $CO_2$ emissions from fuel combustion activities. The calculation sheet for the Reference Approach (Table 1.A (b) of the 2010 CRF) is reproduced as Table C.4 of Annex C 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 whites spirit respectively. Ireland's only oil refinery is a small hydroskimming refinery where there is no production of other petroleum products normally used for non-energy purposes, such as bitumen, lubricants, plastics and asphalt. The expanded SEAI energy balance sheets now record the import of some of these products, thereby allowing improved completeness in the Reference Approach estimation of $CO_2$ emissions and carbon storage. A significant amount of natural gas feedstock was traditionally used in ammonia production in Ireland but the company closed in 2003 and there is consequently no feedstock use of natural gas since then.

## 3.4 Comparison between Sectoral Approach and Reference Approach

The national energy consumption and $CO_2$ emissions estimates obtained using the Sectoral Approach usually differ to some extent from the corresponding values resulting from the Reference Approach, Table C.5 of Annex C. 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 2010 are very minor, indicating that in the Reference Approach, energy use and $CO_2$ emissions were 0.44 per cent and 0.41 per cent lower than in the Sectoral Approach. The differences between the two approaches for liquid, solid and gaseous fuels are presented in Table C.5 of annex C.

## 3.5 Memo Items

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

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

The national energy balance sheets include marine bunkers and international aviation as specific items and the emissions may be calculated directly. The allocation of fuels to marine bunkers in the national energy balance is achieved on the basis of particular tax and excise rates applicable to the sale of such fuels. The allocation of jet kerosene use to international aviation (bunker fuel) is done by subtracting jet kerosene used in civil aviation estimated by the inventory agency, described in section 3.2.1.3 above, from total jet kerosene fuel sales compiled by SEAI. In 2010, the amount of jet kerosene fuel allocated to domestic aviation was 1.6 per cent of the total recorded under air transport in the energy balance.

## 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 2010 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. In 2011, considerable effort was made by the EPA inventory team and SEAI to reconcile the energy data provided through the ETS for electricity generation (1.A.1.a) with the data in SEAI's national energy balance.

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 $CO_2$ 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 $CO_2$ values are transferred directly to the national inventory and consistency of results is guaranteed. In the case where the $CO_2$ estimates from ETS do not completely cover the category, as for 1.A.2, the benefit is realised as better information on fuels and more representative emission factors, which improves the top-down estimates of emissions obtained using the energy balance.

The inventory agency has begun to carry out verification on civil aviation emission estimates using data sourced from Eurocontrol through the EU's Working Group 1 of the Climate Change Committee. Verification work has not been completed in time for this reporting round and will be documented in the submission for 2013.

## 3.7 Recalculations in Energy

Recalculations have been undertaken in the *Energy* sector for the years 1990-2009 to account for the following revisions and improvements:

- Revised energy data in sub-categories 1.A.1(a), 1.A.1(b) and 1.A.1(c) to harmonise fuel data in the energy balance with ETS bottom up data. These revisions to the energy statistics affected $CH_4$ and $N_2O$ emissions from 2004 to 2009;

- Revised energy data in all sub-categories in sector 1.A.2. These revisions to the energy statistics increased sector emissions for all years from 1990-2007 from 0.3 to 1.7 per cent and reduced emissions in 2008 and 2009 by 1.1 and 2.6 per cent respectively;

- Revisions to transport sub-categories civil aviation (1.A.3(a)), road transport (1.A.3(b)) and navigation (1.A.3(d)) were carried out for all years from 1990 to 2009. The impact of these recalculations was to reduce sector emissions by 0.3 per cent in 1990 and by 4.5 per cent in 2009;

    - Civil aviation emissions were revised based on new flight data and methodology as described in section 3.2.1.3 above. Overall emissions decreased from 13.9 per cent in 1990 to 46.4 per cent in 2009;
    - Road transport emissions decreased by 0.2 per cent in 1990 to 5.9 per cent in 2009;
    - Revised road fuel use data for all years from 1990 to 2009.The largest changes occurred in 2008 and 2009 with reductions of 4.4 and 5.9 per cent respectively;
    - The inventory agency revised the sulphur content of leaded gasoline (2003-2009) in the COPERT model to match the sulphur content of unleaded gasoline. This impacted on the emissions of $CH_4$ and $N_2O$ with substantial reductions in $N_2O$ emissions ranging from 20.1 per cent in 2003 to 15.2 per cent in 2006;
    - Revised gasoil data for navigation for all years from 1990 to 2009 which completed the time series as outlined in NIR 2011;

- Revised energy data in all sub-categories in sector 1.A.4. Overall emissions from this sector reduced by 0.2 per cent in 1990 and 0.4 per cent in 2009;

    - Sub-category 1.A.4(a) emissions decreased due to reallocation of gasoil from commercial to navigation (1.A.3(d)). Emissions decreased by 0.8 per cent in 1990 and by 5.8 per cent in 2009;
    - Sub-category 1.A.4(b) emissions decreased due to revised fuel data, in particular, LPG use. Emissions decreased by an average 0.6 per cent between 1990 and 2009;
    - Sub-category 1.A.4(c) emissions increased for the years 2003 to 2009 by 15.3 per cent in 2003 to 24.3 per cent in 2009. This sub-category now includes marine diesel used in national fishing for the last 8 years of the time series as discussed in section 3.2.1.4 above.

The results of the recalculations are given by category and gas in Tables 3.4, 3.5, 3.6 and 3.7.

## 3.8 Planned Improvements in Energy

The changes referred to above for 2010 conclude a series of improvements affecting activity data, emission factors and methodologies that have been applied to inventories for the *Energy* sector over recent years. The inventory agency believes that $CO_2$ from this sector, which accounts for 98.5 per cent of emissions, are accurately quantified and there is therefore little scope for further improvement in the inventories as delivered in the 2011 submission. No substantial changes are foreseen for inventory submissions relating to the remaining years of the Kyoto Protocol commitment period 2008-2012 other than updating the road transport model version as made available by the developers. It is planned to use COPERT 4 version 9.0, or a revised update, for the 2013 submission.

*Table 3.4. 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimates in 2011 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 | 16,453.29 | 15,761.31 | 15,383.33 | 15,771.30 | 15,027.01 | 14,533.81 | 14,640.70 | 13,071.58 |
| 1.A.2. | Manuf Ind and Constn | 3,961.80 | 4,062.70 | 3,755.65 | 3,968.80 | 4,219.83 | 4,321.22 | 4,154.61 | 4,532.93 | 4,552.83 | 4,763.69 | 5,591.25 | 5,536.11 | 5,257.85 | 5,448.32 | 5,833.52 | 5,938.91 | 5,827.21 | 6,058.07 | 5,710.54 | 4,547.75 |
| 1.A.3. | Transport | 5,134.89 | 5,340.04 | 5,788.75 | 5,760.26 | 6,004.83 | 6,237.14 | 7,294.09 | 7,648.48 | 9,019.96 | 9,979.27 | 10,716.35 | 11,229.01 | 11,422.22 | 11,597.63 | 12,229.83 | 12,991.96 | 13,681.81 | 14,333.43 | 14,208.51 | 13,121.36 |
| 1.A.4. | Other Sectors | 10,539.72 | 10,660.73 | 9,785.95 | 9,756.57 | 9,893.24 | 9,726.22 | 9,750.17 | 9,453.08 | 9,938.23 | 9,768.76 | 9,943.65 | 10,313.16 | 10,187.14 | 10,474.09 | 10,512.71 | 11,006.18 | 10,774.32 | 10,507.82 | 11,198.31 | 10,695.95 |
| 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 | 35.11 |
| 1 | Total | 31,006.04 | 31,889.85 | 31,816.80 | 31,985.98 | 32,952.60 | 33,800.16 | 35,429.54 | 36,522.30 | 38,770.36 | 40,423.36 | 42,476.79 | 44,534.17 | 43,389.44 | 43,907.61 | 44,025.34 | 45,764.93 | 45,357.21 | 45,492.71 | 45,809.30 | 41,471.75 |
| | | Recalculated 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| | | 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 | -0.09 | -0.01 | 0.01 | 0.01 | 0.08 | 0.05 |
| 1.A.2. | Manuf Ind and Constn | -0.02 | 0.28 | 0.34 | 0.44 | 0.53 | 0.60 | 0.66 | 0.38 | 0.79 | 0.97 | 0.90 | 1.13 | 1.23 | 1.21 | 1.34 | 1.35 | 1.43 | 1.47 | -1.08 | -2.59 |
| 1.A.3. | Transport | -0.34 | -0.79 | -1.27 | -1.31 | -1.57 | -1.06 | -1.91 | -2.15 | -2.70 | -2.84 | 0.13 | 0.27 | 0.27 | 0.57 | 1.29 | 0.68 | 1.34 | 1.01 | -3.28 | -4.54 |
| 1.A.4. | Other Sectors | -0.21 | -0.32 | -0.39 | -0.44 | -0.49 | -0.50 | -0.68 | -0.59 | -0.85 | -1.06 | -1.27 | -1.47 | -1.66 | -1.75 | -2.32 | -2.09 | -2.76 | -2.37 | -0.39 | -0.44 |
| 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 | 0.41 |
| 1 | Total | -0.13 | -0.20 | -0.31 | -0.32 | -0.36 | -0.26 | -0.50 | -0.55 | -0.75 | -0.84 | -0.15 | -0.13 | -0.17 | -0.11 | -0.05 | -0.14 | -0.06 | -0.03 | -1.22 | -1.82 |

*Table 3.5. Percentage Change in $CO_2$ Emissions from Energy due to Recalculations*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Estimates in 2011 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 11,158.61 | 11,617.34 | 12,279.74 | 12,297.59 | 12,634.28 | 13,317.47 | 14,031.86 | 14,692.87 | 15,080.52 | 15,732.98 | 16,050.38 | 17,266.56 | 16,345.34 | 15,643.44 | 15,283.51 | 15,657.29 | 14,906.98 | 14,406.63 | 14,495.44 | 12,926.12 |
| 1.A.2. | Manuf Ind and Constn | 3,943.24 | 4,043.95 | 3,739.67 | 3,951.98 | 4,203.13 | 4,303.94 | 4,136.41 | 4,514.22 | 4,532.89 | 4,743.35 | 5,567.48 | 5,511.27 | 5,233.94 | 5,423.36 | 5,806.19 | 5,908.11 | 5,798.04 | 6,029.39 | 5,684.12 | 4,525.21 |
| 1.A.3. | Transport | 5,039.39 | 5,242.11 | 5,685.51 | 5,646.50 | 5,880.60 | 6,106.55 | 7,144.83 | 7,482.37 | 8,826.58 | 9,783.76 | 10,512.66 | 11,017.18 | 11,215.64 | 11,396.54 | 12,027.84 | 12,792.15 | 13,483.34 | 14,143.87 | 14,057.55 | 12,976.90 |
| 1.A.4. | Other Sectors | 10,052.71 | 10,179.94 | 9,363.67 | 9,342.68 | 9,505.45 | 9,353.16 | 9,396.49 | 9,128.26 | 9,600.35 | 9,481.15 | 9,653.50 | 10,029.54 | 9,905.96 | 10,200.31 | 10,245.73 | 10,724.73 | 10,501.67 | 10,244.92 | 10,923.78 | 10,428.42 |
| 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 |
| 1 | Total | 30,193.96 | 31,083.34 | 31,068.59 | 31,238.76 | 32,223.46 | 33,081.11 | 34,709.59 | 35,817.73 | 38,040.34 | 39,741.24 | 41,784.02 | 43,824.56 | 42,700.89 | 42,663.65 | 43,363.27 | 45,082.28 | 44,690.04 | 44,824.81 | 45,160.89 | 40,856.64 |
| | | | | | | | | | | | Recalculated Estimates in 2012 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 11,158.61 | 11,617.34 | 12,279.74 | 12,297.59 | 12,634.28 | 13,317.47 | 14,031.86 | 14,692.87 | 15,080.52 | 15,732.98 | 16,050.38 | 17,266.56 | 16,345.85 | 15,643.76 | 15,265.22 | 15,657.29 | 14,906.98 | 14,406.63 | 14,495.44 | 12,926.12 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| | | | | | | | | | | | Percentage Change in CO2 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 | -0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.A.2. | Manuf Ind and Constn | -0.02 | 0.28 | 0.34 | 0.44 | 0.53 | 0.60 | 0.67 | 0.38 | 0.80 | 0.97 | 0.91 | 1.13 | 1.23 | 1.22 | 1.34 | 1.36 | 1.43 | 1.48 | -1.09 | -2.60 |
| 1.A.3. | Transport | -0.34 | -0.79 | -1.27 | -1.21 | -1.39 | -0.87 | -1.70 | -1.86 | -2.37 | -2.56 | 0.46 | 0.59 | 0.58 | 0.84 | 1.54 | 0.89 | 1.52 | 1.02 | -3.28 | -4.55 |
| 1.A.4. | Other Sectors | -0.22 | -0.33 | -0.41 | -0.46 | -0.50 | -0.52 | -0.70 | -0.61 | -0.87 | -1.09 | -1.30 | -1.50 | -1.70 | -1.79 | -2.38 | -2.15 | -2.82 | -2.43 | -0.48 | -0.54 |
| 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 |
| 1 | Total | -0.13 | -0.20 | -0.31 | -0.30 | -0.33 | -0.23 | -0.46 | -0.49 | -0.68 | -0.78 | -0.06 | -0.05 | -0.09 | -0.05 | 0.00 | -0.08 | -0.02 | -0.04 | -1.28 | -1.87 |

*Table 3.6. Percentage Change in $CH_4$ Emissions from Energy due to Recalculations*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Estimates in 2011 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 5.56 | 5.57 | 5.61 | 6.11 | 6.17 | 6.58 | 7.51 | 7.80 | 7.74 | 8.37 | 9.19 | 9.64 | 9.13 | 8.56 | 7.49 | 7.72 | 7.31 | 7.31 | 7.30 | 6.69 |
| 1.A.2. | Manuf Ind and Constn | 5.60 | 5.66 | 4.74 | 5.01 | 4.85 | 5.04 | 5.41 | 5.49 | 5.93 | 6.00 | 7.04 | 7.41 | 7.16 | 7.48 | 8.28 | 9.43 | 9.03 | 8.85 | 8.15 | 7.05 |
| 1.A.3. | Transport | 36.28 | 37.43 | 40.41 | 36.58 | 35.08 | 37.67 | 38.86 | 37.59 | 38.56 | 37.99 | 35.01 | 33.63 | 30.50 | 28.67 | 27.13 | 25.83 | 24.69 | 23.64 | 22.83 | 20.90 |
| 1.A.4. | Other Sectors | 378.91 | 370.36 | 315.51 | 307.25 | 272.18 | 246.42 | 245.96 | 216.23 | 228.74 | 176.62 | 176.21 | 168.42 | 165.85 | 157.80 | 154.94 | 161.87 | 157.62 | 153.70 | 164.02 | 170.58 |
| 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 | 35.11 |
| 1 | Total | 557.44 | 546.38 | 489.09 | 476.71 | 436.21 | 409.88 | 407.83 | 372.61 | 373.06 | 318.35 | 312.50 | 310.80 | 281.59 | 828.77 | 263.79 | 261.42 | 245.51 | 253.09 | 253.55 | 240.32 |
| | | | | | | | | | | | Recalculated Estimates in 2012 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 5.56 | 5.57 | 5.61 | 6.11 | 6.17 | 6.58 | 7.51 | 7.80 | 7.74 | 8.37 | 9.19 | 9.64 | 9.13 | 8.56 | 7.58 | 7.73 | 7.34 | 7.55 | 6.08 | 5.89 |
| 1.A.2. | Manuf Ind and Constn | 5.60 | 5.66 | 4.75 | 5.02 | 4.86 | 5.05 | 5.41 | 5.50 | 5.94 | 6.02 | 7.06 | 7.43 | 7.19 | 7.50 | 8.31 | 9.45 | 9.06 | 8.88 | 8.15 | 7.02 |
| 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 |
| 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 |
| 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 |
| 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 |
| | | | | | | | | | | | Percentage Change in CH4 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 | 1.27 | 0.02 | 0.42 | 3.26 | -16.67 | -11.86 |
| 1.A.2. | Manuf Ind and Constn | 0.00 | 0.07 | 0.09 | 0.11 | 0.15 | 0.17 | 0.17 | 0.10 | 0.20 | 0.25 | 0.23 | 0.28 | 0.30 | 0.29 | 0.30 | 0.27 | 0.30 | 0.33 | -0.02 | -0.38 |
| 1.A.3. | Transport | 0.02 | -0.04 | -0.35 | -0.27 | -0.36 | -0.22 | -0.41 | -0.47 | -0.63 | -0.72 | 0.19 | 0.28 | 0.58 | 0.76 | 1.27 | 1.20 | 1.87 | 1.31 | -2.33 | -2.64 |
| 1.A.4. | Other Sectors | -0.02 | -0.02 | -0.03 | -0.03 | -0.04 | -0.04 | -0.06 | -0.06 | -0.09 | -0.14 | -0.17 | -0.21 | -0.24 | -0.36 | -0.48 | -0.42 | -0.56 | -0.50 | 0.09 | 0.74 |
| 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 | 0.41 |
| 1 | Total | -0.01 | -0.02 | -0.05 | -0.04 | -0.05 | -0.04 | -0.07 | -0.08 | -0.12 | -0.16 | -0.07 | -0.08 | -0.07 | -0.04 | -0.11 | -0.13 | -0.15 | -0.08 | -0.63 | 0.02 |

*Table 3.7. Percentage Change in $N_2O$ Emissions from Energy due to Recalculations*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Estimates in 2011 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 74.37 | 76.09 | 78.28 | 74.89 | 76.33 | 77.35 | 81.22 | 81.64 | 78.98 | 80.93 | 80.92 | 87.99 | 98.82 | 109.31 | 92.34 | 106.29 | 112.72 | 119.86 | 137.96 | 138.78 |
| 1.A.2. | Manuf Ind and Constn | 12.95 | 13.09 | 11.24 | 11.81 | 11.84 | 12.24 | 12.79 | 13.22 | 14.02 | 14.34 | 16.73 | 17.43 | 16.74 | 17.48 | 19.04 | 21.38 | 20.14 | 19.83 | 18.27 | 15.50 |
| 1.A.3. | Transport | 59.21 | 60.51 | 62.83 | 77.18 | 89.14 | 92.93 | 110.39 | 128.52 | 154.83 | 157.52 | 168.69 | 178.20 | 176.08 | 172.42 | 174.87 | 173.98 | 173.78 | 165.91 | 128.13 | 123.56 |
| 1.A.4. | Other Sectors | 108.10 | 110.43 | 106.77 | 106.64 | 115.61 | 126.65 | 107.72 | 108.59 | 109.14 | 110.99 | 113.94 | 115.20 | 115.33 | 115.97 | 112.04 | 119.58 | 115.03 | 109.20 | 110.51 | 96.95 |
| 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 |
| 1 | Total | 254.63 | 260.12 | 259.12 | 270.51 | 292.93 | 309.17 | 312.12 | 331.96 | 356.96 | 363.77 | 380.27 | 398.81 | 406.97 | 415.19 | 398.28 | 421.22 | 421.66 | 414.81 | 394.86 | 374.79 |
| | | | | | | | | | | | Recalculated Estimates in 2012 Submission (Gg CO2eq) | | | | | | | | | | |
| 1.A.1. | Energy Industries | 74.37 | 76.09 | 78.28 | 74.89 | 76.33 | 77.35 | 81.22 | 81.64 | 78.98 | 80.93 | 80.92 | 87.99 | 98.82 | 109.31 | 95.92 | 105.28 | 114.25 | 121.19 | 151.39 | 145.66 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| | | | | | | | | | | | Percentage Change in N2O 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 | 3.87 | -0.95 | 1.36 | 1.10 | 9.73 | 4.96 |
| 1.A.2. | Manuf Ind and Constn | 0.00 | 0.04 | 0.05 | 0.07 | 0.09 | 0.10 | 0.10 | 0.06 | 0.12 | 0.16 | 0.15 | 0.17 | 0.19 | 0.18 | 0.19 | 0.17 | 0.20 | 0.22 | 0.34 | 0.08 |
| 1.A.3. | Transport | 0.01 | -1.52 | -1.78 | -9.65 | -14.24 | -13.94 | -16.18 | -19.52 | -21.94 | -20.52 | -20.43 | -19.39 | -19.02 | -17.49 | -16.09 | -14.82 | -12.67 | 0.52 | -2.78 | -3.85 |
| 1.A.4. | Other Sectors | -0.05 | -0.06 | -0.07 | -0.07 | -0.07 | -0.05 | -0.10 | -0.10 | -0.13 | -0.15 | -0.18 | -0.22 | -0.26 | 0.44 | 0.44 | 0.36 | 0.14 | 0.20 | 8.21 | 8.41 |
| 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 |
| 1 | Total | -0.02 | -0.38 | -0.46 | -2.78 | -4.36 | -4.21 | -5.75 | -7.59 | -9.55 | -8.93 | -9.11 | -8.72 | -8.29 | -7.13 | -6.03 | -6.25 | -4.81 | 0.59 | 4.81 | 2.75 |

# Chapter Four

# Industrial Processes

## 4.1 Overview of the Industrial Processes Sector

The list of activities under *Industrial Processes* in the IPCC reporting format is given in Table 4.1. Some of these activities are well known sources of one particular greenhouse gas, such as cement production for $CO_2$ or adipic acid production in the case of $N_2O$, while others may be more important in terms of their indirect greenhouse gas emissions. Major industrial processes within the chemical sector and metal production that are common to many other developed countries have never been an important part of the Irish economy. Consequently, many of the production processes listed in Table 4.1 are not relevant to the inventories of greenhouse gases in Ireland. Historically, the four key industrial sources are cement and lime production under *2.A Mineral Products* and ammonia and nitric acid production under *2.B Chemical Industry.* The nitric acid and ammonia plants, both operated by Irish Fertilizer Industries, ceased production in 2002 and 2003, respectively. 2*.A.3 Limestone and Dolomite Use* is a relevant activity in Ireland due to the use of a small amount of limestone to abate $SO_2$ emissions in peat-fired electricity generating stations and the use of limestone by a number of companies as a raw material. *2.A.4 Soda Ash Production and Use* is also a minor source of emissions and is reported in this submission for the full time-series 1990-2010.

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

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

Table 4.2 presents the estimates of greenhouse gas emissions for *Industrial Processes* over the period 1990-2010 for the relevant sources in Ireland. They indicate contributions of 5.8 per cent and 3.2 per cent to total national emissions in 1990 and 2010, respectively. As such, the sector is not a particularly important one in the Irish greenhouse gas inventories. Ammonia and nitric acid production were the principal sources of emissions in the sector in 1990, accounting for approximately two-thirds of the total, but the plants ceased operation in 2003 and 2002 respectively, leaving cement production as the dominant emission source thereafter.

The combined contribution of HFC, PFC and $SF_6$ to the total emissions for *Industrial Processes* remains small and highly variable from year to year. 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 is used in the methodology. This is expected to give considerably more accurate emission estimates, and therefore a more certain trend with time.

Emissions of $SF_6$ 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 1990-2010.

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

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

* ammonia and nitric acid plants closed down in 2003 and 2002 respectively.

*Table 4.2. Emissions from Industrial Processes 1990-2010*

| | Gas | Unit | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.A.1 Cement Production | $CO_2$ | kt | 884.00 | 782.00 | 753.00 | 729.00 | 859.00 | 879.00 | 983.00 | 1145.00 | 1059.00 | 1166.00 | 1700.90 | 1851.19 | 1859.80 | 2126.95 | 2295.08 | 2357.06 | 2347.85 | 2374.06 | 2106.73 | 1326.78 | 1105.11 |
| 2.A.2 Lime Production | $CO_2$ | kt | 214.08 | 192.23 | 162.40 | 204.89 | 205.43 | 187.51 | 198.24 | 221.89 | 211.66 | 170.07 | 190.43 | 189.40 | 190.31 | 206.26 | 201.54 | 183.48 | 180.30 | 196.71 | 187.80 | 156.40 | 192.41 |
| 2.A.3 Limestone & Dolomite | $CO_2$ | kt | 0.15 | 0.14 | 0.13 | 0.11 | 0.13 | 0.18 | 0.17 | 0.24 | 0.23 | 0.25 | 0.18 | 4.50 | 2.17 | 2.38 | 3.55 | 4.29 | 2.64 | 2.32 | 2.71 | 1.54 | 1.03 |
| 2.A.4 Soda Ash Production & | $CO_2$ | kt | 0.10 | 0.09 | 0.07 | 0.11 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.05 | 0.07 | 0.09 | 0.05 | 0.06 | 0.08 | 0.08 | 0.06 | 0.06 | 0.04 | 0.05 | 0.07 |
| 2.A.7 Glass Production | $CO_2$ | kt | 13.33 | 13.06 | 12.59 | 12.52 | 12.31 | 11.97 | 11.63 | 11.46 | 11.05 | 10.96 | 10.71 | 10.14 | 5.13 | 0.55 | 0.58 | 0.48 | 0.49 | 0.45 | 0.31 | 0.02 | 0.00 |
| 2.A.7 Other Mineral Products | $CO_2$ | kt | 5.07 | 4.88 | 4.79 | 4.50 | 4.79 | 5.46 | 5.27 | 6.23 | 6.08 | 6.37 | 6.49 | 6.12 | 5.91 | 6.12 | 6.23 | 7.41 | 7.40 | 6.83 | 4.00 | 0.53 | 0.42 |
| | | | | | | | | | | | | | | | | | | | | | | | |
| 2.B.1 Ammonia Production* | $CO_2$ | Gg | 990.23 | 1030.32 | 1003.56 | 946.19 | 1056.63 | 973.44 | 922.85 | 1073.12 | 1058.81 | 942.82 | 882.30 | 1041.18 | 810.90 | 0.30 | NO | NO | NO | NO | NO | NO | NO |
| 2.B.2 Nitric Acid Production* | $N_2O$ | kt $CO_2$ eq | 1035.40 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.20 | 812.20 | 812.45 | 584.35 | 292.18 | NO | NO | NO | NO | NO | NO | NO | NO |
| | | | | | | | | | | | | | | | | | | | | | | | |
| Emissions of HFC | HFC | Gg $CO_2$ eq | 1.31 | 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 |
| Emissions of PFC | PFC | Gg $CO_2$ eq | 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 |
| Emissions of SF6 | $SF_6$ | Gg $CO_2$ eq | 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 Industrial Processes | | | 3179.27 | 2890.58 | 2819.91 | 2810.41 | 3088.51 | 3082.73 | 3230.46 | 3686.58 | 3530.66 | 3595.44 | 4222.47 | 4329.90 | 3754.95 | 3068.02 | 3173.00 | 3297.22 | 3297.06 | 3310.43 | 3029.12 | 2110.20 | 1933.62 |

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

The IPCC Level 3 emission source categories relevant under *2.A Mineral Products* in 2010 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 glass and bricks and ceramics under *2.A.7 Other Mineral Products*. Total $CO_2$ emissions from these activities amounted to 1229.05 Gg, in 2010 of which cement production accounted for 85.1 per cent.

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

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

Up until the year 2000, one company operated two cement plants in Ireland. A second company opened a new cement plant in 2000 and a third cement producer entered the market in 2003, bringing the total number of plants to four. In 2004, plant-specific information relating to $CO_2$ emissions in 2002 and 2003 was obtained by the EPA for all cement plants for the development of Ireland's First National Allocation Plan (NAP1) under Directive 2003/87/EC (EP and CEU, 2003) on emissions trading in the EU. The reported process $CO_2$ emissions for each plant in 2002 and 2003 were calculated using the Tier 2 method according to the guidelines for the monitoring and reporting of greenhouse gas emissions in Decision 2004/156/EC that supports Directive 2003/87/EC. This method is fully consistent with the Tier 2 method in the IPCC good practice guidance and its application employs reliable data on clinker production, corrected as appropriate for CKD, and CaO content of the clinker. As the EU ETS subsequently became operational, plant specific $CO_2$ emissions and corresponding clinker production data are also available for all cement plants for the years 2004 through 2010 and these data are used directly to report emissions for category 2.A.1 in Ireland. The annual results incorporate verification of fuel use, limestone and carbonate use, combustion and process $CO_2$ estimates in accordance with Decision 2004/156/EC. Total process emissions for cement production in 2010 were 1105.11 Gg $CO_2$. The plant-specific emission factors for process $CO_2$ emissions in 2010 ranged from 0.523 to 0.552 t $CO_2$/ t clinker with a weighted average of 0.538 t $CO_2$/ t clinker, which is very similar to the 2009 values. Additional information is provided in Table E.1 of annex E.

For the two original cement plants that were operated by the single cement producer, the company concerned supplied estimates of process emissions for the years 1990-2001 that it had calculated internally in line with the specific information provided for the years 2002 and 2003 and used for NAP1. The associated values of annual clinker production were not provided. For the purposes of complete and consistent reporting, the inventory agency estimated annual clinker production for the years 1990-2001 based on the plant specific process emission factors available for the two plants for the years from 2002 onwards. This is appropriate, as the company has always used the same local on-site supply of limestone, and the time-series of process $CO_2$ emissions for cement production overall may therefore be considered consistent for the period 1990-2010. 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.

Process emissions of $CO_2$ from cement production have declined by 53.5 per cent since 2007, falling from a peak of 2374.06 Gg $CO_2$ in 2007, to 1,105.11 Gg $CO_2$ in 2010. 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 $CO_2$ emissions from lime manufacture for the development of NAP1 under Directive 2003/87/EC on ETS. These were calculated in accordance with the methods described in the supporting Decision 2004/156/EC, thus providing detailed information on emission estimates and activity data for another important source of $CO_2$ emissions in *Industrial Processes*. The $CO_2$ estimates for lime production in 2010 have been obtained from the ETS returns to the EPA. The implied emission factor for aggregated lime production was 0.765 t $CO_2$/t lime in 2010, which is very similar to that for the other years for which ETS data are available. Data provided by the lime producers form the basis for emissions over the period 1990-2004. The implied emission factors for the 1990-2004 time-series indicated by the information supplied by the lime producers are in the range 0.753 to 0.877 t $CO_2$/t lime produced with an average of 0.82 t $CO_2$/t lime. EU ETS data for the years 2005 to 2010 are used to confirm the estimates for the years 1990-2004, as given in Table 4.2.

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

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

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

Soda ash (sodium carbonate, $Na_2CO_3$) is a white crystalline solid that is used as a raw material in a large number of industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. The emissions associated with soda ash use by one company in Ireland are reported by the company under ETS for the years 2005-2010 and have been used directly in the inventory. Activity data for years prior to the ETS data were sourced by the inventory agency from the company. These data were combined with an emission factor of 0.41 t $CO_2$/t soda ash, indicated by the ETS data. This approach has allowed a full 1990-2010 time series of emissions to be included in the inventory.

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

The emissions of $CO_2$ from glass production 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.

In the case of bricks and ceramics, the ETS data for two companies provide estimates of emissions for the years 2005-2010 and a further two companies for the years 2005-2008 which have now ceased trading, along with the corresponding quantities of carbonate input materials and the relevant emission factors. The emission factors for clay bricks and flue liners are in the range 0.026 to 0.049 tonne $CO_2$/tonne carbonate input while the emission factor for ceramic tiles averages 0.062 tonne $CO_2$/tonne carbonate input. The emissions for the years prior to ETS are calculated from the companies' estimates of material use and their respective average ETS emission factors. Additional detailed information is available in Table E.4 in Annex E.

Glass production is treated as a separate sub-category under 2.A.7, and a full time-series of $CO_2$ emissions has been developed. The production of bottle glass has been the major source of emissions. The $CO_2$ emissions are estimated from the annual production quantities obtained from the company for the development of annual inventories for heavy metals. Equation 2.11 of the 2006 IPCC guidelines and the emission factor of 0.21 kg $CO_2$/kg glass are used. Allowance is made for recycled glass, which is assumed to be 5 per cent in 1990, increasing to 30 per cent in 2002 when the plant closed. In the case of crystal glass, the $CO_2$ emissions are based on the use of potassium carbonate and sodium carbonate use (soda ash) as reported under ETS, using the emission factors of 0.415 t $CO_2$/t $Na_2CO_3$ and 0.267 t CO2/t $K_2CO_3$, provided by the ETS monitoring and reporting guidelines. The company concerned has supplied estimates for all years up to and including 2009, when the plant closed. Emissions from the production of glass-based insulation materials is also based largely on soda ash use although small amounts of dolomite and limestone were also used up to 2005. The emissions of $CO_2$ from glass production amounted to 13.3 kt in 1990 and have reduced to 0.02 kt in 2009, due to plant closures. The last glass manufacturing plant closed in 2009. Additional detailed information is available in Table E.3 in Annex E.

## 4.3 Emissions from Chemical Industry (2.B)

Emissions of $CO_2$ and $N_2O$ 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 $CO_2$ as a by-product. Urea was one of the main end products of the plant, which was formed when the ammonia produced and the $CO_2$ by-product reacted together to form prills (small particles) of urea. The other main product, liquid ammonia, was stored and transported to Irish Fertilizer Industries other plant where it underwent further processing (discussed in section 4.3.2 Nitric Acid Production below). Carbon dioxide emissions from ammonia production are estimated from the natural gas feedstocks to the plant as indicated in the national energy balance provided by SEAI. In accordance with the 1996 IPCC guidelines, it is assumed that no feedstock carbon is sequestered in urea and the emission factor is 54.94 kg $CO_2$/TJ, the value for indigenous natural gas, which equates to 2.3 tonne $CO_2$/tonne natural gas. The $CO_2$ emissions from ammonia production were 990.23 Gg in 1990 and 0.30 Gg in 2003, the last year of operation.

### 4.3.2 Nitric Acid Production (2.B.2)

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

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

### 4.4.1 Special Studies

The compilation of emission estimates for fluorinated gases presents major challenges for inventory agencies because they emanate from diverse sources that are entirely different to those traditionally covered by atmospheric emissions inventories. In addition, the use of many of the substances concerned is continuing to change very rapidly in the marketplace. Issues of confidentiality are common among many of the source activities concerned and this also hinders the inventory process and the transparency of reporting in relation to fluorinated gases (F-gases). The first attempts to quantify emissions of HFC, PFC and $SF_6$ in Ireland were made for the year 1995 for inclusion in Ireland's Second National Communication published in 1997 (DOE, 1997). Little was known at that time about the sources of these fluorinated gases and the methodologies to estimate their emission were not well established. The results for 1995 were therefore regarded as tentative and incomplete. However, the indications were that, in common with emissions from industrial processes in general in Ireland, those of HFC, PFC and $SF_6$ were likely to be small.

In 2000, the EPA commissioned special studies on HFC, PFC and $SF_6$ emissions, led by the Clean Technology Centre (CTC) at Cork Institute of Technology that were designed to identify the important sources in Ireland and to quantify the emissions in 1998 on the basis of separate bottom-up and top-down methodologies. The reports on these studies (O'Doherty and McCulloch, 2002 and O'Leary *et al*, 2002) describe a very comprehensive investigation into the emissions of fluorinated gases in Ireland and the bottom-up method provided a readily applicable approach that could be used for developing inventories of these gases for other years.

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

As part of the general round of improvements conducted for the 2006 submission, the inventory agency decided that it would be useful to again examine, on a contract basis, the known sources of HFC, PFC and $SF_6$ emissions over an extended time period. The contract was undertaken jointly by CTC and UK consultants NETCEN, the latter having considerable experience in developing emission inventories for the UK. The work and results are fully described in a supplementary document (Adams *et al*, 2005). The intention was to re-assess the use and application of the various substances in the Irish market as a whole, initially to compile the best possible estimates of emissions in 2004, and to make revisions as appropriate for earlier years based on better information, particularly for 1995 (the base year adopted by Ireland with respect to HFC, PFC and $SF_6$) and for those years (2001-2003) for which the estimates had been produced by the inventory agency. A second objective of the study was to extend the F-gas emissions time-series back to 1990 so that Ireland could make available information that had been lacking for the years 1990-2004, requested under Decision 280/2004/EC, to enable the European Union to complete the inventories at the European level for all years. In performing this update of the previous emission inventories for fluorinated gases, a number of users and distributors were contacted and any data obtained were used for estimating emissions of the various gases for the period 2001-2004. Where data allowed, emission estimates were calculated following the guidance for individual sub-categories provided by IPCC good practice guidance. The approach developed by Adams *et* al. (2005) is used for this submission with some minor recalculations due to the availability of new data. Recalculations for HFCs, PFCs and $SF_6$ are discussed in section 4.6.

Emission estimates for 1990-2010 are shown in Table 4.3. In 2010, air conditioning (stationary and mobile combined) and refrigeration account for some 59.1 per cent of the total F-gas emission. The emission estimates clearly indicate that the combined emissions of HFC, PFC and $SF_6$ have generally increased year on year. This overall trend largely reflects the increasing use of HFCs across a range of applications (e.g. often as replacements in applications where the use of CFC and HCFCs is no longer permitted under the Montreal Protocol) and hence the presence of larger fluid banks from which operational leakage potentially occurs. In contrast, PFC emissions have decreased while emissions of $SF_6$ fluctuate significantly. This 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. $SF_6$ emissions also generally decline but with large fluctuations.

### 4.4.2 HFC, PFC and $SF_6$ Time-Series 1990-2010

In the following sections a brief description is provided for the activities for which emissions of HFCs PFCs and $SF_6$ are estimated for the time-series 1990-2010. 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 $SF_6$, 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)

HFC's 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:

Potential emissions = production + import – export – destruction

As there is no manufacture of fluorinated gases in Ireland, the production term above is zero. Imported HFCs are calculated using the data supplied as described above. Exports are calculated on the basis of refrigeration unit manufacturers' share of exports. 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 from the Department of Transport, Tourism and Sport and assumed rates of air-conditioning unit penetration in the national vehicle fleet. The methodology used takes account of vehicle lifetime, the percentage of vehicles having HFC in their air-conditioning systems, average charge per unit, product manufacturing emissions, effective lifetime leakage rates (incorporating emissions from normal operating losses and accidental releases arising from collision damage) and decommissioning losses.

### 4.4.2.2 Foam Blowing (2.F.2)

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. 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)

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 (0.005), 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 0.05, falling to 0.025 in 2005 and remains at this value for each subsequent year. The third stage factor (0.001) covers the disposal of the product due to decommissioning. Potential emissions account for the total available product.

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

For the purposes of estimating emissions Aerosols and Metered Dose Inhalers are treated separately in the inventory calculations. The category aerosols, is one which covers a large number of products. In general there are four major sub-categories; personal-care products (e.g. deodorant, hair care and shaving foams), household products (e.g. air fresheners, furniture polish and oven and fabric cleaners), industrial products (e.g. cleaning sprays, pipe freezers and lubricants) and other general products (e.g. klaxons, tyre inflators and silly string). The two HFCs of interest are HFC-134a and HFC-152a. In previous submissions the assumed species ratio was 90 per cent: 10 per cent, respectively for HFC-134a and HFC-152a. This assumption has now been revised on the basis of updated information (AEA 2011) which suggests a species ratio of 97 per cent: 3 per cent in 1990 and 96 per cent: 4 per cent, respectively for HFC-134a and HFC-152 in 2010. There is no trade association for aerosol manufacturers or importers in Ireland. 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) recommended the use of a population based proxy to estimate Irish emissions from those for the UK, which are based on trade data, 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 HFC134a 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. Total emissions are calculated based on reported manufacturing losses 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)

The semiconductor industry uses HFCs, PFCs and $SF_6$ in manufacturing processes. Both HFCs and PFCs are used in the cleaning of chambers used for chemical vapour deposition processes, dry plasma etching, vapour phase soldering and vapour phase blanketing, leak testing of hermetically sealed components and as coolants. Cleaning and etching during semiconductor manufacture account for the majority of emissions from the category. In addition $SF_6$ is used in the etching processes. There are a small number of large semiconductor manufacturers in Ireland. These installations provide data on the annual use and estimated emissions of HFCs, PFCs and $SF_6$ in their plants over the full time series 1990-2010.

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

$SF_6$ is used for electrical insulation, arc quenching, and for current interruption in equipment used in the transmission and distribution of electricity. The Electricity Supply Board (ESB) is the owner of both the high and low voltage distribution systems and the owner and operator of the medium and lower voltage distribution systems in Ireland. The company supplies an estimate of $SF_6$ emissions from their equipment 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 $SF_6$.

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

This category includes emissions of $SF_6$ from minor uses within Ireland including emissions from double glazed windows, medical applications, sporting goods and as a gas-air tracer in leak detection. $SF_6$ was previously used as an insulation gas in double-glazing, however its use has been phased out in response to 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 $SF_6$ was discontinued in window insulation after 2000, the bank of gas in installed units is an emission source and is therefore accounted for in emission estimates. Recalculated estimates for this source were undertaken in this submission to account for the bank of $SF_6$ 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 timeseries 1990-2010.

$SF_6$ is used in certain medical application such as eye surgery where it is used to seal retinal holes internally and to hold reattached retina in place. Use of the gas is small with one hospital reporting the use of one 10-litre cylinder every three years. Based on this data, it is assumed that a similar quantity is used in a total of 10 hospitals, which undertake similar procedures. In previous submissions a transcription error occurred whereby the estimate suggested an accumulation of the stock of $SF_6$. 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.

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

The remaining minor uses of $SF_6$ in Ireland are as a tracer gas for leak detection in the testing of seals on cans containing tennis balls and as a tracer gas for agricultural research to determine the rates of $CH_4$ emissions from enteric fermentation in cattle. The latter source is considered negligible in an Irish context. The use of $SF_6$ in leak detection was previously a relatively large source in the period 1990-2004. However the company who used $SF_6$ for the purpose of leak detection has since ceased trading and this sub category is no longer a source of emissions of $SF_6$ 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 $SF_6$ emissions. The use of Monte Carlo Simulation complies with IPCC Good Practice Tier 2 approaches to uncertainty estimation.

Emission estimates are made using the same methodology and data sources for each year of the time series 1995-2010 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.

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.

## 4.6 Recalculations for *Industrial Processes*

Recalculations in the Industrial Processes sector in this submission are confined to HFC's and $SF_6$. The compilation of emission estimates for HFC's, PFC's and $SF_6$ for this submission was reviewed externally by an independent consultant, qualified as a UNFCCC expert reviewer for the Industrial Processes sector. The recalculations are as follows:

- HFC emissions from Mobile Air Conditioning (2F1) have been revised for 2005-2009. This is due in part to the use of a revised disposal factor of 10 per cent for end of life vehicles (AEA, 2011). In addition the assumed penetration of air conditioning units containing HFC's in vehicles is now assumed to reach 90 per cent by 2010 (AEA, 2011). The result of this recalculation is an increase in HFC emissions from Mobile Air Conditioning of 2.7 per cent in 2009.

- HFC emissions from Refrigeration and Air Conditioning (2F1) have been revised for 2009 due to the provision of revised manufacturing loss emissions by one of the installations that provide information to the inventory agency. The result of this recalculation is a reduction of 13.7 per cent in HFC emissions from Refrigeration and Air Conditioning in 2009.

- HFC emissions from Foams (2F2) have been revised for 2000-2009. This is due to the use of revised estimates of GDP values for Ireland and the OECD in conjunction with the data provided on global sales by AFEAS. The net effect of this recalculation is a reduction in HFC emissions from Foams (2F2) of 4.6 per cent in 2009.

- HFC emissions from Fire Extinguishers (2F3) have been revised for 1991-2009. This is due to the use of a revised product life factor of 0.049 (AEA, 2011) compared to the value of 0.01 used in previous submissions. As a result of this recalculation HFC emissions from Fire Extinguishers (2F3) increased by 141.4 per cent for 2009.

- HFC emissions from Aerosols (2F4) have been revised for the timeseries 1990-2009 due to the publication of revised species ratios for HFC-134a and HFC-152 contained in AEA (2011). The species ratio used is 97 per cent HFC-134a, 3 per cent HFC-152 in 1990 and 96 per cent HFC-134a, 4 per cent HFC-152 in 2009. The approach used in previous submissions assumed a species ration of 90 per cent HFC-134a and 10 per cent HFC-152 for all years (Adams et al. 2005). In addition revised estimates for the sector from the UK inventory have also been taken into account following the methodology as described in section 4.4.2.4. The effect of this recalculation is a 2.6 per cent reduction in HFC emissions from Aerosols (2F4) for 2009.

- HFC emissions from Metered Dose Inhalers (2F4) have been revised for the timeseries 2007-2009 as a result of revised manufacturing loss data provided to the inventory agency by one of the installations in this sector. HFC emissions for 2009 are increased by 82.9 per cent for 2009 as a result.

- $SF_6$ emissions from Semiconductor Manufacture (2F7) have been revised for 2009 as a result of revised data supplied to the inventory agency by one of the installations in the this sector. Emissions of $SF_6$ from Semiconductor Manufacture for 2009 are reduced by 50.7 per cent as a result of this recalculation.

- $SF_6$ emissions from Windows/Soundproofing (2F7) have been revised for the timeseries 1990-2009. Double glazed windows were first introduced in Ireland in 1978, thus there is a bank of $SF_6$ in windows manufactured and installed prior to 1990 which will contribute to the emissions from leakage in the period 1990-2009. The net effect of this recalculation is an increase in $SF_6$ emissions for the sector of 25.4 per cent and 50.3 per cent in 1990 and 2009, respectively.

- Emissions of $SF_6$ from Sporting Goods (2F7) have been revised for 1998-2009 as a result of revised estimates submitted by the UK to the UNFCCC. UK emission estimates for this sector are used in conjunction with population estimates for the UK and Ireland to develop emission estimates for Ireland. Emissions of $SF_6$ from sporting goods in 2009 are reduced by 71.4 per cent as a result of this recalculation.

- The net effect of the recalculations outlined above is an increase of 4.0 per cent in HFC emissions and decrease in $SF_6$ emissions of 41.5 per cent in 2009. In total this equates to an increase in emissions for the Industrial Processes sector as a whole of 0.3 per cent for 2009.

These revisions have a relatively minor impact on total national emissions.

## 4.7 Improvements in *Industrial Processes*

The inventory agency operates a continuous improvement approach to the inventory. To deliver this, the agency will continue to use verified $CO_2$ emissions estimates that are reported under the EU emissions trading scheme as the most reliable data for emission sources within category *2.A*. In addition, for this reporting year, the agency engaged an independent consultant, on a contract basis, who is a qualified UNFCCC expert reviewer for the Industrial Processes sector. This has led to the improvements and recalculations as outlined above. The agency also 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. This approach has been found to be an efficient way of improving, developing and adopting latest research and information relevant to inventory compilation.

*Table 4.3. Emissions of HFC, PFC and $SF_6$ from Industrial Processes 1990-2010 (Gg $CO_2$ eq)*

| IPCC Source Category | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.F.1 Refrigeration and Air-Conditioning | NO | 3.322 | 3.512 | 3.690 | 3.984 | 4.481 | 7.145 | 21.581 | 42.377 | 49.256 | 52.645 | 49.094 | 64.505 | 112.523 | 135.164 | 153.045 | 196.885 | 175.357 | 172.363 | 128.014 | 158.543 |
| 2.F.1 Mobile Air Conditioning | NO | NO | NO | 1.222 | 5.068 | 10.141 | 16.357 | 25.077 | 38.230 | 54.119 | 70.461 | 83.365 | 96.376 | 110.148 | 126.120 | 147.209 | 169.042 | 191.999 | 210.196 | 210.426 | 216.418 |
| 2.F.2 Foams | NO | NO | 0.016 | 0.063 | 0.303 | 0.644 | 1.107 | 1.779 | 3.619 | 5.222 | 6.253 | 9.109 | 11.344 | 13.449 | 16.767 | 19.272 | 21.424 | 23.455 | 25.055 | 26.349 | 27.397 |
| 2.F.3 Fire-extinguishers | 0.219 | 2.516 | 4.846 | 7.256 | 9.904 | 12.772 | 15.891 | 19.285 | 22.978 | 26.995 | 31.367 | 32.792 | 33.870 | 34.341 | 34.065 | 32.861 | 37.547 | 42.819 | 48.749 | 55.421 | 62.928 |
| 2.F.4 Aerosols | 0.621 | 0.623 | 0.696 | 1.745 | 6.986 | 24.488 | 48.072 | 80.641 | 105.407 | 78.279 | 85.399 | 92.579 | 83.391 | 89.867 | 82.974 | 98.103 | 97.408 | 85.819 | 90.622 | 84.491 | 77.811 |
| 2.F.4 Metered Dose Inhalers | NO | NO | NO | NO | NO | NO | 0.020 | 0.059 | 0.081 | 0.105 | 0.675 | 9.062 | 16.992 | 18.211 | 18.409 | 21.738 | 21.638 | 11.058 | 14.056 | 13.440 | 16.575 |
| 2.F.7 Semiconductor manufacture | 0.468 | 0.604 | 0.739 | 1.011 | 1.282 | 1.825 | 2.937 | 4.633 | 3.877 | 9.418 | 12.379 | 3.101 | 1.884 | 2.644 | 1.357 | 2.225 | 3.159 | 3.393 | 3.627 | 2.925 | 3.366 |
| **TOTAL HFC** | **1.308** | **7.065** | **9.810** | **14.987** | **27.528** | **54.350** | **91.528** | **153.054** | **216.568** | **223.396** | **259.178** | **279.102** | **308.362** | **381.183** | **414.856** | **474.453** | **547.102** | **533.900** | **564.668** | **521.067** | **563.037** |
| 2.F.7 Semiconductor manufacture | 0.093 | 7.622 | 15.151 | 30.209 | 45.266 | 75.382 | 103.085 | 130.823 | 61.870 | 195.933 | 305.406 | 295.984 | 212.403 | 228.795 | 182.427 | 168.340 | 148.320 | 130.579 | 106.197 | 65.570 | 37.022 |
| **TOTAL PFC** | **0.093** | **7.622** | **15.151** | **30.209** | **45.266** | **75.382** | **103.085** | **130.823** | **61.870** | **195.933** | **305.406** | **295.984** | **212.403** | **228.795** | **182.427** | **168.340** | **148.320** | **130.579** | **106.197** | **65.570** | **37.022** |
| 2.F.7 Semiconductor manufacture | 0.478 | 4.732 | 8.986 | 17.495 | 26.003 | 43.020 | 62.140 | 81.260 | 52.580 | 16.730 | 31.070 | 20.435 | 28.584 | 59.917 | 32.647 | 65.554 | 27.516 | 30.199 | 41.025 | 20.931 | 18.251 |
| 2.F.8 Electrical equipment | 21.510 | 22.466 | 23.422 | 24.378 | 25.334 | 26.290 | 26.386 | 37.284 | 25.238 | 34.990 | 7.787 | 32.050 | 22.786 | 38.446 | 21.553 | 23.518 | 28.106 | 29.827 | 10.898 | 13.982 | 12.906 |
| 2.F.9 Other - window soundproofing | 0.540 | 0.560 | 0.579 | 0.598 | 0.617 | 0.636 | 0.654 | 0.672 | 0.690 | 0.565 | 0.432 | 0.292 | 0.290 | 0.287 | 0.284 | 0.281 | 0.278 | 0.275 | 0.273 | 0.270 | 0.267 |
| 2.F.9 Other - medical applications | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 | 0.797 |
| 2.F.9 Other - sporting goods | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.596 | 2.111 | 2.075 | 2.076 | 3.086 | 3.793 | 7.279 | 11.480 | 6.199 | 4.421 | 3.683 | 2.257 | 2.290 |
| 2.F.9 Other - gas-air tracers | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 12.189 | 6.095 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **TOTAL $SF_6$** | **35.514** | **40.744** | **45.973** | **55.456** | **64.940** | **82.931** | **102.165** | **132.202** | **93.090** | **67.381** | **54.349** | **67.839** | **67.732** | **115.428** | **68.654** | **101.629** | **62.896** | **65.520** | **56.676** | **38.236** | **34.511** |
| **TOTAL HFC, PFC and $SF_6$** | **36.915** | **55.430** | **70.934** | **100.652** | **137.735** | **212.663** | **296.778** | **416.080** | **371.528** | **486.710** | **618.933** | **642.925** | **588.497** | **725.405** | **665.937** | **744.422** | **758.318** | **729.999** | **727.541** | **624.872** | **634.571** |

### *Table 4.4. Percentage Change in Total Emissions from Industrial Processes due to Recalculations 1990-2009*

| | | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Estimates in 2011 Submission (Gg $CO_2$eq) | | | | | | | | | |
| 2.A.1 | Cement Production | $CO_2$ | 884.00 | 782.00 | 753.00 | 729.00 | 859.00 | 879.00 | 983.00 | 1,145.00 | 1,059.00 | 1,166.00 | 1,700.90 | 1,851.19 | 1,859.80 | 2,126.95 | 2,295.08 | 2,357.06 | 2347.85 | 2374.06 | 2106.73 | 1326.78 |
| 2.A.2 | Lime Production | $CO_2$ | 214.08 | 192.23 | 162.40 | 204.89 | 205.43 | 187.51 | 198.24 | 221.89 | 211.66 | 170.07 | 190.43 | 189.40 | 190.31 | 206.26 | 201.54 | 183.48 | 180.30 | 196.71 | 187.80 | 156.40 |
| 2.A.3 | Limestone and Dolomite Use | $CO_2$ | 0.15 | 0.14 | 0.13 | 0.11 | 0.13 | 0.18 | 0.17 | 0.24 | 0.23 | 0.25 | 0.18 | 4.50 | 2.17 | 2.38 | 3.55 | 4.29 | 2.64 | 2.32 | 2.71 | 1.54 |
| 2.A.4 | Soda Ash Production and Use | $CO_2$ | 0.10 | 0.09 | 0.07 | 0.11 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.05 | 0.07 | 0.09 | 0.05 | 0.06 | 0.08 | 0.08 | 0.06 | 0.06 | 0.04 | 0.05 |
| 2.A.7 | Bricks and Tiles | $CO_2$ | 5.07 | 4.88 | 4.79 | 4.50 | 4.79 | 5.46 | 5.27 | 6.23 | 6.08 | 6.37 | 6.49 | 6.12 | 5.91 | 6.12 | 6.23 | 7.41 | 7.40 | 6.83 | 4.00 | 0.53 |
| 2.A.7 | Glass Production | $CO_2$ | 13.33 | 13.06 | 12.59 | 12.52 | 12.31 | 11.97 | 11.63 | 11.46 | 11.05 | 10.96 | 10.71 | 10.14 | 5.13 | 0.55 | 0.58 | 0.48 | 0.49 | 0.45 | 0.31 | 0.02 |
| 2.B.1 | Ammonia Production | $CO_2$ | 990.23 | 1,030.32 | 1,003.56 | 946.19 | 1,056.63 | 973.44 | 922.85 | 1,073.12 | 1,058.81 | 942.82 | 882.30 | 1,041.18 | 810.90 | 0.30 | NO | NO | NO | NO | NO | NO |
| 2.B.2 | Nitric Acid Production | $N_2O$ | 1,035.40 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.20 | 812.20 | 812.45 | 584.35 | 292.18 | NO | NO | NO | NO | NO | NO | NO |
| 2.F.7 | Consumption of Halocarbons and $SF_6$ | HFCs | 0.69 | 5.27 | 6.17 | 9.44 | 19.97 | 44.85 | 76.11 | 133.35 | 191.95 | 198.25 | 231.23 | 253.05 | 278.14 | 351.42 | 387.29 | 436.66 | 509.17 | 500.76 | 520.88 | 500.92 |
| 2.F.7 | Consumption of Halocarbons and $SF_6$ | 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 |
| 2.F.7 | Consumption of Halocarbons and $SF_6$ | $SF_6$ | 35.40 | 40.64 | 45.87 | 55.35 | 64.83 | 82.83 | 102.06 | 132.10 | 94.19 | 68.87 | 55.81 | 69.30 | 69.95 | 118.18 | 66.64 | 95.46 | 67.46 | 68.75 | 60.83 | 65.30 |
| 2 | Total | | 3,178.55 | 2,888.68 | 2,816.16 | 2,804.76 | 3,080.85 | 3,073.12 | 3,214.94 | 3,666.77 | 3,507.14 | 3,571.78 | 4,195.97 | 4,305.31 | 3,726.95 | 3,041.01 | 3,143.42 | 3,253.26 | 3,263.69 | 3,280.52 | 2,989.49 | 2,117.12 |
| | | | | | | | | | | | | | Recalculated Estimates in 2012 Submission (Gg $CO_2$eq) | | | | | | | | | |
| 2.A.1 | Cement Production | $CO_2$ | 884.00 | 782.00 | 753.00 | 729.00 | 859.00 | 879.00 | 983.00 | 1,145.00 | 1,059.00 | 1,166.00 | 1,700.90 | 1,851.19 | 1,859.80 | 2,126.95 | 2,295.08 | 2,357.06 | 2,347.85 | 2,374.06 | 2,106.73 | 1,326.78 |
| 2.A.2 | Lime Production | $CO_2$ | 214.08 | 192.23 | 162.40 | 204.89 | 205.43 | 187.51 | 198.24 | 221.89 | 211.66 | 170.07 | 190.43 | 189.40 | 190.31 | 206.26 | 201.54 | 183.48 | 180.30 | 196.71 | 187.80 | 156.40 |
| 2.A.3 | Limestone and Dolomite Use | $CO_2$ | 0.15 | 0.14 | 0.13 | 0.11 | 0.13 | 0.18 | 0.17 | 0.24 | 0.23 | 0.25 | 0.18 | 4.50 | 2.17 | 2.38 | 3.55 | 4.29 | 2.64 | 2.32 | 2.71 | 1.54 |
| 2.A.4 | Soda Ash Production and Use | $CO_2$ | 0.10 | 0.09 | 0.07 | 0.11 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.05 | 0.07 | 0.09 | 0.05 | 0.06 | 0.08 | 0.08 | 0.06 | 0.06 | 0.04 | 0.05 |
| 2.A.7 | Bricks and Tiles | $CO_2$ | 5.07 | 4.88 | 4.79 | 4.50 | 4.79 | 5.46 | 5.27 | 6.23 | 6.08 | 6.37 | 6.49 | 6.12 | 5.91 | 6.12 | 6.23 | 7.41 | 7.40 | 6.83 | 4.00 | 0.53 |
| 2.A.7 | Glass Production | $CO_2$ | 13.33 | 13.06 | 12.59 | 12.52 | 12.31 | 11.97 | 11.63 | 11.46 | 11.05 | 10.96 | 10.71 | 10.14 | 5.13 | 0.55 | 0.58 | 0.48 | 0.49 | 0.45 | 0.31 | 0.02 |
| 2.B.1 | Ammonia Production | $CO_2$ | 990.23 | 1,030.32 | 1,003.56 | 946.19 | 1,056.63 | 973.44 | 922.85 | 1,073.12 | 1,058.81 | 942.82 | 882.30 | 1,041.18 | 810.90 | 0.30 | NO | NO | NO | NO | NO | NO |
| 2.B.2 | Nitric Acid Production | $N_2O$ | 1035.40 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.45 | 812.20 | 812.20 | 812.45 | 584.35 | 292.18 | NO | NO | NO | NO | NO | NO | NO |
| 2.F. | Consumption of Halocarbons and $SF_6$ | HFCs | 1.31 | 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 |
| 2.F. | Consumption of Halocarbons and $SF_6$ | 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 |
| 2.F. | Consumption of Halocarbons and $SF_6$ | $SF_6$ | 35.51 | 40.74 | 45.97 | 55.46 | 64.94 | 82.93 | 102.17 | 132.20 | 93.09 | 67.38 | 54.35 | 67.84 | 67.73 | 115.43 | 68.65 | 101.63 | 62.90 | 65.52 | 56.68 | 38.24 |
| 2 | Total | | 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 | 2,110.20 |
| | | | | | | | | | | | | | Percentage Change in Total Emissions due to Recalculations | | | | | | | | | |
| 2.A.1 | Cement Production | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.A.2 | Lime Production | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.A.3 | Limestone and Dolomite Use | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.A.4 | Soda Ash Production and Use | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.A.7 | Bricks and Tiles | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.A.7 | Glass Production | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.B.1 | Ammonia Production | $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NA | NA | NA | NA | NA | NA |
| 2.B.2 | Nitric Acid Production | $N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NA | NA | NA | NA | NA | NA | NA |
| 2.F. | Consumption of Halocarbons and $SF_6$ | HFCs | 88.74 | 33.97 | 59.05 | 58.68 | 37.82 | 21.19 | 20.26 | 14.78 | 12.83 | 12.68 | 12.09 | 10.29 | 10.86 | 8.47 | 7.12 | 8.66 | 7.45 | 6.62 | 8.41 | 4.02 |
| 2.F. | Consumption of Halocarbons and $SF_6$ | PFCs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2.F. | Consumption of Halocarbons and $SF_6$ | $SF_6$ | 0.31 | 0.27 | 0.23 | 0.19 | 0.16 | 0.13 | 0.10 | 0.08 | -1.16 | -2.16 | -2.61 | -2.11 | -3.17 | -2.33 | 3.02 | 6.46 | -6.76 | -4.69 | -6.83 | -41.45 |
| 2 | Total | | 0.02 | 0.07 | 0.13 | 0.20 | 0.25 | 0.31 | 0.48 | 0.54 | 0.67 | 0.66 | 0.63 | 0.57 | 0.75 | 0.89 | 0.94 | 1.35 | 1.02 | 0.91 | 1.33 | -0.33 |

# Chapter Five

# Solvent and Other Product Use

## 5.1 Overview of *Solvent and Other Product Use* Sector (Source Category 3)

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

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

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

## 5.2 NMVOC and $CO_2$ Inventory Time Series

The levels of solvent use and the emissions from solvents have changed substantially in response to product replacement and reformulation and emission controls being implemented under Integrated Pollution Prevention Control (IPPC) and the Solvents Directive (CEC, 1999). Given these developments, the inventories of NMVOC emissions from solvent use were assessed in 2005 when a project was commissioned to carry out an in-depth analysis of the specified NMVOC source categories (CTC, 2005). This work enabled the best possible estimates of emissions for the period 1990- 2004 to be derived, and built upon earlier commissioned work in 1998 (Finn et al, 2001). The revised estimates for the time series 1990-2003 indicated lower NMVOC emissions than had been previously reported and used as the basis for estimating $CO_2$ in the sector *Solvent and Other Product Use.* In 2010, 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 was developed 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 were no annual specific data is available. These are combined with Irish statistics for the number of vehicles, population, housing stock and a range of other activity data. In some instances activity data is currently not available in Ireland and where this occurs emission estimates are undertaken using Irish and UK population statistics and UK emission data. In other instances, emissions are estimated using GDP as a surrogate activity data.

The estimates of $CO_2$ emissions from Solvent and Other Product Use for the period 1990-2010 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 2010. 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 2010. 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 2003-2009 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 $CO_2$ Emissions from Solvent and Other Product Use 1990-2010***

| Year | 3A Paint Application | 3B Degreasing, dry cleaning, electronics | 3C Chemical Products and Manufacturing & Processing | 3D Other Use of Solvents | Total NMVOC emissions | Estimated $CO_2$ from NMVOC |
|---|---|---|---|---|---|---|
| | Mg NMVOC | | | | | Gg $CO_2$ |
| 1990 | 6,829 | 2,704 | 3,538 | 12,606 | 25,677 | 80.03 |
| 1991 | 6,956 | 2,704 | 3,538 | 13,041 | 26,239 | 81.78 |
| 1992 | 7,175 | 2,704 | 3,538 | 12,973 | 26,391 | 82.25 |
| 1993 | 7,400 | 2,704 | 3,538 | 12,866 | 26,508 | 82.62 |
| 1994 | 7,694 | 2,692 | 3,538 | 12,924 | 26,847 | 83.67 |
| 1995 | 7,972 | 2,896 | 3,538 | 12,993 | 27,399 | 85.39 |
| 1996 | 8,294 | 2,605 | 3,538 | 12,960 | 27,397 | 85.39 |
| 1997 | 8,556 | 2,425 | 3,538 | 13,035 | 27,554 | 85.88 |
| 1998 | 8,998 | 2,110 | 3,538 | 13,148 | 27,795 | 86.63 |
| 1999 | 8,636 | 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 | 12,796 | 24,279 | 75.67 |
| 2008 | 7,002 | 1,270 | 2,532 | 13,039 | 23,844 | 74.31 |
| 2009 | 6,244 | 1,178 | 2,532 | 13,084 | 23,038 | 71.80 |
| 2010 | 6,159 | 1,178 | 2,532 | 13,101 | 22,970 | 71.59 |

*Table 5.2 Recalculations for Solvent and Other Product Use 1990-2009*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimates in 2011 Submission (Gg) | | | | | | | | | | | | | | | | | | | |
| 3.A | Paint Application | 6.829 | 6.956 | 7.175 | 7.400 | 7.694 | 7.972 | 8.294 | 8.556 | 8.998 | 8.636 | 8.251 | 8.334 | 8.503 | 8.345 | 8.271 | 8.044 | 7.938 | 7.648 | 7.013 | 6.241 |
| 3.B | Degreasing, dry cleaning, electronics | 2.704 | 2.704 | 2.704 | 2.704 | 2.692 | 2.896 | 2.605 | 2.425 | 2.110 | 2.022 | 1.890 | 1.669 | 1.081 | 1.158 | 1.142 | 1.246 | 1.364 | 1.304 | 1.270 | 1.178 |
| 3.C | Chemical Products and Manufacturing | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.370 | 3.203 | 3.035 | 2.868 | 2.700 | 2.532 | 2.532 | 2.532 | 2.532 | 2.532 | 2.532 |
| 3.D | Other Use of Solvents | 12.606 | 13.041 | 12.973 | 12.866 | 12.924 | 12.993 | 12.960 | 13.035 | 13.148 | 12.838 | 12.017 | 11.961 | 11.806 | 11.666 | 11.771 | 11.939 | 12.275 | 12.798 | 13.043 | 13.085 |
| 3 | Total NMVOC emissions | 25.677 | 26.239 | 26.391 | 26.508 | 26.847 | 27.399 | 27.397 | 27.554 | 27.795 | 26.866 | 25.361 | 24.999 | 24.258 | 23.868 | 23.717 | 23.760 | 24.109 | 24.282 | 23.859 | 23.036 |
| 3 | Estimated $CO_2$ from NMVOC | 80.028 | 81.780 | 82.250 | 82.617 | 83.674 | 85.394 | 85.387 | 85.875 | 86.626 | 83.731 | 79.041 | 77.913 | 75.605 | 74.390 | 73.917 | 74.053 | 75.140 | 75.680 | 74.360 | 71.797 |
| | | Recalculated Estimates in 2012 Submission (Gg) | | | | | | | | | | | | | | | | | | | |
| 3.A | Paint Application | 6.829 | 6.956 | 7.175 | 7.400 | 7.694 | 7.972 | 8.294 | 8.556 | 8.998 | 8.636 | 8.251 | 8.334 | 8.503 | 8.345 | 8.272 | 8.044 | 7.937 | 7.648 | 7.002 | 6.244 |
| 3.B | Degreasing, dry cleaning, electronics | 2.704 | 2.704 | 2.704 | 2.704 | 2.692 | 2.896 | 2.605 | 2.425 | 2.110 | 2.022 | 1.890 | 1.669 | 1.081 | 1.158 | 1.142 | 1.246 | 1.364 | 1.304 | 1.270 | 1.178 |
| 3.C | Chemical Products and Manufacturing | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.538 | 3.370 | 3.203 | 3.035 | 2.868 | 2.700 | 2.532 | 2.532 | 2.532 | 2.532 | 2.532 | 2.532 |
| 3.D | Other Use of Solvents | 12.606 | 13.041 | 12.973 | 12.866 | 12.924 | 12.993 | 12.960 | 13.035 | 13.148 | 12.838 | 12.017 | 11.961 | 11.806 | 11.667 | 11.773 | 11.943 | 12.264 | 12.796 | 13.039 | 13.084 |
| 3 | Total NMVOC emissions | 25.677 | 26.239 | 26.391 | 26.508 | 26.847 | 27.399 | 27.397 | 27.554 | 27.795 | 26.866 | 25.361 | 24.999 | 24.258 | 23.870 | 23.719 | 23.765 | 24.097 | 24.279 | 23.844 | 23.038 |
| 3 | Estimated $CO_2$ from NMVOC | 80.028 | 81.780 | 82.250 | 82.617 | 83.674 | 85.394 | 85.387 | 85.875 | 86.626 | 83.731 | 79.041 | 77.913 | 75.605 | 74.395 | 73.924 | 74.067 | 75.102 | 75.671 | 74.313 | 71.802 |
| | | 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 | -0.01 | 0.00 | -0.16 | 0.05 |
| 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 |
| 3.C | Chemical Products and Manufacturing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 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 | 0.01 | 0.02 | 0.03 | -0.09 | -0.02 | -0.03 | -0.01 |
| 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 | 0.01 | 0.01 | 0.02 | -0.05 | -0.01 | -0.06 | 0.01 |
| 3 | Estimated $CO_2$ 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 | 0.01 | 0.01 | 0.02 | -0.05 | -0.01 | -0.06 | 0.01 |

# Chapter Six

# Agriculture

## 6.1 Overview of Agriculture Sector

The IPCC Level 3 source categories in *Agriculture,* where $CH_4$ and $N_2O$ are the key greenhouse gases, are listed in Table 6.1. The agricultural activities of particular importance in Ireland are those under *4.A Enteric Fermentation, 4.B Manure Management* and *4.D Agricultural Soils*, some of which are identified as being among the largest greenhouse gas emission sources in the country. The inventory time-series for the years 1990-2010 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. Although the practice of field burning of agricultural residues did exist on a small scale in the past, the emissions are considered negligible, and this practice has been discontinued since the mid 1990s.

The methods provided by the IPCC good practice guidance are applied as completely as possible for agricultural emission sources pertaining to Irish circumstances. The IPCC methods require considerable detailed information on activity data, emission factors and other input parameters for the emission calculations. There were major changes in the inventories for *Agriculture* in the 2006 submission with the adoption of Tier 2 methods for $CH_4$ emissions from enteric fermentation in cattle and also improvements in estimates of emissions from manure management. Both of these developments were based on the results of major research and an extensive Farm Facilities Survey (Hyde et al., 2008). This research, together with other relevant work related to the development of an nitrogen-flow approach to $NH_3$ emissions and regulations on the implementation of SI 788 of 2005 (DEHLG, 2005), SI 378 of 2006 (DEHLG, 2006), SI 101 of 2009 (DEHLG, 2009) 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. Some amendments have been made to the methodology for estimating emissions from livestock since the last submission. These revisions have been primarily as a result of the development of an N-flow approach to $NH_3$ emissions from agriculture. In addition, some minor revisions have occurred due to the use of one annual average population characterisation for cattle and some other livestock. Finally, an improvement in the compilation of animal populations by the Central Statistics Office (CSO) has also prompted minor revisions.

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 F.1 of Annex F.

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

***Table 6.1. Level 3 Source Category Coverage for Agriculture***

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

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

In 2010, the emissions from Agriculture were 17,909.69 Gg $CO_2$ equivalent or 28.6 per cent of national emissions. This proportion has decreased in relative terms from 35.6 per cent in 1990 as the emissions from energy use increased significantly while emissions from Agriculture decreased by 8.8 per cent. Methane accounted for 59.4 per cent and $N_2O$ accounted for 40.6 per cent of the emissions in the sector in 2010. The $CH_4$ emissions from enteric fermentation in cattle and the $N_2O$ emissions associated with large inputs of chemical and organic nitrogen to agricultural soils are the major emission categories.

## 6.2 $CH_4$ Emissions from Enteric Fermentation (4.A)

### 6.2.1 Overall Approach

Implementation of the IPCC good practice guidance for GHG inventories requires that Parties use Tier 2 (i.e. detailed country-specific) methods for key sources of emissions. Prior to the inventory submission in 2006, Ireland used Tier 1 methods to estimate $CH_4$ emissions from enteric fermentation. At the time this basic approach showed that enteric fermentation in dairy and non-dairy cattle produced 8.5 per cent and 3.6 per cent respectively of total GHG emissions in 2003. The Tier 1 approach also showed that, in 1990, enteric fermentation in non-dairy cattle was the single largest individual source of greenhouse gas emissions in Ireland, accounting for 9.6 per cent of the national total. The recommendation to use Tier 2 methods had been made in several annual review reports of Ireland's inventory submissions to the UNFCCC. As a result, a major research project funded by the EPA was undertaken to provide appropriate Tier 2 emission factors for $CH_4$ from enteric fermentation for the Irish cattle herd. In addition, a Farm Facilities Survey (Hyde et al., 2008) provided detailed data on manure management practices to support the adoption of a higher tier method. The Farm Facilities Survey was conducted on a representative sample of farms, the results of which are available at both national level and for each of the three designated Nitrates Directive regions (SI 788 of 2005 (DEHLG, 2005), SI 378 of 2006 (DEHLG, 2006), SI 101 of 2009 (DEHLG, 2009) 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 $CH_4$ production. Substantial further subdivision was incorporated for dairy and beef cattle to adequately describe the wide range of cattle rearing and finishing systems applicable in Ireland. In total, dairy cows were covered by 12 systems and 18 system types were analysed for suckler cows, while up to 30 systems were examined for both male and female beef cattle (O'Mara 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 2010. 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<br>Female < 1 year | Male 1 – 2 years<br>Female 1 – 2 years | Male > 2 years<br>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). 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 *unites fourragere lait* (UFL), where 1 UFL is the net energy value of 1 kg of barley at 86 per cent dry matter and is equal to 7.11 MJ net energy for lactation ($NE_l$). This international energy system, which is well established and used locally in Ireland, was considered more appropriate to the local conditions than the system and equations used by the IPCC guidelines and IPCC good practice guidance. The energy gains and losses refer to intra-annual changes for the animal and do not mean that average body weight for animals in the dairy herd is increasing from year to year. The live-weight of 535 kg for dairy cows is an indicative weight supplied by the Department of Agriculture, Food and the Marine, as dairy cow live-weights are not in general monitored on farms. The live-weight is adopted as the reference point for the annual emission factor derivation for the herd and is chosen to be consistent with other parameters relevant to the estimation of emissions from cattle, e.g. manure production.

The important equations are:

Maintenance $NE_l$ requirements (MJ) = 9.96 + (0.6 x LW/100), where LW is live-weight.
A 10 per cent activity allowance was added for the housed period and a 20 per cent allowance was added for the grazing period as outlined by INRA (1989);

$NE_l$ (MJ) required per kg milk = 0.376 * fat content + 0.209 * protein content + 0.948;

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

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

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

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

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

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

### 6.2.3 Enteric Fermentation in Beef Cattle

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

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

### 6.2.4 Enteric Fermentation in Other Cattle

Bulls for breeding and in-calf heifers account for on average 6 per cent of the national cattle herd. Separate production systems were not defined for these categories because of 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 3rd 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 1990–2010 in respect of the 11 principal classifications are presented in Table F.2 of Annex F. The emission factor for dairy cows in 1990 is very close to the IPCC default emission factor of 100 kg $CH_4$/head/year for highly productive dairy cattle in Western Europe. The corresponding value for 2010 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 2010, 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 $CH_4$ Emission Factors for 1990, 2007, 2008, 2009 and 2010***

| | Enteric Fermentation (kg/head/year) | | | | | Manure Management (kg/head/year) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2007 | 2008 | 2009 | 2010 | 1990 | 2007 | 2008 | 2009 | 2010 |
| Dairy cows | 101.38 | 109.81 | 109.99 | 108.54 | 112.09 | 21.60 | 20.58 | 20.61 | 20.42 | 20.75 |
| Suckler cows | 74.03 | 73.87 | 74.92 | 72.78 | 73.34 | 14.25 | 14.08 | 14.30 | 13.83 | 13.96 |
| Male cattle < 1 year | 30.46 | 29.69 | 29.71 | 29.77 | 29.68 | 8.41 | 7.91 | 7.91 | 7.90 | 7.87 |
| Male cattle 1 - 2 years | 62.22 | 59.19 | 59.07 | 58.57 | 59.06 | 16.89 | 14.02 | 13.95 | 13.88 | 14.07 |
| Male cattle > 2 years | 55.08 | 38.58 | 36.98 | 38.84 | 39.48 | 5.16 | 2.25 | 2.02 | 2.28 | 2.38 |
| Female cattle < 1 year | 27.05 | 27.77 | 27.70 | 27.63 | 27.01 | 8.41 | 7.91 | 7.91 | 7.90 | 7.87 |
| Female cattle 1 - 2 years | 53.54 | 46.60 | 47.00 | 47.71 | 48.62 | 14.93 | 9.91 | 10.08 | 10.44 | 10.76 |
| Female cattle > 2 years | 21.65 | 22.42 | 22.55 | 22.63 | 22.63 | 0.33 | 0.34 | 0.34 | 0.35 | 0.35 |
| Bulls for breeding | 86.38 | 81.55 | 81.55 | 81.55 | 81.55 | 23.79 | 18.95 | 18.95 | 18.95 | 18.95 |
| Dairy in-calf heifers | 51.82 | 50.16 | 50.16 | 50.16 | 50.16 | 13.40 | 10.93 | 10.93 | 10.93 | 10.93 |
| Beef in-calf heifers | 55.42 | 53.68 | 53.68 | 53.68 | 53.68 | 15.61 | 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 F.2 of Annex F. As a result, the implied emission factors produced by the CRF related to total populations of sheep and swine in Ireland are lower than the IPCC base default values for these animal categories.

## 6.3 $CH_4$ Emissions from Manure Management (4.B)

### 6.3.1 $CH_4$ emissions from manure management in cattle

The decomposition of the organic material in animal manures may be a significant source of $CH_4$ emissions if anaerobic conditions prevail in the animal waste management systems being used. The estimation of such emissions requires information on the quantity of manure production for the animal groups concerned, the type of waste management systems employed and the $CH_4$ production potential of the wastes. Information obtained from a national farm facilities survey (Hyde et al., 2008) and the work on emission factors for enteric fermentation in cattle described in section 6.2 is the basis of the $CH_4$ emission factors for manure management. The results of the farm facilities survey (Hyde et al., 2008) provide a much improved representation of animal waste allocation among the relevant waste management systems in the country while the excretion of organic matter by cattle is fully characterised as part of the analysis of their feed and energy requirements relating to enteric fermentation (O'Mara 2006). The main results of the farm facilities survey pertinent to inventory calculations are outlined in Tables F.4.1 and F.4.2 of Annex F.

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 ($B_O$) of animal waste, the allocation to animal waste management system based on the farm facilities survey (Hyde et al., 2008) and the corresponding values of MCF (methane conversion factor) given for the cool climate zone in Table 4.10 of the IPCC good practice guidance. Ireland uses the value of 0.24 $m^3$ $CH_4$/kg VS (the value for dairy cattle in the IPCC good practice guidance) for $B_O$ for all cattle based on input from agricultural experts who advise that the methane potential of dairy cattle manures and non-dairy cattle manures in Ireland is the same, given the similarity of their grass-based feeding systems. The emission factors for cattle are given in Table 6.3.

### 6.3.2 $CH_4$ emissions from manure management in other livestock

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

## 6.4 $N_2O$ Emissions from Manure Management (4.B)

Nitrogen excretion rates have been adopted in Ireland for all animal categories for which annual census data are published by the CSO. In 2011, the inventory agency reviewed the applicability of the nitrogen excretion rates used in the inventory in collaboration with the Department of Agriculture, Food and the Marine, agricultural researchers and animal nutritionists. Revised nitrogen excretion rates are provided in Tables F.5.1 and F.5.2 of Annex F and the new methodology is outlined in Section 6.8.1. In the case of cattle, the excretion rates are consistent with the nitrogen content of cattle feed intake as analysed in conjunction with the determination of Tier 2 $CH_4$ emission factors for cattle. The nitrogen excretion rates are used by the inventory agency, along with the information on the allocation of animal manures to each applicable animal waste management system from the Farm Facilities Survey (Hyde et al., 2008) as the basis of CRF Table 4.B (b).

Approximately two-thirds of animal manure nitrogen is excreted at pasture annually, reflecting the relatively short period that cattle and sheep are housed in Ireland. Animal manures excreted at pasture are unmanaged and the associated emissions are accounted for under agricultural soils (Section 6.5.1). In 2010 the bulk of animal manures in housing were managed in liquid storage systems (93.8 per cent and 75.8 per cent for dairy cattle and other cattle respectively, and 100 per cent for swine) for eventual spreading on agricultural lands. The remainder of animal manures produced in-house are in solid manure systems. The emission factors given by the IPCC good practice guidance indicate that 1 kg of nitrogen per tonne of nitrogen handled in liquid manure storage systems is lost as $N_2O$ while the corresponding loss is 20 kg per tonne for nitrogen in solid manure storage systems. These default emission factors, for which uncertainty ranges up to 100 per cent, are assigned in the IPCC good practice guidance, are used to estimate $N_2O$ emissions from manure management in Ireland. The $N_2O$ emissions from manures managed in liquid and solid storage systems in 2010 amounted to 1.43 Gg $N_2O$.

## 6.5 $N_2O$ Emissions from Agricultural Soils (4.D)

Agricultural soils are the principal source of $N_2O$ emissions in Ireland. The IPCC methodologies for the source categories concerned involve a simple accounting of all inputs of nitrogen to agricultural soils and the subsequent application of default rates of nitrogen loss to the atmosphere as $N_2O$. The primary nitrogen inputs are subject to complex processes and partitioning between various nitrogen compounds within soils and the emissions are highly dependent on soil properties and meteorology. The methodologies are therefore simplified and they are based on a consideration of separate direct and indirect contributions to national emissions. Ireland uses the IPCC good practice guidance methodology completely to estimate $N_2O$ emissions from agricultural soils and the procedure may be followed from the description below. Values for each of the terms used in the calculation of direct and indirect soil emissions for the full time series 1990-2010 are presented in Table F.6 of Annex F.

### 6.5.1 Direct Soil Emissions (4.D.1)

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

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

where

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

The estimates of direct $N_2O$ emissions from agricultural soils for the years 1990-2010 take into account the nitrogen inputs from all of these sources, except that due to the cultivation of organic soils. Tillage farming in Ireland is concentrated in the south and southeast of the country while the bulk of organic soils occur in the midlands and west. Nitrogen inputs due to the cultivation of organic soils are thus considered negligible. The equation for estimating $N_2O$ emissions in Ireland reported in sub-category *4.D.1 Direct Soil Emissions* therefore becomes

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

Where

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

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

$F_S = SS_l * NSSF$

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

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

and

$N_{fert}$ = total amount of synthetic fertiliser nitrogen applied to soils (kg N)
$Frac_{GASF}$ = fraction of synthetic fertiliser nitrogen that volatilises as $NH_3$ (0.029 in 2010)
$N_{ex}$ = 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 2010)
$Frac_{GASM1}$ = fraction of animal manure nitrogen that volatilises as $NH_3$ during housing, manure storage and landspreading (0.359 in 2010)
$N_2O\text{-}N_{hs}$ = amount of animal manure nitrogen emitted as $N_2O$ in housing and storage (kg $N_2O$-N)
$SS_l$ = quantity of sewage sludge spread on agricultural lands (kt)
NSSF = nitrogen fraction of sewage sludge (3 per cent of dry solids)
$Crop_i$ = production of nitrogen-fixing crop i (kt)
$Res_i/Crop_i$ = residue to crop product mass ratio of nitrogen-fixing crop i
$DMF_i$ = dry matter fraction of nitrogen-fixing crop i
$NCRF_i$ = nitrogen fraction of nitrogen-fixing crop i
$Crop_j$ = production of crop j (including nitrogen-fixing crops) (kT)
$Res_j/Crop_j$ = residue to crop product mass ratio of crop j (including nitrogen-fixing crops)
$DMF_j$ = dry matter fraction of crop j (including nitrogen-fixing crops)
$NCRF_j$ = nitrogen fraction of crop j (including nitrogen-fixing crops)

The annual statistics on nitrogen fertiliser use ($N_{fert}$) are obtained from the Department of Agriculture, Food and the Marine while the organic nitrogen inputs ($N_{ex}$) are outlined in section 6.4. A significant proportion of the nitrogen applied to soils in synthetic fertilisers and animal manures is volatilised as $NH_3$ and $NO_X$. These proportions, $Frac_{GASF}$ and $Frac_{GASM}$ respectively in the IPCC guidelines, must be taken into account in order to determine the amount of nitrogen available for direct $N_2O$ production. The IPCC good practice guidance gives the default proportions of chemical fertiliser and animal manure nitrogen lost in this way as 10 per cent and 20 per cent, respectively. The volatilisation rates for Ireland are, however, determined in an elaborate $NH_3$ inventory for agriculture (Duffy et al, 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 2010 values of $Frac_{GASM1}$ and $Frac_{GASM2}$ are 0.359 and 0.056, respectively indicating an overall volatilisation rate of 0.172 for animal manure nitrogen.

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 0.029 and 0.359, respectively in 2010 from the $NH_3$ inventory. Published estimates of sludge production (O'Leary et al, 1997; O'Leary and Carty, 1998; O'Leary et al, 2000; Smith et al, 2003; Smith et, 2004; Smith et al, 2007; Monaghan et al, 2009) and the proportion applied on agricultural lands are used to estimate $F_S$ on the basis of 3 percent nitrogen content in sewage sludge with typical dry solids content of 25 per cent (Fehily Timoney, 1985). The estimate of $F_S$ is included in $N_2O_{direct}$ without deduction for volatilisation and the value is added to $F_{AM}$ for reporting purposes in CRF Table 4.D. Although the amount of sludge spreading on land is increasing, it contributed less than 1 per cent of the organic nitrogen input to agricultural soils in 2010. Table F.7 of Annex F shows the total quantity of nitrogen applied each year to agricultural soils through sewage sludge for the time series 1990-2010.

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 2010 for category *4.D.1 Direct Soil Emissions* amounted to 9.28 Gg, of which synthetic fertilisers accounted for 6.91 Gg, 2.15 Gg was due to land spreading of animal manures and crops (N-fixing and crop residue) produced 0.23 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.

### 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 2010, 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 2010 was 8.50 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

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

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

where

$N_2O_{indirect-dep}$ = the indirect emissions of $N_2O$ due to atmospheric nitrogen deposition
$N_2O_{indirect-leach}$ = 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 2010)
$Frac_{LEACH}$ = fraction of synthetic fertiliser nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2010)
$EF_4$ = $N_2O$ emission factor for nitrogen inputs from atmospheric deposition
$EF_5$ = $N_2O$ emission factor for nitrogen leaching

The expressions for the indirect emissions of $N_2O$ due to atmospheric nitrogen deposition ($N_2O_{indirect-dep}$) and the indirect emissions of $N_2O$ due to nitrogen leaching ($N_2O_{indirect-leach}$) are slightly modified to be consistent with those for estimating direct emissions in section 6.5.1 and to account for the two separate volatilisation fractions $Frac_{GASM1}$ and $Frac_{GASM2}$. There is no contribution to $N_2O_{indirect-dep}$ from $F_S$, the nitrogen input from sludge spreading, but $F_S$ increases $N_2O_{indirect-leach}$ through its inclusion in $F_{AM}$. The default value for $Frac_{LEACH}$, the fraction of nitrogen lost through leaching, in the IPCC Guidelines is 30 per cent. Estimates of the nitrogen loads in Irish rivers reported under the OSPAR Convention (NEUT, 1999) suggest that approximately 10 per cent of all applied nitrogen in Irish agriculture is lost through leaching. More recent research (Ryan et al., 2006; Del Prado et al., 2006 and Richards et al., 2009) also suggest an average value of 10%. The value of 0.1 is thus considered to be a more realistic estimate of $Frac_{LEACH}$ for Irish conditions than the default value of 0.3 and it is used in this submission, as it was for previous submissions.

The IPCC default values of the emission factors $EF_4$ and $EF_5$ (0.01 kg $N_2O$-N/kg $NH_3$-N emitted for synthetic fertilizer and animal waste nitrogen and 0.025 kg $N_2O$-N/kg N leached) are used to estimate indirect $N_2O$ emissions. Total indirect emissions in 2010 amounted to 4.27 Gg $N_2O$, or approximately 46 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 $CH_4$ emissions from enteric fermentation and manure management for 1990 and 2003 onwards.

The use of country-specific information in relation to manure management has reduced the uncertainties associated with the estimation of $N_2O$ from manure management and agricultural soils. A comparison of the uncertainties associated with emission estimates prior to the use of Tier 2 methodologies for $CH_4$ and the use of country-specific information in relation to manure management are shown in Table 6.4. Large uncertainties still remain in relation to the $N_2O$ emissions from the agricultural sector due primarily to uncertainties in the emission factors. These uncertainties are the main determinant behind uncertainty in total national emissions outlined in Table 1.8.

The emission time series for agriculture 1990–2010 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 1990-2010.

*Table 6.4 Uncertainties in Activity Data and Emission Factors*

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

## 6.7 Quality Assurance and Quality Control

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

There is significant collaboration between inventory experts, agriculture researchers and the Department of Agriculture, Food and Marine, which grew out of the improved inventory methodologies for both $CH_4$ and $NH_3$. These collaborations are maintained by the inventory agency and are an important part of the overall QA/QC procedures being undertaken on an annual basis.

In addition, for this reporting year, the agency engaged an independent consultant, on a contract basis, who is a qualified UNFCCC expert reviewer for Agriculture. The entire compilation for the 2012 submission was reviewed accordingly by this consultant.

## 6.8 Recalculations in Agriculture

### 6.8.1 Revision of N excretion values for livestock

Following a recommendation in the UNFCCC Review Report 2010 [FCCC/ARR/2010/IRL] to "increase consistency between the Tier 2 model to estimate $CH_4$ from Enteric Fermentation and Manure Management and the N excretion values used in sector 4.D Agricultural Soils", the inventory agency reviewed the N excretion values in use in the national inventory for all categories of livestock. This review was carried out in consultation with the Department of Agriculture, Food and the Marine and Teagasc during 2011.

In previous submissions Ireland utilised a fixed value of 85 kg N/head/year for dairy cows for each year. However between 1990 and 2010 the milk yield per cow has increased from 4,192 kg milk/cow/year to 5,322 kg milk/cow/year. The IPCC 2006 Guidelines for National Greenhouse Gas Inventories (Chapter 10, Volume 4) provides a Tier 2 methodology for the estimation of annual N excretion rates. This methodology requires data which is already used in the estimation of Tier 2 emission factors for $CH_4$ from enteric fermentation (e.g. milk production, GE intake, per cent crude protein in the diet). Revised N excretion rates were thus estimated for each year of the timeseries using the Tier 2 approach provided in the IPCC 2006 Guidelines and the parameters required for the estimation of Tier 2 emission factors for $CH_4$ from enteric fermentation and manure management developed by O'Mara (2006).

In the case of the other cattle categories it was established that the N excretion values used in previous submissions included losses of $NH_3$ from animal housing and manure storage. This led to a double counting in the quantity of $NH_3$ loss to the atmosphere from the management of manures from those animal categories. Double-counting of $NH_3$ losses was also found to have occurred for poultry and some sub-categories of sheep and goats. The N excretion values for these animal categories were updated to remove the effect of double counting and are shown together with the previously used values in Tables F.5.1 and F.5.2 of Annex F.

The adoption of revised N excretion values for livestock also led to the development of a revised approach for estimating $NH_3$ emissions from agriculture. This revised approach uses an N-flow methodology as opposed to the emission factor approach, which was previously used, thus maintaining consistency in the estimation of emissions for $CH_4$, $N_2O$ and $NH_3$.

### 6.8.2 Other recalculations

A key change in this inventory submission is the development of one annual average population characterisation for estimating emissions from cattle and some other livestock. This compares with previous submissions where two annual population characterisations were used i.e. one in June and one in December. This improvement was adopted following the EU consistency checks of Ireland's annual submissions under Decision 280/2004 for the 2011 inventory submission whereby the product of animal populations and N excretion values for dairy cows and other cattle did not equal the sum of animal waste management practices in CRF Table 4.B.(b). Following the recommendations of O'Mara (2006), the inventory agency continues to use the average annual population for breeding cattle (i.e. dairy cows and suckler cows). The June census figures are used for all other categories of cattle to account for the movement of animals from a lower age cohort into a higher age cohort during the year.

Minor revisions were undertaken as a result of Central Statistics Office (CSO) improvements in data gathering for the 2010 Census of Agriculture. The Census of Agriculture 2010 was the first census to use a combination of administrative records held by the Department of Agriculture, Food and the Marine (DAFM) and completed paper questionnaires. In particular, the national cattle herd population was obtained from DAFM's Animal Identification and Movement (AIM) system (formerly the Cattle Movement Monitoring System (CMMS)). The AIM/CMMS system was introduced at the beginning of 2000 and involves electronically recording data on bovine animal movements in Ireland (DAFF, 2004; 2005; 2006; 2007; 2008, 2009, 2010, DAFM, 2011). Revised population statistics for the national cattle herd are used accordingly in this submission.

The net effect of the revisions to livestock statistics and nitrogen excretion values for livestock is an increase of 2.5 per cent in total carbon dioxide equivalent emission in 2009 (Table 6.5)

## 6.9 Improvements in Agriculture

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

Other countries are in similar positions, in that they are using relatively sophisticated methods for estimating emissions from enteric fermentation and manure management, but do not have the data to allow a Tier 2 approach for estimating emissions of $N_2O$ from soils.

The EPA and the Department of Agriculture, Food and the Marine are actively pursuing the opportunities for both $CH_4$ and $N_2O$ emissions research in Ireland with a number of projects being currently funded. It is also envisaged that feed intake parameters and assumed nitrogen content of feeds will continue to be reviewed and updated as necessary allowing for the refinement of the Tier 2 emission factors for enteric fermentation and manure management and the refinement of N excretion values for livestock.

## *Table 6.5 Percentage change in emissions from Agriculture due to Recalculations*

| | | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Estimates in 2011 Submission (Gg)** | | | | | | | | | | | | | | | | | | | |
| 4.A | Enteric Fermentation | $CH_4$ | 452.88 | 457.11 | 460.01 | 462.00 | 459.78 | 459.71 | 470.23 | 480.53 | 488.13 | 476.21 | 453.60 | 448.39 | 445.05 | 441.10 | 441.25 | 438.49 | 436.38 | 421.98 | 420.20 | 414.30 |
| 4.B | Manure Management | $CH_4$ | 111.11 | 112.06 | 113.12 | 113.42 | 112.65 | 112.18 | 116.05 | 118.83 | 120.53 | 115.97 | 110.20 | 110.12 | 110.16 | 108.39 | 107.71 | 107.45 | 106.56 | 102.99 | 102.80 | 101.88 |
| 4.B | Manure Management | $N_2O$ | 1.12 | 1.17 | 1.19 | 1.21 | 1.23 | 1.25 | 1.27 | 1.31 | 1.36 | 1.37 | 1.30 | 1.27 | 1.29 | 1.28 | 1.27 | 1.27 | 1.24 | 1.20 | 1.18 | 1.18 |
| 4.D.1 | Direct Soil emissions | $N_2O$ | 9.10 | 8.94 | 8.73 | 9.08 | 9.65 | 10.16 | 9.94 | 9.26 | 10.34 | 10.57 | 9.80 | 8.98 | 8.90 | 9.42 | 8.98 | 8.67 | 8.30 | 7.86 | 7.60 | 7.55 |
| 4.D.2 | Pasture Range and Paddock | $N_2O$ | 9.38 | 9.52 | 9.71 | 9.65 | 9.62 | 9.60 | 9.83 | 9.98 | 10.22 | 10.02 | 9.59 | 9.44 | 9.27 | 9.33 | 9.32 | 9.27 | 9.19 | 8.85 | 8.80 | 8.77 |
| 4.D.3 | Indirect emissions | $N_2O$ | 4.30 | 4.32 | 4.32 | 4.42 | 4.53 | 4.63 | 4.68 | 4.61 | 4.90 | 4.91 | 4.65 | 4.40 | 4.37 | 4.46 | 4.34 | 4.28 | 4.21 | 4.02 | 3.96 | 3.96 |
| 4 | Total Methane | $CH_4$ | 563.99 | 569.17 | 573.13 | 575.41 | 572.43 | 571.89 | 586.28 | 599.37 | 608.66 | 592.19 | 563.80 | 558.51 | 555.21 | 549.49 | 548.96 | 545.95 | 542.94 | 524.97 | 523.01 | 516.18 |
| 4 | Total Nitrous oxide | $N_2O$ | 23.90 | 23.94 | 23.95 | 24.35 | 25.03 | 25.63 | 25.71 | 25.16 | 26.82 | 26.88 | 25.35 | 24.09 | 23.84 | 24.49 | 23.91 | 23.48 | 22.94 | 21.93 | 21.53 | 21.46 |
| 4 | Total ($CO_2$ eq) | $CO_2$ eq | 19,253.54 | 19,373.38 | 19,460.45 | 19,632.45 | 19,781.89 | 19,956.01 | 20,283.20 | 20,387.58 | 21,097.26 | 20,769.39 | 19,697.27 | 19,197.63 | 19,049.57 | 19,131.03 | 18,940.60 | 18,744.48 | 18,514.50 | 17,823.45 | 17,657.35 | 17,491.31 |
| | | | **Recalculated Estimates in 2012 Submission (Gg)** | | | | | | | | | | | | | | | | | | | |
| 4.A | Enteric Fermentation | $CH_4$ | 455.91 | 459.97 | 464.11 | 463.20 | 460.35 | 460.89 | 473.31 | 482.83 | 488.90 | 473.70 | 452.14 | 448.69 | 442.98 | 441.31 | 440.77 | 430.07 | 430.92 | 424.04 | 422.70 | 416.12 |
| 4.B | Manure Management | $CH_4$ | 112.08 | 113.04 | 114.26 | 113.94 | 112.98 | 112.64 | 116.97 | 119.57 | 120.94 | 115.83 | 110.18 | 110.46 | 109.93 | 108.66 | 107.87 | 107.85 | 107.29 | 105.03 | 105.07 | 103.52 |
| 4.B | Manure Management | $N_2O$ | 1.40 | 1.46 | 1.47 | 1.47 | 1.49 | 1.51 | 1.57 | 1.62 | 1.66 | 1.60 | 1.53 | 1.54 | 1.53 | 1.52 | 1.54 | 1.56 | 1.52 | 1.50 | 1.51 | 1.49 |
| 4.D.1 | Direct Soil emissions | $N_2O$ | 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 |
| 4.D.2 | Pasture Range and Paddock | $N_2O$ | 9.25 | 9.41 | 9.59 | 9.57 | 9.56 | 9.59 | 9.83 | 10.05 | 10.30 | 10.06 | 9.64 | 9.56 | 9.46 | 9.48 | 9.45 | 9.06 | 9.07 | 8.89 | 8.82 | 8.74 |
| 4.D.3 | Indirect emissions | $N_2O$ | 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 | Total Methane | $CH_4$ | 567.99 | 573.01 | 578.38 | 577.14 | 573.33 | 573.54 | 590.28 | 602.40 | 609.83 | 589.52 | 562.32 | 559.15 | 552.92 | 549.97 | 548.64 | 537.92 | 538.21 | 529.07 | 527.77 | 519.64 |
| 4 | Total Nitrous oxide | $N_2O$ | 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 |
| 4 | Total ($CO_2$ eq) | $CO_2$ eq | 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 |
| | | | **Percentage Change in Total Emissions due to Recalculations** | | | | | | | | | | | | | | | | | | | |
| 4.A | Enteric Fermentation | $CH_4$ | 0.67 | 0.63 | 0.89 | 0.26 | 0.12 | 0.26 | 0.65 | 0.48 | 0.16 | -0.53 | -0.32 | 0.07 | -0.47 | 0.05 | -0.11 | -1.92 | -1.25 | 0.49 | 0.59 | 0.44 |
| 4.B | Manure Management | $CH_4$ | 0.87 | 0.87 | 1.01 | 0.46 | 0.30 | 0.41 | 0.80 | 0.62 | 0.33 | -0.13 | -0.02 | 0.31 | -0.20 | 0.25 | 0.14 | 0.37 | 0.68 | 1.99 | 2.21 | 1.60 |
| 4.B | Manure Management | $N_2O$ | 25.08 | 24.73 | 22.82 | 21.47 | 21.11 | 20.83 | 23.68 | 23.69 | 21.68 | 16.54 | 17.03 | 21.41 | 18.29 | 18.91 | 20.90 | 23.01 | 22.81 | 25.01 | 28.08 | 26.71 |
| 4.D.1 | Direct Soil emissions | $N_2O$ | 7.26 | 7.36 | 7.22 | 7.14 | 6.75 | 6.67 | 7.84 | 8.80 | 7.40 | 6.23 | 6.78 | 8.05 | 7.62 | 7.14 | 7.87 | 8.58 | 8.89 | 9.68 | 10.22 | 9.56 |
| 4.D.2 | Pasture Range and Paddock | $N_2O$ | -1.40 | -1.17 | -1.16 | -0.78 | -0.70 | -0.13 | 0.10 | 0.64 | 0.80 | 0.36 | 0.55 | 1.23 | 1.96 | 1.59 | 1.42 | -2.23 | -1.35 | 0.41 | 0.33 | -0.37 |
| 4.D.3 | Indirect emissions | $N_2O$ | 3.47 | 3.42 | 3.58 | 2.81 | 2.58 | 2.66 | 2.55 | 2.77 | 2.52 | 1.35 | 0.93 | 2.92 | 2.78 | 2.89 | 2.85 | 1.84 | 2.31 | 3.64 | 4.31 | 4.14 |
| 4 | Total Methane | $CH_4$ | 0.71 | 0.67 | 0.92 | 0.30 | 0.16 | 0.29 | 0.68 | 0.51 | 0.19 | -0.45 | -0.26 | 0.12 | -0.41 | 0.09 | -0.06 | -1.47 | -0.87 | 0.78 | 0.91 | 0.67 |
| 4 | Total Nitrous oxide | $N_2O$ | 4.02 | 4.10 | 3.94 | 3.93 | 3.84 | 4.09 | 4.70 | 5.24 | 4.72 | 3.67 | 3.88 | 5.14 | 5.11 | 4.87 | 5.14 | 3.86 | 4.33 | 5.67 | 6.07 | 5.44 |
| 4 | Total ($CO_2$ eq) | $CO_2$ eq | 1.98 | 1.99 | 2.07 | 1.70 | 1.60 | 1.80 | 2.26 | 2.32 | 1.98 | 1.20 | 1.39 | 2.07 | 1.73 | 1.98 | 1.98 | 0.60 | 1.13 | 2.65 | 2.86 | 2.49 |

# 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 may be 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 by assuming that a unit of land subject to a change of use remains in the conversion sub-category for 20 years before it is reported in the top-level category to which it has been converted. The revised 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 emissions of $CO_2$ to or removals of $CO_2$ 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. Here above-ground biomass and below-ground biomass are treated together. The IPCC good practice guidance on LULUCF provides basic methodologies for calculating changes in carbon pools where land areas form the basic activity data and carbon stock change is determined from a number of other parameters. Various levels of land sub-division may be used to capture differences due to climate, management system, vegetation type or other factors influencing carbon exchange. As for other sectors of the inventory, the IPCC good practice guidance for LULUCF also provides higher tier methods for estimating emissions and removals, which may be used if the necessary data are available. The liming of agricultural lands, which produces $CO_2$ emissions, is another important source included in the LULUCF sector. Emissions of $N_2O$ in the LULUCF sector are reported for such activities as soil disturbance associated with land-use conversion to cropland and optionally for drainage of forest land and wetlands, while taking into account potential overlap with the *Agriculture* sector in some cases. Emissions of $N_2O$ and $CH_4$ are also to be reported for biomass burning.

## 7.2 Overview of LULUCF Sector

### 7.2.1 Sector Coverage

The 2006 inventory submission included the results of Ireland's first attempts to comply with the reporting requirements of Decision 13/CP.9 for the LULUCF sector. Following the same approach, complete coverage of the relevant gases has been achieved for the years 1990-2010 in all IPCC land categories, as indicated by Table 7.1, whereas in submissions prior to 2006 Ireland reported $CO_2$ estimates only in respect of carbon stock change in forests and $CO_2$ emissions from the liming of agricultural soils. 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 1990-2010. 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 3Source Category Coverage for Land Use, Land-Use Change and Forestry***

| 5 Land Use Land-Use Change and Forestry | Carbon Stock Change Emissions of $CO_2$ | | | $CH_4$ | $N_2O$ |
|---|---|---|---|---|---|
| | Biomass | DOM | Soils | | |
| A. Forest Land | | | | | |
| 1. Forest Land remaining Forest Land | All | All | All, NA | All | Part, IE |
| 2. Land converted to Forest Land | All | All | All, NA | NA | IE |
| B. Cropland | | | | | |
| 1. Cropland remaining Cropland | NO | NO | NO* | NA | IE |
| 2. Land converted to Cropland | All | NO | All | NA | All |
| C. Grassland | | | | | |
| 1. Grassland remaining Grassland | NO | NO | 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 | NO | NO | NO | 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 2010 inventory for LULUCF (the 2012 submission) follows the same general approach and methodologies as those used for the submissions from 2008 to 2011. However, in the case of *5.A Forest Land*, there are some significant modifications in regard to the treatment of areas and other parameters in order to be as consistent as possible in reporting emissions and removals for forests under the Convention and under the Kyoto Protocol. In particular there has been a major reappraisal of the emission factor and transition time (i.e. the period over which the soil is a source of emissions) following afforestation on organic soils.

Following recommendations of the 2007 in-country review of Ireland's national inventory, emissions of $N_2O$ and $CH_4$ were reported by Ireland for the first time in the 2008 submission with the exception of $N_2O$ emissions from the use of fertiliser in forests The amount of nitrogen fertilizer used in forests is negligible compared to that used in agriculture and therefore all $N_2O$ emissions from nitrogen fertilization are reported in the *Agriculture* sector and the notation key IE is used in CRF Table 5(I). Information regarding the occurrence of forest wildfires in Ireland is available to facilitate the reporting of $CH_4$ and $N_2O$ emissions from biomass burning in CRF Table 5(V).

The estimates of emissions and removals from LULUCF over the period 1990-2010 are presented in Table 7.2 for all land-use categories. The LULUCF sector was a significant net source of emissions up to 1997 and was a net sink of carbon in most years thereafter, 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 release from soils in *5.A.2 Land Converted to Forest Land* and the $CO_2$ emissions from agricultural lime application on Grassland and Cropland. The increase in carbon stocks in living biomass in the category *5.A.1 Forest Land remaining Forest Land* is the dominant removal that offsets $CO_2$ emissions.

The Wetland, Settlements and Other Land categories are comparatively less important in terms of emissions or removals but Cropland constitutes a significant net source of carbon to the atmosphere towards the end of the time series. The inclusion of $CH_4$ and $N_2O$ through the coverage of additional emission sources has a very minor effect on total emissions from LULUCF. The results contained in the 2012 submission for the years 1990-2010 for the LULUCF sector according to the requirements of Decision 13/CP.9 are not directly comparable with those provided in respect of land use change and forestry in submissions prior to 2006, as prior to 2006 the LULUCF was incomplete.

### 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, the areas converted to the categories and their associated greenhouse gas emissions and removals. The IPCC *Wetlands* category has been split 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 1990-2010 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 Ch11). 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. It should be noted, the relationship between areas afforested since 1990 (Article 3.3 sub-category AR) are not consistent with convention area in lands converted to forest land due to the 20 year transition period applied to convention areas under LULUCF. However chapter 11 outlines the relationships between these areas and described why areas are different for the 2 reporting categories.

#### 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 (FIPS95), afforestation and deforestation data (see Appendix F). The areas under forest land include open areas within boundaries and unclassified areas, which could not be categories into species or productivity classes using the areal interpretation. Unclassified areas typically represent clearfelled and replanted areas with insufficient canopy to characterise using remote techniques. The biomass CSC for these areas are conservatively assumed to be zero. However, 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 (F-L) is based on an analysis of the EU Coordination of Information on the Environment (CORINE) land cover data set. Deforestation in identified forests areas (see Appendix F) 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.

Other land use categories (i.e. non-forest land) are then re-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.

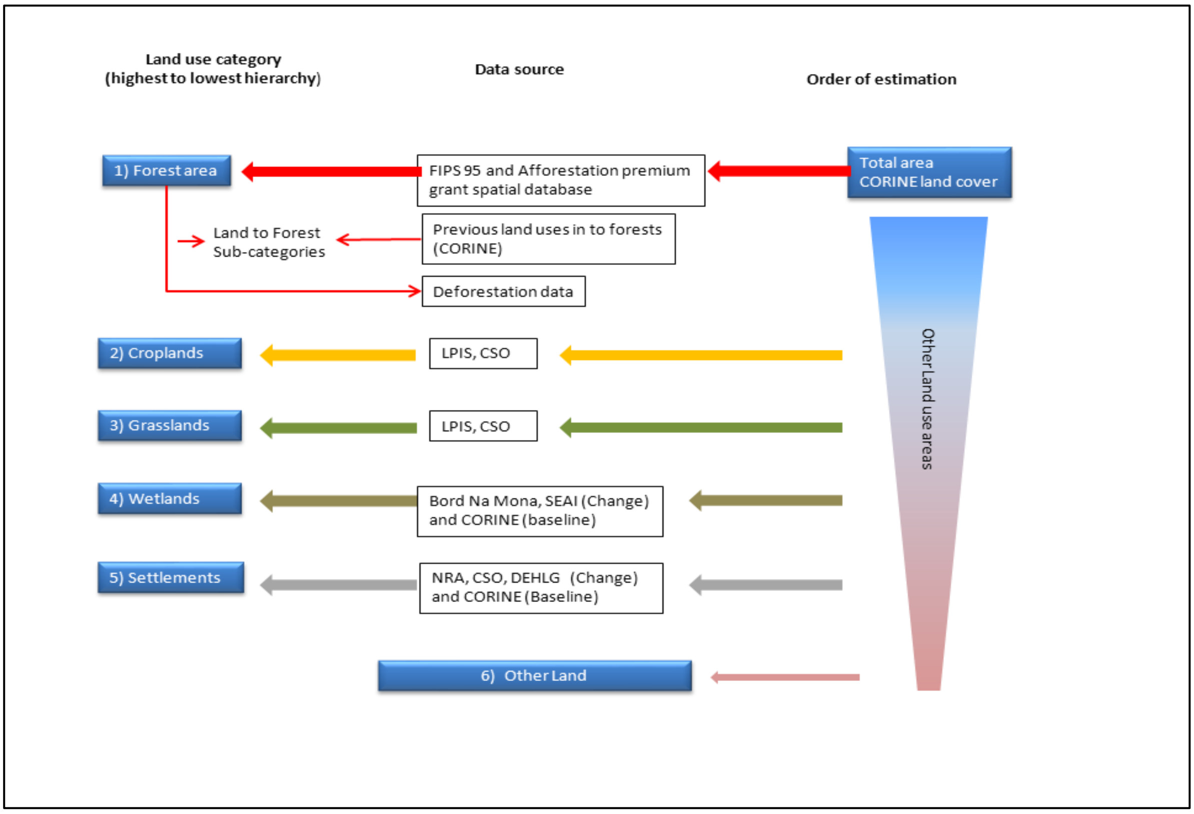


*Figure 7.1: Methodologies and hierarchy of determining land use areas and transitions*

See table 7.3 for a detailed description of data sources. Other Land is derived as the land not included in the forest, cropland, wetland and settlement areas. This included natural grasslands not used for agricultural purposes and as such is the residual land area not included on the other land categories.

### Land use change trends

The total area of forest, including open areas in forests, has increased by 46.2 per cent between 1990 (481,074 ha) and 2010 737,446 ha, this includes recent afforested and replantation areas which have not yet reached full canopy and open areas within forest areas (e.g. roads). However, the proportion of *Forest Land* to total land in the country is only 10.2 per cent, which is low compared to many other Annex I Parties.

*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 11.2 per cent, followed by C*ropland* at 5.7 per cent with *Forest Land* accounting for the remaining 6.8 per cent of the total.  The major land-use change since 1990 has been the conversion of grassland and peatland to forest land.

*Table 7.2. Emissions[a] and Removals[a] from Land Use Land-Use Change and Forestry 1990-2010 (Gg $CO_2$ eq)*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Estimates in 2011 Submission (Gg $CO_2$eq.) | | | | | | | | | | |
| **5.A** | **Forest Land** | **-371.02** | **-398.42** | **-226.93** | **-281.32** | **-224.46** | **-260.04** | **-234.04** | **-355.87** | **-471.10** | **-505.71** | **-355.14** | **-481.87** | **-623.31** | **-856.85** | **-477.93** | **-635.28** | **-709.10** | **-1,194.68** | **-1,826.71** | **-1,475.29** | **-1,371.23** |
| 5.A.1 | Forest Land remaining Forest Land ($CO_2$) | -803.41 | -943.34 | -659.95 | -617.89 | -319.17 | -144.99 | -44.16 | 63.92 | -194.76 | -251.67 | 216.73 | 346.07 | 29.48 | -792.14 | -309.21 | -455.88 | -448.51 | -1034.12 | -1903.59 | -2143.56 | -2010.25 |
| 5.A.2 | Land converted to Forest Land ($CO_2$) | 412.72 | 521.37 | 408.56 | 309.94 | 66.84 | -145.48 | -221.60 | -449.84 | -306.13 | -284.35 | -604.55 | -863.97 | -685.70 | -104.34 | -205.90 | -214.51 | -296.20 | -197.18 | 39.01 | 630.96 | 594.77 |
| 5.A | Biomass burning ($CH_4$ and $N_2O$) | 2.93 | 1.88 | 1.21 | 2.44 | 2.80 | 3.82 | 4.25 | 2.32 | 1.23 | 1.00 | 2.51 | 5.01 | 1.15 | 7.10 | 4.14 | 1.50 | 1.50 | 1.69 | 2.06 | 1.16 | 7.62 |
| 5.A | Drainage of soils | 16.74 | 21.66 | 23.25 | 24.19 | 25.08 | 26.61 | 27.47 | 27.73 | 28.57 | 29.32 | 30.17 | 31.02 | 31.76 | 32.53 | 33.04 | 33.61 | 34.11 | 34.93 | 35.82 | 36.15 | 36.63 |
| **5.B** | **Cropland** | **20.00** | **21.19** | **25.23** | **24.84** | **-50.73** | **-23.01** | **42.25** | **76.77** | **23.20** | **-1.25** | **44.86** | **133.92** | **128.23** | **175.40** | **133.86** | **160.03** | **106.54** | **130.54** | **442.41** | **253.80** | **252.44** |
| 5.B.1 | Cropland remaining Cropland | 20.00 | 21.19 | 9.65 | -58.90 | -87.54 | -62.86 | -25.13 | -20.09 | -39.12 | -63.57 | -22.25 | -28.22 | -34.70 | -35.32 | -26.31 | -0.14 | -53.63 | -29.63 | -20.59 | -27.28 | -28.64 |
| 5.B.2 | Land converted to Cropland | NO | NO | 15.35 | 80.79 | 33.86 | 36.90 | 62.65 | 92.12 | 57.59 | 57.59 | 62.37 | 153.86 | 152.62 | 197.28 | 146.73 | 146.73 | 146.73 | 146.73 | 437.64 | 255.72 | 255.72 |
| 5.B | Agricultural Lime Application[b] | 36.66 | 32.51 | 26.31 | 36.95 | 27.48 | 50.28 | 50.29 | 44.31 | 31.42 | 38.86 | 37.25 | 40.48 | 29.70 | 43.19 | 26.44 | 26.85 | 25.49 | 37.22 | 29.71 | 33.45 | 32.09 |
| 5.B.2 | Emissions from soil disturbance | NA,NO | NA,NO | 0.23 | 2.95 | 2.95 | 2.95 | 4.73 | 4.73 | 4.73 | 4.73 | 4.73 | 8.28 | 10.31 | 13.44 | 13.44 | 13.44 | 13.44 | 13.44 | 25.36 | 25.36 | 25.36 |
| **5.C** | **Grassland** | **493.58** | **568.21** | **441.17** | **355.04** | **409.09** | **706.38** | **698.02** | **661.41** | **468.63** | **568.82** | **611.91** | **557.86** | **511.95** | **577.06** | **409.57** | **248.28** | **306.38** | **351.33** | **338.21** | **243.25** | **208.50** |
| 5.C.1 | Grassland remaining Grassland | 602.37 | 600.55 | 484.15 | 397.96 | 460.77 | 719.23 | 717.91 | 688.66 | 519.11 | 627.23 | 616.85 | 591.17 | 545.15 | 608.11 | 512.03 | 529.69 | 510.33 | 523.98 | 525.21 | 533.41 | 570.61 |
| 5.C.2 | Land converted to Grassland | -108.80 | -32.34 | -42.98 | -42.92 | -51.68 | -12.85 | -19.89 | -27.25 | -50.48 | -58.41 | -4.94 | -33.30 | -33.20 | -31.04 | -102.46 | -281.41 | -203.95 | -172.65 | -187.00 | -290.16 | -362.11 |
| 5.C | Agricultural Lime Application[b] | 318.38 | 282.64 | 229.29 | 320.35 | 242.16 | 444.32 | 433.74 | 379.17 | 274.16 | 344.37 | 329.14 | 344.80 | 244.20 | 343.57 | 214.35 | 239.89 | 229.37 | 339.54 | 232.50 | 273.88 | 275.24 |
| **5.D** | **Wetlands** | **50.66** | **49.02** | **49.47** | **47.43** | **45.42** | **43.89** | **41.40** | **39.80** | **38.48** | **49.28** | **63.44** | **61.52** | **58.80** | **56.10** | **42.48** | **45.72** | **74.37** | **71.44** | **41.54** | **39.47** | **39.81** |
| 5.D.1 | Wetlands remaining Wetlands | 47.07 | 45.48 | 45.95 | 43.94 | 41.96 | 40.47 | 38.04 | 36.49 | 35.21 | 46.07 | 43.52 | 42.08 | 39.83 | 37.60 | 24.45 | 27.71 | 30.82 | 33.13 | 35.87 | 38.71 | 38.68 |
| 5.D.2 | Land converted to Wetlands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 16.80 | 16.43 | 16.05 | 15.68 | 15.30 | 15.30 | 40.87 | 35.65 | 3.04 | -1.85 | -1.46 |
| 5.D | Drainage of soils | 3.59 | 3.55 | 3.52 | 3.49 | 3.46 | 3.42 | 3.36 | 3.32 | 3.27 | 3.21 | 3.11 | 3.01 | 2.92 | 2.82 | 2.73 | 2.71 | 2.69 | 2.66 | 2.64 | 2.62 | 2.59 |
| **5.E** | **Settlements** | **9.22** | **8.52** | **8.62** | **9.13** | **10.97** | **9.83** | **12.46** | **13.65** | **14.74** | **15.78** | **37.30** | **42.85** | **40.93** | **45.34** | **46.57** | **50.81** | **34.24** | **32.92** | **30.37** | **19.80** | **23.33** |
| 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 | 9.22 | 8.52 | 8.62 | 9.13 | 10.97 | 9.83 | 12.46 | 13.65 | 14.74 | 15.78 | 37.30 | 42.85 | 40.93 | 45.34 | 46.57 | 50.81 | 34.24 | 32.92 | 30.37 | 19.80 | 23.33 |
| **5.F** | **Other Land** | **-1.06** | **0.28** | **-13.17** | **-14.41** | **-17.49** | **-4.25** | **-27.74** | **-35.05** | **-41.30** | **-35.44** | **-10.35** | **-25.58** | **-43.83** | **-41.84** | **-78.43** | **-86.54** | **-113.71** | **-99.73** | **-133.99** | **-116.69** | **-183.26** |
| 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 | -1.06 | 0.28 | -13.17 | -14.41 | -17.49 | -4.25 | -27.74 | -35.05 | -41.30 | -35.44 | -10.35 | -25.58 | -43.83 | -41.84 | -78.43 | -86.54 | -113.71 | -99.73 | -133.99 | -116.69 | -183.26 |
| **5.G** | **G. Other** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** |
| **5** | **TOTAL LULUCF $CO_2$ (net emissions/removals)** | **178.11** | **221.70** | **256.19** | **107.64** | **138.52** | **435.99** | **492.54** | **362.60** | **-5.15** | **53.21** | **351.49** | **241.39** | **26.64** | **-100.68** | **22.77** | **-268.25** | **-353.02** | **-760.90** | **-1,174.04** | **-1,100.95** | **-1,102.61** |
| **5** | **TOTAL LULUCF GHGs (net emissions/removals)** | **201.37** | **248.79** | **284.41** | **140.71** | **172.81** | **472.80** | **532.35** | **400.71** | **32.66** | **91.47** | **392.02** | **288.70** | **72.78** | **-44.79** | **76.12** | **-216.98** | **-301.28** | **-708.17** | **-1108.17** | **-1035.66** | **-1030.41** |

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

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

*Table 7.3. Land Use Categories*

| Land Use Category | Definition and Coverage | Area 1990 (ha) | Area 2010 (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 | 737,446 | National Forest Inventory (NFI)<br>FIPS (Forest Inventory and Planning System) 1995<br>COILLTE database<br>Forest Service Premiums database<br>CORINE Land Cover<br>General Soil Map<br>Deforestation statistics | Grassland<br>Wetland<br>Settlement<br>Otherland | Grassland & Wetland |
| Cropland | Permanent crops and tillage areas (including setaside) recorded by the Central Statistics Office (CSO) | 404,563 | 384,600 | 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 | 4,140,385 | 3,733,450 | CSO, CORINE Land Cover<br>LPIS (Land Parcels information System)<br><br>General Soil Map for Ireland | Cropland | Other Land |
| Wetlands | Natural unexploited wetlands | 1,226,549 | 1,094,860 | CORINE Land Cover<br>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 | 73,401 | 52975 | Bord na Mona (BNM) area statistics; Expert opinion | Wetlands, Grassland | |
| Settlements | Urban areas, roads, airports and the footprint of industrial, commercial/institutional and residential buildings | 98,145 | 114,893 | CORINE Land Cover; National Roads Authority (NRA) road construction statistics; CSO housing stock, house completions and other construction floor area statistics; General Soil Map | | Grassland |
| Other Land | Natural grasslands not in use for agricultural purposes, water bodies, bare rock | 687,669 | 993,562 | 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 1990-2010 (ha)*

| | Forest | Grassland | Cropland | Managed Wetland[1] | Unmanaged Wetland | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|---|
| **1989** | **465,278** | **4,129,585** | **424,648** | **74,000** | **1,235,026** | **97,777** | **685,448** | **7,111,785** |
| Forest | 465,268 | | | | | 10 | | 465,278 |
| Grassland | 4,737 | 4,121,849 | | | | 310 | 2,689 | 4,129,585 |
| Cropland | 1,582 | 18,475 | 404,563 | | | 28 | | 424,648 |
| Peatland | 320 | 61 | | 73,401 | 219 | | | 74,000 |
| Wetland | 8,696 | | | | 1,226,330 | | | 1,235,026 |
| Settlements | | | | | | 97,777 | | 97,777 |
| Other land | 472 | | | | | 20 | 684,980 | 685,473 |
| **1990** | **481,074** | **4,140,385** | **404,563** | **73,401** | **1,226,549** | **98,145** | **687,669** | **7,111,785** |
| Forest | 481,064 | | | | | 10 | | 481,074 |
| Grassland | 5,736 | 4,134,367 | | | | 282 | | 4,140,385 |
| Cropland | 1,915 | 929 | 401,694 | | | 25 | | 404,563 |
| Peatland | 320 | 61 | | 72,466 | 554 | | | 73,401 |
| Wetland | 10,594 | | | | 1,215,955 | | | 1,226,549 |
| Settlements | | | | | | 98,145 | | 98,145 |
| Other land | 572 | 14,896 | | | | 18 | 672,183 | 687,669 |
| **1991** | **500,201** | **4,150,253** | **401,694** | **72,466** | **1,216,509** | **98,480** | **672,183** | **7,111,785** |
| Forest | 500,191 | | | | | 10 | | 500,201 |
| Grassland | 5,002 | 4,119,655 | 2,618 | | | 286 | 22,692 | 4,150,253 |
| Cropland | 1,670 | | 399,998 | | | 26 | | 401,694 |
| Peatland | 320 | 61 | | 71,958 | 127 | | | 72,466 |
| Wetland | 9,198 | | | | 1,207,310 | | | 1,216,509 |
| Settlements | | | | | | 98,480 | | 98,480 |
| Other land | 499 | | | | | 19 | 671,665 | 672,183 |
| **1992** | **516,879** | **4,119,716** | **402,616** | **71,958** | **1,207,437** | **98,821** | **694,358** | **7,111,785** |
| Forest | 516,869 | | | | | 10 | | 516,879 |
| Grassland | 4,791 | 4,099,263 | 12,797 | | | 306 | 2,558 | 4,119,716 |
| Cropland | 1,600 | | 400,988 | | | 28 | | 402,616 |
| Peatland | 320 | 61 | | 71,226 | 352 | | | 71,958 |
| Wetland | 8,799 | | | | 1,198,638 | | | 1,207,437 |
| Settlements | | | | | | 98,821 | | 98,821 |
| Other land | 478 | | | | | 20 | 693,860 | 694,358 |
| **1993** | **532,857** | **4,099,324** | **413,785** | **71,226** | **1,198,990** | **99,185** | **696,418** | **7,111,785** |
| Forest | 532,846 | | | | | 10 | | 532,857 |
| Grassland | 5,830 | 4,087,409 | | | | 380 | 5,705 | 4,099,324 |
| Cropland | 1,946 | 1,504 | 410,301 | | | 34 | | 413,785 |
| Peatland | 320 | 61 | | 70,682 | 163 | | | 71,226 |
| Wetland | 10,772 | | | | 1,188,219 | | | 1,198,990 |
| Settlements | | | | | | 99,185 | | 99,185 |
| Other land | 582 | | | | | 25 | 695,812 | 696,418 |
| **1994** | **552,295** | **4,088,974** | **410,301** | **70,682** | **1,188,381** | **99,634** | **701,517** | **7,111,785** |
| Forest | 552,295 | | | | | | | 552,295 |
| Grassland | 6,846 | 4,080,355 | 1,381 | | | 392 | | 4,088,974 |
| Cropland | 2,371 | | 407,895 | | | 35 | | 410,301 |
| Peatland | 140 | 30 | | 69,873 | 639 | | | 70,682 |
| Wetland | 13,375 | | | | 1,175,007 | | | 1,188,381 |
| Settlements | | | | | | 99,634 | | 99,634 |
| Other land | 645 | 7,462 | | | | 26 | 693,385 | 701,517 |
| **1995** | **575,672** | **4,087,847** | **409,277** | **69,873** | **1,175,646** | **100,086** | **693,385** | **7,111,785** |

[1] 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 the wetland in an undisturbed state or wetland that may have been disturbed in the past but not actively managed since 1990.

| | Forest | Grassland | Cropland | Managed Wetland[1] | Unmanaged Wetland | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|---|
| Forest | 575,672 | | | | | | | 575,672 |
| Grassland | 6,028 | 4,032,277 | 9,418 | | | 497 | 39,628 | 4,087,847 |
| Cropland | 2,098 | | 407,134 | | | 45 | | 409,277 |
| Peatland | 140 | 30 | | 68,626 | 1,077 | | | 69,873 |
| Wetland | 11,819 | | | | 1,163,827 | | | 1,175,646 |
| Settlements | | | | | | 100,086 | | 100,086 |
| Other land | 563 | | | | | 32 | 692,790 | 693,385 |
| **1996** | **596,319** | **4,032,307** | **416,552** | **68,626** | **1,164,904** | **100,660** | **732,417** | **7,111,785** |
| Forest | 596,319 | | | | | | | 596,319 |
| Grassland | 3,164 | 4,015,910 | | | | 544 | 12,689 | 4,032,307 |
| Cropland | 1,143 | 1,260 | 414,100 | | | 49 | | 416,552 |
| Peatland | 140 | 30 | | 67,739 | 717 | | | 68,626 |
| Wetland | 6,377 | | | | 1,158,526 | | | 1,164,904 |
| Settlements | | | | | | 100,660 | | 100,660 |
| Other land | 276 | | | | | 36 | 732,106 | 732,417 |
| **1997** | **607,420** | **4,017,200** | **414,100** | **67,739** | **1,159,243** | **101,289** | **744,794** | **7,111,785** |
| Forest | 607,420 | | | | | | | 607,420 |
| Grassland | 3,612 | 4,002,016 | | | | 587 | 10,985 | 4,017,200 |
| Cropland | 1,293 | 4,754 | 408,000 | | | 53 | | 414,100 |
| Peatland | 140 | 30 | | 66,845 | 724 | | | 67,739 |
| Wetland | 7,229 | | | | 1,152,014 | | | 1,159,243 |
| Settlements | | | | | | 101,289 | | 101,289 |
| Other land | 321 | | | | | 38 | 744,435 | 744,794 |
| **1998** | **620,015** | **4,006,800** | **408,000** | **66,845** | **1,152,738** | **101,967** | **755,420** | **7,111,785** |
| Forest | 620,015 | | | | | | | 620,015 |
| Grassland | 3,534 | 4,002,637 | | | | 629 | | 4,006,800 |
| Cropland | 1,267 | 5,777 | 400,900 | | | 57 | | 408,000 |
| Peatland | 140 | 30 | | 65,539 | 1,136 | | | 66,845 |
| Wetland | 7,081 | | | | 1,145,658 | | | 1,152,738 |
| Settlements | | | | | | 101,967 | | 101,967 |
| Other land | 313 | 8,956 | | | | 41 | 746,109 | 755,420 |
| **1999** | **632,350** | **4,017,400** | **400,900** | **65,539** | **1,146,794** | **102,694** | **746,109** | **7,111,785** |
| Forest | 632,178 | | | | | 171 | | 632,350 |
| Grassland | 4,308 | 4,011,759 | 816 | | | 517 | | 4,017,400 |
| Cropland | 1,570 | | 399,284 | | | 46 | | 400,900 |
| Peatland | 327 | 75 | | 63,509 | 1,628 | | | 65,539 |
| Wetland | 8,449 | | | | 1,138,175 | | | 1,146,623 |
| Settlements | | | | | | 102,694 | | 102,694 |
| Other land | 356 | 30,066 | | | | 34 | 715,824 | 746,280 |
| **2000** | **647,187** | **4,041,900** | **400,100** | **63,509** | **1,139,803** | **103,462** | **715,824** | **7,111,785** |
| Forest | 647,016 | | | | | 171 | | 647,187 |
| Grassland | 4,239 | 3,994,425 | 16,113 | | | 738 | 26,555 | 4,042,071 |
| Cropland | 1,547 | | 398,487 | | | 66 | | 400,100 |
| Peatland | 327 | 75 | | 61,565 | 1,542 | | | 63,509 |
| Wetland | 8,317 | | | | 1,131,315 | | | 1,139,632 |
| Settlements | | | | | | 103,462 | | 103,462 |
| Other land | 349 | | | | | 48 | 715,427 | 715,824 |
| **2001** | **661,795** | **3,994,500** | **414,600** | **61,565** | **1,132,857** | **104,486** | **741,983** | **7,111,785** |
| Forest | 661,624 | | | | | 171 | | 661,795 |
| Grassland | 4,116 | 3,948,525 | 9,865 | | | 661 | 31,503 | 3,994,671 |
| Cropland | 1,505 | | 413,035 | | | 59 | | 414,600 |
| Peatland | 327 | 75 | | 59,617 | 1,546 | | | 61,565 |
| Wetland | 8,083 | | | | 1,124,603 | | | 1,132,686 |

| | Forest | Grassland | Cropland | Managed Wetland[1] | Unmanaged Wetland | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|---|
| Settlements | | | | | | 104,486 | | 104,486 |
| Other land | 337 | | | | | 43 | 741,603 | 741,983 |
| **2002** | **675,992** | **3,948,600** | **422,900** | **59,617** | **1,126,149** | **105,421** | **773,106** | **7,111,785** |
| Forest | 675,821 | | | | | 171 | | 675,992 |
| Grassland | 2,329 | 3,931,649 | 13,785 | | | 837 | | 3,948,600 |
| Cropland | 910 | | 421,915 | | | 75 | | 422,900 |
| Peatland | 327 | 75 | | 57,670 | 1,545 | | | 59,617 |
| Wetland | 4,688 | | | | 1,121,291 | | | 1,125,979 |
| Settlements | | | | | | 105,421 | | 105,421 |
| Other land | 158 | 2,176 | | | | 55 | 770,888 | 773,277 |
| **2003** | **684,232** | **3,933,900** | **435,700** | **57,670** | **1,122,836** | **106,559** | **770,888** | **7,111,785** |
| Forest | 684,061 | | | | | 171 | | 684,232 |
| Grassland | 2,522 | 3,869,079 | | | | 886 | 61,584 | 3,934,071 |
| Cropland | 974 | 11,846 | 422,800 | | | 80 | | 435,700 |
| Peatland | 327 | 75 | | 55,726 | 1,542 | | | 57,670 |
| Wetland | 5,054 | | | | 1,117,612 | | | 1,122,665 |
| Settlements | | | | | | 106,559 | | 106,559 |
| Other land | 177 | | | | | 58 | 770,653 | 770,888 |
| **2004** | **693,114** | **3,881,000** | **422,800** | **55,726** | **1,119,154** | **107,754** | **832,237** | **7,111,785** |
| Forest | 692,943 | | | | | 171 | | 693,114 |
| Grassland | 2,629 | 3,862,816 | | | | 1,055 | 14,671 | 3,881,171 |
| Cropland | 1,010 | 37,896 | 383,800 | | | 95 | | 422,800 |
| Peatland | 133 | 88 | | 55,288 | 216 | | | 55,726 |
| Wetland | 5,451 | | | | 1,113,533 | | | 1,118,983 |
| Settlements | | | | | | 107,754 | | 107,754 |
| Other land | 188 | | | | | 69 | 831,980 | 832,237 |
| **2005** | **702,353** | **3,900,800** | **383,800** | **55,288** | **1,113,749** | **109,144** | **846,652** | **7,111,785** |
| Forest | 702,336 | | | | | 17 | | 702,353 |
| Grassland | 2,386 | 3,875,326 | | | | 1,231 | 22,187 | 3,901,131 |
| Cropland | 804 | 4,086 | 378,800 | | | 111 | | 383,800 |
| Peatland | 133 | 88 | | 54,872 | 195 | | | 55,288 |
| Wetland | 4,117 | | | | 1,109,301 | | | 1,113,418 |
| Settlements | | | | | | 109,144 | | 109,144 |
| Other land | 238 | | | | | 80 | 846,333 | 846,652 |
| **2006** | **710,015** | **3,879,500** | **378,800** | **54,872** | **1,109,496** | **110,583** | **868,519** | **7,111,785** |
| Forest | 710,010 | | | | | 5 | | 710,015 |
| Grassland | 2,137 | 3,876,095 | | | | 1,268 | | 3,879,500 |
| Cropland | 718 | 668 | 377,300 | | | 114 | | 378,800 |
| Peatland | 133 | 88 | | 54,386 | 265 | | | 54,872 |
| Wetland | 3,659 | | | | 1,105,539 | | | 1,109,198 |
| Settlements | | | | | | 110,583 | | 110,583 |
| Other land | 194 | 19,649 | | | | 83 | 848,891 | 868,816 |
| **2007** | **716,852** | **3,896,500** | **377,300** | **54,386** | **1,105,804** | **112,054** | **848,891** | **7,111,785** |
| Forest | 716,785 | | | | | 66 | | 716,852 |
| Grassland | 1,792 | 3,780,912 | 49,614 | | | 992 | 63,233 | 3,896,544 |
| Cropland | 625 | | 376,586 | | | 89 | | 377,300 |
| Peatland | 133 | 88 | | 53,889 | 275 | | | 54,386 |
| Wetland | 3,385 | | | | 1,102,375 | | | 1,105,760 |
| Settlements | | | | | | 112,054 | | 112,054 |
| Other land | 85 | | | | | 65 | 848,740 | 848,891 |
| **2008** | **722,806** | **3,781,000** | **426,200** | **53,889** | **1,102,651** | **113,266** | **911,974** | **7,111,785** |
| Forest | 722,788 | | | | | 18 | | 722,806 |
| Grassland | 1,989 | 3,770,942 | | | | 727 | 7,342 | 3,781,000 |

| | Forest | Grassland | Cropland | Managed Wetland[1] | Unmanaged Wetland | Settlements | Other land | Total |
|---|---|---|---|---|---|---|---|---|
| Cropland | 665 | 16,770 | 408,700 | | | 65 | | 426,200 |
| Peatland | 133 | 88 | | 53,432 | 235 | | | 53,889 |
| Wetland | 3,656 | | | | 1,098,995 | | | 1,102,651 |
| Settlements | | | | | | 113,266 | | 113,266 |
| Other land | 26 | | | | | 47 | 911,900 | 911,974 |
| **2009** | **729,256** | **3,787,800** | **408,700** | **53,432** | **1,099,230** | **114,124** | **919,244** | **7,111,785** |
| Forest | 729,201 | | | | | 55 | | 729,256 |
| Grassland | 2,454 | 3,710,149 | | | | 618 | 74,579 | 3,787,800 |
| Cropland | 831 | 23,213 | 384,600 | | | 56 | | 408,700 |
| Peatland | 133 | 88 | | 52,975 | 235 | | | 53,432 |
| Wetland | 4,605 | | | | 1,094,624 | | | 1,099,229 |
| Settlements | | | | | | 114,124 | | 114,124 |
| Other land | 220 | | | | | 40 | 918,983 | 919,244 |
| **2010** | **737,446** | **3,733,450** | **384,600** | **52,975** | **1,094,860** | **114,893** | **993,562** | **7,111,785** |

The Irish forest reporting model (CARBWARE) was initially developed (version 4) for Convention reporting of forest lands under LULUCF (described by Gallagher et al., 2004). The model uses species information from FIPS95 and applies species specific forestry commission yield tables to derive stand volume, which is converted to biomass (see eq 7.2 and 7.3 below). The model also estimates DOM (litter and deadwood) using country specific methods (section 7.3.2 below) and soil CSC is determined using country specific approaches (see sections 7.3.3.1.4 and 7.3.3.1.5 below).

A major review of the CARBWARE model, for reporting under the Convention, took place in 2011. A number of errors in coding where discovered and corrected and, as a result, it is now possible to demonstrate consistency between the total areas reported for all land uses in the CRF tables and the annual land use change matrix presented in Table 7.4.

It is important to note that a different version of the CARBWARE model (version 5) is used for reporting ARD activities under the Kyoto Protocol (see Chapter 11). This provides more accurate estimates of CSC for all pools based on national forest inventory information, completed for the first time in 2006. The KP version of CARBWARE could not be applied to Convention reporting areas because there is no historic NFI information prior to 2006. Therefore a volume based assessment of biomass is done for Convention reporting as described above. Forest biomass CSC estimated for Convention reporting are lower than those reported for KP forests because of the underestimation of volume in young crops less than 7 years old. These are conservatively assumed to have a CSC of zero because there is no detectable volume increment (see section 7.3.1). The same assumption is applied to DOM CSC for Convention reporting to ensure consistency with methodologies used for biomass estimation. Reporting of soil CSC are done in the same way for both KP and Convention reporting. It is envisaged that the models used for Convention and KP reporting will be harmonised once the second NFI is completed in 2013. It is proposed to use the KP version of CARBWARE and back casting techniques for Convention reporting when the next NFI is completed.

### 7.2.3 Soil Type and Soil Organic Carbon

In Ireland, $CO_2$ emissions from soils, which are the dominant source of carbon emissions on land conversion categories in LULUCF, are estimated using the tier 1 method of the IPCC GPG.

Soil organic carbon (SOC) is the basic parameter in the IPCC estimation methods for determining carbon stock changes in soils. With the exception of forest soils, the organic carbon status of Irish soils under native vegetation is established from the soil type and the default reference soil organic carbon stocks ($SOC_{ref}$) for cold, temperate moist regions (Tables 3.2.4, 3.3.3 and 3.4.4 of the IPCC good practice guidance on LULUCF). The General Soil Map of Ireland (Gardiner and Radford, 1980) is the basic data source for soil type information in Ireland. Mineral soils as identified from the general soil map are allocated to the HAC (high activity clay), LAC (low activity clay), sandy and humic soil classes used by the IPCC, while peats are allocated to the IPCC wetlands class as shown on Table 7.5, based on detailed national assessment of soil carbon stocks in Ireland (Tomlinson, 2003). The values of $SOC_{ref}$ appropriate to each soil association may then be assigned using the correspondence to IPCC classes given in Table 7.5. The distribution of CORINE Land Use over IPCC soil classes was established in the same way to facilitate complete correspondence between land use, soil and $SOC_{ref}$.

Forest soil carbon stock changes in mineral soils are demonstrated not to be a source (see Chapter 11), so are not reported in accordance with requirements set out under annex 1 of 15CMP/1 paragraph 6e. Organic forest soil EF are based on tier 2 method assuming a transition time of 50 years, after which no emission occur (see section 7.3). The areas for mineral, organo-mineral and organic soils under forestry are derived from National forest inventory permanent sample plot data (see section 7.3) and the generalised soils map for afforested areas after 2006.

***Table 7.5. Soil Class Coverage and Soil Organic Carbon***

| General Soil Map Soil Association | IPCC Soil Class | | | | | Proportion of Soil Association in Area of Ireland |
|---|---|---|---|---|---|---|
| | HAC | LAC | Peaty/ Humic | Sandy Soil | Wetlands Soil | |
| basin peat | | | | | 0.34 | 0.06 |
| brown earth | | 0.19 | | | | 0.13 |
| brown podzolic | | 0.21 | | | | 0.15 |
| gley | | 0.30 | | | 0.02 | 0.22 |
| grey brown podzolic | | 0.30 | | | | 0.21 |
| lithosol | | | 0.22 | 1.00 | | 0.04 |
| lowland blanket peat | | | | | 0.31 | 0.05 |
| podzol | | | 0.78 | | | 0.08 |
| Renzinas | 1.00 | | | | | 0.01 |
| upland blanket peat | | | | | 0.33 | 0.06 |
| Proportion of IPCC Soil Class in Area of Ireland | 0.01 | 0.71 | 0.10 | 0.01 | 0.17 | 1.00 |
| $SOC_{ref}$ (t C/ha) | 95 | 85 | 115 | 71 | 87 | |

## 7.2.4 Estimation of Emissions from Soils

### 7.2.4.1 Mineral Soils

The annual change in SOC in mineral soils over the appropriate transition period determines the carbon emissions or removals for the various land-use conversion categories as follows:

$$\Delta C = A * ( SOC_0 - SOC_{0\text{-}T} ) / T \qquad (7.1)$$

$$SOC = SOC_{ref} * F_{LU} * F_{MG} * F_I$$

where

- $\Delta C$ = annual change in carbon stocks
- A = area of land converted from a former land use
- $SOC_0$ = soil organic carbon stock for current land use
- $SOC_{0\text{-}T}$ = soil organic carbon stock for former land use
- $SOC_{ref}$ = reference soil organic carbon under native vegetation for a given soil type in area A
- T = transition period
- $F_{LU}$ = stock change factor for land use or land-use change type
- $F_{MG}$ = stock change factor for management regime
- $F_I$ = stock change factor for organic matter input

The factors $F_{LU}$, $F_{MG}$ and $F_I$ account for changes in SOC due to management practices that impact on soil carbon. Table 7.6 shows the value of these factors derived from the product of $F_{LU}$, $F_{MG}$ and $F_I$ taken from Table 3.3.4 of the IPCC good practice guidance on LULUCF for the land uses defined for Ireland (Table 7.3). Equation 7.1 is the basic Tier 1 methodology used for estimating emissions from mineral soils for all land-use categories as described in the following sections. The default transition period of 20 years is applied for all mineral soils. The estimation procedure is performed following a simple approach that provides estimates of emissions from soils for the defined land uses in accordance with the IPCC good practice guidance for LULUCF and the available information for the country. It involves the identification and quantification of the land areas subject to a change of use, the application of the data in Table 7.5 to assign $SOC_{ref}$ for the soil types in those land areas and the calculation of carbon stock change on the basis of the factors given in Table 7.6.

***Table 7.6. Value of F stock change factors for SOC***

| Land Use | $F_{LU}$ | $F_{MG}$ | $F_I$ | F, Stock change |
|---|---|---|---|---|
| Cropland | 0.71 | 1.09 | 1.11 | 0.86 |
| Improved grassland | 1.0 | 1.0 | 1.14 | 1.14 |
| Unimproved grassland | 1.0 | 1.0 | NA | 1.0 |
| Rough grazing | 1.0 | 0.95 | NA | 0.95 |
| Other agricultural land (Native grassland) | 1.0 | 1.0 | NA | 1.0 |

#### 7.2.4.2 Organic Soils

The basic methodology for estimating emissions from organic soils is to assign a direct annual carbon loss rate that accounts for the oxidation of organic matter due to drainage, tillage or disturbance of the land area concerned. The default emission factors of 0.25 t C/ha per year for managed grassland soils and 1 t C/ha per year for cultivated cropland soils in cold temperate climatic regions given in the IPCC good practice guidance for LULUCF are adopted for Ireland. Tier 2 EFs are used for forest organic soils based on country specific information (Byrne and Farrell, 2005, see section 7.3.3.1.4 and 7.3.3.1.5).

## 7.3 Forest Land (Category 5.A)

### 7.3.1 Carbon Stock Change in Living Biomass

Previous NIRs have described Ireland's well-established Tier 2 methodology used to estimate the annual increase in forest carbon stocks in Ireland's expanding forests. A detailed account of the model used (CARBWARE version 4) is available (Gallagher et al, 2004). The output from the model has been updated to include 2010 forestry data. This is a static model, which has been used to calculate the total standing carbon content of forests year-on-year using Irish forest yield models and appropriate values of biomass expansion factor, wood density and carbon content for the various tree species to be found in Irish forests. Wood harvest is determined separately from national statistics and converted to carbon using the same values of biomass expansion factor and carbon content. In the submissions up to 2005, the value of carbon removals reported for a particular year in LULUCF Table 5.A of the former CRF is the difference between standing carbon stock at the end of that year and carbon stock at the end of the previous year. This value represents the total for the above-ground biomass and below-ground biomass pools in both *5.A.1 Forest Land Remaining Forest Land* and *5.A.2 Land Converted to Forest Land* under the present reporting scheme.

Given that it quantifies annual change in forest biomass, the CARBWARE version 4 model is retained as the basic methodological tool for estimating carbon stock increment in LULUCF categories 5.A.1 and 5.A.2. To account for age-class differences in stand volume the areas within categories 5.A.1 and 5.A.2 are appropriately split on the basis of the age of forests. The age class categories are based on the mean yield class of the most commonly occurring species in Ireland, Sitka spruce (see Gallagher et al., 2004). Version 4 of the model, as used to date, only accounts for total forest area in the following age classes

(i) Areas of young forest from 7 to 25 years of age. Biomass CSC for age classes less than 7 years old are assumed to be zero because timber volume is not defined for such young crops in the yield class tables. Gallagher et al (2004) acknowledge that this is a conservative under estimation of biomass CSC. As mentioned above this will be revised when a repeat NFI becomes available so that Convention reporting of biomass CSC can be harmonised using CARBWARE v 5;

(ii) Areas of mature forests greater than 25 years old and

(iii) Cleared and unclassified areas, which are assumed not to store carbon in the biomass and DOM carbon pool. This area class represents total identified forest area by the Forest Service less age class categories (i) and (ii) as located by remote sensing and classified in the Forestry Inventory and Planning System (FIPS) (Fogarty, 1999).

The age class, (i) and (ii) categories, are then further broken down in to species categories to provide species and age class strata (Gallagher et al., 2004). The area representing category *5.A.2 Land Converted to Forest Land* is determined from the afforestation area statistics based on a 20 year land use transition (see annex G and table G.1).These areas would therefore only include young forests in class (i) above. The area for category *5.A.1 Land Remaining Forest Land* (includes age class categories (i), (ii) and (iii)) is then the total forest area less that for category 5.A.2 (see Annex G). The allocation of carbon uptake to above-ground biomass and below-ground biomass is achieved by partitioning between these two carbon pools in the ratio 0.8:0.2 (Black et al., 2009). Carbon storage in this approach is attributed only to forests old enough to have biomass (i.e. more than six years old), rather than to all planted areas. The CARBWARE model does not cover deforestation and therefore cannot provide information on forest lands converted to other land categories. Other methodologies are used to report on deforestation activities. The following paragraphs summarise the carbon accounting methodology applied for carbon stock change in living biomass in the CARBWARE v4 model. The activity data (forest areas, afforestation rates, harvest, etc) and the estimated carbon stock changes in biomass for *5.A Forest Land* are compiled in Table G.1 of Annex G for the years 1990-2010.

#### 7.3.1.1 Forest Area and Species

A time series of forest strata by area and age was constructed for the years 1990-2010 using information from the FIPS base year of 1995 and the total forest area as given by the Forest Service. The FIPS survey data comprise recorded and interpreted information on areas and species for identified state forests and private forests. The young crop (7 to 25 years of age inclusive) and mature crop (greater than 25 years) classes in FIPS were broken down by species to provide nine individual strata. A third broad class covering cleared/unclassified areas was included so that the total Forest Service area was accounted for in all years. This area class includes felled areas in which forest cover had not been re-established (up to 5 years after felling), recent plantings less than 7 years old, which are assumed to have no measurable biomass CSC, and other productive un-forested areas. Areas which had not been replanted after 5 years are assumed to be deforested (see Chapter11)

Having established the basic area-species matrix for 1995, the corresponding data for the years 1996 to 2010 were obtained by accounting for annual changes in area per species, using annual data on planting and clear felling rates (Annex G), while also taking into account the progression of forested areas between the cleared, young and mature categories on the basis of age. The process was worked in reverse (backward extrapolation) for the years 1994 to 1990 to obtain consistent time-series data for this period, as shown in Annex G.

The total forest areas shown in column G in Table G.1 of Annex G have been slightly revised up to 2010 to be consistent with areas reported under Article 3.3 of the Kyoto Protocol described in Chapter 11 of this NIR. The areas presented in the Convention CRF tables, i.e. corresponding to columns E and F of Table F.1, are now equivalent to the sum of the afforestation, reforestation and deforestation and forest management areas shown in the supplementary reporting related to the Kyoto Protocol (Table 11.1 of Chapter 11). The area adjustment has resulted in recalculation for the entire time series.

#### 7.3.1.2 Volume

The FIPS survey results do not contain timber volume (to a top diameter of 7 cm) or increment data. Therefore, the volume of stem wood was determined from Irish yield models (Hamilton *et al*, 1971; Forest Service, 2000) and is based on periodic current annual increment (Gallagher et al., 2004). The Coillte average weighted yield class (wood production model) was applied to all public and private sector forests for each of the FIPS categories. Main crop volume after thinning was used for conifers. The volume after thinning was used because increment was expressed net of harvest; hence biomass losses or gains are reported as net gains or losses in the CRF tables. The stand volumes used were assumed for young and mature conifers at ages of 15 and 35 years, respectively (Gallagher et al., 2004). This would represent the mean stand volume after thinning for conifer crops in age classes (i) and (ii) described above.Young broadleaved crops were allocated a nominal standing volume of 10 $m^3$/ha (Gallagher et al., 2004).

The mean net volume per ha in mature broadleaved forests was determined from the total timber volume recorded in the inventory of private woodlands (Purcell, 1979), divided by area. Mixed mature forest volume was based on an average for the mature other conifers and broadleaves strata. The standing volume is reduced by 15 per cent to allow for forest roads and rides (open areas based on FIPS 95). The reduced volumes are multiplied by biomass expansion factors (BEF) of 2 for young forests and 1.4 for mature forests (which give a weighted BEF of 1.64 for all forests), dry density in the range 0.35-0.55, depending on species and age, and carbon fraction (0.5) to obtain biomass (t C/ha) according to equations 7.2 and 7.3 below (also see Gallagher et al., 2004). The BEF used represents the total biomass ratio to total timber biomass (defined to timber to a top height of 7cm, Black et al., 2004).

#### 7.3.1.3 Harvest

Coillte records are the main source of data for wood harvesting. These data (Table G.1 of Annex G) are compiled using data national data submitted to the FAO and EUROSTAT. For earlier years Coillte harvesting records were used. The annual wood harvest volumes for the main species (broadleaves, spruce, pine and other conifers) are converted to carbon using the average carbon content of 0.5, dry carbon densities of 0.35 to 0.55 depending on species and weighted biomass expansion factor of 1.64, as in the case of volume increment. Harvest volumes include firewood, which is estimated to be in the region of 30,000 $m^3$/year.

#### 7.3.1.4 Carbon Stock Change

The mean carbon stock of each age class and species strata (i.e. FIPS category) for the **above ground** (AB) and **below ground** (BB) C pools were calculated from the mean standing volume (V, to top diameter of 7cm) of the forest stand, as specified by the FIPS category, a basic density (D) in the range 0.35 to 0.55 (depending on tree species), a biomass expansion factor (BEF) of 1.64$t/t^{-1}$, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2 (Black et al, 2009).

$$TOTAL_{(AB)} = (V \times D \times BEF \times CF) \times (1 - R) \quad (7.2)$$

$$TOTAL_{(BB)} = V \times D \times BEF \times CF \times R \quad (7.3)$$

Hence total biomass C = $C_{(AB)} + C_{(BB)}$

The equations are similar to those used in the IPCC GPG (2006) eq. 2.8 PG 2.12 Chapter 2. However, these are mean estimates for FIRS category strata and the term (1-R) is included for above ground biomass because BEF is defined as the ratio of total biomass to timber biomass. Similarly, the term R is included in the below ground biomass calculation. The carbon stock change (ΔC) in biomass for any given year (tn) was then calculated using the sub-category area (A) and total biomass C stock (C):

$$\Delta C = A * [(C_{tn+1} - C_{tn})] \quad (7.4)$$

The changes in biomass are reported net of harvest and therefore include gains and losses. The net change is the increment less the harvest, as the thinning volumes have already been deducted in the data used and the areas are net of clear-felled volumes.

#### 7.3.1.5 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):

$$C_{L(Total)} = C_{L(AB)} + C_{L(BB)} = TOTAL_{(Biomass)} lost \quad (7.5)$$

The carbon stock **losses ($C_L$)** 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 $1.68 t/t^{-1}$, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2, as described in Eq 7.2 and 7.3 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 Chapter 11 for details). There is, however, no activity data for deforestation data prior to 2006. Therefore, mean implied emission factors for the period 2006-2010 (biomass gains and losses) are applied to area data to derive estimated of losses in the years before 2006.

### 7.3.2 Carbon Stock Change in Dead Organic Matter

Dead organic matter consists of the dead wood and litter pools. For dead wood the Tier 1 approach is used, which assumes that input is equal to output and therefore the net carbon stock change is zero for both forest remaining forest and land converted to forest categories (Section 3.2.1.2 and 3.2.2.2 of the GPG for LULUCF). In the case of litter, the litter pool carbon stock changes submitted in 2009 have been recalculated using country specific data. Litterfall for broadleaf (based on sycamore ask, birch, yield class 6) and conifer crops (based on Sitka spruce yield class 16) was calculated using the Tier 3 methodology. The annual litterfall was determined as a function of leaf biomass using algorithms based on diameter at breast height (DBH) and height (H) for broadleaves (Johansson, 1992) and conifers (Tobin et al., 2006). Litterfall was then calculated using a mean leaf lifetime of 5 years for conifers, i.e. 20 per cent of leaf biomass per year (Tobin et al., 2006), and 1 year for broadleaves assuming all leaves are lost each year. Additional litter inputs from harvesting activities are also taken into account. The decay constant for litter was assumed to be 0.14 t C/ha/yr based on experimental data taken from published Irish research (Saiz et al., 2007). Based on these analyses the mean net litter stock change for broadleaves was 0.31 t C/ha/yr young crops (< 20 years old) and 1.49 t C/ha/yr for old crops (>20 years old). The net litter stock change in conifer crops based on Sitka spruce yield class 16 was 0.5 t C/ha/yr for young crops (< 20 years old). This value is consistent with recently published values of 0.43 t C/ha/yr for a Sitka spruce chronosequence (Black et al., 2009). The net accumulation of litter in mature conifer crops varied from 0.7 t C/ha/yr for thinned plantations to 1.2 t C/ha/yr for unthinned areas. It is assumed that 74 per cent of all conifer crops are thinned, based on National Forest inventory statistics (NFI, 2007). Therefore a weighted mean of 0.67 ha/yr was used for old conifer crops (>20 years old). Modification of the litter pool emission factors based on new research information has prompted a recalculation of the time series 1990-2007 (see recalculations). This methodology is also broadly consistent with the method used for reporting on Article 3.3 activities (Chapter 11).

It is assumed that afforested and reforested areas less than 7 years old do not contribute to the dead organic matter pool, which is consistent with the approach above for estimating the carbon stock change in living biomass. Young forest areas, computed for rolling 20-year periods (e.g. 1971-1990, 1972-1991 etc), are split as 7 per cent broadleaf and 93 per cent conifer based on the species distribution in the 1995 FIPS baseline year. The area of mature forests is calculated as total forest area less young forest area and reforested area for the preceding seven years. This represents the litter producing area assuming there is no litter input in the first 7 years following reforestation. It is also assumed that the reforested area equals the harvested area. The broad leaf and conifer proportions for old forests are 31 per cent and 69 per cent, respectively, again chosen on the basis of the 1995 FIPS baseline year species distribution.

The accumulated litter and DOM pool was assumed to be immediately oxidised when deforestation occurs (see Chapter 11). 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$^{st}$ 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.

### 7.3.3 Net Carbon Stock Change in Soils

#### 7.3.3.1 All Forest Lands (5.A.1 and 5.A.2)

There has been an annual increase in the national forest area since 1970. 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. In order to maintain consistency, the land areas used for estimating carbon stock changes in soil are those used by DAFM in the estimation of carbon stock changes in forest biomass and in dead organic matter. The same split of the total for *5.A.2.Land Converted to Forest Land* is applied for all years (Table G.1 of Annex G) with *5.A.2.3 Wetlands Converted to Forest Land* accounting for 57 per cent of the total area.

Using GIS analysis, land areas were allocated to the conversion categories 5.A.2.1 through 5.A.2. Lands converted to forest land were determined from the FIPS (database, supplied by the Forest Service, which records the areas converted as spatially defined areas. The Forest Service GIS database is a comprehensive description of all existing holdings and activities dating back to 1920. This database system provides detailed information on individual land conversion areas and plantation date from 1990 for private afforestation under grant-aided schemes. Prior to 1990, total annual afforestation area was used to provide annual afforestation data from 1920.

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. Where the previous land use was clearly anomalous, for example where it was indicated by CORINE that the afforested area was a water body, it was assumed that the trees were actually planted on a sub-area of unimproved grassland, which is included in the category 5.F Other Land.

Forest soils[2] 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. Previously, 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 form 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 F-F (younger than 50 years) and F-L 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 (15 per cent of the total area, the same as the volume Gallagher et al., 2004), 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 11.3.2.2 and under organic soils below).

[2] 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 7.7: Area (in kha) of different forest soils types over the times series for forest land remaining forests*

| Year | Total Area[1] | Adjusted for open area[2] | Sites >50 years old[3] | Organic soils[4] | Organo-mineral soil[5] | Mineral soils[6] | Total organic years[7] |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **1990** | 305.6 | 259.8 | 66.4 | 64.7 | 31.1 | 97.5 | 161.6 |
| **1991** | 315.7 | 268.4 | 66.5 | 73.6 | 30.9 | 97.4 | 172.8 |
| **1992** | 325.7 | 276.8 | 66.7 | 82.2 | 33.3 | 94.6 | 187.6 |
| **1993** | 335.5 | 285.1 | 65.8 | 90.8 | 35.5 | 93.0 | 200.8 |
| **1994** | 344.7 | 293.0 | 65.0 | 95.7 | 38.1 | 94.2 | 209.3 |
| **1995** | 353.6 | 300.6 | 63.4 | 100.2 | 38.9 | 98.0 | 213.9 |
| **1996** | 361.9 | 307.6 | 63.4 | 105.7 | 38.9 | 99.6 | 220.6 |
| **1997** | 369.9 | 314.4 | 72.0 | 113.6 | 38.3 | 90.5 | 239.0 |
| **1998** | 377.8 | 321.1 | 72.6 | 120.1 | 39.2 | 89.3 | 249.0 |
| **1999** | 385.3 | 327.5 | 72.2 | 124.8 | 39.9 | 90.6 | 255.3 |
| **2000** | 390.7 | 332.1 | 70.4 | 129.0 | 40.7 | 92.0 | 259.6 |
| **2001** | 396.2 | 336.8 | 70.1 | 134.8 | 41.7 | 90.1 | 268.1 |
| **2002** | 401.9 | 341.6 | 69.3 | 139.7 | 42.6 | 90.0 | 274.5 |
| **2003** | 407.0 | 346.0 | 69.9 | 143.9 | 42.9 | 89.3 | 280.8 |
| **2004** | 411.8 | 350.1 | 69.0 | 147.2 | 42.9 | 91.0 | 283.7 |
| **2005** | 416.2 | 353.8 | 68.1 | 147.3 | 43.0 | 95.4 | 282.4 |
| **2006** | 422.8 | 359.4 | 69.9 | 148.5 | 46.3 | 94.7 | 289.7 |
| **2007** | 430.8 | 366.2 | 71.4 | 151.1 | 48.4 | 95.3 | 296.8 |
| **2008** | 442.2 | 375.9 | 73.0 | 157.6 | 48.6 | 96.8 | 306.3 |
| **2009** | 457.2 | 388.6 | 77.1 | 158.7 | 50.9 | 101.8 | 313.6 |
| **2010** | 472.9 | 401.9 | 76.0 | 164.4 | 52.7 | 108.8 | 320.7 |

*[1] Total area includes open areas*
*[2] Adjusted area for 15 % open area within forest areas (roads, extraction routes, biodiversity etc).*
*[3] No emissions from organic soils on sites older than 50 years old, (Data source NFI)*
*[4] Organic soils include all soils with a > 20% C and an organic layer greater than 30 cm (e.g. Blanket peats, fens, cutaway peats. All organic soils are assumed to be drained. These areas are used in eq 7.5.*
*[5] Organo-mineral soils are mineral soils with an organic overlay of < 30cm. These include peaty podsols and peaty gleys (Source NFI). These areas are used in eq 7.6*
*[6] Mineral soils are shown not to be a source so are reported as zero (NA). These include brown earths, podsols, gleys, brown podsolics, lithosols etc. (Source NFI).*
*[7] Area presented in CRF Tables. The total area of organic soils includes open areas and organic soils with forests older than 50 years old*

*Table 7.8 Area (in kha) of different forest soils types over the times series for land converted to forest land*

| Year | Total Area[1] | Adjusted for open area[2] | Organic soils[3] | Organo-mineral soil[4] | Mineral soils[5] | Total organic area[6] |
|---|---|---|---|---|---|---|
| | | | | | | |
| **1990** | 175.4 | 149.1 | 83.8 | 22.4 | 42.9 | 124.9 |
| **1991** | 184.5 | 156.8 | 84.0 | 24.4 | 48.4 | 127.5 |
| **1992** | 191.2 | 162.5 | 85.4 | 25.3 | 51.8 | 130.3 |
| **1993** | 197.4 | 167.8 | 85.2 | 25.8 | 56.8 | 130.6 |
| **1994** | 207.6 | 176.4 | 88.1 | 25.8 | 62.6 | 133.9 |
| **1995** | 222.1 | 188.8 | 93.7 | 28.7 | 66.4 | 144.0 |
| **1996** | 234.5 | 199.3 | 98.4 | 29.5 | 71.4 | 150.4 |
| **1997** | 237.5 | 201.9 | 98.3 | 29.6 | 74.0 | 150.5 |
| **1998** | 242.2 | 205.9 | 97.2 | 31.5 | 77.2 | 151.4 |
| **1999** | 247.0 | 210.0 | 96.7 | 32.3 | 80.9 | 151.8 |
| **2000** | 256.5 | 218.0 | 97.7 | 34.5 | 85.9 | 155.5 |
| **2001** | 265.6 | 225.8 | 99.3 | 36.8 | 89.6 | 160.2 |
| **2002** | 274.1 | 233.0 | 99.7 | 38.5 | 94.8 | 162.6 |
| **2003** | 277.2 | 235.6 | 100.9 | 38.8 | 95.9 | 164.4 |
| **2004** | 281.3 | 239.1 | 101.6 | 39.6 | 97.9 | 166.1 |
| **2005** | 286.1 | 243.2 | 103.3 | 40.3 | 99.6 | 168.9 |
| **2006** | 287.2 | 244.1 | 103.7 | 40.4 | 100.0 | 169.6 |
| **2007** | 286.0 | 243.1 | 103.3 | 40.3 | 99.6 | 168.9 |
| **2008** | 280.6 | 238.5 | 101.3 | 39.5 | 97.7 | 165.7 |
| **2009** | 272.1 | 231.3 | 98.3 | 38.3 | 94.7 | 160.6 |
| **2010** | 264.6 | 224.9 | 95.5 | 37.2 | 92.1 | 156.2 |

[1] *Total area includes open areas*
[2] *Adjusted area for 15 % open area within forest areas (roads, extraction routes, biodiversity etc).*
[3] *Organic soils include all soils with a > 20% C and an organic layer greater than 30 cm (e.g. Blanket peats, fens, cutaway peats. All organic soils are assumed to be drained. These areas are used in eq 7.5.*
[4] *Organo-mineral soils are mineral soils with an organic overlay of < 30cm. These include peaty podsols and peaty gleys (Source NFI). These areas are used in eq 7.6*
[5] *Mineral soils are shown not to be a source and are reported as zero (NA). These include brown earths, podsols, gleys, brown podsolics, lithosols etc. (Source NFI).*
[6] *Area presented in CRF under total area of organic soils includes open areas*

### 7.3.3.1.1 Soil and land use transition matrices

Once the area for the 3 broad soil categories were established, these were further disaggregated in to the previous land use categories under lands converted to forest land (CRF 5A.2.1 to 2.5) using NFI PSP and CORINE 1990 and 2000, as described above. Table 7.9 shows the breakdown of organic soils under the different land use categories converted into forest land. The proportional areas for the period 1990 to 2000 were adjusted using linear interpolation to reflect the change in soil type and land conversions between CORINE 1990 and 2000. The organic soil areas afforested in other land was derived from the difference of all afforested organic soils minus cropland, grassland, and wetlands. The proportionate areas within each land use conversion after 2000 was assumed to be constant. Most organic soil conversions to forestry occur in the Wetland category, primarily representing peat soils. There are no conversions from Settlements to forestry. Cropland conversion to forests only occurred on soils types represented by peaty mineral soils (organo-mineral categories).

*Table 7.9 Percentage of organic soils in each land use type converted to forest land under CRF 5A 2.1, 2.2, 2.3 and 2.5*

| | Cropland | Grassland | Wetland | Other |
|---|---|---|---|---|
| 1990 | 1.4 | 16.9 | 77.7 | 4.1 |
| 1991 | 1.4 | 16.6 | 79.4 | 2.6 |
| 1992 | 1.4 | 16.0 | 80.0 | 2.6 |
| 1993 | 1.4 | 15.7 | 81.8 | 1.1 |
| 1994 | 1.4 | 15.3 | 83.2 | 0.1 |
| 1995 | 1.4 | 14.3 | 82.2 | 2.1 |
| 1996 | 1.4 | 13.7 | 82.4 | 2.5 |
| 1997 | 1.4 | 13.0 | 82.9 | 2.8 |
| 1998 | 1.3 | 12.3 | 83.3 | 3.0 |
| 1999 | 1.3 | 11.6 | 84.1 | 2.9 |
| 2000 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2001 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2002 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2003 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2004 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2005 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2006 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2007 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2008 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2009 | 1.4 | 11.2 | 86.9 | 0.6 |
| 2010 | 1.4 | 11.2 | 86.9 | 0.6 |

#### 7.3.3.1.2 Mineral soils - Forest Land remaining Forest Land (5.A.1)

Under the Tier 1 approach it is assumed that the carbon stock changes (CSC) in soil organic matter for category *5.A.1 Forest Land remaining Forest Land, FF,* on mineral soils are not a source (see Chapter 11), regardless of changes in forest management, forest type and disturbance. Mineral CSC is therefore not reported in accordance with requirements set out under annex 1 of 15 CMP/1 paragraph 6e.The notation key NO is therefore used for mineral soils under this land category in CRF Table 5.A.

#### 7.3.3.1.3 Mineral soils - Land converted to Forest Land (5.A.2)

National forest soils data base analysis and chronosequence soil stock changes (Black et al., 2009; Wellock et al., 2011 Chapter 11) shows that there is no significant change in mineral soil C stocks for up to 30 years following transitions between grasslands and forest land. (see Chapter 11.3.1.2.). Therefore, Ireland has elected not to account for mineral soil C stock changes following afforestation and deforestation form and into grassland uses, because we demonstrate that this pool is not a source across different mineral soil types. However, research in this area is on-going and new methods will be developed if new trends emerge. The notation key NA is therefore used for mineral soils under this land category in CRF Table 5.A.

In previous submission, an inconsistency arose between the attribution of previous land use for reporting of biomass and litter carbon pools and soils. This is resolved in the 2012 submission. For biomass and litter pools, it was assumed that 10 per cent of afforested areas had previously been under Cropland, It has been assumed in the soils analysis that no afforestation occurred on cropland. In the 2012 submission, the soils analysis has been revised to provide consistency with the other carbon pools. This has a knock on effect on the areas reported for all land uses, where the area of afforestation on cropland is no longer subtracted from Grasslands, Wetlands and Other Lands.

#### 7.3.3.1.4 Organic soils

Ireland now uses a new 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 soils 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, 2010). 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).

The emission for peat soils (i.e. organic soils with a depth greater than 30 cm) is based on published data from Byrne and Farrell, 2005).

$$\Delta C_{So} = \sum_i \left( A_i \times EF_{soil} \right) \quad (7.6)$$

The area ($A_i$) of peat soils ($i$) is multiplied by the $EF_{soil}$ of 0.59 t C $ha^{-1}$ $year^{-1}$ for the first 50 years following afforestation.

#### 7.3.3.1.5 Organo-mineral soils

Emission from peaty/mineral soils ($j$) is calculated in the same way, but with the addition of a soils depth function (SD) to account for a smaller organic C pool loss:

If soil depth < 30 cm then, $\Delta C_{So} = \sum_j \left( A_j \times (EF_{soil} \times SD \right)$ ………………………………… (7.7)

Where,

$$SD = \frac{depth(cm)}{30cm} \quad (7.8)$$

Organic layer depth was obtained from the NFI plots. Where data was not supplied or missing an organic soil layer depth of 15 cm was assumed for these soils types (e.g peaty gleys and peaty podsols).

### 7.3.4 Emissions from Biomass Burning

Estimates of emissions from forest biomass burning in Ireland relate to forest wildfires. The estimates are improved in this submission following some amendments to areas based on new information from the Forest Service. 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*. The emissions are, however, only reported in the forest land remaining forest because no geographically explicit data on fires are available to distinguish between fires occurring in these categories. Forest land subject to wildfires in the young forest land class under *5.A.1 Forest Land Remaining Forest Land* is equally distributed among all species cohorts;
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. 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 is determined as described under section 7.3.1 using the forest areas burned over the period 1990 to 2010.
5) The direct effect of wildfires on DOM are now included in the oxidation biomass, based on the mean DOM C stock (per ha) for a yield class 16 Sitka spruce forest (the most representative productivity and forest type in Ireland). The mean C stock for the DOM over one rotation up to 50 years is 10.2 t C per ha, equivalent to 20,400 kg biomass per ha. 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 CARBWARE 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.

### 7.3.5 Emissions of $N_2O$ from Fertilisation

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

### 7.3.6 Emissions of $N_2O$ from Drainage

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

The NFI data was used to derive a breakdown of areas for drained mineral, rich organic and poor organic soils over the time-series 1969 to 2005, based on planting year, soil type and cultivation type. Soils were assumed not to be drained if there was no cultivation or if pit planting was employed during forest establishment. It is assumed that all organic soils are drained. This includes previously drained sites, such as cutaway peats, where drainage occurred before afforestation occurred. Sites were then further categorised in to mineral (soils with no organic layer), rich N organic (peaty-gleys) and poor N organic (all remaining peats and peaty mineral soils). The total area subjected to drainage was also adjusted by a factor of 0.85 to account for open areas within forest areas, where no drainage occurs. The proportion of the three tier 1 soil types subjected to drainage for the young and mature time-series are determined from this soil/drainage matrix. The default emission factors were used for mineral, poor organic and rich organic soils (IPCC GPG, LULUCF Appendix 3a.2; Table 3a.2.1 pp 3.275.). The inclusion of $N_2O$ emissions from forest soils contributes emissions of 17 to 36 Gg $CO_2$ equivalents for the years 1990 to 2010.

### 7.3.7 Deforestation Areas

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 and 0.12 kHa in 2010 (see Ch 11 and Table 7.7). 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.

#### *New methodology*

Lack of a method to record historic land use change was a previously significant gap in the previous LULUCF inventory, until the 2009 submission. The following approached are used to determine deforestation areas. (see Annex G):

#### 1) Sampling approach: NFI grid points and aerial photography

This is a modification of approach 3, where the grids or centroids are sampled using a systematic sampling procedure adopted in the NFI (see Chapter 11).

Assessment of ca.18000 NFI point intersects with aerial photographs form 2000 and 2006 provides the opportunity to report deforestation for this period. This method identified 15 NFI PSP grid samples, which were deemed to be deforested between 2000 and 2006. The current land uses of these previously deforested lands were determined from photo interpretation using the 2006 images.

Assessments of deforestation from 1995 to 2000 were based on a GIS intersection of the 18000 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 appendix on deforestation methodology for detailed information).

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

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

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

### 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 2011 submission. These activity data come from felling licence applications and are limited to the years 2006, 2007, 2008 and 2009. 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 2011. 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. Based on experience and expert judgement, it is considered that all forest land uncertified for replanting is restocked within three years following clear fell. The breakdown of land-use conversion from forest land into other categories for the years 1990 to 2009 is shown in Table 7.7.

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.

The final deforestation trends for the period 1990 to 2010 were derived using a combination of the approaches described above (and see Annex G).

***Table 7.10. The new deforestation, land use change and soil type matrix showing annual deforestation areas (ha/ year) associated with different land uses and soils categories***

| | | | | | | Land use/soil type | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | Grassland | | | Setlement | | | Wetland | | | Other | |
| | | Mineral | Organic | Organo mineral | Mineral | Organic | Organo mineral | Mineral | Organic | Organo mineral | Mineral | Organic | Organo mineral |
| **1990-1994** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 20.6 | 2.5 | NO | 5.7 | 10.2 | NO | NO | NO | NO | NO | 2.2 | NO | NO |
| % | 100 | 12.2 | | 27.9 | 49.4 | | | | | | 10.5 | | |
| **1995-1999** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 333.3 | 266.7 | NO | NO | NO | NO | NO | NO | NO | NO | 66.6 | NO | NO |
| % | 100 | 80 | | | | | | | | | 20 | | |
| **2000-2006** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 857.1 | 342.8 | NO | 57.4 | 171.4 | NO | NO | 56.6 | 114 | NO | 57.4 | 57.4 | NO |
| % | 100 | 40 | | 6.7 | 20 | | | 6.6 | 13.3 | | 6.7 | 6.7 | |
| **2006** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 375.8 | 5.3 | NO | 19.7 | 17.1 | NO | 0.6 | NO | 299.9 | 30.8 | 3.1 | NO | NO |
| % | 100 | 1.4 | | 5.2 | 4.5 | | 0.2 | | 79.9 | 8.2 | 0.8 | | |
| **2007** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 338.7 | 0.6 | 14.5 | NO | 4.6 | 0.8 | NO | NO | 297.2 | NO | 8.6 | 124 | NO |
| % | 100 | 0.2 | 4.3 | | 1.4 | 0.2 | | | 87.7 | | 2.5 | 3.7 | |
| **2008** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 294.6 | 80.3 | NO | 66.5 | NO | NO | NO | NO | 24.5 | 21.2 | 101 | NO | 1.1 |
| % | 100 | 27.2 | | 22.6 | | | | | 8.3 | 7.2 | 34.3 | | 0.4 |
| **2009** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 196.9 | 5.1 | NO | NO | 15.4 | 1.5 | 1.5 | NO | NO | NO | 121.1 | 19.9 | 32.4 |
| % | 100 | 2.6 | | | 7.8 | 0.8 | 0.7 | | | | 61.5 | 10.1 | 16.4 |
| **2010** | | | | | | | | | | | | | |
| Area (ha yr$^{-1}$) | 124 | 39.7 | NO | NO | 7.9 | NO | 47.2 | NO | 6.5 | NO | 18.5 | 4.5 | 6.1 |
| % | 100 | 18.5 | | | 6.3 | | 37.9 | | 3.7 | | 14.8 | 3.2 | 4.9 |

* No transition from forests to croplands were detected
[a] Source CORINE CLC 1990-2000
[b] Source FIPS 95 and NFI 1995-2000
[c]NFI 2000-2006
[d] Felling licence information

## 7.4 Cropland (Category 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 submissions prior to 2008, it was maintained that approximately 3,000ha of peatland was subject to inversion tillage. This was based on a GIS analysis, which superimposed high resolution Land Parcel Information System data on lower resolution soil distribution maps and contradicted the general acceptance that there was negligible cultivation of organic soils in Ireland. Following the in-country review in 2007 and 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 peat occurs, and the GIS result can be regarded as indicating zero cultivation within the error margins associated with this type of analysis. Therefore, the organic soil area designated as being under cropland in submissions prior to 2008 has been reallocated to mineral soils and cropland organic soils are designated as "not occurring", i.e. "NO" in the CRF tables. This action has a knock-on effect in other land use categories, as new cropland areas on organic soils are no longer required to transfer to, or from, grasslands, with an equivalent change in the dynamics of transfer of mineral soils between classes.

Croplands are assumed to revert to natural grassland status during set-aside (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 includes 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. 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

#### 7.4.2.1 Cropland remaining Cropland: Perennial Crops

Agricultural data from the CSO is not explicit regarding the national area of land under perennial (woody) crops. However, in Ireland, these are exclusively fruit crops (e.g. apples, berries) and are included in the total CSO fruit area. However, this would also include non-woody soft fruits (e.g. strawberries). The total fruit area reported in 1990 was 1.54 kha, and in 2009 it was 1.60 kha. It can therefore be reasonably assumed that the area of perennial woody cropland has been constant over the reporting period, the crops are well established and in a dynamic equilibrium with respect to carbon stocks, and changes in area and stocks are negligible. The estimated change is less than the uncertainty in the survey data. Therefore, no estimate has been made for carbon loss within this category of Cropland remaining Cropland.

### 7.4.2.2 Cropland in Transition

The living biomass stock change relates to the aggregate of, above-ground and below-ground biomass mass and its estimation is based on the difference between initial and final carbon content of biomass for the lands converted. In the conversion of land to cropland, it is assumed under the Tier 1 approach that the dominant vegetation from the initial land use is removed entirely. The carbon stock change is then quantified as the net sum of carbon lost on conversion and the carbon added by the first year's growth of crops. Grassland is the only relevant land-use type undergoing conversion to cropland in Ireland. The dry matter content of grassland is taken as 12.0 tonnes/ha (based on the discussion in Table 3.4.9 of the IPCC GPG[3]) 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 due to growth in crop biomass after one year for annual crops. The carbon stock change in biomass on the area (A) converted to cropland is then calculated from Equation 3.3.8 of the IPCC good practice guidance as follows:

$$\Delta C = A * [ (C_{after} - C_{before}) + \Delta C_{growth} ] \qquad (7.9)$$

$$\Delta C = A * [ (12.0 * 0.5 - 0.0) + 5.0 ]$$

That is an overall loss of carbon stock in the conversion from grassland to cropland.

## 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 very high proportions (98 per cent) of croplands are located on Low Activity Clay (LAC) soils. It is assumed that only grasslands on LAC soils are suitable for direct conversion to croplands, which is consistent with the requirement for cropland productivity. It is therefore reasonable to assume that all grassland areas converted to croplands are also on LAC soils and that no other land categories are converted to croplands.

For cropland remaining cropland, farm management and input practices, are assumed to have been constant over the inventory period for these established croplands. It is assumed that the SOC will have attained equilibrium with respect to direct anthropogenic inputs. Therefore the SOC will not have changed for mineral soils, with the exception of those lands going to set-aside for short periods within the transition period of 20 years. In line with expert opinion it is assumed that no cultivation occurs on organic soils, as discussed in 7.4.1. For cropland in transition, the carbon stock changes in mineral soils are estimated using equation 7.10.

$$\Delta C = A * ( SOC_{crop} - SOC_{grass} ) / T \qquad (7.10)$$

Where $SOC_{grass} = SOC_{LAC} * F_{grass} = 85 * 1.14 \text{ t C ha}^{-1}$
$SOC_{crop} = SOC_{LAC} * F_{crop} = 85 * 0.86 \text{ t C ha}^{-1}$
T=20 years

Therefore, there is a loss of carbon from soils in conversion from grassland to cropland.

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[3] 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.

### 7.4.4 $N_2O$ Emissions in Cropland

Soil disturbance associated with land-use conversions to cropland result in minor emissions of $N_2O$. Emissions from this category were reported in the 2008 submission for the first time following recommendations from the in-country review conducted in 2007. Such emissions are estimated for mineral soils in category 5.B.2.2 Grassland Converted to Cropland and the estimates are included in CRF Table 5(III). The estimates are calculated from the change in soil organic carbon over the 20 year transition period, obtained using Equation 7.1 for the land-use and soil type converted to cropland, and the soil C: N ratio as follows:

$$N_2O = (\Delta C \ / R_{C:N}) * 44/28 \qquad (7.11)$$

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 (Category 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. The methodology for estimating Grassland area has not changed from the previous submission. Any revisions are due to the knock-on effects of changes in other land classes.

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 sheep farming policy, 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 potentially underestimates the effect of rough grazing, but insufficient data exists to quantify the impact. However, as the area of rough grazing has been generally declining in the period since 1990, with rough grazing areas either reverting to natural grassland or converted to improved grassland, the assumption of constant biomass is unlikely to have caused a systematic underestimation of the overall emissions.

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 it is only possible to derive net changes in agricultural areas (grassland and croplands) from the CSO statistics. 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 the Marine. 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 CSO are undertaking a major revision of methodology used to estimate utilised agricultural area. Revised areas for selected crops are available from 2008-2010. However, the analysis of other agricultural areas has not been completed in time for the 2012 submission. Therefore, in order to provide an estimate of change grassland area for this submission, the recent trends in grassland areas (2007-2009) have been extrapolated to 2010. It is anticipated that a recalculation of the 2012 submission will be required next year because of this, with a backwards re-analysis of agricultural areas likely.

### 7.5.2 Carbon Stock Changes in Grassland

The carbon stock changes are estimated 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

Living biomass here refers to the aggregate of above-ground and below-ground 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 7.9 above. The biomass value of cropland converted to grassland is taken to be 5 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. As noted in section 7.4.2.1, it is not possible to determine a robust estimate of possible conversion of perennial cropland to grassland. However, as also noted, the area involved is likely negligible. 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 reseeding. 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[4].

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 $SOC_{ref}$ to correct for land use and farming practice. The principal conversion affecting carbon stock change in soils is that from native grassland to rough grazing, which causes a decrease in soil carbon. Conversely, it can be seen from Table 7.6 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 managed 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 $CO_2$ emissions are calculated using the default emission factor of 120 kg C/tonne lime. Estimates are calculated for both grassland and cropland areas assuming equal rates of application on both 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 (Category 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

[4] 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.

the UNFCCC In the 2012 submission, *5.D.1 Wetlands Remaining Wetlands* have been subdivided into two categories: Exploited Wetlands Remaining Wetlands and Unexploited Wetlands Remaining Wetlands.

### 7.6.1.1 Unmanaged Wetland Areas

In this context, unmanaged wetland refers to areas of wetland which are undisturbed, or not actively managed or drained. The initial 1990 unmanaged or 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-1, (see section 7.6.2).

### 7.6.1.2 Managed Wetland Areas

In this context, managed wetlands refer to peatland areas managed and drained for the purpose of extraction of peat from both fuel and horticultural use. The major commercial actor in this area is Bord na Mona (The Irish Peat Board), which is a state owned company. The commercial exploitation of wetlands as peatlands by Bord na Mona 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 reserved. However, these lands have been transferred to the National Parks and Wildlife Service for conservation.

Also, a small area of exploited wetland has been restored to ecosystem function through drainage management and rewetting. This has led to an uptake of carbon in the revitalised biomass.

Bord na Mona supplies the area estimates for the company’s commercial peat harvesting activities. The data for Bord na Mona commercial peat extraction areas are given as totals for consecutive five-year periods for a variety of peatland categories (Table 7.7). 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$^3$ for peat m $^{-3}$ (McGoff et al. 2007). This new approach ensures consistency between the quantities of peat combusted in *1.A.4.b Residential* and the area of private peat exploitation in LULUCF. More recent data is not available for 2009 activity, however, discussion with Bord na Mona concurred with the decision to project activity in the period 2006-2008 into 2010.

***Table 7.11 Area Statistics for Peatlands (ha)***

| | 1985-1990 | 1991-1995 | 1996-2000 | 2001-2005 | 2006-2008 | Vegetation Cover |
|---|---|---|---|---|---|---|
| **Peatland Category** | | | | | | |
| Active Production Bog | 49,715 | 48,961 | 46,319 | 43,761 | 43,642 | None |
| Production Reserve (Drained) | 16,250 | 14,100 | 12,772 | 5,930 | 4,693 | Heather |
| Fringe Bog (Undrained) | 8,300 | 8,300 | 8,300 | 8,300 | 8,300 | Heather dominated Bog Vegetation |
| Partially Drained | 3,090 | 3,090 | 3,090 | 3,090 | 3,090 | Typical Bog vegetation |
| Undrained Intact Bog | 4,150 | 2,508 | - | - | 0 | Intact Bog vegetation |
| **Cutaway Areas** | | | | | | |
| Forestry (Plantation) | 2,500 | 4,000 | 4,000 | 4,200 | | Conifers |
| Forestry (Natural) | - | 100 | 800 | 2,235 | 4,200 | Birch / Willow |
| Wetland (Acidic) | 483 | 483 | 2,703 | 9,044 | 2,635 | Eriophorum, Carex, Sphagnum |
| Wetland (Alkaline) | 250 | 1,250 | 2,150 | 3,200 | 9,735 | Typha, Phragmites, Open water |
| Lands Sold/Transferred | 2,541 | 1,946 | 2,658 | 374 | 3,200 | |
| Total owned (at end of period) | 84,738 | 82,792 | 80,134 | 79,760 | | |

## 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 previous submissions, 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 which is now used in this submission.

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 t C ha$^{-1}$yr$^{-1}$ up to an equilibrium of 3 t C ha$^{-1}$.

### 7.6.2.2 Soils

The $CO_2$ emissions associated with the combustion of peat are accounted for in the *Energy* sector. An additional loss of carbon is associated with drainage and the exposure of the new peat surface annually after harvesting takes place. The annual activity data are the active production areas of Bord na Mona bog (Table 7.7), together with the areas of peatland in use by private commercial enterprises and by domestic users. All exploited peatland are nutrient-poor, as they are raised bogs (where the accumulation of peat has decoupled from river or ground water nutrient sources) or rain-fed blanket bogs. The appropriate carbon emission factor is 0.2 t C/ha, given for boreal and temperate climatic regions in the IPCC good practice guidance. The activity land area in respect of the soils carbon pool is the value that appears in CRF Table 5.D. This area is significantly larger than that relevant to the estimation of carbon stock change in biomass above.

### 7.6.3 Emissions of Non-$CO_2$ Gases

In the submissions prior to 2006, no estimate was reported for $N_2O$ emissions associated with the drainage of peatlands for commercial exploitation, as this is an optional reporting category in the LULUCF sector, therefore the notation key NE was used in CRF Table 5 (II). This position was reviewed following the in-country review of Ireland's GHG inventory in 2007. Emissions of $N_2O$ due to the drainage of peatlands are now reported and utilise the IPCC Tier 1 approach.

## 7.7 Settlements (Category 5.E)

### 7.7.1 Areas of Settlements

The area of settlements in 1990 is that given by CORINE 1990. Land converted to settlements is the area taken up by new road building, available from the National Roads Authority, and the area covered by new residential, commercial and industrial construction based on CSO annual statistics, which are extracted from floor area records for permitted development. An incomplete time series of housing types (for the years 1995-2010) was used to estimate the residential building footprint from floor area. It was assumed that approximately 50 per cent of the planning permits granted for construction were for green-field sites previously not part of the urban fabric.

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 shows 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 (Category 5.F)

### 7.8.1 Areas of Other Land

The category *5.F Other Land* includes all lands not classified under the categories 5.A through 5.E. It represents the difference between the sum of categories 5.A through 5.E and the total land area of Ireland. A large part of *5.F Other Land* is not relevant in terms of its potential for emissions or removals 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 in show 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 masks. 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 $ha^{-1}$ in the year of conversion.

## 7.9 Uncertainties in *LULUCF*

Detailed land-use datasets extending over a considerable time period are required in order to apply even the most basic Tier 1 methods of the IPCC good practice guidance to estimate emissions and removals of greenhouse gases in the land-based approach for the LULUCF sector. The analysis for the several land-use categories invariably means that datasets differing in terms of format, spatial resolution, reference years and other attributes need to be combined for national coverage of sources and sinks. It follows that a high degree of uncertainty is associated with the land area activity data in general. This is especially true of the conversion categories, which are in many cases the land-use categories having the greatest impact on carbon pools. Large uncertainties are also inherent in the parameters that determine carbon stock change factors and in the emission factors for $N_2O$ as indicated by the wide error ranges given in the good practice guidance. It is also difficult to assess to what extent the given values for broad climatic regions are relevant to Irish circumstances. For the first time, Ireland has submitted a Tier 1 level uncertainty analysis for all land uses. The Tier 1 methodology has been applied at the lowest level of disaggregation in the inventory. It has not been possible to maintain the distinction between uncertainty in activity data and emission factors in reporting uncertainty at a high level Therefore is not possible to applied Tier 1 methodology to assess Type A and Type B uncertainty and trends. Further analysis will be undertaken to address this issue in future submissions. The uncertainties in reported emissions and removals are large for the sectors overall.

## 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.

## 7.11 Recalculations in LULUCF

The recalculations for LULUCF include a number of methodological refinements 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 1990-2009 due to methodological improvements and in response to recommendations made in the ARR 2011. The impact of these recalculations on total GHG emissions in the LULUCF sector is a net decrease in removals of 52.3 per cent for 2009. The main recalculations took place in the following categories:

- Forest land areas for forest land remaining forest land were recalculated to correct for an error picked up in the QA/QC exercise in 2011. This prompted a recalculation of emissions or removals for all pools;
- Use of new EF and area matrices for organic forest soils, which are now also calculated for forest land remaining forest land (section 7.3.3). There was also a calculation error for soils under forest land in the previous which has since been corrected. This has resulted in a 6.6 per cent increase in $CO_2$(C) emissions form organic soils in the forest remaining forests. Emissions from the organic soils on lands converted to forest land decreased by 33 per cent, primarily due to an error in the applied emission factor in the 2011 submission. The recalculation has a larger impact on the trend changes over the time series because emission form organic soils are now also estimated for forest lands remaining forests (F-F). As a result F-F are a net emission in some years (see Table 7.9). These were not reflected in the previous submission due to calculations errors;
- Emissions from fires were recalculated for the 2012 submission to account for emissions from the DOM pool. There was also an error in the entry of cells into the CRF, where areas of burned forest lands were not included in previously submitted values. In this submission, the combination of a correction to the transcription error

and recalculation (inclusion of the DOM in fire emissions) has resulted in a 130 to 171 per cent increase in $CO_2$ emission across the time series, when compared to the 2011 submission. For 2009, the recalculation (2012 submission) accounted to an increase in emissions of 64 per cent, when compared to the 2011 submission;

- The areas subjected to drainage were revised based on evidence that the drained areas could have been underestimated in previous submissions. The areas of organic soils were previously considered not to be drained if the drainage attribute for sites in the NFI database where noted as poorly drained soils. This does not, however, consider that drainage could have been implemented in these sites despite the poor drainage of soils (i.e. drainage was not effective). It is now assumed that all forested organic soils are drained or were previously drained prior to afforestation. However, it is also assumed that organic soils converted back to wetlands to not continue to result in $N_2O$ emissions because drains are blocked to facilitate natural re-colonisation of peatland species. The adjustment for open areas by a factor of 0.85 resulted in an increase in the IEF from 0.09 kg N2O-N per ha (i.e value reported represent drained land only (Table 5II, CRF), in the previous submission, to 0.14 kg N2O-N per ha. The increased IEF is also due to a change in the proportion of nutrient poor and rich organic soil areas. For 2009, emission of $N_2O$ from drained forest lands increased from 0.051 to 0.12 Gg $N_2O$, when the new area adjustments were made;
- Estimates have been made for the regrowth of vegetative cover for all land uses after deforestation events;
- Recalculations based on the revision of area of land use changes due to afforestation from all land uses have been implemented. This is largely the knock-on impact of making a new provision of 10 per cent of afforestation to occur on cropland.

The net effect of the recalculations is outlined are shown in Table 7.9.

## 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 1990-2010. The present submission also contains estimates for 2008-10 in respect of activities under Article 3.3 of the Kyoto Protocol (Chapter 11), which are fully consistent with Convention reporting for LULUCF. Even though a rather simplified approach has had to be followed for many land-use categories due to the level of information available, the assessment of emissions and removals according to the reporting requirements of Decision 13/CP.9 has identified a number of important $CO_2$ emission sources, in addition to the well-known carbon sink in forests. Extensive further work has been conducted to improve completeness, methodologies and data treatment for this submission and to apply some refinements due to approaches taken for estimating emissions and removals for Article 3.3 activities. The inventory agency is continuing to collaborate with the bodies from which the key land-use and forestry datasets are obtained and has established formal arrangements for the provision of the data within the national system, in the same way as for other sectors. The agency’s capacity on GIS continues to be developed, which facilitates the assessment and integration of available datasets. It is intended to apply this capacity in a more detailed treatment of soils for future submissions.

The results of the national forest inventory are now being applied more extensively in the LULUCF inventory and this submission reflects further improvements given by this data source and by supporting research projects on climate change and forestry being undertaken over the period from 2007 to 2012. The CARBWARE development project has improved forest carbon stock change reporting tools and software to make available an integrated system that meets the reporting needs of the Convention and the Kyoto Protocol with respect to forest land. It also draws on data from the on-going 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.

It is envisaged that a fully consistent methodological approach will be applied to both convention and Kyoto forest areas when the second NFI is completed in 2012 and there is sufficient recent data to facilitate a backward extrapolation of the historic time series. FERS and the reporting agency is also exploring the possibility of changing the time series form a 20 year transition to land areas remaining in land use categories and lands converted to other land use categories before and after 1990 only. This will also ensure a consistent methodological approach with Article 3.3 and Article 3.4 activities, if elected post 2012. 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.

*Table 7.12 Percentage Change in Emissions and Removals from LULUCF due to Recalculations 1990-2009*

*a) 2011 Submission (Gg $CO_2$ eq)*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Estimates in 2011 Submission (Gg $CO_2$eq.)** | | | | | | | | | | | | | | | | | | | |
| **5.A** | **Forest Land** | **-1,137.80** | **-1,206.43** | **-1,078.00** | **-1,174.08** | **-1,155.73** | **-1,220.77** | **-1,259.54** | **-1,399.50** | **-1,534.03** | **-1,568.11** | **-1,432.28** | **-1,592.87** | **-1,776.61** | **-2,014.09** | **-1,687.09** | **-1,840.75** | **-1,882.91** | **-2,407.67** | **-3,051.70** | **-2,684.78** |
| 5.A.1 | Forest Land remaining Forest Land ($CO_2$) | -1,165.11 | -1,336.37 | -1,086.37 | -1,085.90 | -817.26 | -650.07 | -598.31 | -514.18 | -795.82 | -862.17 | -408.71 | -312.77 | -680.45 | -1,506.00 | -1,084.20 | -1,234.54 | -1,204.12 | -1,840.03 | -2,739.54 | -2,988.58 |
| 5.A.2 | Land converted to Forest Land ($CO_2$) | 15.62 | 118.08 | -3.53 | -100.99 | -351.68 | -585.09 | -676.21 | -899.52 | -752.19 | -720.02 | -1,038.63 | -1,296.59 | -1,111.36 | -525.83 | -619.75 | -622.36 | -695.14 | -584.18 | -329.03 | 287.45 |
| 5.A | Biomass burning ($CH_4$ and $N_2O$) | 1.22 | 0.78 | 0.50 | 1.01 | 1.15 | 1.55 | 1.71 | 0.94 | 0.50 | 0.40 | 1.01 | 2.00 | 0.46 | 2.83 | 1.65 | 0.60 | 0.60 | 0.68 | 0.83 | 0.43 |
| 5.A | Drainage of soils | 10.47 | 11.08 | 11.40 | 11.81 | 12.06 | 12.83 | 13.28 | 13.26 | 13.47 | 13.67 | 14.05 | 14.49 | 14.74 | 14.92 | 15.21 | 15.56 | 15.75 | 15.85 | 16.04 | 15.92 |
| **5.B** | **Cropland** | **20.00** | **21.19** | **16.96** | **14.14** | **-56.61** | **-31.92** | **53.17** | **29.77** | **10.74** | **-13.71** | **27.61** | **113.39** | **105.70** | **153.06** | **113.84** | **140.00** | **86.51** | **110.51** | **361.95** | **209.28** |
| 5.B.1 | Cropland remaining Cropland | 20.00 | 21.19 | 9.65 | -58.90 | -87.54 | -62.86 | -25.13 | -20.09 | -39.12 | -63.57 | -22.25 | -28.22 | -34.70 | -35.32 | -26.31 | -0.14 | -53.63 | -29.63 | -21.17 | -27.95 |
| 5.B.2 | Land converted to Cropland | NO | NO | 7.01 | 69.96 | 27.85 | 27.85 | 73.33 | 44.89 | 44.89 | 44.89 | 44.89 | 132.98 | 129.63 | 174.41 | 126.18 | 126.18 | 126.18 | 126.18 | 359.47 | 213.58 |
| 5.B | Agricultural Lime Application[b] | 36.66 | 32.51 | 26.31 | 36.95 | 27.48 | 50.28 | 50.29 | 44.31 | 31.42 | 38.86 | 37.25 | 40.48 | 29.70 | 43.19 | 26.44 | 26.85 | 25.49 | 37.22 | 29.13 | 32.77 |
| 5.B.2 | Emissions from soil disturbance | NA,NO | NA,NO | 0.29 | 3.08 | 3.08 | 3.08 | 4.97 | 4.97 | 4.97 | 4.97 | 4.97 | 8.62 | 10.77 | 13.97 | 13.97 | 13.97 | 13.97 | 13.97 | 23.65 | 23.65 |
| **5.C** | **Grassland** | **494.41** | **557.74** | **432.39** | **345.76** | **175.47** | **406.60** | **441.83** | **523.18** | **335.82** | **423.33** | **506.11** | **489.30** | **493.62** | **587.97** | **376.19** | **238.39** | **301.41** | **325.61** | **289.74** | **226.30** |
| 5.C.1 | Grassland remaining Grassland | 621.96 | 583.23 | 529.88 | 618.43 | 523.23 | 718.43 | 707.71 | 648.51 | 543.48 | 613.68 | 598.42 | 614.06 | 512.83 | 611.56 | 480.18 | 505.69 | 494.10 | 604.27 | 493.69 | 535.16 |
| 5.C.2 | Land converted to Grassland | -127.54 | -25.49 | -97.49 | -272.67 | -347.76 | -311.84 | -265.88 | -125.33 | -207.66 | -190.35 | -92.31 | -124.76 | -19.22 | -23.59 | -103.98 | -267.30 | -192.69 | -278.66 | -203.95 | -308.86 |
| 5.C | Agricultural Lime Application[b] | 318.38 | 282.64 | 229.29 | 320.35 | 242.16 | 444.32 | 433.74 | 379.17 | 274.16 | 344.37 | 329.14 | 344.80 | 244.20 | 343.57 | 214.35 | 239.89 | 229.37 | 339.54 | 233.08 | 274.55 |
| **5.D** | **Wetlands** | **50.22** | **49.32** | **48.76** | **48.02** | **45.83** | **44.36** | **42.54** | **41.01** | **39.46** | **51.25** | **67.38** | **65.03** | **62.70** | **60.25** | **46.14** | **47.76** | **66.71** | **65.20** | **40.53** | **38.55** |
| 5.D.1 | Wetlands remaining Wetlands | 46.63 | 45.77 | 45.24 | 44.53 | 42.37 | 40.94 | 39.18 | 37.69 | 36.19 | 48.04 | 46.58 | 44.28 | 41.98 | 39.68 | 25.55 | 27.15 | 28.75 | 30.31 | 33.19 | 36.10 |
| 5.D.2 | Land converted to Wetlands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 17.64 | 17.68 | 17.74 | 17.69 | 17.80 | 17.93 | 35.37 | 32.40 | 4.87 | NO |
| 5.D | Drainage of soils | 3.59 | 3.55 | 3.52 | 3.49 | 3.46 | 3.42 | 3.36 | 3.32 | 3.27 | 3.21 | 3.17 | 3.07 | 2.98 | 2.88 | 2.79 | 2.69 | 2.59 | 2.48 | 2.47 | 2.46 |
| **5.E** | **Settlements** | **9.13** | **8.40** | **8.51** | **8.98** | **10.84** | **10.07** | **12.74** | **13.99** | **15.06** | **16.20** | **31.15** | **36.77** | **34.48** | **39.04** | **40.50** | **45.28** | **33.99** | **33.94** | **33.79** | **21.34** |
| 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 |
| 5.E.2 | Land converted to Settlements | 9.13 | 8.40 | 8.51 | 8.98 | 10.84 | 10.07 | 12.74 | 13.99 | 15.06 | 16.20 | 31.15 | 36.77 | 34.48 | 39.04 | 40.50 | 45.28 | 33.99 | 33.94 | 33.79 | 21.34 |
| **5.F** | **Other Land** | **-0.97** | **0.25** | **-13.00** | **-0.31** | **-2.06** | **7.06** | **-15.75** | **0.31** | **1.41** | **6.91** | **11.87** | **-2.16** | **-4.93** | **11.90** | **-23.65** | **5.09** | **-11.77** | **2.29** | **-31.75** | **16.25** |
| 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 |
| 5.F.2 | Land converted to Other Land | -0.97 | 0.25 | -13.00 | -0.31 | -2.06 | 7.06 | -15.75 | 0.31 | 1.41 | 6.91 | 11.87 | -2.16 | -4.93 | 11.90 | -23.65 | 5.09 | -11.77 | 2.29 | -31.75 | 16.25 |
| **5.G** | **G. Other** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** |
| **5** | **TOTAL LULUCF $CO_2$ (net emissions/removals)** | **-580.30** | **-584.92** | **-600.10** | **-776.87** | **-1,002.01** | **-805.49** | **-748.33** | **-813.73** | **-1,153.75** | **-1,106.40** | **-811.35** | **-918.73** | **-1,114.00** | **-1,196.45** | **-1,167.69** | **-1,397.04** | **-1,438.98** | **-1,903.11** | **-2,400.42** | **-2,215.51** |
| **5** | **TOTAL LULUCF GHGs (net emissions/removals)** | **-565.01** | **-569.52** | **-584.38** | **-757.48** | **-982.25** | **-784.60** | **-725.01** | **-791.24** | **-1131.53** | **-1084.15** | **-788.15** | **-890.55** | **-1085.06** | **-1161.86** | **-1134.08** | **-1364.23** | **-1406.07** | **-1870.12** | **-2357.43** | **-2173.06** |

***b) 2012 Submission (Gg $CO_2$ eq)***

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | **Estimates in 2011 Submission (Gg $CO_2$eq.)** | | | | | | | | | | | |
| **5.A** | **Forest Land** | **-371.02** | **-398.42** | **-226.93** | **-281.32** | **-224.46** | **-260.04** | **-234.04** | **-355.87** | **-471.10** | **-505.71** | **-355.14** | **-481.87** | **-623.31** | **-856.85** | **-477.93** | **-635.28** | **-709.10** | **-1,194.68** | **-1,826.71** | **-1,475.29** | **-1,371.23** |
| 5.A.1 | Forest Land remaining Forest Land ($CO_2$) | -803.41 | -943.34 | -659.95 | -617.89 | -319.17 | -144.99 | -44.16 | 63.92 | -194.76 | -251.67 | 216.73 | 346.07 | 29.48 | -792.14 | -309.21 | -455.88 | -448.51 | -1034.12 | -1903.59 | -2143.56 | -2010.25 |
| 5.A.2 | Land converted to Forest Land ($CO_2$) | 412.72 | 521.37 | 408.56 | 309.94 | 66.84 | -145.48 | -221.60 | -449.84 | -306.13 | -284.35 | -604.55 | -863.97 | -685.70 | -104.34 | -205.90 | -214.51 | -296.20 | -197.18 | 39.01 | 630.96 | 594.77 |
| 5.A | Biomass burning ($CH_4$ and $N_2O$) | 2.93 | 1.88 | 1.21 | 2.44 | 2.80 | 3.82 | 4.25 | 2.32 | 1.23 | 1.00 | 2.51 | 5.01 | 1.15 | 7.10 | 4.14 | 1.50 | 1.50 | 1.69 | 2.06 | 1.16 | 7.62 |
| 5.A | Drainage of soils | 16.74 | 21.66 | 23.25 | 24.19 | 25.08 | 26.61 | 27.47 | 27.73 | 28.57 | 29.32 | 30.17 | 31.02 | 31.76 | 32.53 | 33.04 | 33.61 | 34.11 | 34.93 | 35.82 | 36.15 | 36.63 |
| **5.B** | **Cropland** | **20.00** | **21.19** | **25.23** | **24.84** | **-50.73** | **-23.01** | **42.25** | **76.77** | **23.20** | **-1.25** | **44.86** | **133.92** | **128.23** | **175.40** | **133.86** | **160.03** | **106.54** | **130.54** | **442.41** | **253.80** | **252.44** |
| 5.B.1 | Cropland remaining Cropland | 20.00 | 21.19 | 9.65 | -58.90 | -87.54 | -62.86 | -25.13 | -20.09 | -39.12 | -63.57 | -22.25 | -28.22 | -34.70 | -35.32 | -26.31 | -0.14 | -53.63 | -29.63 | -20.59 | -27.28 | -28.64 |
| 5.B.2 | Land converted to Cropland | NO | NO | 15.35 | 80.79 | 33.86 | 36.90 | 62.65 | 92.12 | 57.59 | 57.59 | 62.37 | 153.86 | 152.62 | 197.28 | 146.73 | 146.73 | 146.73 | 146.73 | 437.64 | 255.72 | 255.72 |
| 5.B | Agricultural Lime Application[b] | 36.66 | 32.51 | 26.31 | 36.95 | 27.48 | 50.28 | 50.29 | 44.31 | 31.42 | 38.86 | 37.25 | 40.48 | 29.70 | 43.19 | 26.44 | 26.85 | 25.49 | 37.22 | 29.71 | 33.45 | 32.09 |
| 5.B.2 | Emissions from soil disturbance | NA,NO | NA,NO | 0.23 | 2.95 | 2.95 | 2.95 | 4.73 | 4.73 | 4.73 | 4.73 | 4.73 | 8.28 | 10.31 | 13.44 | 13.44 | 13.44 | 13.44 | 13.44 | 25.36 | 25.36 | 25.36 |
| **5.C** | **Grassland** | **493.58** | **568.21** | **441.17** | **355.04** | **409.09** | **706.38** | **698.02** | **661.41** | **468.63** | **568.82** | **611.91** | **557.86** | **511.95** | **577.06** | **409.57** | **248.28** | **306.38** | **351.33** | **338.21** | **243.25** | **208.50** |
| 5.C.1 | Grassland remaining Grassland | 602.37 | 600.55 | 484.15 | 397.96 | 460.77 | 719.23 | 717.91 | 688.66 | 519.11 | 627.23 | 616.85 | 591.17 | 545.15 | 608.11 | 512.03 | 529.69 | 510.33 | 523.98 | 525.21 | 533.41 | 570.61 |
| 5.C.2 | Land converted to Grassland | -108.80 | -32.34 | -42.98 | -42.92 | -51.68 | -12.85 | -19.89 | -27.25 | -50.48 | -58.41 | -4.94 | -33.30 | -33.20 | -31.04 | -102.46 | -281.41 | -203.95 | -172.65 | -187.00 | -290.16 | -362.11 |
| 5.C | Agricultural Lime Application[b] | 318.38 | 282.64 | 229.29 | 320.35 | 242.16 | 444.32 | 433.74 | 379.17 | 274.16 | 344.37 | 329.14 | 344.80 | 244.20 | 343.57 | 214.35 | 239.89 | 229.37 | 339.54 | 232.50 | 273.88 | 275.24 |
| **5.D** | **Wetlands** | **50.66** | **49.02** | **49.47** | **47.43** | **45.42** | **43.89** | **41.40** | **39.80** | **38.48** | **49.28** | **63.44** | **61.52** | **58.80** | **56.10** | **42.48** | **45.72** | **74.37** | **71.44** | **41.54** | **39.47** | **39.81** |
| 5.D.1 | Wetlands remaining Wetlands | 47.07 | 45.48 | 45.95 | 43.94 | 41.96 | 40.47 | 38.04 | 36.49 | 35.21 | 46.07 | 43.52 | 42.08 | 39.83 | 37.60 | 24.45 | 27.71 | 30.82 | 33.13 | 35.87 | 38.71 | 38.68 |
| 5.D.2 | Land converted to Wetlands | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 16.80 | 16.43 | 16.05 | 15.68 | 15.30 | 15.30 | 40.87 | 35.65 | 3.04 | -1.85 | -1.46 |
| 5.D | Drainage of soils | 3.59 | 3.55 | 3.52 | 3.49 | 3.46 | 3.42 | 3.36 | 3.32 | 3.27 | 3.21 | 3.11 | 3.01 | 2.92 | 2.82 | 2.73 | 2.71 | 2.69 | 2.66 | 2.64 | 2.62 | 2.59 |
| **5.E** | **Settlements** | **9.22** | **8.52** | **8.62** | **9.13** | **10.97** | **9.83** | **12.46** | **13.65** | **14.74** | **15.78** | **37.30** | **42.85** | **40.93** | **45.34** | **46.57** | **50.81** | **34.24** | **32.92** | **30.37** | **19.80** | **23.33** |
| 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 | 9.22 | 8.52 | 8.62 | 9.13 | 10.97 | 9.83 | 12.46 | 13.65 | 14.74 | 15.78 | 37.30 | 42.85 | 40.93 | 45.34 | 46.57 | 50.81 | 34.24 | 32.92 | 30.37 | 19.80 | 23.33 |
| **5.F** | **Other Land** | **-1.06** | **0.28** | **-13.17** | **-14.41** | **-17.49** | **-4.25** | **-27.74** | **-35.05** | **-41.30** | **-35.44** | **-10.35** | **-25.58** | **-43.83** | **-41.84** | **-78.43** | **-86.54** | **-113.71** | **-99.73** | **-133.99** | **-116.69** | **-183.26** |
| 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 | -1.06 | 0.28 | -13.17 | -14.41 | -17.49 | -4.25 | -27.74 | -35.05 | -41.30 | -35.44 | -10.35 | -25.58 | -43.83 | -41.84 | -78.43 | -86.54 | -113.71 | -99.73 | -133.99 | -116.69 | -183.26 |
| **5.G** | **G. Other** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** |
| **5** | **TOTAL LULUCF $CO_2$ (net emissions/removals)** | **178.11** | **221.70** | **256.19** | **107.64** | **138.52** | **435.99** | **492.54** | **362.60** | **-5.15** | **53.21** | **351.49** | **241.39** | **26.64** | **-100.68** | **22.77** | **-268.25** | **-353.02** | **-760.90** | **-1,174.04** | **-1,100.95** | **-1,102.61** |
| **5** | **TOTAL LULUCF GHGs (net emissions/removals)** | **201.37** | **248.79** | **284.41** | **140.71** | **172.81** | **472.80** | **532.35** | **400.71** | **32.66** | **91.47** | **392.02** | **288.70** | **72.78** | **-44.79** | **76.12** | **-216.98** | **-301.28** | **-708.17** | **-1108.17** | **-1035.66** | **-1030.41** |

## *c) Percentage Change*

| | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Percentage Change in Total Emissions due to Recalculations** | | | | | | | | | | | | | | | | | | | |
| **5.A** | **Forest Land** | **-67.39** | **-66.97** | **-78.95** | **-76.04** | **-80.58** | **-78.70** | **-81.42** | **-74.57** | **-69.29** | **-67.75** | **-75.20** | **-69.75** | **-64.92** | **-57.46** | **-71.67** | **-65.49** | **-62.34** | **-50.38** | **-40.14** | **-45.05** |
| 5.A.1 | Forest Land remaining Forest Land ($CO_2$) | -31.04 | -29.41 | -39.25 | -43.10 | -60.95 | -77.70 | -92.62 | -112.43 | -75.53 | -70.81 | -153.03 | -210.65 | -104.33 | -47.40 | -71.48 | -63.07 | -62.75 | -43.80 | -30.51 | -28.27 |
| 5.A.2 | Land converted to Forest Land ($CO_2$) | 2542.36 | 341.53 | -11660.59 | -406.90 | -119.01 | -75.14 | -67.23 | -49.99 | -59.30 | -60.51 | -41.79 | -33.37 | -38.30 | -80.16 | -66.78 | -65.53 | -57.39 | -66.25 | -111.85 | 119.51 |
| 5.A | Biomass burning ($CH_4$ and $N_2O$) | 139.74 | 140.96 | 141.31 | 141.46 | 143.08 | 146.07 | 148.33 | 147.60 | 147.40 | 147.34 | 148.99 | 150.43 | 151.64 | 151.36 | 151.43 | 151.80 | 150.82 | 149.39 | 146.61 | 171.35 |
| 5.A | Drainage of soils | 59.86 | 95.59 | 103.93 | 104.89 | 107.91 | 107.37 | 106.87 | 109.04 | 112.03 | 114.41 | 114.66 | 114.04 | 115.50 | 118.06 | 117.26 | 115.99 | 116.59 | 120.33 | 123.34 | 127.00 |
| **5.B** | **Cropland** | **0.00** | **0.00** | **48.80** | **75.63** | **-10.39** | **-27.92** | **-20.52** | **157.85** | **116.00** | **-90.87** | **62.45** | **18.11** | **21.32** | **14.59** | **17.59** | **14.31** | **23.15** | **18.12** | **22.23** | **21.28** |
| 5.B.1 | Cropland remaining Cropland | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -2.75 | -2.41 |
| 5.B.2 | Land converted to Cropland | NA | NA | 118.83 | 15.48 | 21.57 | 32.47 | -14.56 | 105.21 | 28.28 | 28.28 | 38.94 | 15.70 | 17.74 | 13.11 | 16.29 | 16.29 | 16.29 | 16.29 | 21.75 | 19.73 |
| 5.B | Agricultural Lime Application[b] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.05 |
| 5.B.2 | Emissions from soil disturbance | NA | NA | -20.76 | -4.21 | -4.21 | -4.21 | -4.75 | -4.75 | -4.75 | -4.75 | -4.75 | -4.02 | -4.27 | -3.78 | -3.78 | -3.78 | -3.78 | -3.78 | 7.23 | 7.23 |
| **5.C** | **Grassland** | **-0.17** | **1.88** | **2.03** | **2.68** | **133.14** | **73.73** | **57.99** | **26.42** | **39.55** | **34.37** | **20.90** | **14.01** | **3.71** | **-1.85** | **8.87** | **4.15** | **1.65** | **7.90** | **16.73** | **7.49** |
| 5.C.1 | Grassland remaining Grassland | -3.15 | 2.97 | -8.63 | -35.65 | -11.94 | 0.11 | 1.44 | 6.19 | -4.48 | 2.21 | 3.08 | -3.73 | 6.30 | -0.56 | 6.63 | 4.75 | 3.29 | -13.29 | 6.38 | -0.33 |
| 5.C.2 | Land converted to Grassland | -14.70 | 26.90 | -55.92 | -84.26 | -85.14 | -95.88 | -92.52 | -78.26 | -75.69 | -69.31 | -94.65 | -73.31 | 72.76 | 31.59 | -1.46 | 5.28 | 5.84 | -38.04 | -8.31 | -6.05 |
| 5.C | Agricultural Lime Application[b] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.25 | -0.24 |
| **5.D** | **Wetlands** | **0.88** | **-0.60** | **1.47** | **-1.23** | **-0.90** | **-1.06** | **-2.69** | **-2.93** | **-2.50** | **-3.84** | **-5.86** | **-5.40** | **-6.22** | **-6.89** | **-7.93** | **-4.28** | **11.48** | **9.58** | **2.49** | **2.38** |
| 5.D.1 | Wetlands remaining Wetlands | 0.94 | -0.65 | 1.58 | -1.32 | -0.98 | -1.14 | -2.92 | -3.19 | -2.72 | -4.09 | -6.55 | -4.97 | -5.12 | -5.25 | -4.31 | 2.07 | 7.17 | 9.31 | 8.07 | 7.24 |
| 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 |
| 5.D | Drainage of soils | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.89 | -1.95 | -2.01 | -2.07 | -2.15 | 0.72 | 3.82 | 7.17 | 6.83 | 6.49 |
| **5.E** | **Settlements** | **1.03** | **1.46** | **1.36** | **1.69** | **1.21** | **-2.46** | **-2.22** | **-2.40** | **-2.15** | **-2.58** | **19.75** | **16.56** | **18.72** | **16.12** | **15.00** | **12.20** | **0.73** | **-2.99** | **-10.11** | **-7.25** |
| 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 |
| 5.E.2 | Land converted to Settlements | 1.03 | 1.46 | 1.36 | 1.69 | 1.21 | -2.46 | -2.22 | -2.40 | -2.15 | -2.58 | 19.75 | 16.56 | 18.72 | 16.12 | 15.00 | 12.20 | 0.73 | -2.99 | -10.11 | -7.25 |
| **5.F** | **Other Land** | **8.86** | **NA** | **1.33** | **4537.15** | **750.04** | **NA** | **76.11** | **-11503.45** | **-3025.09** | **NA** | **NA** | **1086.53** | **788.15** | **NA** | **231.58** | **-1801.82** | **865.69** | **NA** | **NA** | **NA** |
| 5.F.1 | Other Land remaining Other Land | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 5.F.2 | Land converted to Other Land | 8.86 | NA | 1.33 | 4537.15 | 750.04 | NA | 76.11 | -11503.45 | -3025.09 | NA | NA | 1086.53 | 788.15 | NA | 231.58 | -1801.82 | 865.69 | NA | NA | NA |
| **5.G** | **G. Other** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** |
| **5** | **TOTAL LULUCF $CO_2$ (net emissions/removals)** | **-130.69** | **-137.90** | **-142.69** | **-113.86** | **-113.82** | **-154.13** | **-165.82** | **-144.56** | **-99.55** | **-104.81** | **-143.32** | **-126.27** | **-102.39** | **-91.59** | **-101.95** | **-80.80** | **-75.47** | **-60.02** | **-51.09** | **-50.31** |
| **5** | **TOTAL LULUCF GHGs (net emissions/removals)** | **-135.64** | **-143.69** | **-148.67** | **-118.58** | **-117.59** | **-160.26** | **-173.43** | **-150.64** | **-102.89** | **-108.44** | **-149.74** | **-132.42** | **-106.71** | **-96.15** | **-106.71** | **-84.09** | **-78.57** | **-62.13** | **-52.99** | **-52.34** |

# 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 where $CH_4$ is the gas concerned. Landfills represent a key emission category in Ireland and the emission estimates of $CH_4$ are considered to be reasonably well quantified in the national inventory. The treatment of wastewaters in anaerobic systems may be an important source of $CH_4$ for some Parties. In Ireland, however, all wastewater treatment is aerobic and consequently it is not a source of $CH_4$ emissions. The anaerobic treatment of sludge is a source of $CH_4$ emissions and is included in the inventory. $N_2O$ emissions arising from the production of human sewage are also included.

The 2012 submission shows total GHG emissions of 888,74 Gg $CO_2$ equivalent in the *Waste* sector in 2010, of which 6.A Solid Waste disposal accounts for 81.9 per cent and the remainder was due to wastewater treatment. The latest estimates show that emissions in the waste sector have decreased by 31.7 per cent from 1990 to 2010 due to a 38.0 per cent decrease in $CH_4$ emissions from 6.A Solid Waste disposal.

Unlike many other developed countries, Ireland has not used waste incineration as a waste management option to any significant extent to date. Incineration of municipal waste currently does not take place and the incineration of clinical wastes was discontinued around 1995. The practice of incineration is now mainly confined to the destruction of liquid vapours by a small number of chemical and pharmaceutical companies. The quantities of both greenhouse gases and indirect gases concerned are considered negligible. However, the incineration of municipal waste will become an additional source of emissions for inclusion in the national inventory from the 2013 submission following the commissioning of a newly built waste incinerator in the second half of 2011. A second incinerator is also proposed, however, the future of this facility in unclear.

*Table 8.1. Level 3 Source Category and Gas Coverage for Waste*

| Waste | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| A. Solid Waste Disposal on Land | | | |
| 1. Managed Waste Disposal on Land | NA | All | NA |
| 2. Unmanaged Waste Disposal Sites | NA | All | NA |
| 3. Other | NO | NO | NO |
| B. Wastewater Handling | | | |
| 1. Industrial Wastewater | NA | All | NO |
| 2. Domestic and Commercial Wastewater | NA | All | All |
| 3. Other | NO | NO | NO |
| C. Waste Incineration | NO | NO | NO |
| D. Other | NO | NO | NO |

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

## 8.2 Solid Waste Disposal (6.A)

### 8.2.1 Methodological Issues

The development of a national waste management strategy for Ireland (DELG, 1998) recognised the need for comprehensive analysis of the $CH_4$ production potential of landfills, particularly in view of the need to reduce the amount of municipal solid waste being placed in landfills. A modified form of the IPCC Tier 2 First Order Decay (FOD) method was therefore adopted as the most appropriate basis on which to assess annual $CH_4$ emissions. This allowed reasonable predictions of emission estimates to be made and was used up to the 2009 submission. Since then, the more detailed methodology provided in the 2006 IPCC Guidelines has been adopted and is described in detail in Section 8.2.2.

### 8.2.2 Methodology for $CH_4$ Generation from Solid Waste Disposal

While the method previously used to estimate and report Ireland's $CH_4$ emissions from landfills stood up to scrutiny in the UNFCCC review process, the inventory team was aware that the simple approach used to estimate $CH_4$ generation could be improved. The previous method did not adequately reflect the major changes in landfill operation and management after 1998 (introduction of licences for landfill operation) and it did not allow for the use of all information available for landfills. The inventory team determined that more detailed analysis was needed to address the inadequate representation of the cumulative time-dependent production of $CH_4$ which was determined on the basis of total waste disposal – effectively as a single hypothetical landfill. Therefore, the inventory team, in its capacity as the national entity responsible for compiling GHG inventories, adopted the methodology for estimating $CH_4$ production given in the 2006 IPCC Guidelines for use in the 2010 and subsequent submissions.

The 2006 IPCC guidelines provide an improved methodology and an associated model for estimating $CH_4$ emissions from landfills. The model is a simple first-order decay 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 $CH_4$ and $CO_2$ annually. The model is applied on a multi-phase basis where data on waste composition from national waste statistics are used directly to quantify the amount of the various constituents that produce DOC. The model contains ranges of default values for DOC content and methane generation rate constant of the waste constituents from which values appropriate to national circumstances may be selected. A methane correction factor (MCF) is used to account for the effect of landfill type and level of management on $CH_4$ generation. In the 2006 IPCC guidelines, the MCF varies from 0.4 for shallow unmanaged landfills to 1.0 for fully anaerobic deep and managed landfills. Analyses undertaken, as part of the improved methodology introduced in the 2010 submission, for both individual sites and groups of landfills shows annual MCF values increasing over time to reflect the change from generally shallow, poorly-managed landfills before 1998 (and therefore pre-landfill licensing) to well controlled and engineered landfills in subsequent years.

The model from the 2006 IPCC guidelines was applied for the five 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 runs were used to account for sewage sludge and street cleanings (Table H.1 of Annex H). 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). One of the five largest landfills and all landfills in four of the landfill groups selected for analysis are closed sites. The five largest landfills account for approximately 40 per cent of the municipal waste disposal in Ireland over the period 1990-2010. This means that the remaining 60 per cent of municipal waste disposal, which is accounted for in landfills assigned to one of seven separate groups, has a significant bearing on the estimates of $CH_4$ generation, particularly for the early years of the 1990-2010 time-series. Table H.1 of Annex H provides a compilation of the input data for the IPCC model runs.

*Waste Quantity and Composition*

The EPA commenced the development of the National Waste Database (NWD) in the early 1990s to address a severe lack of information on waste production and waste management practices in Ireland. The database was needed to support radical reform of national policy and legislation on waste pursuant to the Waste Management Act of 1996 and subsequent Government strategies on sustainable development (DELG, 1997) and waste management (DELG, 1998). National statistics generated from this database published on a three-year cycle, and interim reports published on a yearly basis since 2001 by the EPA (Carey et al, 1996; Crowe et al, 2000; Meaney et al, 2003; Collins et al, 2004a; Collins et al, 2004b; Collins et al, 2005; Le Bolloch et al, 2006; Le Bolloch et al, 2007; Le Bolloch et al, 2009; McCoole et al, 2009; McCoole et al, 2011; McCoole et al, 2012) 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 12 IPCC spreadsheet 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 31 per cent in 1995 to 21.8 per cent in 2010, which reflects the increase in recycling of paper. The NWD is used to give the values for all years in the period 1995 to 2010. 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 31 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 2010. The IPCC default proportions of DOC content are used for all these constituents (Annex H). 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 H) 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 2011 to obtain data for 2010 from the 49 sites.

Information on the number of flares in use, together with data relating to flare capacity, run time and performance was used to estimate the volume of landfill gas flared at each site. The tonnage of $CH_4$ flared was calculated from landfill gas volume by accounting for gas temperature (assumed to be ambient air temperature) and 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 2010 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 $CH_4$ production, utilisation and flaring are presented in Table 8.2.

***Table 8.2. Methane Emissions from Solid Waste Disposal 1990-2010***

| | Methane Generation (Tonnes) | Methane Flaring (Tonnes) | Methane Utilisation (Tonnes) | Methane Recovery (Tonnes) | Percent Methane Recovery | Methane Emissions (Tonnes) | Methane Emissions (Gg $CO_2$eq) |
|---|---|---|---|---|---|---|---|
| 1990 | 55,859 | 0 | 0 | 0 | 0 | 55,859 | 1,173 |
| 1991 | 59,607 | 0 | 0 | 0 | 0 | 59,607 | 1,252 |
| 1992 | 62,499 | 0 | 0 | 0 | 0 | 62,499 | 1,312 |
| 1993 | 64,862 | 0 | 0 | 0 | 0 | 64,862 | 1,362 |
| 1994 | 67,141 | 0 | 0 | 0 | 0 | 67,141 | 1,410 |
| 1995 | 69,031 | 0 | 0 | 0 | 0 | 69,031 | 1,450 |
| 1996 | 71,114 | 599 | 5,877 | 6,476 | 9 | 64,638 | 1,357 |
| 1997 | 73,813 | 592 | 18,354 | 18,946 | 26 | 54,867 | 1,152 |
| 1998 | 76,362 | 770 | 17,632 | 18,402 | 24 | 57,960 | 1,217 |
| 1999 | 79,214 | 1,097 | 19,317 | 20,414 | 26 | 58,800 | 1,235 |
| 2000 | 84,000 | 3,855 | 19,818 | 23,674 | 28 | 60,326 | 1,267 |
| 2001 | 89,812 | 3,901 | 20,159 | 24,060 | 27 | 65,752 | 1,381 |
| 2002 | 95,240 | 8,773 | 16,108 | 24,881 | 26 | 70,359 | 1,478 |
| 2003 | 100,027 | 13,084 | 13,781 | 26,865 | 27 | 73,163 | 1,536 |
| 2004 | 103,961 | 23,180 | 16,749 | 39,930 | 38 | 64,031 | 1,345 |
| 2005 | 108,426 | 28,638 | 20,947 | 49,585 | 46 | 58,841 | 1,236 |
| 2006 | 113,239 | 29,034 | 21,346 | 50,380 | 44 | 62,859 | 1,320 |
| 2007 | 117,897 | 40,396 | 30,558 | 70,954 | 60 | 46,943 | 986 |
| 2008 | 121,967 | 46,640 | 32,909 | 79,548 | 65 | 42,418 | 891 |
| 2009 | 123,404 | 52,051 | 35,404 | 87,454 | 71 | 35,950 | 755 |
| 2010 | 122,915 | 51,183 | 37,091 | 88,274 | 72 | 34,641 | 727 |

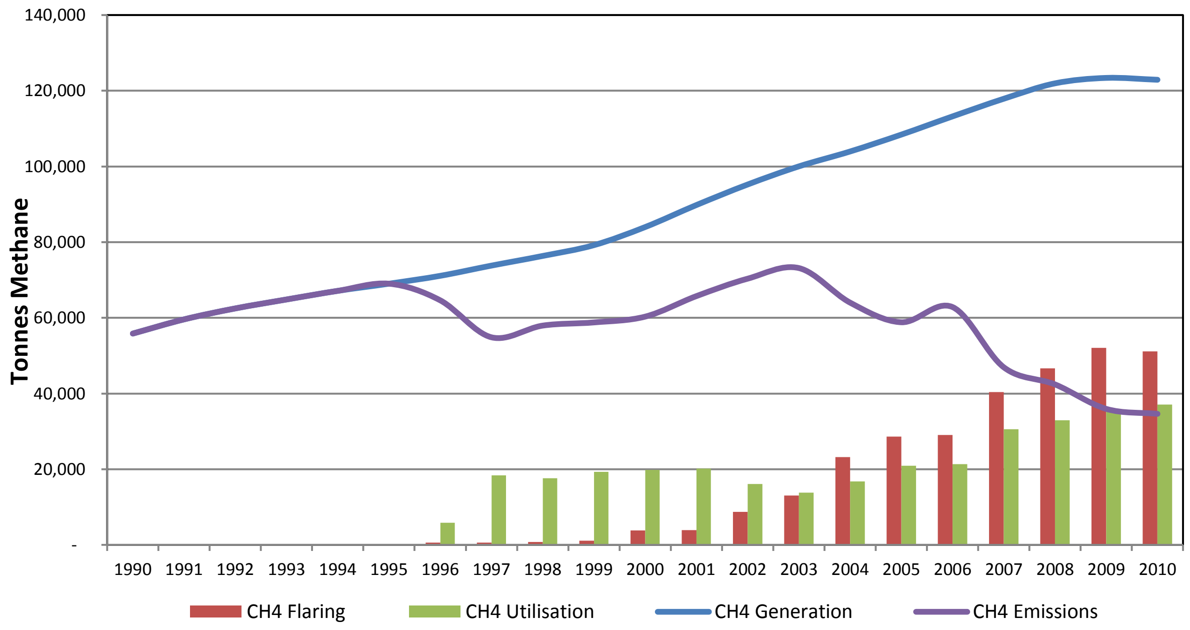



***Figure 8.1. Methane Emissions from Solid Waste Disposal 1990-2010***

Table 8.2 and Figure 8.1 present the results for 6.A Solid Waste Disposal. These estimates of $CH_4$ generation obtained using the model in the IPCC 2006 Guidelines are considered more robust than estimates developed previous to the 2010 submission. The estimates show a steady increase in $CH_4$ production over the period 1990-2010, reflecting Ireland's strong dependence on solid waste disposal to landfills. The utilisation of $CH_4$ remained generally constant up to 2006 since becoming established in 1996. The quantity of $CH_4$ utilised has subsequently almost doubled with the installation of engines at a number of the newer larger landfills and expansion at other sites. The quantity of $CH_4$ flared increased sharply from 2003 onwards. This reflects the proliferation of the use of enclosed flares as a means of odour control at landfills throughout the country, all of which operate under EPA licence and stringent environmental controls. Methane recovery through flaring and utilisation reached 71.8 per cent in 2010. Due to the rapidly increasing level of $CH_4$ flared after 2003, the emissions show a steady decline from the 2003 level of 1,536.42 Gg $CO_2$eq to 727.46 Gg $CO_2$eq in 2010. The emissions in 2010 are 38.0 per cent lower than in 1990.

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

### 8.3.1. $CH_4$ Emissions from Wastewater and Sludge (6.B.1, 6.B.2)

The only source of emissions from wastewater handling in Ireland is the anaerobic treatment of sludge.

Approximately two-thirds of the population in Ireland is served by urban wastewater treatment plants, which are based on aerobic systems with no emissions of $CH_4$.

The other one-third of the population uses septic tanks to treat wastewater mainly for individual houses in non-urban areas (Smith et al., 2004). $CH_4$ emissions from septic tanks are deemed not to occur in Ireland. Consequently the notation key "NO" is reported for $CH_4$ 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 $15^{o}$C, it is generally only for short periods of time and only in certain areas of the country. Thus, the combination of the use of modern domestic chemicals and low prevailing temperatures in septic tanks means that $CH_4$ emissions from septic tanks are deemed not to occur in Ireland.

Sludge is produced in all of the primary, secondary and tertiary stages of wastewater treatment. The anaerobic stabilisation of sludge makes it safe for disposal and is a source of $CH_4$ in Ireland. The amount of wastewater sludge produced in Ireland is available from biennial reports on urban wastewater treatment. It is reported that approximately three per cent of this sludge is treated anaerobically (O' Leary et al. 1997, 2000; O'Leary and Carty, 1998; Smith et al. 2003; 2004, 2007; Monaghan et al. 2009). The average BOD of industrial wastewater sludge is 60 kg/t (40 per cent of the typical BOD content of treated industrial wastewater) and DOC is estimated as the product of average BOD content and tonnes of dry solids of sludge. The emission factor for $CH_4$ is derived from the Revised 1996 IPCC Guidelines (equation 11 on page 6.21) using the IPCC default value of 0.6 for $B_o$, 0.3 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 $CH_4$ 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[5] and SBF (the fraction of BOD that readily settles) of 0.395, which is a combination of 0.35 for conventional primary sedimentation and 0.045 for secondary sedimentation tanks. The emission factor for $CH_4$ is derived as for industrial sludge.

The sludge from wastewater treatment is disposed of in landfills, used as organic fertiliser on agricultural lands or in composting. The quantity of sludge that is disposed of in landfills contributes to $CH_4$ emissions from SWDS and is accounted for in emission estimates for CRF category *6.A.1 Solid Waste Disposal on Land*. The proportion of sludge disposed of in SWDS was 42 per cent of sludge produced (tonnes of dry solids) in 1990 and 54 per cent in 2000. Since then, the value has fallen substantially, to 5 per cent in 2006 and has remained at this proportion since then. The sludge applied to agricultural land contributes to $N_2O$ emissions from soils and is included in emission estimates for CRF category *4.D.1 Direct soil emissions* as discussed in section 6.5.1 of this report. The proportion of sludge applied to agricultural lands has significantly increased in recent years from 12 per cent of both industrial and domestic sludge in 1990 to 83 and 70 per cent for industrial and domestic sludge respectively in 2010.

### 8.3.2 $N_2O$ Emissions from Human Sewage (6.B.2.b)

Human consumption of food results in the production of sewage, which is processed in septic tanks or in wastewater treatment facilities. This treated waste is disposed of directly onto land, into the soil through percolation areas or discharged to a water body. Nitrous oxide can be produced during these processes through nitrification and denitrification. This source of

[5] 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

emissions was first included in inventory estimates as part of the recalculation exercise undertaken for the 2002 submission. Since then the methodology has improved with $N_2O$ emission estimates derived using the IPCC methodology and the accompanying default values.

$N_2O$ emissions are estimated by taking the IPCC default value of 0.16 for the nitrogen content in protein and applying the default emission factor of 0.01 (kg $N_2O$-N/ kg sewage produced) to obtain the quantity of nitrogen in sewage ultimately entering the atmosphere as $N_2O$. Emission estimates are provided in Table 8.3.

***Table 8.3 Estimates of $N_2O$ emissions from human sewage 1990-2010***

| Year | Protein (g/day) | Days | Pop (million) | N fraction (IPCC default) | EF (IPCC default) | $N_2O$ * (Gg) |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | |
| 1990 | 114.3 | 365 | 3.506 | 0.16 | 0.01 | 0.368 |
| 1991 | 115.2 | 365 | 3.526 | 0.16 | 0.01 | 0.373 |
| 1992 | 118.5 | 366 | 3.555 | 0.16 | 0.01 | 0.388 |
| 1993 | 115.5 | 365 | 3.574 | 0.16 | 0.01 | 0.379 |
| 1994 | 112.5 | 365 | 3.586 | 0.16 | 0.01 | 0.370 |
| 1995 | 108.6 | 365 | 3.601 | 0.16 | 0.01 | 0.359 |
| 1996 | 108.7 | 366 | 3.626 | 0.16 | 0.01 | 0.363 |
| 1997 | 111.1 | 365 | 3.664 | 0.16 | 0.01 | 0.374 |
| 1998 | 112.2 | 365 | 3.703 | 0.16 | 0.01 | 0.381 |
| 1999 | 114.2 | 365 | 3.742 | 0.16 | 0.01 | 0.392 |
| 2000 | 117.2 | 366 | 3.790 | 0.16 | 0.01 | 0.409 |
| 2001 | 114.8 | 365 | 3.847 | 0.16 | 0.01 | 0.405 |
| 2002 | 114.2 | 365 | 3.917 | 0.16 | 0.01 | 0.411 |
| 2003 | 114.2 | 365 | 3.979 | 0.16 | 0.01 | 0.417 |
| 2004 | 114.2 | 366 | 4.044 | 0.16 | 0.01 | 0.425 |
| 2005 | 114.2 | 365 | 4.131 | 0.16 | 0.01 | 0.433 |
| 2006 | 114.2 | 365 | 4.240 | 0.16 | 0.01 | 0.444 |
| 2007 | 114.2 | 365 | 4.339 | 0.16 | 0.01 | 0.455 |
| 2008 | 114.2 | 366 | 4.422 | 0.16 | 0.01 | 0.465 |
| 2009 | 114.2 | 365 | 4.459 | 0.16 | 0.01 | 0.467 |
| 2010 | 114.2 | 365 | 4.471 | 0.16 | 0.01 | 0.469 |

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

## 8.4 Uncertainties and Time-Series Consistency

The methodologies used in the derivation of emissions estimates from the waste sector are consistent over the time-series. In the case of category 6.A, this consistency applies to all three components that determine the ultimate emissions, i.e. $CH_4$ generation, $CH_4$ flared and $CH_4$ utilised. Adoption of the model in the 2006 IPCC Guidelines is justified by the information available for its detailed application. In addition, this approach brings Ireland into line with other Parties using this methodology in advance of the expected mandatory use of these guidelines for inventory reporting post-2012.

Despite continuous improvements in national data, the overall uncertainty associated with estimating $CH_4$ emissions from source category 6.A is high at 32.0 per cent. This uncertainty is primarily due to the length of the historical period that must be taken into account. Uncertainty estimates for the source category are calculated using equations 6.3 and 6.4 of the IPCC Good Practice Guidance. Uncertainties of 20 per cent are assumed in relation to the quantity of MSW, its composition and DOC contents, giving a combined uncertainty of 34.6 per cent for activity data using equation 6.4. The emission factor uncertainty is also 34.6 per cent, when 20 per cent is taken as the uncertainty for the fraction of DOC dissimilated, MCF and decay rate constant. This gives an uncertainty of 48.9 per cent for $CH_4$ generation again using equation 6.4, which is combined with uncertainties of 30 per cent and 10 per cent for $CH_4$ flaring and utilisation, respectively using equation 6.3 to give an uncertainty of 32.0 per cent for emissions. The Tier 1 uncertainty analysis is presented in Table 1.9 of this report.

Uncertainties in estimates of emissions from the source category 6.B arise due to the quality of source data, wastewater production estimates, its chemical parameters in terms of COD or BOD, the methane producing capacity and its treatment. The only source of emissions from wastewater handling in Ireland is the anaerobic treatment of sludge, for which uncertainty estimates of 10 per cent and 30 per cent are assigned to the activity data and emission factor used, respectively.

## 8.5 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.

## 8.6 Recalculations for Waste

The validation exercise that was undertaken with respect to landfill gas survey returns identified the need to review both the information on utilisation engines supplied by both landfill operators and related data in the national energy balance. It was found that the data provided in the energy balance did not include the utilisation plants that had been installed since 2007. As a result the quantity of $CH_4$ recovered in this manner was underestimated for the years 2007, 2008 and 2009 and consequently led to an overestimation of emissions from *6.A. Solid Waste Disposal on Land* for these years. The net effect of this recalculation is a reduction in emissions of 21.7 per cent, 24.9 per cent and 35.6 per cent for 2007, 2008 and 2009, respectively.

In *6.B.2 Human Sewage* a minor recalculation was undertaken for the years 2004 and 2008 to account for the quantity of sewage produced over 366 days instead of 365 days in each of these leap years.

## 8.7 Improvements in Waste

The inventory agency believes that the use of the model provided by the 2006 IPCC Guidelines, adopted since the 2010 submission, is justified as a robust estimation methodology where its flexibility in accommodating changes to input parameters to suit national circumstances is fully exploited. The application of the model to individual landfills and to groups of landfills with similar characteristics accounts for the known management and life cycle of landfills in Ireland as well as the quantity and composition of waste. This approach also captures the time dependency of methane generation in a more representative manner than the previous approach which was based on one hypothetical landfill site. The adoption of the refined methodology since the 2010 submission simplifies the task of the inventories team with regard to inventory preparation and during the UNFCCC review process. It also provides a convenient basis on which to incorporate further modifications in respect of particular data items or model parameters. In addition, it provides an efficient and improved mechanism for undertaking emissions projections in relation to landfills.

The inventory agency intends to continue its annual surveys of landfill operations to determine landfill gas flaring and utilisation statistics. This data is collated with other units involved in reporting within the EPA such as annual environmental reports and EPRTR and this collaboration ensures an element of consistency in environmental reporting in this area.

*Table 8.4 Recalculated Estimates for Waste 1990-2009*

| | | | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Estimates in 2011 Submission (Gg $CO_2$ eq.) | | | | | | | | | |
| 6.A.1 | Managed Waste Disposal on Land | $CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | 901.25 | 951.53 | 1,083.40 | 1,197.41 | 1,275.66 | 1,104.63 | 1,014.31 | 1,115.44 | 1,016.49 | 951.32 | 918.49 |
| 6.A.2 | Unmanaged Waste Disposal Sites | $CH_4$ | 1,173.05 | 1,251.74 | 1,312.47 | 1,362.09 | 1,409.97 | 1,449.66 | 1,357.39 | 1,152.20 | 1,217.16 | 333.55 | 315.32 | 297.38 | 280.13 | 260.75 | 240.02 | 221.35 | 204.59 | 189.50 | 175.87 | 163.49 |
| 6.B.1.b | Industrial Wastewater | $CH_4$ | 1.96 | 1.98 | 1.99 | 2.00 | 2.01 | 1.96 | 1.97 | 3.80 | 3.84 | 4.08 | 4.23 | 4.39 | 4.47 | 4.26 | 5.11 | 5.19 | 5.29 | 5.40 | 5.51 | 5.61 |
| 6.B.2.b | Domestic & Commercial Wastewater | $CH_4$ | 12.76 | 12.84 | 12.94 | 13.01 | 13.06 | 12.71 | 12.80 | 16.51 | 16.68 | 17.74 | 17.96 | 18.63 | 18.97 | 18.11 | 18.40 | 9.35 | 9.54 | 9.73 | 9.93 | 10.12 |
| 6.B.2 | Human Sewage | $N_2O$ | 114.00 | 115.55 | 120.16 | 117.44 | 114.77 | 111.26 | 112.44 | 115.82 | 118.20 | 121.56 | 126.70 | 125.65 | 127.27 | 129.27 | 131.38 | 134.20 | 137.75 | 140.97 | 143.67 | 144.88 |
| 6 | Total | $CO_2$ eq. | 1,301.78 | 1,382.10 | 1,447.56 | 1,494.55 | 1,539.80 | 1,575.59 | 1,484.60 | 1,288.32 | 1,355.88 | 1,378.18 | 1,415.74 | 1,529.45 | 1,628.24 | 1,688.06 | 1,499.54 | 1,384.39 | 1,472.62 | 1,362.10 | 1,286.28 | 1,242.59 |
| | | | | | | | | | | | | | Recalculated Estimates in 2012 Submission (Gg $CO_2$ eq.) | | | | | | | | | |
| 6.A.1 | Managed Waste Disposal on Land | $CH_4$ | NO | NO | NO | NO | NO | NO | NO | NO | NO | 901.25 | 951.53 | 1,083.40 | 1,197.41 | 1,275.66 | 1,104.63 | 1,014.31 | 1,115.44 | 796.29 | 714.92 | 591.46 |
| 6.A.2 | Unmanaged Waste Disposal Sites | $CH_4$ | 1,173.05 | 1,251.74 | 1,312.47 | 1,362.09 | 1,409.97 | 1,449.66 | 1,357.39 | 1,152.20 | 1,217.16 | 333.55 | 315.32 | 297.38 | 280.13 | 260.75 | 240.02 | 221.35 | 204.59 | 189.50 | 175.87 | 163.49 |
| 6.B.1.b | Industrial Wastewater | $CH_4$ | 1.96 | 1.98 | 1.99 | 2.00 | 2.01 | 1.96 | 1.97 | 3.80 | 3.84 | 4.08 | 4.23 | 4.39 | 4.47 | 4.26 | 5.11 | 5.19 | 5.29 | 5.40 | 5.51 | 5.61 |
| 6.B.2.b | Domestic & Commercial Wastewater | $CH_4$ | 12.76 | 12.84 | 12.94 | 13.01 | 13.06 | 12.71 | 12.80 | 16.51 | 16.68 | 17.74 | 17.96 | 18.63 | 18.97 | 18.11 | 18.40 | 9.35 | 9.54 | 9.73 | 9.93 | 10.12 |
| 6.B.2 | Human Sewage | $N_2O$ | 114.00 | 115.55 | 120.16 | 117.44 | 114.77 | 111.26 | 112.44 | 115.82 | 118.20 | 121.56 | 126.70 | 125.65 | 127.27 | 129.27 | 131.74 | 134.20 | 137.75 | 140.97 | 144.06 | 144.88 |
| 6 | Total | $CO_2$ eq. | 1,301.78 | 1,382.10 | 1,447.56 | 1,494.55 | 1,539.80 | 1,575.59 | 1,484.60 | 1,288.32 | 1,355.88 | 1,378.18 | 1,415.74 | 1,529.45 | 1,628.24 | 1,688.06 | 1,499.90 | 1,384.39 | 1,472.62 | 1,141.90 | 1,050.28 | 915.56 |
| | | | | | | | | | | | | | Percentage Change in Total Emissions due to Recalculations | | | | | | | | | |
| 6.A.1 | Managed Waste Disposal on Land | $CH_4$ | 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 | -21.66 | -24.85 | -35.61 |
| 6.A.2 | Unmanaged Waste Disposal Sites | $CH_4$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6.B.1.b | Industrial Wastewater | $CH_4$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6.B.2.b | Domestic & Commercial Wastewater | $CH_4$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 6.B.2 | Human Sewage | $N_2O$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 |
| 6 | Total | $CO_2$ eq. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | -16.17 | -18.35 | -26.32 |

# Chapter Nine

# Other Sources

The sector *Other* in the IPCC source sector classification (Table 2.A, 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 I 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 Explanations and Justifications for Recalculations

The foregoing chapters describe recalculations and improvements for the individual Level 1 source sectors of the inventory undertaken for the 2012 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 2012 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 2012 submission CRF tables. The original and revised numerical values of the emissions estimates for the years 1990-2009, along with the changes related to methods, activity data and emission factors are detailed in the respective CRF Tables 8(a) and 8(b). The principal changes that that give rise to recalculated estimates for the years 1990-2009 included in the 2012 submission are outlined below.

### Recalculations in Energy

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

- Revised energy data in sub-categories 1.A.1(a), 1.A.1(b) and 1.A.1(c) to harmonise fuel data in the energy balance with ETS bottom up data. These revisions to the energy statistics affected $CH_4$ and $N_2O$ emissions from 2004 to 2009

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

- Revised energy data in all sub-categories in sector 1.A.2. These revisions to the energy statistics increased sector emissions for all years from 1990-2007 from 0.3 to 1.7 per cent and reduced emissions in 2008 and 2009 by 1.1 and 2.6 per cent respectively.

### *1.A.3 Transport*

- Revisions to transport sub-categories civil aviation 1.A.3(a), road transport 1.A.3(b) and navigation 1.A.3(d) were carried out for all years from 1990 to 2009. The impact of these recalculations was to reduce sector emissions by 0.3 per cent in 1990 and by 4.5 per cent in 2009;
- Civil aviation emissions were revised based on new flight data and methodology as described in chapter 3 section 3.2.1.3. Overall sub-category emissions decreased from 13.9 per cent in 1990 to 46.4 per cent in 2009;
- Road transport emissions decreased by 0.2 per cent in 1990 to 5.9 per cent in 2009;
- Revised road fuel use data for all years from 1990 to 2009.The largest changes occurred in 2008 and 2009 were reductions were 4.4 and 5.9 per cent respectively;
- The inventory agency revised the sulphur content of leaded gasoline (2003-2009) in the COPERT model to match the sulphur content of unleaded gasoline. This impacted on the emissions of $CH_4$ and $N_2O$ with substantial reductions in $N_2O$ emissions ranging from 20.1 per cent in 2003 to 15.2 per cent in 2006;
- Revised gasoil data for navigation for all years from 1990 to 2009 which completed the time series as outlined in NIR 2011.

### *1.A.4 Other Sectors*

- Revised energy data in all sub-categories in sector 1.A.4. Overall emissions from this sector reduced by 0.2 per cent in 1990 and 0.4 per cent in 2009;
- Sub-category 1.A.4(a) emissions decreased due to reallocation of gasoil from commercial/services to navigation 1.A.3(d). Emissions decreased by 0.8 per cent in 1990 and by 5.8 per cent in 2009;
- Sub-category 1.A.4(b) emissions decreased due to revised fuel data, in particular, LPG use. Emissions decreased by an average 0.6 per cent between 1990 and 2009;
- Sub-category 1.A.4(c) emissions increased for the years 2003 to 2009 by 15.3 per cent in 2003 to 24.3 per cent in 2009. This sub-category now includes marine diesel used in national fishing for the last 8 years of the time series as discussed in chapter 3 section 3.2.1.4.

## Recalculations in Industrial Processes

Recalculations in the Industrial Processes sector in this submission are confined to HFC’s and $SF_6$. The compilation of emission estimates for HFC’s, PFC’s and $SF_6$ for this submission was reviewed externally by an independent consultant, qualified as a UNFCCC expert reviewer for the Industrial Processes sector. The recalculations are outlined below.

*2.F Consumption of Halocarbons and $SF_6$*

- HFC emissions from Mobile Air Conditioning 2.F.1 have been revised for 2005-2009. This is due in part to the use of a revised disposal factor of 10 per cent for end of life vehicles (AEA, 2011). In addition the assumed penetration of air conditioning units containing HFCs in vehicles is now assumed to reach 90 per cent by 2010 (AEA, 2011). The result of this recalculation is an increase in HFC emissions from this sub-category of 2.7 per cent in 2009;

- HFC emissions from Refrigeration and Air Conditioning 2.F.1 have been revised for 2009 due to the provision of revised manufacturing loss emissions by one of the installations that provide information to the inventory agency. The result of this recalculation is a reduction of 13.7 per cent in HFC emissions from this sub-category in 2009;

- HFC emissions from Foam Blowing 2.F.2 have been revised for 2000-2009. This is due to the use of revised estimates of GDP values for Ireland and the OECD in conjunction with the data provided on global sales by AFEAS. The net effect of this recalculation is a reduction in HFC emissions from this sub-category of 4.6 per cent in 2009;

- HFC emissions from Fire Extinguishers 2.F.3 have been revised for 1991-2009. This is due to the use of a revised product life factor of 0.049 (AEA, 2011) compared to the value of 0.01 used in previous submissions. As a result of this recalculation HFC emissions from this sub-category increased by 141.4 per cent for 2009;

- HFC emissions from Aerosols 2.F.4 have been revised for the time series 1990-2009 due to the publication of revised species ratios for HFC-134a and HFC-152 contained in AEA (2011). The species ratio used is 97 per cent HFC-134a, 3 per cent HFC-152 in 1990 and 96 per cent HFC-134a, 4 per cent HFC-152 in 2009. The approach used in previous submissions assumed a species ration of 90 per cent HFC-134a and 10 per cent HFC-152 for all years (Adams et al. 2005). In addition revised estimates for the sector from the UK inventory have also been taken into account following the methodology as described in chapter 4 section 4.4.2.4. The effect of this recalculation is a 2.6 per cent reduction in HFC emissions from this sub-category for 2009;

- HFC emissions from Metered Dose Inhalers 2.F.4 have been revised for 2007-2009 as a result of revised manufacturing loss data provided to the inventory agency by one of the installations in this sector. HFC emissions increased by 82.9 per cent for 2009 as a result of this change;

- $SF_6$ emissions from Semiconductor Manufacture 2.F.7 have been revised for 2009 as a result of revised data supplied to the inventory agency by one of the installations in this sector. Emissions of $SF_6$ from this sub-category for 2009 are reduced by 50.7 per cent as a result of this recalculation;

- $SF_6$ emissions from Windows/Soundproofing 2.F.7 have been revised for the time series 1990-2009. Double glazed windows were first introduced in Ireland in 1978, thus there is a bank of $SF_6$ in windows manufactured and installed prior to 1990 which will contribute to the emissions from leakage in the period 1990-2009. The net effect of this recalculation is an increase in $SF_6$ emissions for the sub-category of 25.4 per cent and 50.3 per cent in 1990 and 2009, respectively;

- Emissions of $SF_6$ from Sporting Goods 2.F.7 have been revised for 1998-2009 as a result of revised estimates submitted by the UK to the UNFCCC. UK emission estimates for this sector are used in conjunction with population estimates for the UK and Ireland to develop emission estimates for Ireland. Emissions of $SF_6$ from this sub-category in 2009 are reduced by 71.4 per cent as a result of this recalculation;

The net effect of the recalculations outlined above is an increase of 4.0 per cent in HFC emissions and decrease in $SF_6$ emissions of 41.5 per cent in 2009. In total this equates to an increase in emissions for the Industrial Processes sector as a whole of 0.3 per cent for 2009.

## Recalculations in Solvent and Other Product Use

Recalculation for *Solvent and Other Product Use* are minor and confined to the period 2003-2009 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 reduce emissions in 2009 by 0.01 per cent.

## Recalculations in Agriculture

The following significant changes were implemented in the Agriculture sector in this inventory submission. The inventory agency developed an annual average population characterisation for estimating emissions from cattle and some other livestock. This compares with previous submissions where two annual population characterisations were used i.e. one in June and one in December. Additional minor improvements in animal population statistics were undertaken by CSO after the census of agriculture in 2010. Further information is outlined in chapter 6 section 6.8.2.

The inventory agency reviewed the N excretion values in use in the national inventory for all categories of livestock following a recommendation in a UNFCCC review report. This review was carried out in consultation with the Department of Agriculture, Food and the Marine and Teagasc during 2011. Additional information on the revision of nitrogen excretion rates for livestock can be found in chapter 6 section 6.8.1 and tables F.5.1 and F.5.2 of Annex F.

The net effect of the revisions to livestock statistics and nitrogen excretion values for livestock is an increase of 2.0 per cent in total agricultural emissions in 1990 and 2.5 per cent total emissions in 2009.

## Recalculations in LULUCF

The recalculations for LULUCF include a number of methodological refinements resulting mainly from wider use of the national forest inventory (NFI) 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 1990-2009 due to methodological improvements and in response to recommendations made in the ARR 2011. The main recalculations are presented below.

### *5.A Forest Land*

- Forest land areas for forest land remaining forest land were recalculated to correct for an error picked up in the QA/QC exercise in 2011. This prompted a recalculation of emissions or removals for all pools;
- Use of new EF and area matrices for organic forest soils, which are now also calculated for forest land remaining forest land, chapter 7 section 7.3.3. There was

also a calculation error for soils under forest land in the previous submission which has since been corrected. This has resulted in a 6.6 per cent increase in $CO_2$ emissions form organic soils in the forest remaining forests. Emissions from the organic soils on lands converted to forest land decreased by 33 per cent, primarily due to an error in the applied emission factor in the 2011 submission. The recalculation has a larger impact on the trend changes over the time series because emission form organic soils are now also estimated for forest land remaining forest land (F-F). As a result F-F are a net emission in some years (see Table 7.9). These were not reflected in the previous submission due to calculations errors;

- Emissions from wildfires were recalculated for the 2012 submission to account for emissions from the DOM pool. There was also an error in the entry of cells into the CRF, where areas of burned forest lands were not included in previously submitted values. In this submission, the combination of a correction to the transcription error and recalculation (inclusion of the DOM in wildfire emissions) has resulted in a 130 to 171 per cent increase in $CO_2$ emission across the time series, when compared to the 2011 submission. For 2009, the recalculation resulted in an increase in emissions of 64 per cent.

### *5.A Forest Land and 5.D Wetlands*

- The areas subjected to drainage were revised based on evidence that the drained areas could have been underestimated in previous submissions. The areas of organic soils were previously considered not to be drained if the drainage attribute for sites in the NFI database where noted as poorly drained soils. This does not, however, consider that drainage could have been implemented in these sites despite the poor drainage of soils (i.e. drainage was not effective). It is now assumed that all forested organic soils are drained or were previously drained prior to afforestation. However, it is also assumed that organic soils converted back to wetlands to not continue to result in $N_2O$ emissions because drains are blocked to facilitate natural re-colonisation of peatland species. The adjustment for open areas by a factor of 0.85 resulted in an increase in the IEF from 0.09 kg $N_2O$-N per ha (i.e value reported represent drained land only (Table 5II, CRF), in the previous submission, to 0.14 kg $N_2O$-N per ha. The increased IEF is also due to a change in the proportion of nutrient poor and rich organic soil areas. For 2009, emission of $N_2O$ from drained forest lands increased from 0.051 to 0.12 Gg $N_2O$, when the new area adjustments were made.

### *5.A-5.F All Land uses*

- Estimates have been made for the regrowth of vegetative cover for all land uses after deforestation events;
- Recalculations based on the revision of area of land use changes due to afforestation from all land uses have been implemented. This is largely the knock-on impact of making a new provision of 10 per cent of afforestation to occur on cropland.

The impact of these recalculations on total GHG emissions in the LULUCF sector is a net decrease in removals of 52.3 per cent for 2009.

## Recalculations in Waste

### *6.A Solid Waste Disposal on Land*

The validation exercise that was undertaken with respect to landfill gas survey returns identified the need to review both the information on utilisation engines supplied by both landfill operators and related data in the national energy balance. It was found that the data provided in the energy balance did not include the utilisation plants that had been installed since 2007. As a result the quantity of $CH_4$ recovered in this manner was underestimated for the years 2007, 2008 and 2009 and consequently led to an overestimation of emissions from *6.A. Solid Waste Disposal on Land* for these years. The net effect of this recalculation is a reduction in emissions of 21.7 per cent, 24.9 per cent and 35.6 per cent for 2007, 2008 and 2009, respectively.

#### *6.B.2 $N_2O$ from human sewage*

In *6.B.2, $N_2O$ from Human Sewage,* a minor recalculation was undertaken for the years 2004 and 2008 to account for the quantity of sewage produced over 366 days instead of 365 days in each of these leap 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 1990-2009 according to greenhouse gas and the IPCC sectors, respectively. The overall effect on total emissions excluding LULUCF varies from an increase of 0.62 per cent in 1990 to a decrease of 1.05 per cent in 2009, Table 10.2 (c). The reduction in the last two years of the time-series is due to the impact of the revisions for road transport 1.A.3(b) and solid waste disposal on land 6.A.1 in these years. The other significant revisions are similar in all years, in particular, the changes in civil aviation and agriculture. 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 1990-2009 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 and 2010 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 I summarises the issues raised in the UNFCCC 2010 review and Ireland’s response to those issues through the 2011 submission and the current submission. It may be stated therefore that the inventory material being submitted in 2012 broadly meets the principles of transparency, completeness, consistency, comparability and accuracy laid down in the UNFCCC reporting guidelines.

Ireland's draft Annual Review Report for submission 2011 (FCCC/ARR/2011/IRL) was received by the inventory agency on the 11th of April 2012. Due to the late delivery of this report, the inventory agency was unable to implement the recommendations in this inventory submission.

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 a secondary MOU to formalise data collection by COFORD, the Council for Forest Research and Development, which is responsible for reporting on afforestation and deforestation areas related to LULUCF under the Convention and Article 3.3 activities under the Kyoto Protocol. The MOU were put into effect between COFORD and the Forest Service and between COFORD and Coillte. 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 2011 NIR*

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | DESCRIPTION OF METHODS<br>Categories where the 2012 NIR includes major changes in methodological descriptions compared to the 2011 NIR | RECALCULATIONS<br>Sub-categories where changes are reflected in recalculations of previous year estimates | REFERENCE<br>Reference to sub-category, gas, pages in the NIR, Annex |
|---|---|---|---|
| **Total (Net Emissions)** | | ✓ | |
| **1. Energy** | | ✓ | |
| A. Fuel Combustion (Sectoral Approach) | | ✓ | |
| 1. Energy Industries | | ✓ | |
| 2. Manufacturing Ind & Const | | ✓ | |
| 3. Transport | ✓ | ✓ | 1.A.3a Civil Aviation CO2, CH4 and N2O. See section 3.2.2.3.1 of NIR 2012 1.A3.d Navigation time series update for all years. See section 3.2.1.3.3 of NIR 2012 |
| 4. Other Sectors | | ✓ | Submission now includes Fishing in sector 1.A.4c for years 2003 to 2010. See section 3.2.1.4 of NIR 2012 |
| 5. Other | | | |
| B. Fugitive Emissions from Fuels | | | |
| 1. Solid Fuels | | | |
| 2. Oil and Natural Gas | | | |
| **2. Industrial Processes** | | ✓ | |
| A. Mineral Products | | | |
| B. Chemical Industry | | | |
| C. Metal Production | | | |
| D. Other Production | | | |
| E. Production of Halocarbons and SF6 | | | |
| F. Consumption of Halocarbons and SF6 | | ✓ | Changes to HFCs and SF6 in sector 2.F. See section 4.6 of NIR 2012 |
| G. Other | | | |
| **3. Solvent and Other Product Use** | | ✓ | |
| **4. Agriculture** | | ✓ | Revised animal characterisation to one poulation instead of two previously. See section 6.1 and 6.8.2 of NIR 2012. |
| A. Enteric Fermentation | | ✓ | See above |
| B. Manure Management | ✓ | ✓ | Revised Nitrogen excretion rates for all livestock types. See section 6.4 and 6.8.1 of NIR 2012 and Tables F.5.1 and F.5.2 of Annex F. |
| C. Rice Cultivation | | | |
| D. Agricultural Soils | ✓ | ✓ | Revised Nitrogen excretion rates for all livestock types. See section 6.4 and 6.8.1 of NIR 2012 and Tables F.5.1 and F.5.2 of Annex F. |
| E. Prescribed Burning of Savannas | | | |
| F. Field Burning of Agricultural Residues | | | |
| G. Other | | | |
| **5. Land Use, Land-Use Change and Forestry** | | ✓ | |
| A. Forest Land | | ✓ | |
| B. Cropland | | ✓ | |
| C. Grassland | | ✓ | |
| D. Wetlands | | ✓ | |
| E. Settlements | | ✓ | |
| F. Other Land | | ✓ | |
| G. Other | | | |
| **6. Waste** | | ✓ | |
| A. Solid Waste Disposal on Land | | ✓ | |
| B. Waste-water Handling | | ✓ | |
| C. Waste Incineration | | | |

| | | | |
|---|---|---|---|
| D. Other | | | |
| **7. Other (as specified in Summary 1.A)** | | | |
| **Memo Items:** | | ✓ | |
| **International Bunkers** | | ✓ | |
| Aviation | | ✓ | |
| Marine | | | |
| **Multilateral Operations** | | | |
| **CO2 Emissions from Biomass** | | ✓ | |

## *Table 10.2 Recalculations by Gas 1990-2009*

***(a) Emissions by Gas 1990 –2009 reported in 2011 Submission (Gg $CO_2$eq)***

| GAS | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (inc net $CO_2$ from LULUCF) | 31,800.65 | 32,602.90 | 32,487.27 | 32,441.82 | 33,443.46 | 34,418.63 | 36,167.88 | 37,547.92 | 39,320.15 | 41,053.36 | 43,842.80 | 46,142.40 | 44,536.77 | 43,884.20 | 44,776.56 | 46,312.09 | 45,864.94 | 45,577.82 | 45,136.41 | 40,198.25 |
| $CO_2$ (exc net $CO_2$ from LULUCF) | 32,380.95 | 33,187.83 | 33,087.37 | 33,218.69 | 34,445.47 | 35,224.12 | 36,916.22 | 38,361.65 | 40,473.90 | 42,159.77 | 44,654.15 | 47,061.14 | 45,650.77 | 45,080.65 | 45,944.25 | 47,709.13 | 47,303.92 | 47,480.93 | 47,536.83 | 42,413.76 |
| $CH_4$ emissions (inc $CH_4$ from LULUCF) | 13,590.29 | 13,766.38 | 13,852.89 | 13,938.62 | 13,883.57 | 13,885.54 | 14,093.58 | 14,132.96 | 14,393.39 | 14,011.56 | 13,442.60 | 13,445.53 | 13,442.75 | 13,929.80 | 13,161.95 | 12,977.36 | 12,983.01 | 12,499.47 | 12,380.36 | 12,178.45 |
| $CH_4$ emissions (exc $CH_4$ from LULUCF) | 13,589.17 | 13,765.66 | 13,852.43 | 13,937.69 | 13,882.51 | 13,884.11 | 14,092.00 | 14,132.10 | 14,392.93 | 14,011.19 | 13,441.67 | 13,443.69 | 13,442.32 | 13,927.20 | 13,160.43 | 12,976.81 | 12,982.46 | 12,498.85 | 12,379.59 | 12,178.05 |
| $N_2O$ emissions (inc $N_2O$ from LULUCF) | 8,827.96 | 8,623.64 | 8,631.68 | 8,767.62 | 8,999.69 | 9,198.66 | 9,230.15 | 9,082.73 | 9,624.49 | 9,652.87 | 9,199.15 | 8,604.04 | 8,245.06 | 8,168.16 | 7,974.16 | 7,867.30 | 7,704.49 | 7,387.30 | 7,254.99 | 7,213.30 |
| $N_2O$ emissions (exc $N_2O$ from LULUCF) | 8,813.80 | 8,608.95 | 8,616.43 | 8,749.17 | 8,980.99 | 9,179.21 | 9,208.40 | 9,061.10 | 9,602.73 | 9,630.98 | 9,176.88 | 8,577.69 | 8,216.54 | 8,136.16 | 7,942.06 | 7,835.04 | 7,672.14 | 7,354.94 | 7,212.77 | 7,171.24 |
| HFCs | 0.69 | 5.27 | 6.17 | 9.44 | 19.97 | 44.85 | 76.11 | 133.35 | 191.95 | 198.25 | 231.23 | 253.05 | 278.14 | 351.42 | 387.29 | 436.66 | 509.17 | 500.76 | 520.88 | 500.92 |
| 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 |
| $SF_6$ | 35.40 | 40.64 | 45.87 | 55.35 | 64.83 | 82.83 | 102.06 | 132.10 | 94.19 | 68.87 | 55.81 | 69.30 | 69.95 | 118.18 | 66.64 | 95.46 | 67.46 | 68.75 | 60.83 | 65.30 |
| **Total including LULUCF** | **54,255.09** | **55,046.46** | **55,039.03** | **55,243.07** | **56,456.79** | **57,705.89** | **59,772.87** | **61,159.89** | **63,686.03** | **65,180.84** | **67,076.99** | **68,810.31** | **66,785.07** | **66,680.55** | **66,549.03** | **67,857.21** | **67,277.40** | **66,164.68** | **65,459.67** | **60,221.79** |
| **Total excluding LULUCF** | **54,820.10** | **55,615.97** | **55,623.41** | **56,000.55** | **57,439.04** | **58,490.49** | **60,497.88** | **61,951.13** | **64,817.57** | **66,264.99** | **67,865.14** | **69,700.85** | **67,870.13** | **67,842.41** | **67,683.11** | **69,221.44** | **68,683.47** | **68,034.80** | **67,817.10** | **62,394.85** |

***(b) Recalculated Emissions by Gas 1990 –2009 reported in 2012 Submission (Gg $CO_2$eq)***

| GAS | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (inc net $CO_2$ 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 |
| $CO_2$ (exc net $CO_2$ 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 |
| $CH_4$ emissions (inc $CH_4$ from LULUCF) | 13,675.79 | 13,847.88 | 13,963.45 | 13,976.04 | 13,903.81 | 13,922.00 | 14,179.60 | 14,197.68 | 14,418.24 | 13,955.68 | 13,412.72 | 13,461.56 | 13,394.99 | 13,943.54 | 13,157.18 | 12,809.32 | 12,884.17 | 12,366.19 | 12,243.46 | 11,924.81 |
| $CH_4$ emissions (exc $CH_4$ from LULUCF) | 13,673.09 | 13,846.14 | 13,962.34 | 13,973.79 | 13,901.23 | 13,918.48 | 14,175.69 | 14,195.54 | 14,417.11 | 13,954.76 | 13,410.41 | 13,456.94 | 13,393.93 | 13,937.00 | 13,153.37 | 12,807.94 | 12,882.78 | 12,364.63 | 12,241.56 | 11,923.74 |
| $N_2O$ emissions (inc $N_2O$ from LULUCF) | 9,131.87 | 8,937.88 | 8,935.16 | 9,068.97 | 9,297.69 | 9,524.62 | 9,600.60 | 9,480.38 | 9,997.74 | 9,941.92 | 9,485.15 | 8,969.81 | 8,605.45 | 8,525.45 | 8,349.07 | 8,139.80 | 8,010.28 | 7,794.14 | 7,701.14 | 7,607.84 |
| $N_2O$ emissions (exc $N_2O$ from LULUCF) | 9,111.30 | 8,912.52 | 8,908.06 | 9,038.14 | 9,265.98 | 9,491.33 | 9,564.71 | 9,444.42 | 9,961.06 | 9,904.58 | 9,446.93 | 8,927.11 | 8,560.37 | 8,476.10 | 8,299.53 | 8,089.93 | 7,959.92 | 7,742.97 | 7,637.16 | 7,543.63 |
| HFCs | 1.31 | 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 |
| 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 |
| $SF_6$ | 35.51 | 40.74 | 45.97 | 55.46 | 64.94 | 82.93 | 102.17 | 132.20 | 93.09 | 67.38 | 54.35 | 67.84 | 67.73 | 115.43 | 68.65 | 101.63 | 62.90 | 65.52 | 56.68 | 38.24 |
| **Total including LULUCF** | **55,363.93** | **56,187.06** | **56,215.55** | **56,378.32** | **57,816.01** | **59,243.87** | **61,325.98** | **62,641.25** | **64,999.05** | **66,288.99** | **68,495.37** | **70,353.52** | **68,227.44** | **68,153.97** | **68,140.28** | **69,098.40** | **68,595.62** | **67,594.53** | **66,458.87** | **60,705.83** |
| **Total excluding LULUCF** | **55,162.55** | **55,938.27** | **55,931.15** | **56,237.60** | **57,643.21** | **58,771.07** | **60,793.62** | **62,240.54** | **64,966.40** | **66,197.52** | **68,103.35** | **70,064.81** | **68,154.67** | **68,198.76** | **68,064.16** | **69,315.38** | **68,896.90** | **68,302.70** | **67,567.04** | **61,741.50** |

### *(c) Percentage Change in Emissions by Gas 1990-2009*

| GAS | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (inc net $CO_2$ from LULUCF) | 2.26 | 2.28 | 2.34 | 2.44 | 3.09 | 3.39 | 2.99 | 2.66 | 2.27 | 2.07 | 2.59 | 2.46 | 2.47 | 2.45 | 2.66 | 2.36 | 2.35 | 2.47 | 1.44 | 0.87 |
| $CO_2$ (exc net $CO_2$ from LULUCF) | -0.12 | -0.19 | -0.29 | -0.28 | -0.31 | -0.21 | -0.43 | -0.46 | -0.64 | -0.73 | -0.06 | -0.05 | -0.09 | -0.05 | 0.00 | -0.08 | -0.02 | -0.03 | -1.21 | -1.80 |
| $CH_4$ emissions (inc $CH_4$ from LULUCF) | 0.63 | 0.59 | 0.80 | 0.27 | 0.15 | 0.26 | 0.61 | 0.46 | 0.17 | -0.40 | -0.22 | 0.12 | -0.36 | 0.10 | -0.04 | -1.29 | -0.76 | -1.07 | -1.11 | -2.08 |
| $CH_4$ emissions (exc $CH_4$ from LULUCF) | 0.62 | 0.58 | 0.79 | 0.26 | 0.13 | 0.25 | 0.59 | 0.45 | 0.17 | -0.40 | -0.23 | 0.10 | -0.36 | 0.07 | -0.05 | -1.30 | -0.77 | -1.07 | -1.12 | -2.09 |
| $N_2O$ emissions (inc $N_2O$ from LULUCF) | 3.44 | 3.64 | 3.52 | 3.44 | 3.31 | 3.54 | 4.01 | 4.38 | 3.88 | 2.99 | 3.11 | 4.25 | 4.37 | 4.37 | 4.70 | 3.46 | 3.97 | 5.51 | 6.15 | 5.47 |
| $N_2O$ emissions (exc $N_2O$ from LULUCF) | 3.38 | 3.53 | 3.38 | 3.30 | 3.17 | 3.40 | 3.87 | 4.23 | 3.73 | 2.84 | 2.94 | 4.07 | 4.18 | 4.18 | 4.50 | 3.25 | 3.75 | 5.28 | 5.88 | 5.19 |
| HFCs | 88.74 | 33.97 | 59.05 | 58.68 | 37.82 | 21.19 | 20.26 | 14.78 | 12.83 | 12.68 | 12.09 | 10.29 | 10.86 | 8.47 | 7.12 | 8.66 | 7.45 | 6.62 | 8.41 | 4.02 |
| 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 |
| $SF_6$ | 0.31 | 0.27 | 0.23 | 0.19 | 0.16 | 0.13 | 0.10 | 0.08 | -1.16 | -2.16 | -2.61 | -2.11 | -3.17 | -2.33 | 3.02 | 6.46 | -6.76 | -4.69 | -6.83 | -41.45 |
| **Total including LULUCF** | **2.04** | **2.07** | **2.14** | **2.06** | **2.41** | **2.67** | **2.60** | **2.42** | **2.06** | **1.70** | **2.11** | **2.24** | **2.16** | **2.21** | **2.39** | **1.83** | **1.96** | **2.16** | **1.53** | **0.80** |
| **Total excluding LULUCF** | **0.62** | **0.58** | **0.55** | **0.42** | **0.36** | **0.48** | **0.49** | **0.47** | **0.23** | **-0.10** | **0.35** | **0.52** | **0.42** | **0.53** | **0.56** | **0.14** | **0.31** | **0.39** | **-0.37** | **-1.05** |

*Table 10.3 Recalculations by IPCC Sector 1990-2009*

***(a) Emissions by IPCC Sector 1990 –2009 reported in 2011 Submission (Gg $CO_2$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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy | 31,006.21 | 31,890.03 | 31,817.00 | 31,986.17 | 32,952.83 | 33,800.38 | 35,429.75 | 36,522.59 | 38,770.66 | 40,461.91 | 42,477.12 | 44,590.54 | 43,389.76 | 43,907.93 | 44,025.63 | 45,765.25 | 45,357.52 | 45,493.05 | 45,809.62 | 41,472.03 |
| 2. Industrial Processes | 3,178.55 | 2,888.68 | 2,816.16 | 2,804.76 | 3,080.85 | 3,073.12 | 3,214.94 | 3,666.77 | 3,507.14 | 3,571.78 | 4,195.97 | 4,305.31 | 3,726.95 | 3,041.01 | 3,143.42 | 3,253.26 | 3,263.69 | 3,280.52 | 2,989.49 | 2,117.12 |
| 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 | 74.05 | 75.14 | 75.68 | 74.36 | 71.80 |
| 4. Agriculture | 19,253.54 | 19,373.38 | 19,460.45 | 19,632.45 | 19,781.89 | 19,956.01 | 20,283.20 | 20,387.58 | 21,097.26 | 20,769.39 | 19,697.27 | 19,197.63 | 19,049.57 | 19,131.03 | 18,940.60 | 18,744.48 | 18,514.50 | 17,823.45 | 17,657.35 | 17,491.31 |
| 5. LULUCF | -565.01 | -569.52 | -584.38 | -757.48 | -982.25 | -784.60 | -725.01 | -791.24 | -1,131.53 | -1,084.15 | -788.15 | -890.55 | -1,085.06 | -1,161.86 | -1,134.08 | -1,364.23 | -1,406.07 | -1,870.12 | -2,357.43 | -2,173.06 |
| 6. Waste | 1,301.78 | 1,382.10 | 1,447.56 | 1,494.55 | 1,539.80 | 1,575.59 | 1,484.60 | 1,288.32 | 1,355.88 | 1,378.18 | 1,415.74 | 1,529.45 | 1,628.24 | 1,688.06 | 1,499.54 | 1,384.39 | 1,472.62 | 1,362.10 | 1,286.28 | 1,242.59 |
| 7. Other | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Total exc LULUCF** | **54,820.10** | **55,615.97** | **55,623.41** | **56,000.55** | **57,439.04** | **58,490.49** | **60,497.88** | **61,951.13** | **64,817.57** | **66,264.99** | **67,865.14** | **69,700.85** | **67,870.13** | **67,842.41** | **67,683.11** | **69,221.44** | **68,683.47** | **68,034.80** | **67,817.10** | **62,394.85** |

***(b) Recalculated Emissions by IPCC Sector 1990 –2009 reported in 2012 Submission (Gg $CO_2$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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy | 30,966.41 | 31,825.30 | 31,718.02 | 31,884.79 | 32,832.64 | 33,711.66 | 35,251.72 | 36,319.94 | 38,478.94 | 40,120.63 | 42,415.19 | 44,532.23 | 43,316.90 | 43,857.59 | 44,002.40 | 45,702.54 | 45,328.88 | 45,479.48 | 45,251.01 | 40,717.85 |
| 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 | 2,110.20 |
| 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 | 71.80 |
| 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 |
| 5. LULUCF | 201.37 | 248.79 | 284.41 | 140.71 | 172.81 | 472.80 | 532.35 | 400.71 | 32.66 | 91.47 | 392.02 | 288.70 | 72.78 | -44.79 | 76.12 | -216.98 | -301.28 | -708.17 | -1,108.17 | -1,035.66 |
| 6. Waste | 1,301.78 | 1,382.10 | 1,447.56 | 1,494.55 | 1,539.80 | 1,575.59 | 1,484.60 | 1,288.32 | 1,355.88 | 1,378.18 | 1,415.74 | 1,529.45 | 1,628.24 | 1,688.06 | 1,499.90 | 1,384.39 | 1,472.62 | 1,141.90 | 1,050.28 | 915.56 |
| 7. Other | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Total exc LULUCF** | **55,162.55** | **55,938.27** | **55,931.15** | **56,237.60** | **57,643.21** | **58,771.07** | **60,793.62** | **62,240.54** | **64,966.40** | **66,197.52** | **68,103.35** | **70,064.81** | **68,154.67** | **68,198.76** | **68,064.16** | **69,315.38** | **68,896.90** | **68,302.70** | **67,567.04** | **61,741.50** |

***(c) Percentage Change in Emissions by Sector 1990-2009***

| SOURCE AND SINK CATEGORIES | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Energy | -0.13 | -0.20 | -0.31 | -0.32 | -0.36 | -0.26 | -0.50 | -0.55 | -0.75 | -0.84 | -0.15 | -0.13 | -0.17 | -0.11 | -0.05 | -0.14 | -0.06 | -0.03 | -1.22 | -1.82 |
| 2. Industrial Processes | 0.02 | 0.07 | 0.13 | 0.20 | 0.25 | 0.31 | 0.48 | 0.54 | 0.67 | 0.66 | 0.63 | 0.57 | 0.75 | 0.89 | 0.94 | 1.35 | 1.02 | 0.91 | 1.33 | -0.33 |
| 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 | 0.01 | 0.01 | 0.02 | -0.05 | -0.01 | -0.06 | 0.01 |
| 4. Agriculture | 1.98 | 1.99 | 2.07 | 1.70 | 1.60 | 1.80 | 2.26 | 2.32 | 1.98 | 1.20 | 1.39 | 2.07 | 1.73 | 1.98 | 1.98 | 0.60 | 1.13 | 2.65 | 2.86 | 2.49 |
| 5. LULUCF | -135.64 | -143.69 | -148.67 | -118.58 | -117.59 | -160.26 | -173.43 | -150.64 | -102.89 | -108.44 | -149.74 | -132.42 | -106.71 | -96.15 | -106.71 | -84.09 | -78.57 | -62.13 | -52.99 | -52.34 |
| 6. Waste | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | -16.17 | -18.35 | -26.32 |
| 7. Other | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Total exc LULUCF** | 0.62 | 0.58 | 0.55 | 0.42 | 0.36 | 0.48 | 0.49 | 0.47 | 0.23 | -0.10 | 0.35 | 0.52 | 0.42 | 0.53 | 0.56 | 0.14 | 0.31 | 0.39 | -0.37 | -1.05 |

# PART II

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

# Chapter 11

# Emissions and Removals from LULUCF Activities under Article 3.3 of the Kyoto Protocol

## 11.1 General Information

### 11.1.1 Introduction

The major item of supplementary information required under Article 7.1 of the Kyoto Protocol is the 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 and 2009 associated with afforestation, reforestation and deforestation in Ireland since 1990. The estimates of emissions and removals for these activities are compiled in supplementary CRF tables similar to those used for submitting the GHG inventory under the Convention as described in Part I of this NIR. The reported net removals of $CO_2$ in 2010 on 279.60 kha of lands subject to afforestation/reforestation since 1990 is estimated at 2,984.89 Gg while there were net emissions of 19.54 Gg $CO_2$ on a deforested area of 8.24 kha. The overall forest sink for Article 3.3 forest increased from 2,451.31 Gg $CO_2$eq in 2008 to 2,984.89 Gg $CO_2$eq in 2010, 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 ARD activities since 1990 is 2,675.10, 2,823.83 and 3,010.18 Gg $CO_2$ in 2008, 2009 and 2010, respectively (Table 11.4). The approach to data collection and the methodologies used to derive the estimates for Article 3.3 activities are described below.

### 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. A different system is used to report for *Forest Land* in the LULUCF inventory under the Convention (Chapter 7) due to a lack of suitable historic activity data, such as forest inventory information (due to completion of second inventory cycle in 2012). However, it is envisaged that a new time series will be reported for both *Forest Land Remaining Forest Land* and *Land Converted to Forest Land* once there 2$^{nd}$ NFI is completed for delivery of data derived using the new methods to enable back extrapolation to 1990.

The newly developed tier 3 CARBWARE system is based on a land transition matrix and detailed forest activity information (See Figure 11.1). The forest **activity data** sources for the Article 3.3 inventory are the National Forest Inventory (NFI) and felling license records compiled by the Forest Service. Memoranda of Understanding have been established between COFORD and these key data providers (Table 1.1) to facilitate timely annual reporting by FERS. Additional information is supplied by the semi-private forestry company (Coillte). The state Forest Information Planning System (FIPS), the Grants Payment Administration Scheme (GPAS) and limited felling licence records are used to derive **spatial data**. The reporting system includes an on-going QA/QC system, whereby model outputs are validated against repeated NFI measurements on a 5 year rolling basis. Additional, external data checks on activity data are carried out by the data suppliers. The first repeat forest inventory on one-fifth of the forest area was completed 2011, with the remaining completed by the end of 2012.

***Table 11.1 Reported Activities and Pools (CRF Table NIR 1)***

| Activity | | Change in carbon pool reported[(1)] | | | | | Greenhouse gas sources reported[(2)] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Above-ground biomass | Below-ground biomass | Litter | Dead wood | Soil | Fertilization[(3)] | Drainage of soils under forest management | Disturbance associated with land-use conversion to croplands | Liming | Biomass burning[(4)] | | |
| | | | | | | | $N_2O$ | $N_2O$ | $N_2O$ | $CO_2$ | $CO_2$ | $CH_4$ | $N_2O$ |
| Article 3.3 activities | Afforestation and Reforestation | R | R | R | R | R | IE | | | NO | R | R | R |
| | Deforestation | R | R | R | R | R | | | NO | R | NO | NO | NO |
| Article 3.4 activities | Forest Management | NA | NA | NA | NA | NA | NA | NA | | NA | NA | NA | NA |
| | Cropland Management | NA | NA | NA | NA | NA | | | NA | NA | NA | NA | NA |
| | Grazing Land Management | NA | NA | NA | NA | NA | | | | NA | NA | NA | NA |
| | Revegetation | NA | NA | NA | NA | NA | | | | NA | NA | NA | NA |

*R indicates the reported carbon pools and emissions from biomass burning;*
*IE (included elsewhere) is used to show that emissions from fertilisation of soils are included under Agriculture*
*Only organo-mineral and organic soils are reported. Mineral soils are shown not to be "a source", so are not reported.*

***Table 11.2 Land Transition Matrix (CRF Table NIR 2) for inventory year 2010***

| To current inventory / From previous inventory year | | Article 3.3 activities | | Article 3.4 activities | | | | Other [(5)] | Total area at the beginning of the current inventory year[(6)] |
|---|---|---|---|---|---|---|---|---|---|
| | | Afforestation and Reforestation | Deforestation | Forest Management (if elected) | Cropland Management (if elected) | Grazing Land Management (if elected) | Revegetation (if elected) | | |
| | | (kha) | | | | | | | |
| Article 3.3 activities | Afforestation and Reforestation | 271.290 | 0.124 | | | | | | 271.414 |
| | Deforestation | | 8.118 | | | | | | 8.118 |
| Article 3.4 activities | Forest Management (if elected) | | NA | NA | | | | | NA |
| | Cropland Management[(4)] (if elected) | NA | NA | | NA | NA | NA | | NA |
| | Grazing Land Management[(4)] (if elected) | NA | NA | | NA | NA | NA | | NA |
| | Revegetation[(4)] (if elected) | NA | | | NA | NA | NA | | NA |
| Other [(5)] | | 8.314 | 0.000 | NA | NA | NA | NA | 6,823.940 | 6,832.254 |
| Total area at the end of the current inventory year | | 279.604 | 8.242 | NA | NA | NA | NA | 6,823.940 | 7,111.786 |

*Areas and changes in areas between the previous and the current inventory year*

***Table 11.3 Key Categories for Article 3.3 Activities (CRF Table NIR 3)***

| KEY CATEGORIES OF EMISSIONS AND REMOVALS | GAS | CRITERIA USED FOR KEY CATEGORY IDENTIFICATION | | | COMMENTS [(3)] |
|---|---|---|---|---|---|
| | | Associated category in UNFCCC inventory[(1)] is key (indicate which category) | Category contribution is greater than the smallest category considered key in the UNFCCC inventory [(1), (4)] (including LULUCF) | Other [(2)] | |
| Specify key categories according to the national level of disaggregation used[(1)] | | | | | |
| Afforestation and Reforestation | CO2 | Forest land remaining forest land, Conversion to forest land | Yes | No | Level assessment |

*Table 11.4 Information Table on Accounting for Activities under Articles 3.3 and 3.4 of the Kyoto Protocol*

| GREENHOUSE GAS SOURCE AND SINK ACTIVITIES | BY(5) | Net emissions/removals(1) | | | | Accounting Parameters[7] | Accounting Quantity[8] |
|---|---|---|---|---|---|---|---|
| | | 2008 | 2009 | 2010 | Total[6] | | |
| | (Gg $CO_2$ equivalent) | | | | | | |
| **A. Article 3.3 activities** | | | | | | | |
| **A.1. Afforestation and Reforestation** | | | | | | | -8,589.642 |
| A.1.1. Units of land not harvested since the beginning of the commitment period[2] | | -2,701.547 | -2,858.382 | -3,029.713 | -8,589.642 | | -8,589.642 |
| A.1.2. Units of land harvested since the beginning of the commitment period[2] | | | | | | | 0.000 |
| *Ireland* | | 250.237 | 26.128 | 44.819 | 321.184 | | 0.000 |
| *All Harvested AR land (101-114)* | | IE,NO | IE,NO | IE,NO | IE,NO | | IE,NO |
| **A.2. Deforestation** | | 26.444 | 34.548 | 19.537 | 80.529 | | 80.529 |
| **B. Article 3.4 activities** | | | | | | | |
| **B.1. Forest Management (if elected)** | | NA | NA | NA | NA | | NA |
| 3.3 offset[3] | | | | | | 0.000 | NA |
| FM cap[4] | | | | | | 916.667 | NA |
| **B.2. Cropland Management (if elected)** | 0.000 | NA | NA | NA | NA | 0.000 | 0.000 |
| **B.3. Grazing Land Management (if elected)** | 0.000 | NA | NA | NA | NA | 0.000 | 0.000 |
| **B.4. Revegetation (if elected)** | 0.000 | NA | NA | NA | NA | 0.000 | 0.000 |

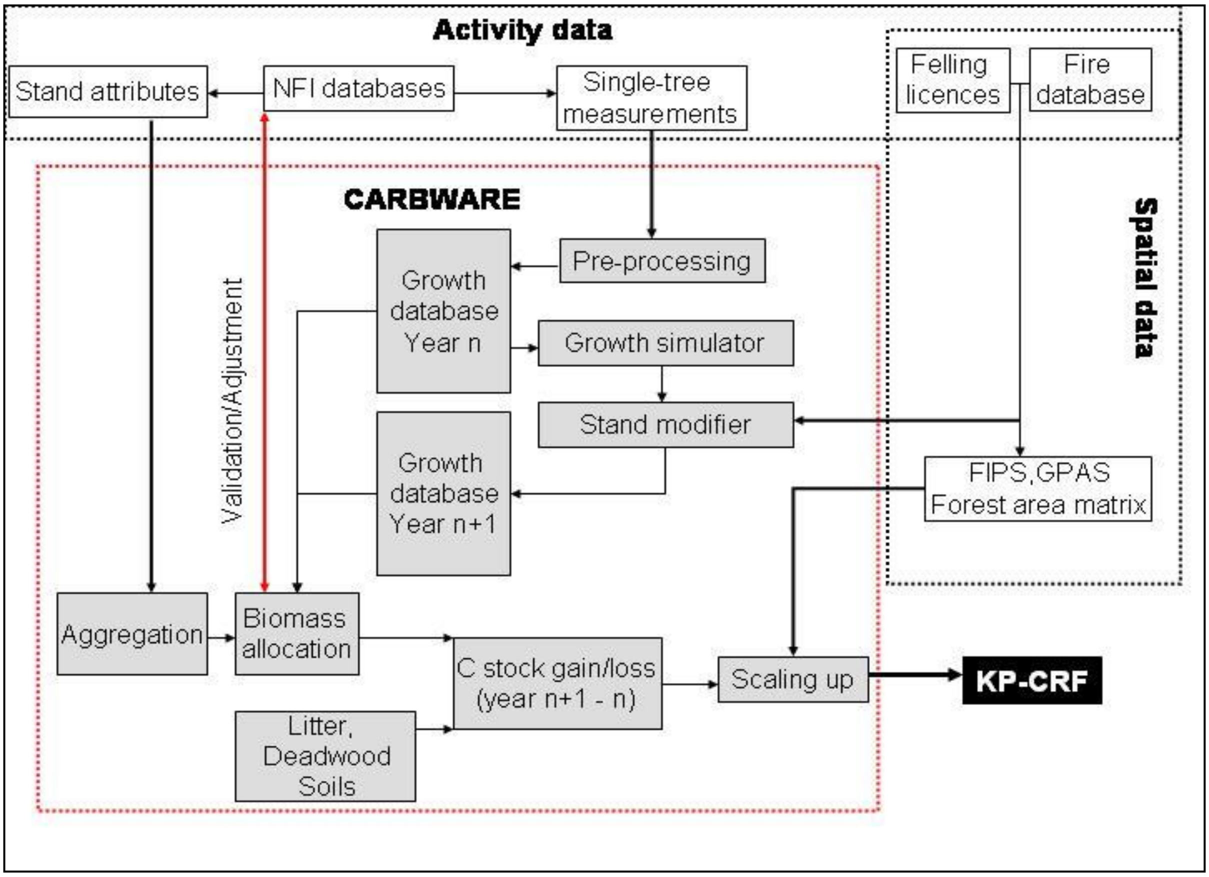



*Figure 11.1: Schematic Overview of Reporting System and CARBWARE Functionality*

## 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 (see section 11.4.2);
- 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;
- In contrast to Convention reporting all age classes are included and reported using CARBWARE v5. This is facilitated because NFI 2006 captures biomass information for all aged trees.

Reforestation activities do not occur in Ireland and the relevant activities under Article 3.3 are limited to afforestation and deforestation. All afforested areas are the result of planting and establishment of forest areas of 5 ha or greater under guidelines of the Forest Service Grant and Premiums Scheme (Forest Service, 2003). All of these forest areas are consistent with the forest definition. The scheme was introduced under European Commission Council Regulation 2080/92 to support afforestation of agricultural land as part of accompanying measures to reform the Common Agricultural Policy. The afforestation grant and premiums dataset captures all areas afforested following successful grant application. Afforestation areas recorded by the Forest Service are verified using a strict control and referrals process, following a post-establishment site visit by a forestry inspector (Forest Service, 2003). All deforestation areas are derived from legally-binding licence applications under the Forestry Act. These provisions fulfil the requirement to demonstrate that afforestation (i.e. planting of non-forest land with trees for development of the forest sector) and deforestation began on or after1 January 1990 and are directly human-induced, which is necessary for the accounting of emissions and removals for activities under Article 3.3. These datasets were primarily digitised using the 1:12560 and 1:2500 Ordnance Survey Ireland (OSI) raster maps (see section 11.2).

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 (Chapter 7), this definition of deforestation has been applied consistently in developing the 1990 to 2010 area time-series. In addition, a consistent time series has been recalculated for deforested areas (Section 7.3), based on new activity data obtained from 2006 onwards (Chapter 7).

## 11.1.4 Comparison of Forest Areas under Convention and Article 3.3 Reporting

There are marked differences in the areas reported under the Convention (See Chapter 7 and Annex G) and those subject to reporting for. Article 3.3 activities. Under Convention reporting, forest areas undergo transitions between categories, whereby areas in *Land Converted to Forest Land (F-L)* move to the *Forest Land Remaining Forest Land (F-F)* category after a transtion period of 20 years. For example, an afforested area in 1980 remains in the F-L category until 1999 and is then transferred to the F-F category in 2000. In reporting under the Protocol, Article 3.3 areas can not move to Article 3.4 areas and deforestation areas can not move to any other category (thus the area can only increase in time). Article 3.4 forest management areas are initially determined at 1990 levels and can, therefore, only decrease in time due to deforestation events. Table 11.5 shows the relationship between areas for Article 3.3 and 3.4 activities and Convention forest areas reported for Ireland. The forest management area is much larger than the afforestation area but Ireland has elected not to account for this activity in the 2008-2012 commitment period.

***Table 11.5 Forest Areas Comparison***

**Forest category areas (kHa) 2010**

| Year | KP areas | | | Convention areas | | Total area |
|---|---|---|---|---|---|---|
| | FM | AR | D | F-F | F-L | |
| 1990 | 465.257 | 15.817 | 0.021 | 305.647 | 175.427 | 481.074 |
| 1991 | 465.237 | 34.964 | 0.041 | 315.737 | 184.464 | 500.201 |
| 1992 | 465.216 | 51.663 | 0.062 | 325.666 | 191.213 | 516.879 |
| 1993 | 465.196 | 67.661 | 0.082 | 335.466 | 197.391 | 532.857 |
| 1994 | 465.175 | 87.120 | 0.103 | 344.725 | 207.570 | 552.295 |
| 1995 | 464.842 | 110.830 | 0.436 | 353.592 | 222.080 | 575.672 |
| 1996 | 464.508 | 131.811 | 0.770 | 361.858 | 234.461 | 596.319 |
| 1997 | 464.175 | 143.245 | 1.103 | 369.885 | 237.535 | 607.420 |
| 1998 | 463.842 | 156.173 | 1.436 | 377.822 | 242.193 | 620.015 |
| 1999 | 463.509 | 168.841 | 1.770 | 385.349 | 247.001 | 632.350 |
| 2000 | 462.651 | 184.536 | 2.627 | 390.681 | 256.506 | 647.187 |
| 2001 | 461.794 | 200.001 | 3.484 | 396.198 | 265.597 | 661.795 |
| 2002 | 460.937 | 215.055 | 4.341 | 401.855 | 274.137 | 675.992 |
| 2003 | 460.080 | 224.152 | 5.198 | 407.023 | 277.209 | 684.232 |
| 2004 | 459.223 | 233.891 | 6.055 | 411.831 | 281.283 | 693.114 |
| 2005 | 458.366 | 243.987 | 6.912 | 416.216 | 286.137 | 702.353 |
| 2006 | 458.126 | 251.890 | 7.287 | 422.809 | 287.206 | 710.015 |
| 2007 | 457.951 | 258.901 | 7.625 | 430.820 | 286.032 | 716.852 |
| 2008 | 457.924 | 264.882 | 7.920 | 442.232 | 280.574 | 722.806 |
| 2009 | 457.873 | 271.383 | 8.118 | 457.160 | 272.096 | 729.256 |
| 2010 | 457.842 | 279.604 | 8.242 | 472.853 | 264.593 | 737.446 |

*FM, Forest management, AR and D are afforested reforested and deforested areas under article 3.3 (see* ***KP CRF Table NIR2****). F-L is lands converted to forests and F-F forest remaining forests (20 year transitions) UNCL, are unclassified forest areas in the F_F category that are reported under Convention reporting, but the CSC is assumed to be zero (see Chapter 7, CRF Tables). For comparison to Convention reporting, KP (3.4)* ***FM = F-F + UNCL+ F-L – AR***
*The AR areas reported in NIR2 and in Table 11.5 are derived from the iFORIS database (see section 11.2.2.1) minus lands taken out of the afforestation scheme (GPAS) due to deforestation (see Table 11.6). The lands taken out of the GPAS are included in the deforestation area (D, Table 11.5).*

## 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. Unharvested and harvested afforestation and deforestation areas are reported within the entire territory of Ireland, with further sub division into species strata (Table 11.6) 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 NIR2 are sub categorised into forest categories in order to transparently report and compare implied carbon stock change factors for different forest and soil types (Tables 5(KP-I)A.1.1 and 5(KP-I)A.1.2). For deforestation activities, (5(KP-I)A.1.2) areas are stratified according to land use activities converted form forest area. This is consistent with forests converted to non-forest lands in LULUCF Convention reporting (CRF 5 B, C, D and E).

### 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 Figure 11.1).

#### 11.2.2.1 Afforestation Areas (Approach 3)

The same methodology is used to derive afforestation areas for KP and Convention reporting of lands converted to forests. However, the time series represented by KP and LULUCF Convention reporting are different as explained in section 11.1.4 above. Ireland adopts approach 3 as set out by the IPCC GPG. Spatially explicit GIS polygons, representing all afforestation areas, were derived from the available FIPS98 spatial layer (see Chapter 7), which represents all forested land in 1998 (620.01 kha in Table 11.5 and Table G.1 Annex G) and digitised maps of afforested areas since 1990 using the Grants and Premiums Administration System (**GPAS**), archived in the **iFORIS** database (Figure 11.2). After attributing the species information with the unique ID from the **Species Data** table, the spatial and attribute data were joined in the **Premiums** layer. 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 **FIPS98** 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. The **Forestry08** layer is derived from the **GPAS08** data and the **Forestry07** layer (Figure 11.2). Some spatial and attribute data (approximately 2 per cent of the afforested areas in iFORIS) has not been captured on a small number of occasions because no spatial or species information was available for the **Premiums** dataset component. Therefore, the official total afforestation area is derived directly from the GPAS and IFORIS database

#### 11.2.2.2 Deforestation Areas (Approach 2/3)

Identical methodological approaches and area estimations are adopted for reporting deforestation under KP and conversion of forest to non-forest land (CRF 5). The Irish Forestry Act provides a legal obligation for land owners to apply for limited felling licences before trees can be felled for non-silvicultural reasons. These licences may only be granted if certain criteria are met and the land owner provides information on the area and volume of timber felled and an indication of future land use. Although the system does identify the areas of forested land that is deforested, the data is not spatially explicit. In addition, this system was only implemented in 2006. Estimates of deforestation for the years 1990-2005 have been reported in previous submissions under the Convention in the category *Forest Land Converted to Settlements*. However a new tracking system is now reported for deforestation areas prior to 2006 (see section 7.3.7). This was derived from CORINE data, the soil map and an intersection with the stratified grid sample used in the NFI for the years 1990 to 2005 (approach 3, see Section 7.3.7, Annex G). Land deforestation was verified using aerial photography when available (1995, 2000 and 2005). By adopting the assumption that immediate oxidation of all carbon pools takes place on deforested land in the year the felling licence is granted, this does not introduce any carbon sink/source bias within the time frame of the commitment period and reference period.

#### 11.2.2.3 Forest Fire Areas (Approach 2)

Areas of forest subjected to wild fires were obtained from Forest Service statistics (See Chapter 7, NIR). 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 subsequently to 2008.

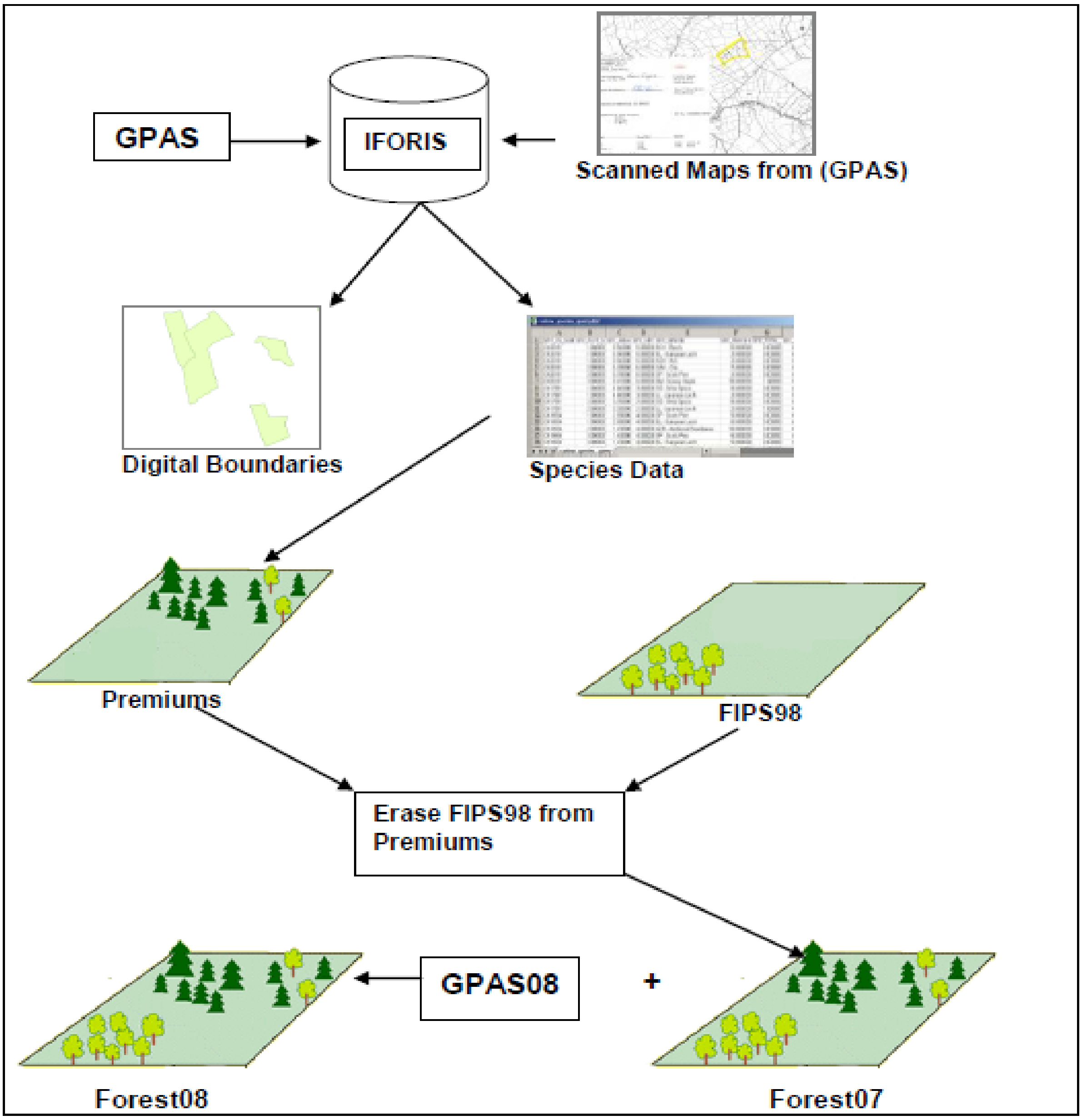



*Figure 11.2 Schematic overview of data and procedures used to create spatially explicit data*

## 11.2.3 Activity Data for Afforestation Areas

### 11.2.3.1 Use of National Forest Inventory data

Activity data used to derive KP estimates for afforestation activities vary considerably to those used for lands converted to forests (as explained in Chapter 7). The major difference is that KP reporting uses latest national forest inventory data to derive C stock change using biomass algorithms. In addition deadwood C is also estimated in KP reporting because NFI data contain deadwood measurements, while a tier 1 approach is adopted for Convention reporting. For biomass estimation, Convention reporting uses volume assessments and BEFs for a age class category 7 to 25 years old. This results in an underestimation of biomass CSC as explained in chapter 7. The methods could not be harmonised because no activity data exists to enable estimation for the historic time series 1990 to 2010. However, as explained in chapter 7 harmonisation will be implemented once the next NFI cycle is completed in 2012.

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. To provide the required activity data for forest areas, 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 2012. 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. These stages are land-use type, land-use category and land-use class (Figure 11.3). They form the basis of the NFI, as the classification process dictates whether the sample points are included in the NFI or not, and also the range of attributes to be collected at the individual sample points.

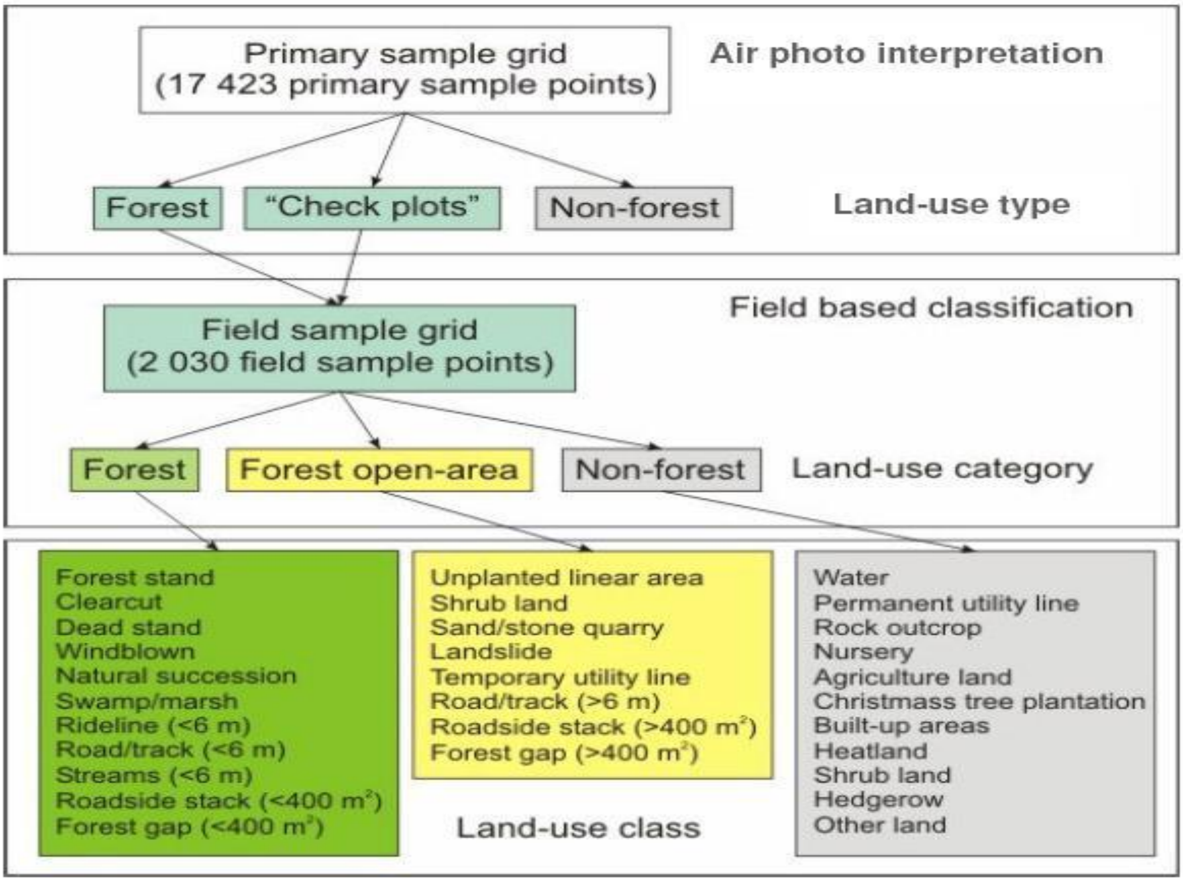
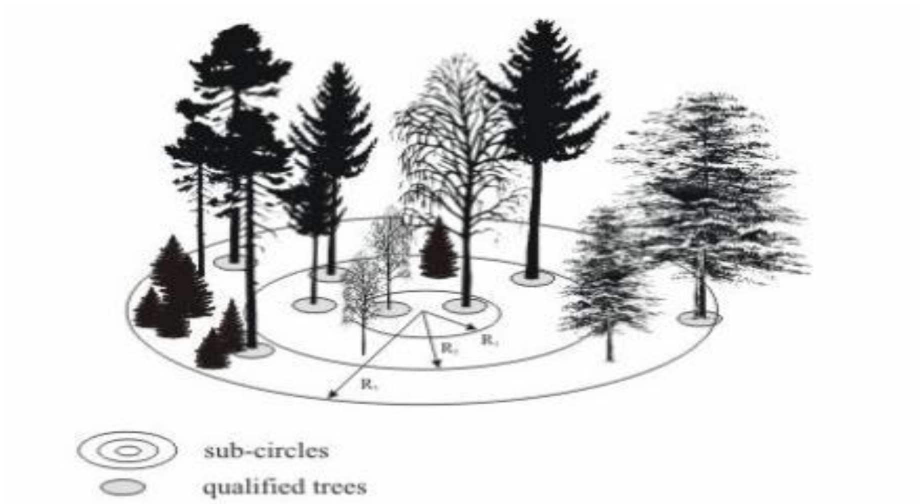



*Figure 11.3 Overview of the NFI classification system (taken from NFI, 2007a)*

The 2 km x 2 km grid is overlaid on the total land base map of the Republic of Ireland to facilitate land-use type (LUT) interpretation using colour air photographs (OSI, 2005). 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$^2$ (i.e. 25.24 m in diameter). Adjustments for slope are automatically made by the laser/range-finding equipment. The concentric circle approach, comprising three concentric circles with different radii is used for tree assessment. Trees of different dimensions are mapped and described on each particular plot (Figure 11.4). Individual trees in the plot are mapped and treemetric data are collected and archived in a GPS format. Forest mensuration measurements are made on selected **individual trees** within the plot based in the position within the plot and the threshold diameter (Figure 11.4)[6]. This information is used to estimate plot-level parameters and to scale up to 1 ha (section 11.3.2.1).




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

***Figure 11.4 The concentric plot design and mapping of individual trees NFI, 2007a***

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

[6] Note: The concentric plot sampling approach used (see Fig 11.4) has implication to uncertainty (see validation and uncertainty sections) i

than 30 cm were classified as peats soils. Mineral soils with an organic layer less than 30 cm were classified as mineral/peat soils.

Forest stand attributes 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 11.6).

***Table 11.6 Forest category codes used in CRF Tables 5 (KP1)***

| Forest_Category_Code | Forest_Category_Description |
|---|---|
| 1 | Spruce (Pure). Mainly Sitka and Norway spruce |
| 2 | Pine (Pure). Prodominantly Scots and lodgepole pine |
| 3 | Larch (Pure) |
| 4 | Other conifers (Pure) |
| 5 | Fast growing broadleaves (Pure) such as ask, Alder, Sycamore, Birch |
| 6 | Slow growing broadleaves (Pure) such as Oak and Beech |
| 7 | Conifer mixes |
| 8 | Broadleaf mix |
| 9 | Conifer/Boradleaf mix |
| 10 | Open areas including biodiversity areas, roads within the forest boundary |
| 11 | Blown areas subjected to windthrow |
| 12 | Scrub, felled or failed areas (planted and unplanted) |
| 13 | New afforestation after 2006 |
| 14 | Natural succession and regenreating land |
| 101 to 115 | Harvested areas. E.g 101 are harvested spruce areas |
| 200 | Burned areas |

*Forest stands were considered to be pure if one species represents 80 % or more of the canopy*

Note: Categories 12 and 14 do not qualify as afforestation or reforestation under Article 3.3 of the KP, so are reported as NO in the CRF tables.

Open areas are planned open areas in afforested areas for extraction roads of biodiversity enhancement. These are, however, assumed to be in steady state and reported as NO.

### 11.2.3.2 Activity Data for Afforestation Areas after 2006

Activity data of land afforested in 2007 and 2008 after the completion of the first NFI was derived by GIS analysis of the updated Premium Layer (Figure 11.2), a digitised map of indicative forest soils (IFS) and intersection with NFI grid co-ordinates (Figure 11.5). The resulting species/soil matrix was used to derive productivity classes and individual tree height values based on CARBWARE growth models (see Annex G3). These tables were used as inputs into the CARBWARE software to generate carbon gains and losses (see Figure 11.1)

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.

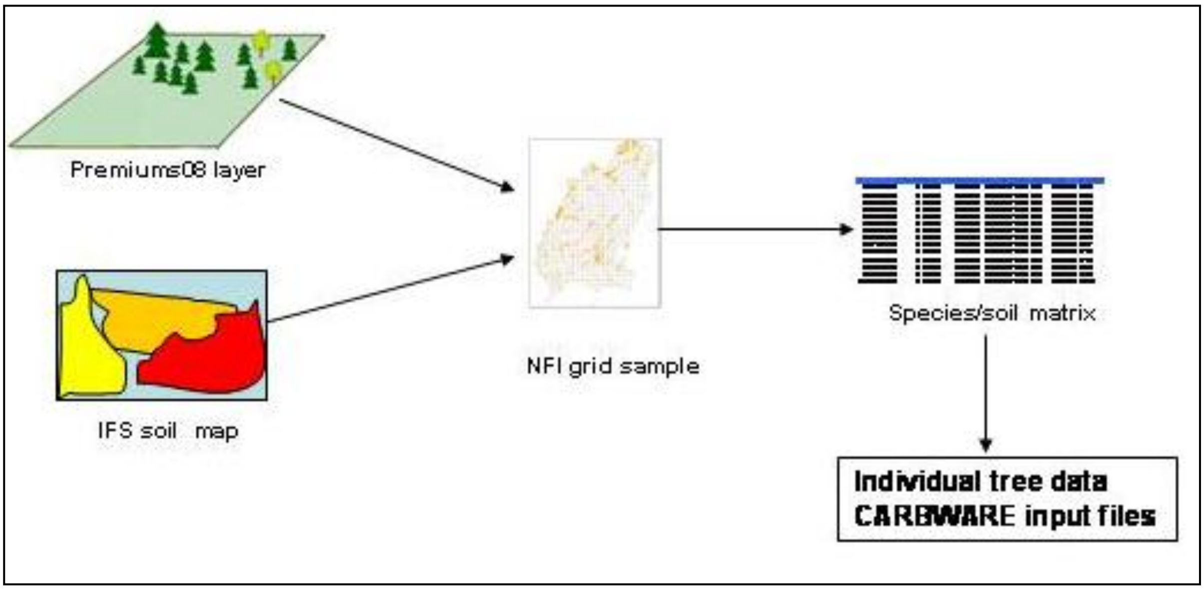



*Figure 11.5 Procedure to derive activity data for Afforestation Areas after 2006*

#### 11.2.3.3 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. The total timber volumes harvested from the afforestation areas (reported in 5(KP-I)A.1.2) was 45,754 $m^3$ in 2007, 85,268 $m^3$ in 2008, 33,503 $m^3$ in 2009 and 72,041 $m^3$ in 2010. No harvesting occurred on afforestation land prior to 2007. Harvesting from the Coillte lands represented 80 to 91 per cent of the total timber harvest from Article 3.3 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.

*Harvesting of State 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 11.6). 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 invoice** information. An **EventsTable** table for use in the **Carbw08_2005** 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 11.1) to ensure adequate timber was removed during a thinning simulation. If the plot did not contain the threshold basal area, replacement plots more suitable for thinning were randomly selected from the same forest area category (AR areas). 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.

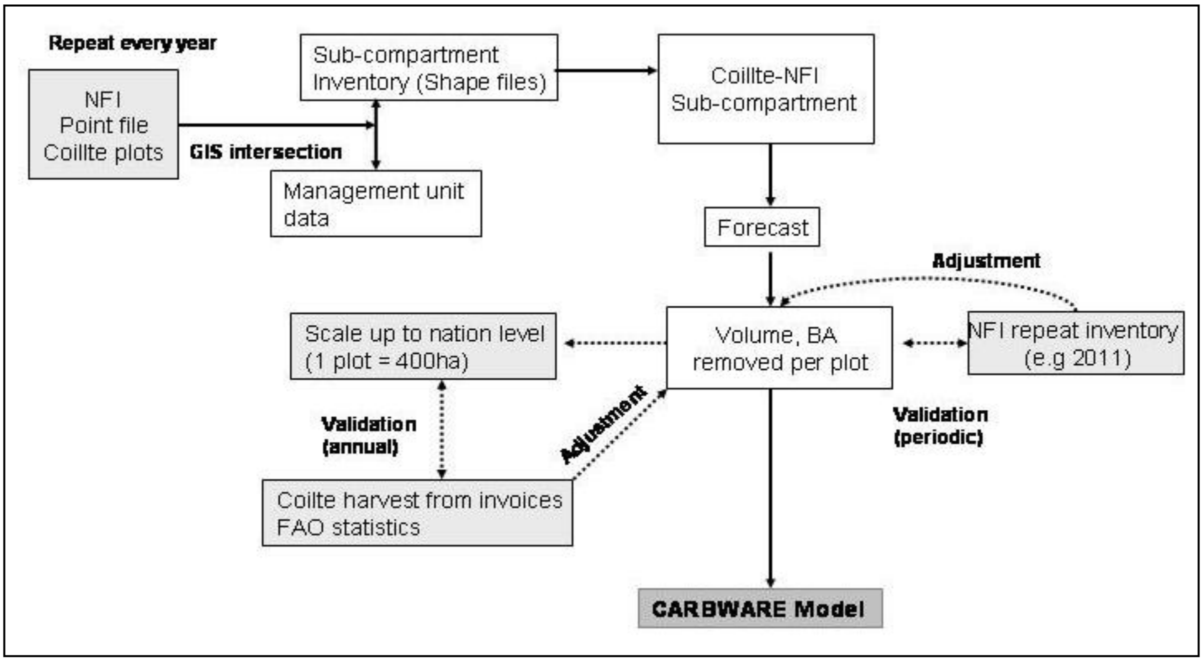



*Figure 11.6 Methodology used to derive harvest information for State Forests*

## *Harvesting of Private Forests*

A GIS layer was created by intersection of **Town land** boundaries and names (OSI) and the **Forest08 layer** compartments (see Figure 11.2) 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 11.7). 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 Carbw08_2005 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 11.1) to ensure adequate timber was removed during a thinning simulation. If plot did not contain the threshold basal area, replacement plots, more suitable for thinning, and from the same forest area category (AR areas), were randomly selected. It will be possible in the future to re-evaluate the activity data 'ground truthed data' from repeat NFI inventories of harvested plots.

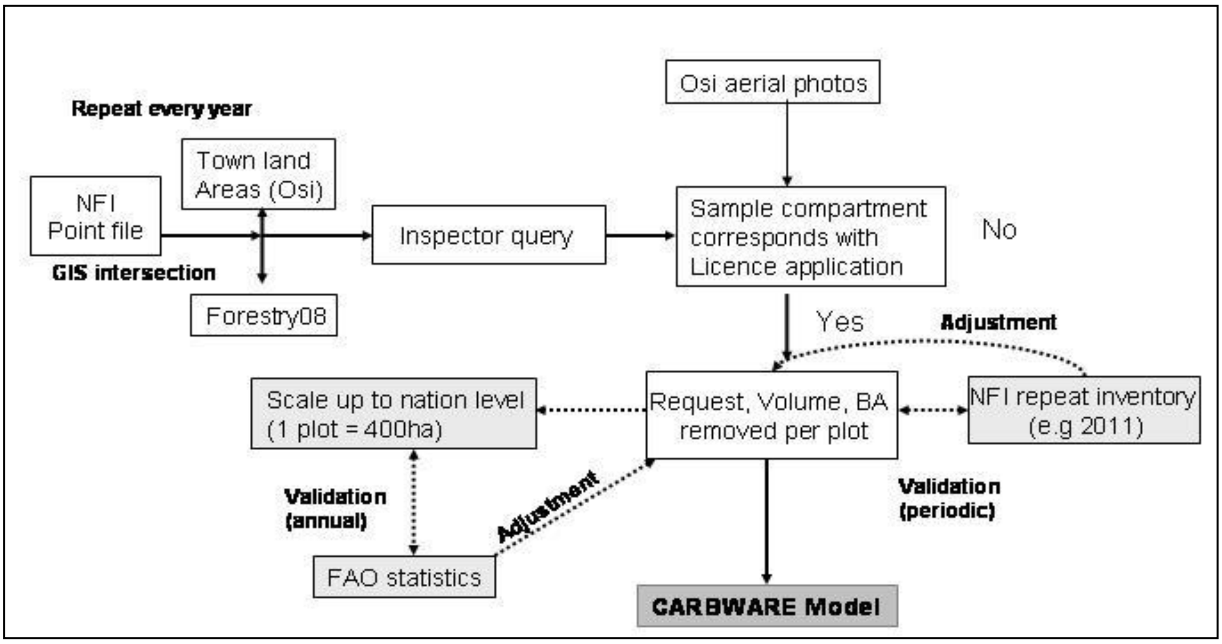



***Figure 11.7 Procedure used to derive harvest activity data for private forested areas***

### *Sub categorisation and statistical adjustment of NFI stratified grid sample*

The afforestation activities (KP (5-1) A1.1 and A1.2) are sub categorised into mutually exclusive forest types for reasons of transparency and comparability (Table 11.2). This categorisation was based on NFI plot measurements and descriptions.

A forest area is assigned to a forest plot based on NFI data detailing the year of planting, species and soil survey information obtained in permanent sample plots (PSP). A PSP is classified as a pure species stand if more than 80 % of the species in the plot are represented by a single species. If species mixtures are less than 79.9 % of a single species then the areas are defined as conifer mixes or conifer broadleaf mixes or broadleaf mixes depending on species breakdown in PSP. Some areas are classified as forest but have no current tree cover due to disturbances (see table 11.2). The soil classification is documented in section 11.2.3. The PSP data is also assigned an identification code where the forest is confirmed to be planted (afforested) after 1989.

Each PSP with a unique forest cohort and soil subcategory represents a forest area of 400ha (so 1 PSP = 500m2 * 20 * 400 = 400ha) due to the stratified sample. The PSP data to the scaled up level of 400ha is then readjusted with the afforestation GPAS data so that the total area from the NFI and GPAs coincide. This is also *done to ensure that afforestation (or any ARD activities) is detected and adjusted to meet the resolution consistent with the forest definition*. 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 Spruce cohort on mineral soils is estimated to be 48 kha based NFI PSP (i.e. 120 plots out of 650 (representing a total of 260 kha) plots for the afforestation categories) and the total GPAS area is 260.47 kha, then the area is readjusted as follows:

New sub-category area (48.09 kha) $= (\frac{120}{650}) \times 260.47$

These calculations are carried out automatically by the CARBWARE software as outlined in section 11.1. The calculation steps are subject to QA/QC checks during the coding of the software.

#### 11.2.3.4 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. 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 chapter 7 section 7.3.7).

All of these deforested areas are reported for the years 1990-2010 (see section 7.3.7). The areas, species, stand age, soil type and volume of timber removed from these areas are used to derive carbon stock changes for biomass, litter, deadwood and soil. The harvest data is first verified using Forestry Commission yield tables to check if volumes removed are within acceptable thresholds. If information is not supplied, the Forestry Commission yield tables are used to derive the relevant information (Edwards and Christy, 1981).

Biomass, litter and deadwood pools for deforestation land was assumed to be immediately oxidised in the year deforestation occurs. 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 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. crop or grasslands). The approach adopted in this case is **conservative** because biomass stock changes in grasslands and croplands represents a sink in the 1$^{st}$ year following conversion of 6 and 5 t C ha$^{-1}$, respectively (Eq 7.2 sections 7.4.2 and 7.5.2, Ch 7 of this NIR and according tier 1 IPCC GPG) other lands also included.

## 11.3 Activity-specific Information

### 11.3.1 Methods for carbon stock change and GHG emission and removal estimates

Ireland has used the methodologies provided in the 2006 IPCC guidelines for estimating carbon stock changes and emissions and removals of greenhouse gases for activities under Article 3.3 of the Kyoto Protocol. Differences between KP and Convention methodologies are discussed above (section 11.2.3.1) and in chapter 7. The estimates are derived using the tier 3 national CARBWARE v 5 model, the utility of which has been expanded considerably using the results of extensive national forest research and the NFI. The total carbon stock changes for a given forest category is calculated as the sum of the changes 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):

$$\Delta C_{lu} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{Li} + \Delta C_{Dw} + \Delta C_{So} \qquad (11.1)$$

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, but the methodologies used to derive these differ for the biomass pool in particular as described previously. Below ground biomass includes all roots up to a diameter of 5cm. Litter is defined as deadwood with a diameter of less than 7cm. This includes abscised needles and leaves. The dead wood pool included all lying and standing deadwood, dead roots and stumps with a diameter greater than 7cm. organic and mineral/organic soils are reported (see section 11.3.1.2)

#### 11.3.1.1 Biomass Carbon Stock Change

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

$$\Delta C = \Delta C_G + \Delta C_L \qquad (11.2)$$

The biomass carbon gains ($\Delta C_G$) for both above-ground biomass (AB) and below-ground biomass (BB) are calculated for each forest category i, listed in table 11.2 using

$$\Delta C_G = \sum_i \left( A_i \times GTOTAL_i \times CF \right) \qquad (11.3)$$

where $A_i$ is the area of the forest category, $GTOTAL_i$ is the biomass change (t dm/ha.yr) in area $A_i$ 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). $GTOTAL_i$ is derived from the sum of all living individual tree components (i.e. AB or BB) within the forest category in the NFI data, for example:

$$GTOTAL_{AB} = AB_n - AB_{n-1} \qquad (11.4)$$

where n is the year of inventory. The $GTOTAL_i$ value for each NFI permanent sample plot normalised to 1 ha (see section 11.3.1.1). The AB and BB of individual trees were calculated using biomass algorithms for different species cohorts based on national research information (Annex J, Table J.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 11.1). The increases in DBH and H of individual trees between NFI years were simulated in the single tree growth models (See J1-B and Table J1-B3 in Annex J). The stocking (number of trees in a plot) is adjusted after every growth simulation cycle using the stand modification module (Figure 11.1), which removes trees based on natural mortality models and harvest activity data (Annex J.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 ($L_{fire}$):

$$\Delta C_{L(AB)} = L_{timber} + L_{HR} + L_{LF} + L_{mort(AB)} + L_{fire} \qquad (11.5)$$

$L_{timber}$ is calculated based on the above-ground biomass removed from harvest, simulated in the stand modification module (Annex J.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:

$$L_{HR} = AG - L_{timber} \qquad (11.6)$$

$L_{LF}$ reflects the transfer of carbon from the AB pool to the litter pool. This is calculated in the **allocation module** (Figure 11.1), based on nationally derived leaf/needle biomass (LB) and the foliage turnover rates ($F_t$) (Tobin et al., 2006):

$$L_{LF} = LB \times F_t \qquad (11.7)$$

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 5 years (i.e. $F_t$ = 0.2) 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 J.2).

The above-ground biomass loss from mortality ($L_{mort(AB)}$) was calculated using DBH and H as dependent variables in biomass algorithms (Annex J, Table J.1). The AB carbon losses associated with fires ($L_{fire}$) was determined as described in section 7.3.4 of Chapter 7. 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 (see sections 11.3.1.2 and 11.3.2.3). 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 ($L_{fire}$):

$$\Delta C_{L(BB)} = L_{HRroot} + L_{mort(BB)} + L_{fire} \qquad (11.8)$$

$L_{HRroot}$ 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 J.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.

Since activity data and methods used to derive deforestation estimates were not based on NFI measurements, but rather felling licence volume estimates, the same approach was adopted as used for Convention reporting. Carbon stock changes associated with deforestation reported in CRF Table 5(KP-I)A.2 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):

$$\Delta C_{L(AB)} = C_{(AB)} \; + \; \Delta C_{L(BB)} = C_{(BB)} \qquad (11.9)$$

The carbon stocks in the AB and BB pools were calculated (as for Convention reporting, see chapter 7) 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, see section 7) of 1.68 t/t$^{-1}$, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2 (Black et al., 2009), as follows

$$TOTAL_{(AB)} = (V \times D \times BEF \times CF) \times (1-R) \quad \text{(11.10)}$$

$$TOTAL_{(BB)} = V \times D \times BEF \times CF \times R \quad \text{(11.11)}$$

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.

#### 11.3.1.2 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 11.7, harvest residue litter input ($L_{HR}$) in equation 11.6, mortality litter inputs ($M_{li}$), and losses associated with decomposition of the litter pool ($L_{decomp}$):

$$\Delta C_{Li} = (L_{LF} + L_{HR} + M_{Li}) - L_{decomp} \quad \text{(11.12)}$$

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

$$M_{Li} = L_{mort(AB)} - L_{mort(tim)} \quad \text{(11.13)}$$

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

$$L_{decomp} = 1 - \left[ \sum [L_{LF}, L_{HR}, M_{Li}, L_{old}]^{-D_{Lt}} \right] \quad \text{(11.14)}$$

$$L_{old} = \sum [\{(L_{LF}, L_{HR}, M_{Li})_{n-1,n-2,n-x}), L_{ini}\}]^{-D_{LI}} \quad \text{(11.15)}$$

where, $L_{ini}$ is the initial litter pool estimated following the completion of the first NFI in 2005 using the methodology described for litter inputs in section 7.3.2 of Chapter 7. Initial litter pool lookup '**stand attribute'** tables were constructed from static yield tables representing different forest categories (Table 11.2, Figure 11.1). 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.

Litter loss estimates from the aboveground C pool (see eq 11.7) for conifer crops have been developed based on national research for high yielding Sitka spruce (see Tobin et al., 2006). This represents ca. a 6 per cent loss (and to litter input) of individual tree aboveground biomass per year for all evergreen conifer crops. This does not include biomass losses from natural mortality. Decomposition losses are also derived from research on *Sitka spruce* crops only (Siaz et al., 2007, Black et al., 2009b). These estimated litter gains and losses have not been validated for other conifer crops or lower productivity sites. For deciduous conifer crops (i.e. Larch) and broadleaves, currently estimated losses can account for a 20 to 60 per cent loss of tree aboveground biomass since all leaves are transferred to the litter pool each year. As a result the net biomass CSC for broadleaf crops is a net loss due to this large litter loss (see 5(KP-I)A.1.1). Based on these results it may be considered that the biomass losses are overestimated and litter inputs are also overestimated. These model discrepancies may be due to:

- Unresolved model paramertisation of needle biomass algorithms for Sitka spruce as evident from the low $r^2$ and high RMSE (see Annex J table J1)
- Over estimation of needle biomass for less productive conifer and broadleaf crops, as evident form the slope of the observed versus estimated leaf biomass relationship (0.79, suggesting an overestimation of leaf biomass by 21 per cent, see slow and fast growing broadleaf leaf algorithms in Annex J, table J1. These are derived from research in beech crops in northern Europe (Bartelink, 1995)
- Current leaf turn-over of 5 years for evergreen conifers is considered to be low, therefore the resulting litter inputs may be high
- As mentioned these models were developed on highly productive stands. We are currently investigating if improvements can be addressed based on new research made available in April 2012.

Based on the estimated net litter CSC IEF of 1.85 t C/ha, for Sitka spruce (see category 1 in 5(KP-I)A.1.1), this could result in a net accumulation of 37 t C in the litter pool per ha over a 20 year period. Based on results published by Black et al (2009b), the accumulation in yield class 24 Sitka spruce stand is 22 t C/ha after 22 years. So it may be considered that litter inputs are over estimated for Irish forests. However, the current approach may conservatively under estimate net biomass sink, but overestimate the litter inputs, which are then decomposed over time. Therefore, the combined net litter and biomass sink is conservatively under estimated using the current approach. This is currently being investigated and will be modified in the next submission. The CARBWARE model v5 is currently been refined to address the issues outlined above for Ireland's next submission.

The accumulated litter pool was assumed to be immediately oxidised when deforestation occurs (i.e. reported as an emission in the CRF 5 (KP-1) A2):

Deforested $\Delta C_{Li} = L_{old} \times -1$ ………………………………………………………….(11.16)

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

### 11.3.1.3 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 ($D_{DW}$):

$$\Delta C_{DW} = (L_{tr} + M_{timber} + L_{mort(BB)} + L_{HRroot}) - D_{DW} \quad \text{.....(11.17)}$$

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

$$L_{tr} = L_{timber} \times RF \quad \text{.....(11.18)}$$

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 J), while $L_{mort(BB)}$ and $L_{HRroot}$ are known from the analysis for the litter pool in the previous section above. The decomposition losses from the new input deadwood carbon pool (eq. 11.17), existing decaying logs ($DL_{old}$) and decaying stumps ($DS_{old}$) are calculated using equation 11.19 based on decomposition factors of 0.095 for stumps and 0.076 for roots (Tobin et al., 2007):

$$D_{DW} = 1 - \left| \sum [L_{tr}, M_{timber}, DL_{old}]^{-D_{\log} \times t} + \sum [L_{mort(BB)}, L_{HRroot}, DS_{old}]^{-D_{St}} \right| \ldots \quad \text{........ (11.19)}$$

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

$$DL_{old} = \sum_i \left[VL_i \times DDC_i \times CF\right]^{-D_{\log} \times t} + \left[\sum (L_{tr}, M_{timber}\right]^{-D_{\log}}_{(n-1,n-2,n-x)} \quad (11.20)$$

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 11.17 and Figure 11.1) within the CARBWARE model for previous years (n). Similarly, decay class and volume functions were used to derive the carbon pool of decaying stumps in NFI sample plots (Tobin et al 2007, NFI, 2007b):

$$DS_{old} = \sum_j \left[VS_j \times DDC_j \times CF\right]^{-D_{St} \times t} + \sum \left[L_{mort(BB)}, L_{HRroot}\right]^{-D_{St}}_{(n-1,n-2,n-x)} \quad (11.21)$$

where VS is the stump volume of the specific decay class (*j*, n=4), DDC is the density of the specific decay class (*i*) and CF is the carbon fraction (0.5). The density and decay classes described by Tobin et al (2007) were used to calculate the deadwood carbon pools in the NFI permanent sample plots (NFI, 2007b). $L_{mort(BB)}$ and $L_{HRroot}$ (n-1, n-2,..x) is the accumulated deadwood from the **stand modifier** functions (equation 11.17 and Figure 11.1) 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 11.1). 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 (see CRF 5 (KP-1) A2) so that

$$\text{Deforested } \Delta C_{DW} = (DL_{old} + DS_{old}) \times -1 \quad (11.22)$$

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.

#### 11.3.1.4 Soil Carbon Stock Change

Soils are classified into three major groups; mineral, peat and peaty/mineral soils (see section 11.2.3). 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. The emission for peat soils given by equation 11.23 is now based on new published data (Byrne and Farrell, 2005), as described for *Land Converted to Forest Land* in section 7.3.3 of this NIR, but information on soil classification and peat depth available from the NFI is also taken into account.

$$\Delta C_{So} = \sum_i \left(A_i \times EF_{soil}\right) \quad (11.23)$$

The area ($A_i$) of the 0.05 ha plots with peat soils is multiplied by 20 to scale the measurement up to 1 ha. The $EF_{soil}$ is 0.58 t C/ha$^{-1}$.yr$^{-1}$ for the first 50 years following afforestation and is zero there after (see Ch 7 section 7.3.3). Emissions from peaty/mineral soils are calculated in the same way (equation 11.24), but a soils depth function (SD) is applied to the emission factor to account for the smaller organic carbon pool available. If soil depth is less than 30 cm then,

$$\Delta C_{So} = \sum_{j} \left( A_j \times EF_{soil} \times SD \right) \quad \ldots\ldots(11.24)$$

and

$$SD = \frac{depth(cm)}{30cm} \quad \ldots\ldots(11.25)$$

### 11.3.1.5 Emissions from Biomass Burning

The reporting of emissions and removals for Article 3.3 activities requires the inclusion of emissions associated with biomass burning, which occurs as controlled burning or through wildfires. Controlled burning is not undertaken in Ireland but wildfires do occur and therefore the inventory includes estimates of $CH_4$ and $N_2O$ emissions due to wildfires. Forest fires are assumed to occur on afforestation lands that are not harvested, which accounted for 36 per cent of the total forest area in 2010. The area of forest burned in wildfires in CRF 5(KP-11) is derived from the total area burned in a given year multiplied by a factor of 0.36. The biomass, litter and deadwood C stock burned was assumed to be represented by the most common species and productivity class (Sitka spruce YC 16). This was derived as the mean in C stock pool weighted using the afforestation rate area and the age class. The weighted mean value for a 20 year old afforested stands from 1990 to 2010 was 49 tC biomass/ha (assuming a C fraction of 50 per cent), including the litter and deadwood pool. The emissions from the biomass, litter and deadwood 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 (Table 3A.1.12 of the IPCC good practice guidance for LULUCF), with emission ratios for $CH_4$ and $N_2O$ of 0.012 and 0.007, respectively (Table 3A.1.15 of the IPCC good practice guidance for LULUCF) and a C:N ratio of 0.01 is assumed for estimating $N_2O$.

Burned areas are assumed not to regenerate following fire unless lands are replanted, as indicated in the NFI. However, since the second NFI is not yet completed it is assumed that lands are not replanted and stock changes in this category area are assumed to not occur (200, burned areas (KP 5 A1.1). This conservative assumption is applied to KP forests only.

### 11.3.1.6 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.

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.

## 11.3.2 Description of the methodologies and assumptions

The following text outlines the specific methodologies applied to KP reporting, since these differ from those used for Convention reporting as discussed in chapter 7 and the section above.

### 11.3.2.1 Datasets used to develop the CARBWARE Models

*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).

*Individual tree sampling in the NFI and scaling assumptions*

Tree measurements within NFI plots were systematically sampled (see Figure 11.4), 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 11.4). 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 11.4 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:

$$\frac{R_3^2}{R_i^2} \quad \text{..........}(11.26)$$

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

In practice, the expansion factor, or weight, is used to estimate plot-level features, e.g. basal area. In such calculations, the number of trees of the *i* th diameter class that were not included in the sample is estimated by $\frac{R_3^2}{R_i^2}$ x $n_i$, where $n_i$ is the number of trees of the *i* th class that are included in the sample. The expansion factor therefore defines the relationship between each included tree and the estimated number of trees of the same class that were not included (Equation 11.26).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \quad \text{..........}(11.27)$$

where $n_{ij}$ _ $EXF_{ij}$ is the product of the expansion factor for the *j* th tree in the *i* th class, and $\check{N}_{ij}$ is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 11.27 is the representative tree number. With minor and obvious changes to the equation, we can calculate other tree-level estimates, including representative basal area, and individual-tree estimates can be aggregated for the entire plot to give plot-level estimates, including representative density. For example the aboveground biomass carbon of a plot (t C/ha) $GTOTAL_{(AB)}$ of a plot is calculated as:

$$GTOTAL_{(AB)} = \frac{\sum[ABij \times EXFij] \times 20}{1000} \quad (11.28)$$

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

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

*Growth models*
The availability of only one NFI cycle meant that that the CARBWARE model had to be developed and adapted to estimate carbon stock changes. This has been done by using diameter increment models for all trees with a DBH greater that 5cm and H increment models for trees with DBH less than 5cm (Annex J1-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 J, Table J.1).

*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 J.2).

#### 11.3.2.2 Validation of growth models

In 2011, 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 to12 per cent of data) was removed prior to model validation. In addition, trees with a DBH increment > 15 cm over 5 year cycle and with increment values higher than 2 times the plot standard deviation were removed from the database. Zero increments from harvested trees were also removed from the database to ensure Wilcoxon ranked tests could be interpreted properly (see validation section). However, no further attempts were made to clean data with erroneous measurements in the remaining data.

b) Partial sampling of trees within a plot

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

$$RMSE = \sqrt{\sum_{1}^{n} \frac{(x_i - X_i)^2}{n-p}} \quad (11.29)$$

where $x_i$ is the predicted value, $X_i$ is the observed diameter increment, p is the number of parameters used and n is the sample number.
The average residual of model accuracy (*e'*) was estimated from observed and predicted residuals,

$$e' = \sum_{1}^{n} \frac{(x_i - X_i)}{n} \quad (11.30)$$

from which the accuracy is derived as the quotient of *e'* and the mean observation value *(m),* the divisor.

The Wilcoxon signed rank test was used to test for significant differences between the observed and predicted values (SPSS v17). The null hypothesis (mean of residuals is equal to zero) was rejected where the p-value of *Z* was > 0.05.

Precision is measured by the standard derivation of the observed and predicted residual values. The theoretical excess error was estimated by cross-validation, where the model is recalibrated repeatedly with the same data set with one randomly selected group of trees are excluded from the calibration in repeated iterations:

$$E_{cross} = \frac{1}{n}[\sum_{1}^{n}(x_i - y_{i-1})^2 - \sum_{i}^{n}(x_i - y_i)^2]. \quad (11.31)$$

where $x_i$ is the observed measurement, $y_{i-1}$ is the estimated increment with the tree group excluded from the calibration and $y_i$ is the estimated increment with the tree group included in the calibration.

*Validation analysis and excess error*

Accuracy, precision and significance of the difference between observed and predicted increments were determined in the same way on the validation datasets.
The empirical excess error ($E_{imp}$) is a measure of the increase of residual variance when the model is applied to an external dataset, not used in the calibration (i.e. validation data).

$$E_{imp}(\%) = \left(\frac{1 - S_{ec}}{S_{ci}}\right) \times 100 \quad (11.32)$$

where $S_{ec}$ is the precision of the calibration dataset and $S_{ei}$ is the precision of the independent validation dataset. This value was used as the error estimate in uncertainty analysis (Table 11.10 code C (DBH and H increment models)

*Stratification of single tree increments*

To estimate the model performance across different species cohorts and DBH groups, data from the NFI validation set were stratified into a < 12cm and 12 to 20 cm classes to investigate the effect of the partial sample in the NFI sampling methodology. Additional DBH classes in 10 cm bins were included to assess accuracy and precision across the all DBH ranges. In some cases, assessments were not made when there were less than 30 trees in the stratified subset.

A comparison of predicted versus observed diameter increment for all species (normalised to a 5 year increment) shows an good agreement with a model accuracy of 0.25 cm (positive bias) or a 9 per cent overestimation of the mean observed increment. Wilcoxin signed rank tests of residuals shown no significant difference (p = 0.16) between observed (2.78 cm) and simulated (2.94 cm) mean increments. The precision was 2.09 cm. The empirical excess error was **11.8 per cent (see Table 11.10 code C)** which is less than the theoretical excess error (31.4 per cent), suggesting that the variation in the NFI model residuals is smaller than the random theatrically expected variation in the calibration dataset.

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 11.7). Stratified cohort groups all had lower empirical excess error (Table 11.7), when compared to the theoretical excess error except for the SGB cohort, suggesting that the variation in the NFI model residuals is smaller than the random theatrically expected variation in the calibration dataset.

For all DBH categories, Spruce, pines, OC and SGB shows good agreement with the model with no significant difference between observed and simulated values (P > 0.05). In contrast, FGB and Larch showed poor agreement with the model predictions significant differences between observed and predicted values (Table 11.7). Larch and FBG showed a 27 per cent lower and 128 per cent higher growth rate than the model prediction, respectively.

***Table 11.7. NFI external validation results showing model performance indicators for different cohorts and size class categories***

| Cohort | <12 cm | 12-20 cm | 20-30 cm | 30-40 cm | >40 cm | All classes |
|---|---|---|---|---|---|---|
| *Spruce* | | | | | | |
| Accuracy | - 0.42 | 0.09 | 0.28 | 0.09 | -0.73 | 0.17 (4.8%) |
| Precision | 1.94 | 1.90 | 1.86 | 1.91 | 2.09 | 2.04 |
| P-value | <0.01 | **0.37** | **0.14** | **0.55** | 0.03 | **0.36** |
| $E_{imp}$ | | | | | | 9.8 % |
| N | 204 | 1234 | 1092 | 226 | 48 | 2804 |
| | | | | | | |
| *Pines* | | | | | | |
| 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 | **0.23** | **0.52** | <0.01 | ND | **0.29** |
| $E_{imp}$ | | | | | | 0.4 % |
| N | 56 | 342 | 379 | 44 | 6 | 827 |
| | | | | | | |
| *Larch* | | | | | | |
| Accuracy | ND | -1.59 | 0.48 | ND | ND | -0.88 (-27.8 %) |
| Precision | ND | 2.13 | 1.38 | ND | ND | 2.14 |
| P-value | ND | <0.001 | **0.05** | ND | ND | <0.001 |
| $E_{imp}$ | | | | | | 7.9 % |
| N | 8 | 54 | 36 | 4 | 0 | 102 |
| | | | | | | |
| *OC* | | | | | | |
| Accuracy % | ND | -0.21 | -0.53 | -1.14 | ND | -0.51 (-21.4 %) |
| Precision | ND | 1.34 | 1.69 | 1.83 | ND | 1.65 |
| P-value | ND | **0.544** | **0.05** | 0.02 | ND | **0.06** |
| $E_{imp}$ | | | | | | 14.7 % |
| N | 5 | 77 | 66 | 31 | 19 | 198 |
| | | | | | | |
| *FGB* | | | | | | |
| Accuracy | <0.001 | 1.44 | 3.06 | 4.19 | ND | 2.0 (128.1 %) |
| Precision | 1.49 | 1.85 | 1.87 | 2.47 | ND | 2.28 |
| P-value | **0.20** | <0.001 | <0.0001 | <0.0001 | ND | <0.0001 |
| $E_{imp}$ | | | | | | 8.7 % |
| N | 64 | 194 | 183 | 35 | 19 | 495 |
| | | | | | | |
| *SGB* | | | | | | |
| Accuracy | ND | -0.28 | -0.23 | -0.67 | -1.24 | -0.50 (-30.5 %) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Precision | ND | 1.27 | 1.73 | 1.70 | 1.91 | 1.68 |
| P-value | ND | **0.37** | **0.75** | **0.17** | <0.001 | **0.11** |
| $E_{imp}$ | | | | | | 55.1% |
| N | 5 | 46 | 75 | 31 | 38 | 208 |

The accuracy values shown are the mean residual in cm, with percentage values in parenthesis, for un-stratified DBH classes only. Precision is expressed as the absolute standard deviation of the residuals in cm. The empirical excess error for each cohort is shown for all DBH categories.

Cohorts were further stratified into DBH classes to assess the influence of the partial sample from concentric circle plots in the NFI and performance across all DBH ranges. The mean increments for DBH classes < 12 cm (i.e. the inner circle plots, with a lower sampling frequency) were significantly under estimated, when compared to modelled estimates (Table 3). There was generally good agreement between observed and predicted values for the 12-20 cm and 20 to 40 cm classes for the Spruce, Pine, OC and SGB cohorts. The growth of a tree larger than 40 cm was generally underestimated, but this represents a relatively small sample size and perhaps a DBH range beyond that of the calibration dataset. It should be noted that calibration data set for FGB ranged from 5 to 30 cm (mean 14 cm, data not shown) and this corresponded with poor performance of the model for DBH classes greater that 12cm (Table 11.7).

### 11.3.2.3 Justification for Omitting a Carbon Pool

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.

#### 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 unforested 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 11.8). Therefore, we opt not to report stock changes for mineral soils because we can demonstrate that the pool is not a source.

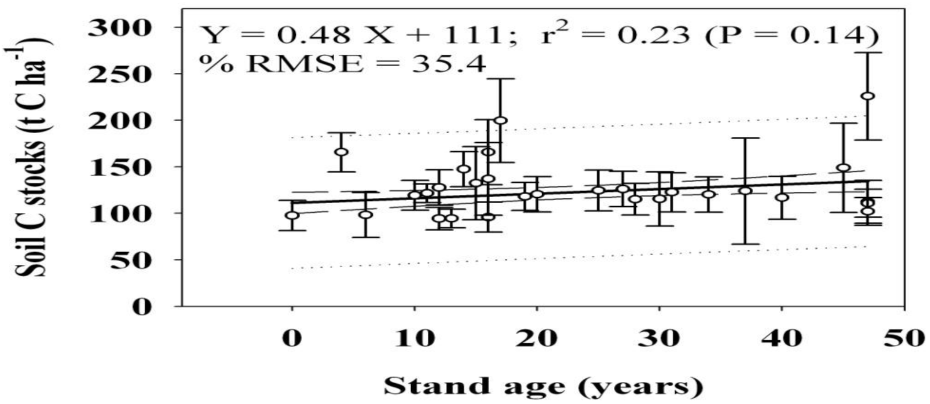



***Figure 11.8 Variation in mineral soil carbon stocks and estimation of $\Delta C_{so}$ using the nationally derived data (n = 30). The solid line represents the linear change on C stock over time. The dashed and dotted lines represent the 95% confidence and prediction intervals***

### 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 NIR, 2010).
- 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 7.3.7)
- 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.
- 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, 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 11.8 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 11.7, and then we classified land use either as forest or grassland (Grassland/Forest pair). The forest grassland pair was categorised because there was a small sample for scrub grasslands and we wanted to test if there was any change in soil C stocks, when all forest types are compared to all grassland types.

***Table 11.9 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 11.8).

To further illustrate this point, Figure 11.9 shows that the mean soil C stock was significantly different within soil types for combined data from forests and grasslands (left panel Figure 11.9). 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 11.9).

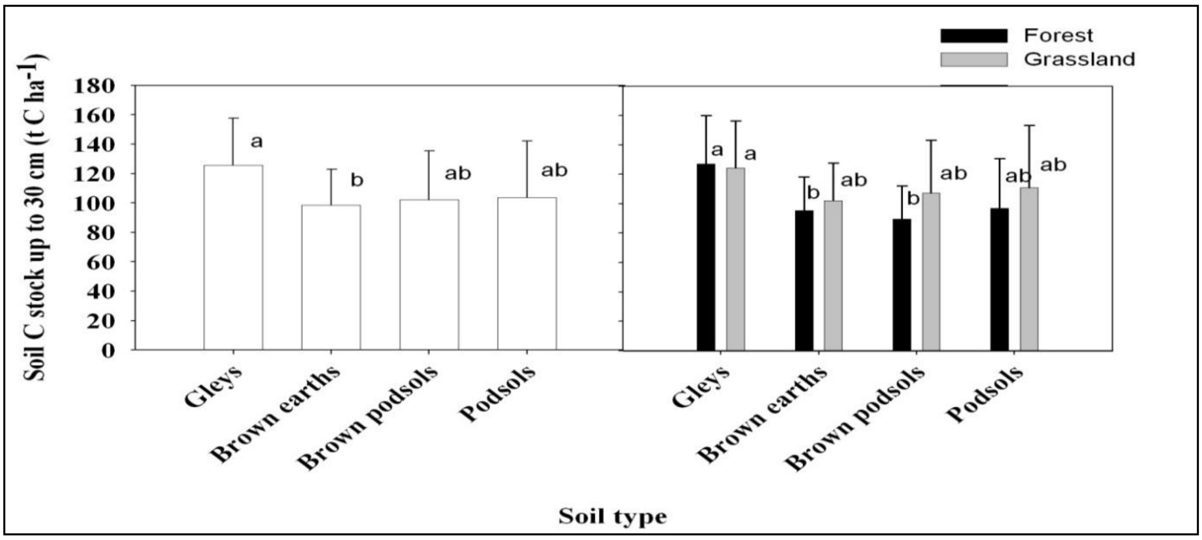



***Figure 11.9 Mean soil C reference values for forest and grasslands at steady state across different mineral soil types. Histogram bars with different letters are significantly different at P < 0.05***

Based on these analysis 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 grasslands 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 form 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 on-going and new methods will be developed if new trends emerge.

#### 11.3.2.4 Factoring Out of Indirect and Natural GHG

Indirect and natural GHG emissions and removals have not been factored out, due to a lack of robust scientific information.

#### 11.3.2.5 Uncertainty Estimates

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 11.10). 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 J2_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. However, many of the input variables are auto correlated with each other, and therefore violate the basic assumption in this approach that inputs are statistically independent. For example, biomass and litter pools are derived from DBH increment models and biomass equations. However the simple tier 1 method is adopted until the capacity to develop Monte Carlo approaches in developed and reported in future submissions.

The percentage input uncertainties in the various methodological parameters used for the analysis of carbon stock change in the relevant carbon pools and for the emissions of non-$CO_2$ gases are listed in Table 11.11. The combined uncertainties of the products of the respective parameters associated with each component pool are calculated using equation 11.33 (equation 6.4 of the IPCC good practice guidance):

$$U_{total} = \sqrt{U_1^2 + U_2^2 + U_3^2 + U_n^2} \qquad (11.33)$$

where $U_{total}$ is the combined uncertainty of the product of the input values $U_1$, $U_2$, $U_3$ and $U_n$ given table 11.5. The calculated percentage uncertainties for pools are given in Table 11.6 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 11.5 as the sum of the uncertainties for carbon pools using equation 11.34 (equation 6.3 of the IPCC good practice guidance):

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + (U_n \times x_n)^2}}{|x_1 + x_2 + x_n|} \quad \text{..........................................(11.34)}$$

where $U_{total}$ is the combined uncertainty, $U_1$, $U_2$ and $U_n$ are the uncertainties of pool estimates (Table 11.11) and $x_1$, $x_2$ and $x_n$ are the mean values for the respective pools reported in the CRF tables. For example, $x_1$ in the uncertainty equation in Table 11.12 for the net $CO_2$ removals for afforestation reported in CRF Table (KP-I)A.1.1 is 2.009 Mg C/ha (the mean net carbon stock change for the AB and BB pools), $x_2$ is the mean net carbon stock change of 1.274 Mg C/ha for the litter pool, $x_3$ is the carbon stock change of 0.01 Mg C/ha for deadwood and $x_4$ is the  carbon stock change of 0.504 Mg C/ha for soils.

*Table 11.10 Uncertainty estimates for individual activity and area data sets*

| Code | Parameter | Sub-category[a] | % uncertainty[b] | Source |
|---|---|---|---|---|
| A | Biomass algorithms | AB and BB, SB, NB, LT | 12.0 | Black et al., 2007 |
| B | Carbon fraction | CF all pools | 0.87 | Black et al., 2007 |
| C | DBH, H increment models | AB, BB | 11.80 | Validations on NFI data (see section 11.3.2.2 and paper in prep for publication) |
| D | Area data | GPAS (11.2.2) | 0.60 | Derived from Black et al, 2009a[c] |
| D | Deforestation area | NFI, CORINE, I OSI (section 7.3.7) | 50.01 | Sample strata uncertainly analysis using new deforestation methods |
| E | Litter | Li | 3.1 | Tobin et al., 2006 |
| F | Deadwood | DW | 22.0 | Tobin et al., 2007 |
| G | Biomass C stock | AG and BB deforestation | 30.1 | Black, 2008; Black et al., 2009b |
| H | Litter C stock | DLold | 30.0 | Black, 2008; Black et al., 2009b |
| I | Deadwood C stock | DSold | 30.0 | Black, 2008; Black et al., 2009b |
| J | Peat soil emission | EFsoil | 90.0 | Assume Tier 1 (Table 2.3.2.3.1 CH AFOLU 2006 IPCC GLs) |
| K | Fire C stocks | Fires | 30.1 | Black, 2008 |
| L | Areas burned | Fires | 50 | Expert judgement |

*a refer to methodology section 11.3.1 and 11.3.2.2*
*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 11.11 Uncertainty estimates of major C pools*

| Code | Component | Reference equation in section 11.3.1 | % uncertainty* equation 11.34 | Individual parameter codes from Table 11.10 |
|---|---|---|---|---|
| TB | Biomass | Eq 11.3 AB and BB | | |
| TBA | | Afforestation | 16.9 | A, B, C, D |
| TBD | | Deforestation | 58.45 | B, D, G |
| Li | Litter | Eq 11.12 Li | | |
| LiA | | Afforestation | 3.28 | B, D, E |
| LiD | | Deforestation | 58.4 | B, D, H |
| DW | Deadwood | Eq 11.7 | | |
| DWA | | Afforestation | 22.03 | B, D, F |
| DWD | | Deforestation | 58.4 | B, D, I |
| So | Soils | Eq 11.23 | 90.0 | D, J |
| FI | Fire | | 58.36 | K, L |

*Table 11.12 Combined uncertainties of reported values in the CRF tables (example shown for inventory year 2010)*

| CRF Table | % uncertainty | Equation 11.33 and variable (See Table 11.4 and CRF totals) |
|---|---|---|
| 5(KP-I)A.1.1 | 19.79 | $\frac{\sqrt{(16.9\times 2.01)^2+(3.28\times 1.27)^2+(22.03\times 0.01)^2+(90\times -0.5)^2}}{\lvert 2.01+1.27+0.01-0.5\rvert}$ |
| 5(KP-I)A.1.2 | 77.31 | $\frac{\sqrt{(16.9\times -6.58)^2+(3.28\times 3.99)^2+(22.03\times 1.5)^2+(90\times -0.57)^2}}{\lvert -6.58+3.99+1.5+0.57\rvert}$ |
| 5(KP-I)A.2 | 46.68 | $\frac{\sqrt{(30.12\times -0.55)^2+(30.02\times -0.47)^2+(30.02\times -0.01)^2+(90\times -0.13)^2}}{\lvert -0.55-0.47-0.01-0.13\rvert}$ |
| 5(KP-II)5* | 58.38 | $\frac{\sqrt{(58.36\times -7.18)^2}}{-7.18}$ |
| | | |
| NIR-3 (total) | 20.46 | $\frac{\sqrt{(19.79\times -3029)^2+(77.31\times 44.8)^2+(46.68\times 19.5)^2+(58.38\times 28.8)^2}}{\lvert -3029+44.8+19.5+28.8\rvert}$ |

*The mean emission per unit area (7.18 Mg) for fires is derived from the $CO_2$ emissions (26.19 Gg) divided by the proportional area of 3.3 forests subjected to fire (376 ha)

Uncertainties were recalculated for the 2008 and 2009 inventory years due to the modification of uncertainty assessments for DBH and H increment models (see Code C Table 11.10). The uncertainty for increment models reduced from 21 per cent (in previous submissions) to 11.8 per cent, based on the new analysis presented in section 11.3.2.2. The overall uncertainty reduced from 26 per cent to 23 per cent for 2008 inventory data and from 23 per cent to 19 per cent for the 2009 inventory data.

## 11.4 Other Information for Article 3.3 Activities

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. These approaches are in accordance with the Annex to Decision 15/CMP.1 paragraphs 6 and 8.

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 cased 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.

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).

## 11.5 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.

## 11.6 Recalculations in KP LULUCF

Numerous changes have been implemented to the KP LULUCF 2008 and 2009 inventories following comments from the 2011 UNFCCC expert review and internal QC/QA checks, these include:

1) Emissions from historically deforested forest areas under (D) now include organic soils emissions for other lands. 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. The recalculation resulted in an increase in emissions from deforested organic soils converted to other lands of 0.05 Gg $CO_2$eq to 0.29 Gg $CO_2$eq, for inventory year 2009.

2) Emissions from burned areas under AR now include estimates from the litter and deadwood pools and are all assumed to be oxidised during wildfire. The recalculation resulted in an increase in emissions from wildfires in AR lands from 3.18 Gg $CO_2$eq to 4.57 Gg $CO_2$eq, for inventory year 2009. See section 11.3.1.5 above.

The 2012 NIR also provides more justification for omitting mineral soil C stock changes, which are reported as NO (see section 11.3.2.2 and CRF 5 (KP-1)1.1, 1.2 and 2.1). These improvements do not influence the net emission removal in the 2012 submission.

# Chapter Twelve

# Information on Accounting of Kyoto Units

## 12.1 Background Information

Ireland's Standard Electronic Format report for 2011 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically – SEF_IE_2012_1_11-13-37 6-1-2012.xls.

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

## 12.2 Summary of Information Reported in the SEF Tables

There was 298,592,471 AAUs in Ireland's National Emission Trading Registry at the end of the year 2011, of which 231,112,024 units were in the Party holding account; 14,588,845 units in the entity holding accounts; 735 units in the other cancellation accounts and 52,890,867 units in the retirement account.

There was 10,808,105 CERs in the registry at the end of 2011: 9,138,714 CERs were held in the entity holding accounts; 2,059 in the other cancellation accounts and 1,667,332 CERs were held in the retirement account.

There was 524,735 ERUs in the registry at the end of 2011; 129,852 ERUs were held on the entity holding accounts and 394,883 ERUs were held in the retirement account.

The registry did not contain any RMUs, t-CERs or l-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 309,925,311 tonnes $CO_2$ eq.

Ireland's assigned amount is 314,184,272 tonnes $CO_2$eq.

*Table 12.1 Information on the SEF tables*

| Annual Submission Item | Reported in 2011 |
|---|---|
| 15/CMP.1 annex I.E paragraph 11:<br><br>Standard electronic format (SEF) | Ireland's Standard Electronic Format report for 2011 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.<br><br>SEF_IE_2012_1_11-13-37 6-1-2012.xls.<br><br>The contents of the SEF report (R1) can also be found in Appendix 1 – *SIAR Supplementary Information*. |

## 12.3 Discrepancies and notifications

There were no discrepant transactions, no CDM notifications, no non-replacements and no invalid units in 2011 (Table 12.2).

*Table 12.2 Discrepancies and notifications*

| Annual Submission Item | Reported in 2011 |
|---|---|
| 15/CMP.1 annex I.E paragraph 12:<br><br>List of discrepant transactions | No discrepant transactions, pursuant of 15/CMP.1 annex I.E paragraph 12, occurred in the 2011 reporting period.<br><br>A report entitled "Discrepant Transactions Report", generated via the Reports Module on Ireland's National Emissions Trading Registry is included in Appendix 1 – *SIAR Supplementary Information* as a pdf and xls file.<br><br>In addition, refer to Separate Electronic Attachment "SIAR Reports 2012-IE v 1.0.xls" Worksheet R2. |
| 15/CMP.1 annex I.E paragraph 13 & 14:<br><br>List of CDM notifications | No CDM notifications were received by the National Registry during the 2011 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14.<br><br>The contents of the Report R3 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document.<br><br>Refer to Separate Electronic Attachment "SIAR Reports 2012-IE v 1.0.xls" Worksheet R3. |
| 15/CMP.1 annex I.E paragraph 15:<br><br>List of non-replacements | No non-replacements occurred during the 2011 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15.<br><br>The contents of the Report R4 can be found in Appendix 1 – *SIAR Supplementary Information* of this document.<br><br>Refer to Separate Electronic Attachment "SIAR Reports 2012-IE v 1.0.xls" Worksheet R4. |

| Annual Submission Item | Reported in 2011 |
| --- | --- |
| 15/CMP.1 annex I.E paragraph 16:<br><br>List of invalid units | No invalid units exist as at 31 December 2011, pursuant of 15/CMP.1 annex I.E paragraph 16.<br><br>The contents of the Report R5 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document.<br><br>Refer to Separate Electronic Attachment "SIAR Reports 2012-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 in 2011 |
|---|---|
| 15/CMP.1 annex I.E<br><br>Publicly accessible information | There was no change regarding publicly accessible information during 2011.<br><br>The following information is publicly accessible via the homepage of Ireland's National Emissions Trading Registry – www.etr.ie<br><br>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.<br><br>**Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)**<br>For security reasons and in accordance with Article 75(9) of the Commission Regulation No 920/2010, it is considered that the representative name and contact 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.<br><br>**JI projects in Ireland (Paragraph 46)**<br>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.<br><br>**Holding and transaction information of units (Paragraph 47)**<br>Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by Commission Regulation.<br><br>Article 10 of EU Regulation 2216/2004/EC, provides that *"All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law."* |

*Table 12.3 (Continued) Publicly Accessible Information*

| Annual Submission Item | Reported in 2011 |
|---|---|
| 15/CMP.1 annex I.E<br>Publicly accessible information | Paragraph 47c<br>Ireland does not host JI projects in line with the National Climate Change Strategy.<br><br>Paragraph 47e<br>Ireland does not perform LULUCF activities and therefore does not issue RMUs<br><br>Paragraph 47g<br>No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date.<br><br>Paragraph 47h<br>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.<br><br>Paragraph 47j<br>No ERUs, CERs, AAUs and RMUs have been retired to date<br><br>Paragraph 47k<br>There is no previous commitment period to carry ERUs, CERs, and AAUs over from. |

## 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 2009 submitted on 13 April 2011 is the most recently reviewed inventory for Ireland (FCCC/ARR/2011/IRL). The total emissions in 2009 amounted to 62,394,847 tonnes $CO_2$ equivalent and five times this estimate is 311,974,235 tonnes $CO_2$ equivalent. This value is greater than 90 per cent of the assigned amount (282,765,845 tonnes $CO_2$ equivalent) determined in the review of Ireland's initial report (FCCC/IRR/2007/IRL) and therefore the commitment period reserve is 282,765,845 tonnes $CO_2$ equivalent.

## 12.6 Accounting for Activities under Article 3.3

In the initial report under the Kyoto Protocol (FCCC/IRR/2007/IRL), Ireland elected to account for 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 and 2010 is not applicable.

# Chapter 13

# Changes in National System

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 Article 3.3 activities. This new MOU has yet to be signed at the time of writing this report.

# 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 changes in the registry during 2011 included changes to contacts and software upgrades to improve functionality and security. The changes are summarised in this chapter and further details, including software release notes and test reports are provided in electronic form as Appendix 1 *SIAR Supplementary Information* to the NIR.

## 14.2 Contacts

| Reporting Item | Reported for 2011 |
|---|---|
| 15/CMP.1 annex II.E paragraph 32.(a)<br><br>Change of name or contact | Addition of contact details:<br><br>**Ms. Jacinta PONZI**<br>Environmental Protection Agency<br>PO Box 3000, Johnstown Castle Estate, Co Wexford.<br><br>Email: j.ponzi@epa.ie / etradmin@epa.ie<br>Telephone: +353 (0)53 91 60600<br>Fax: +353 (0)53 91 60699<br><br>Removal of contact details:<br><br>**Ms. Sinead WHITE**<br><br>Environmental Protection Agency<br>PO Box 3000, Johnstown Castle Estate, Co Wexford.<br><br>Email: s.white@epa.ie / etradmin@epa.ie<br>Telephone: +353 (0)53 91 60600<br>Fax: +353 (0)53 91 60699 |

## 14.3 Information on Changes in National Registry

| Reporting Item | |
|---|---|
| 15/CMP.1 annex II.E paragraph 32.(b)<br>Change of cooperation arrangement | No change of the cooperation arrangement occurred during the 2011 reporting period. |
| 15/CMP.1 annex II.E paragraph 32.(c)<br>Change to database or the capacity of National Registry | Two Greta software upgrades occurred during 2011.<br>Greta Version 5.2 was installed on 20 June 2011 and Version 5.3 was installed on 13 October 2011.<br>Both upgrades have incorporated changes that increased the capacity of the Registry. |

**Software Changes**

A general description of functional changes in Greta Version 5.2 and Version 5.3 are as follows:

Version 5.2

This version included the following changes:

- Improvements to Transaction Finalisation (New Message Flow) thereby further reducing discrepant transactions.
- Introduction of a windows service (AMI) whereby representative contact information is not displayed on Europa, thereby ensuring compliance with the account representative confidentiality requirements of the Registry Regulation.
- Security enhancements including;

➢ Session locking;
➢ Ability to reject blacklisted units;
➢ Dual approval for Registry Administrator transactions;
➢ User logon audit trail;
➢ Generic error on logon failure;

Version 5.3

This version included the following changes

- Further security enhancements through Greta code changes, including:

➢ Guarding against man-in-middle attacks
➢ Guarding against reflected cross-site scripting
➢ Expiring sessions of users when logging out
➢ Issuing a new SessionId when logging out of Greta
➢ Installation package sets directory listing on commoncode virtual directory
➢ Implementing reporting services account lockout mechanism
➢ Encrypting the ViewState

- Enhancements to assist in data migration to the Union Registry, including: Mandatory fields for entry of Company Registration Number and Installation Telephone Numbers 1 and 2.
- Introduction of the Out of Hours Lock: When this security feature is selected, it

will suspend access to the registry outside of the defined office hours.

Each new release also includes a 'maintenance' element whereby high-priority legacy bugs are resolved.
These are detailed in the accompanying release notes in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR.

- Release Notes Version 5.2
- Release Notes Version 5.3

The following capacity-improving measures have been implemented compared to the previously used versions.

Update from Version 5.1 to Version 5.2
Improvements to transaction finalisation: In order to improve performance and reliability, the processing of message flows for external transfers was changed. The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction. The purpose of the additional step is to ensure that a registry cannot transfer units received by external transfer until the ITL have completed the transaction. In Version 5.2, the transaction processing logic was also moved into a dedicated transaction processing service.
The new message flow will help reduce the number of discrepant transactions in production. This enhances the robustness of the system, necessary as the number and size of transactions increases. This results in increased reliability of the registry when operating under a higher work load which effectively increases the capacity of the registry. The dedicated transaction processing service also improved the scalability of the registry allowing it to handle many more concurrent transactions.

Security Enhancements: The security enhancements introduced by Version 5.2 have brought improvements in relation to Registry reliability and performance, effectively increasing Registry capacity.

Update from Version 5.2 to Version 5.3
The additional security enhancements delivered by Version 5.3 have brought further improvements in relation to Registry reliability and performance, effectively increasing Registry capacity.

The following test reports are also attached in Appendix 1 – *SIAR Supplementary Information*:
- Test Report Version 5.2
- Test Report Version 5.3

**Database and Application Backup**
Given the scope of Version 5.2 and Version 5.3, there were no change to the database and application backup in 2011.

**Disaster Recovery Plan**
Given the scope of Version 5.2 and Version 5.3, there was no change to the Disaster Recovery Plan in 2011.

| | |
|---|---|
| **<u>Test Plan and Test Report</u>**<br>Further to the software upgrade Version 5.2 and Version 5.3 the following test plans and reports are attached in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR:<br><br>- Test Plan and Report Version 5.2<br>- Test Plan and Report Version 5.3 | |
| 15/CMP.1 annex II.E paragraph 32.(d)<br>Change of conformance to technical standards | No change in the registry's conformance to technical standards occurred for the 2011 reporting period.<br><br>Greta Version 5.2 implements the new incoming external transfer message flow (ITL RSNCM-13), as raised in CAB and detailed in the Data Exchange Standard. This was installed in IE production on 20 June 2011.<br><br>See the Release Notes and Test Plan and Test Report for Version 5.2 in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR. |
| 15/CMP.1 annex II.E paragraph 32.(e) Change of discrepancies procedures | In order to improve performance and reliability, the processing of message flows for external transfers (ITL RSNCM-13 - as raised in CAB and detailed in the Data Exchange Standard) was changed in Version 5.2.<br><br>The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction. The purpose of the additional step is to ensure that a registry cannot transfer units received by external transfer until the ITL have completed the transaction. The new message flow will help reduce the number of discrepant transactions in production. This enhances the robustness of the system, necessary as the number and size of transactions increases. This results in increased reliability of the registry when operating under a higher work load which effectively increases the capacity of the registry.<br><br>See the Release Notes and Test Plan and Test Report for Version 5.2 in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR. |
| 15/CMP.1 annex II.E paragraph 32.(f)<br>Change of Security | There were no changes to the security plan in 2011.<br><br>In relation to the software, a number of security improvements were made in Greta Version 5.2 and Greta Version 5.3.<br><br>These include:<br>• Session locking;<br>• Ability to reject blacklisted units;<br>• Dual approval for Registry Administrator transactions;<br>• User logon audit trail;<br>• Generic error on logon failure; |

| | |
|---|---|
| | • Guarding against man-in-middle attacks<br>• Guarding against reflected cross-site scripting<br>• Expiring sessions of users when logging out<br>• Issuing a new SessionId when logging out of Greta<br>• Installation package sets directory listing on commoncode virtual directory<br>• Implementing reporting services account lockout mechanism<br>• Encrypting the ViewState<br><br>In addition to software changes, a security guide was also provided with Greta Version 5.1 and Version 5.2. The security guides provide information on general security practices and configuration, to ensure that the GRETA software is configured to be as secure as possible.<br><br>See the Release Notes and Test Plans and Reports for Version 5.1 and Version 5.2 in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR.<br><br>Ireland engaged external auditors in February 2011 to carry out a network security test to identify possible security issues and vulnerabilities in the hosted environment for the Irish National Emission Trading Registry. 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. In addition, an assessment of logs for the period November 2010 – February 2011 was carried out at the same time. The logs continue to be monitored and assessed on a monthly basis. This security test is currently being repeated in March 2012 by external contractors. |
| 15/CMP.1 annex II.E paragraph 32.(g)<br>Change of list of publicly available information | There were no changes to publicly available information in 2011.<br><br>The following information is publicly accessible and as such is available via the homepage of the IE registry – www.etr.ie<br><br>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.<br><br>**Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)**<br>For security reasons and in accordance with Article 75(9) |

| | |
|---|---|
| | of the Commission Regulation No 920/2010, it is considered that the representative name and contact 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.<br><br>**JI projects in Ireland (Paragraph 46)**<br>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.<br><br>**Holding and transaction information of units (Paragraph 47)**<br>Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation.<br><br>Article 10 of EU Regulation 2216/2004/EC, provides that "*All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law.*"<br><br><u>Paragraph 47c</u><br>Ireland does not host JI projects in line with the National Climate Change Strategy.<br><br><u>Paragraph 47e</u><br>Ireland does not perform LULUCF activities and therefore does not issue RMUs<br><br><u>Paragraph 47g</u><br>No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date.<br><br><u>Paragraph 47h</u><br>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.<br><br><u>Paragraph 47j</u><br>No ERUs, CERs, AAUs and RMUs have been retired to date<br><br><u>Paragraph 47k</u> |

| | |
|---|---|
| | There is no previous commitment period to carry ERUs, CERs, and AAUs over from. |
| 15/CMP.1 annex II.E paragraph 32.(h)<br>Change of Internet address | No change of the registry internet address occurred during the 2011 reporting period. |
| 15/CMP.1 annex II.E paragraph 32.(i)<br>Change of data integrity measure | No change of data integrity measures occurred during 2011 in relation to Application Logging, Disaster Recovery, Test Plan and Test Report.<br><br><u>Software Changes</u><br><br>On-going improvements have been made in Greta Version 5.2 with respect to data validation and data relationships.<br><br>In Greta Version 5.2 this improvement relates to a change in the processing of message flows for external transfers. The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction. The purpose of the additional step is to ensure that a registry cannot transfer units received by external transfer until the ITL have completed the transaction. The new message flow will help reduce the number of discrepant transactions in production. This enhances the robustness of the system, necessary as the number and size of transactions increases.<br><br>See the Greta Test Report for Version 5.2 included in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR. |
| 15/CMP.1 annex II.E paragraph 32.(j)<br>Change of test results | <u>Test Plan and Test Report</u><br><br>The following test plans and test results for Greta Version 5.2 and Version 5.3 have been included in the electronic Appendix 1 *SIAR Supplementary Information* to the NIR:<br><br>- GRETA test plan and report for Greta Version 5.2 and Version 5.3<br>- (C)ITL test plan for Greta Version 5.2 and Version 5.3<br>- Certification emails from the European Commission |
| The previous Annual Review Recommendations | The ARR is not yet available |

# 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 guidelines for the preparation of supplementary information required under Article 7.1 of the Kyoto Protocol. These requirements are addressed in this chapter.

## 15.2 Context

As a Member State of the European Union, Ireland's commitments under the Kyoto Protocol are being implemented under Decision 2005/166/EC, governing joint fulfilment under Article 4, and Decision 280/2004/EC, which covers specific emissions monitoring and reporting requirements. In this context, the minimization of adverse impacts on developing countries is also largely dictated by the European Commission's policy on climate change and by its policies and programmes affecting developing countries. Regulation at the European level also controls or influences market conditions, fiscal incentives, tax and duty exemptions and subsidies in all economic sectors in Member States.

The impact assessment of new policy initiatives has been established in the European Union, which allows their potential adverse social, environmental and economic impacts on various stakeholders, including developing country Parties, to be identified and limited at an early stage within the legislative process. Impact Assessment Guidelines specifically address impacts on third countries and also issues related to international relations. This provides a framework in which Member States like Ireland can also ensure a high level of protection of the environment and contribute to the integration of environmental considerations into the preparation and adoption of specified plans and programmes with a view to promoting sustainable development.

## 15.3 Specific Elements

*a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities*

Ireland's electricity market has been deregulated and the levy supporting the use of peat for electricity generation under a Public Service Agreement has been discontinued. Tax incentives contributed to the development of Ireland's most recent gas field off the west coast but such incentives will be severely curtailed for any similar developments in the future under new legislation. Reforms of the Common Agricultural Policy have resulted in changes to subsidies in agriculture, which are now linked to environmental, food safety and animal welfare standards. The EU Emissions Trading Scheme is a market-based emissions control measure which applies to major combustion and process emission sources of $CO_2$ and a carbon tax is being introduced for fossil fuel use outside the ETS.

*b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies*

Environmentally unsound and unsafe technologies may be regarded as technologies that would not conform to the concept of sustainable development and the objective and principles of the UNFCCC. The EC has addressed this issue by developing legislation to ensure that the price for coal produced in Member States is not lower than the price of coal of similar quality available from third countries and by phasing out subsidies on fossil fuel production and consumption by 2010. No environmentally unsound or unsafe technologies are in operation in Ireland.

*c) Cooperating in the technological development of non-energy uses of fossil fuels, and supporting developing country Parties to this end*

The Irish Government is represented on the energy and environment strands of the Seventh Framework Programme (FP7) for Research and Technological Development (RTD). This representation includes the FP7 Energy Programme Committees that focuses on developing and agreeing the annual work programme and strategic vision for the FP7 Energy Work programme 2007–2013. Much of the focus of this (energy theme) initiative is on energy mitigation through supporting technological development and transfer through joint collaborations and calls with emerging economies including India, Russia and Brazil.

The International Energy Agency (IEA) is the energy forum and think-tank for 26 OECD countries. The Irish Government is a Party to four Renewable Energy Implementing Agreements of the IEA on Bioenergy, Ocean, Wind and RE Technology Deployment (RETD). Ireland provides national delegates to the executive committees of the Implementing Agreements and nominates and supports country experts to a number of tasks. The Government also sits on the Committee for Energy research and technology (CERT). Ireland is a member of the EU Expert Group on Technology, which supports the EC in climate negotiations. This expert group is focused on the transfer of technology to reduce the impacts of climate change and on supporting developing countries to this end.

*d) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort*

The EU collaborates with other Annex I and Non-Annex I Parties (Brazil, Saudi Arabia, China, Colombia, India, Korea, Mexico and South Africa) in the Carbon Sequestration Leadership Forum (CSLF). The CSLF is a ministerial-level international climate change initiative that is focused on the development of improved cost-effective technologies for the capture transport and long-term safe storage of $CO_2$. The mission of the CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles. The CSLF will also promote awareness and champion legal, regulatory, financial, and institutional environments conducive to such technologies.

Ireland began its support to the Renewable Energy and Energy Efficiency Partnership (REEEP) in 2005. Following the decision by the Irish Government in 2007 to offset all its carbon emissions from official travel, REEEP was chosen as its implementing partner. REEEP is a Public-Private partnership and was launched by the United Kingdom along with other partners at the Johannesburg World Summit on Sustainable Development in August 2002. By providing opportunities for concerted collaboration among its partners, REEEP aims to accelerate the marketplace for renewable energy and energy efficiency. Funding from Ireland is being prioritised for projects in its programme countries of Ethiopia, Lesotho, Mozambique, Tanzania, Uganda, Zambia and Malawi.

Ireland provides development assistance in line with the priorities expressed by partner countries. To date requests for assistance in the area of technology are primarily in connection with water supply, transport infrastructure and agriculture. An innovative programme in Ethiopia carries out operational participatory research with farmers, extension workers and government officials to identify, develop, and disseminate new agricultural technologies. Some of the successful technologies are based on traditional practices, for example soil conservation techniques. Other new technologies are related to new crop varieties and irrigation. In addition to ODA, private companies also provide technology and advice to developing countries, particularly in the energy sector. Due to the range of funding sources no precise figure is available for funding attributed to technology development and transfer. Ireland's support to REEEP is worth mentioning again here as an example of Ireland's support for technology transfer. REEEP brings the private and public sectors together to facilitate the financing, development and transfer of renewable energy technologies. Ireland believes that this type of public-private collaboration is essential for the development of appropriate and environmentally sound technologies and to facilitate their application and use in developing countries.

*e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities*

The EU contributes to strengthening the capacities of countries engaged in the export of fossil fuels through the work of the Energy Expert Group of the Gulf Cooperation Council (GCC), in particular under the working sub-group on energy efficiency. As part of the EU's research programme, a project called "EUROGULF" was launched with the objective of to analyse The European Commission's planned e-network on clean energy technologies, is aiming to promote research and technical development of clean energy technologies in the GCC countries.

Ireland currently holds the Programme Chair of Renewable Energy and Energy Efficiency Partnership, a Type 2 International NGO. The Renewable Energy and Energy Efficiency Partnership (REEEP) is a global partnership that works to reduce the barriers in policy, regulatory and financial structures that bar and limit the uptake of renewable-energy and energy-efficiency technologies and projects. This Partnership focuses on deployment of projects in sub-Saharan Africa, Asia and Latin America. Ireland is actively involved in the partnership, alongside energy-related organisations from Australia, Austria, Canada, Germany, Italy, Spain, the Netherlands, New Zealand, Norway, the UK, the USA and the European Commission.

Ireland is a founding member of the UNEP SEFI Public Finance Alliance, or 'SEF Alliance'. This is a member-driven coalition of public and publicly backed organisations that finance sustainable-energy markets in various countries, including emerging and developing economies. . Members use the platform to exchange best practices, pool resources, launch joint projects and assist other governments in establishing new or similar financing models. The SEF Alliance is under the remit of the Sustainable Energy Finance Initiative (SEFI) of the

United Nations Environment Programme (UNEP) but is governed directly by its members and pursues activities according to their interests. In 2008, the Alliance published Public Finance for Climate Change Mitigation, which provided an overview of mechanisms being used by the public sector to help scale up the climate mitigation markets, with a particular focus on the clean energy sector. In 2008, the SEF Alliance also published a Public Venture Capital Study which examined current clean-energy venture financing, focusing on the role of public sector-sponsored venture capital.

*f) Assisting developing country Parties which are highly dependent on the export and consumption of fossil fuels in diversifying their economies*

Ireland supports a range of EU activities aimed at reducing dependence on the consumption of fossil fuels, in particular those EU support programmes for the promotion of renewable energies and energy efficiency in developing countries. Renewable energy cooperation with Mediterranean and Gulf countries which led to the Mediterranean Solar Plan, endorsed in 2008 with the objective of installing 20 GW of new generation capacity in solar and other renewable energy sources around the Mediterranean Sea by 2020. Another objective is to create a sub-regional electricity market between Morocco, Tunisia and Algeria and to progressively integrate it with the electricity market of the EU. Important initiatives which target energy efficiency and renewable energy projects in South America, Africa and Asia include the Africa, Caribbean and the Pacific (ACP-E) Energy Facility, the Latin America Investment Facility (LAIF), the Euro-Solar Programme in Latin America and the Global Energy Efficiency and Renewable Energy Fund (GEEREF).

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# Annex A

## Greenhouse Gases GWP and IPCC Reporting Format

***Table A.1 Greenhouse Gases and GWP Values***

| Greenhouse Gas | Chemical Formula | IPCC GWP (1995)[a] |
|---|---|---|
| Carbon Dioxide | $CO_2$ | 1 |
| Methane | $CH_4$ | 21 |
| Nitrous Oxide | $N_2O$ | 310 |
| Hydrofluorocarbons (HFC) | | |
| HFC-23 | $CHF_3$ | 11700 |
| HFC-32 | $CH_2F_2$ | 650 |
| HFC-41 | $CH_3F$ | 150 |
| HFC-43-10mee | $C_5H_2F_{10}$ | 1300 |
| HFC-125 | $C_2HF_5$ | 2800 |
| HFC-134 | $C_2H_2F_4(CHF_2CHF_2)$ | 1000 |
| HFC-134a | $C_2H_2F_4(CH_2FCF_3)$ | 1300 |
| HFC-152a | $C_2H_4F_2(CH_3CHF_2)$ | 140 |
| HFC-143 | $C_2H_3F_3(CHF_2CH_2F)$ | 300 |
| HFC-143a | $C_2H_3F_3(CF_3CH_3)$ | 3800 |
| HFC-227ea | $C_3HF_7$ | 2900 |
| HFC-236fa | $C_3H_2F_6$ | 6300 |
| HFC-245ca | $C_3H_3F_5$ | 560 |
| Perfluorocarbons(PFC) | | |
| Perfluoromethane | $CF_4$ | 6500 |
| Perfluoroethane | $C_2F_6$ | 9200 |
| Perfluoropropane | $C_3F_8$ | 7000 |
| Perfluorobutane | $C_4F_{10}$ | 7000 |
| Perfluorocyclobutane | $c\text{-}C_4F_8$ | 8700 |
| Perfluoropentane | $C_5F_{12}$ | 7500 |
| Perfluorohexane | $C_6F_{14}$ | 7400 |
| Sulphur Hexafluoride | $SF_6$ | 23900 |

(a) GWP (global warming potential) as provided by the IPCC in its Second Assessment Report

*Table A.2 IPCC Reporting Format (Level 1 and Level 2)*

| IPCC SOURCE and SINK CATEGORIES | $CO_2$ | $CH_4$ | $N_2O$ | HFC | PFC | SF6 |
|---|---|---|---|---|---|---|
| **1. Energy** | | | | | | |
| A. Fuel Combustion (Sectoral Approach) | | | | | | |
| 1. Energy Industries | | | | | | |
| 2. Manufacturing Industries and Construction | | | | | | |
| 3. Transport | | | | | | |
| 4. Other Sectors | | | | | | |
| 5. Other | | | | | | |
| B. Fugitive Emissions from Fuels | | | | | | |
| 1. Solid Fuels | | | | | | |
| 2. Oil and Natural Gas | | | | | | |
| **2. Industrial Processes** | | | | | | |
| A. Mineral Products | | | | | | |
| B. Chemical Industry | | | | | | |
| C. Metal Production | | | | | | |
| D. Other Production | | | | | | |
| E. Production of Halocarbons and $SF_6$ | | | | | | |
| F. Consumption of Halocarbons and $SF_6$ | | | | | | |
| G. Other | | | | | | |
| **3. Solvent and Other Product Use** | | | | | | |
| A. Paint Application | | | | | | |
| B. Degreasing and Dry Cleaning | | | | | | |
| C. Chemical Products Manufacture & Processing | | | | | | |
| D. Other | | | | | | |
| **4. Agriculture** | | | | | | |
| A. Enteric Fermentation | | | | | | |
| B. Manure Management | | | | | | |
| C. Rice Cultivation | | | | | | |
| D. Agricultural Soils | | | | | | |
| E. Prescribed Burning of Savannas | | | | | | |
| F. Field Burning of Agricultural Residues | | | | | | |
| G. Other | | | | | | |
| **5. Land-Use Change and Forestry** | | | | | | |
| A. Forestry | | | | | | |
| B. Cropland | | | | | | |
| C. Grassland | | | | | | |
| D. Wetland | | | | | | |
| E. Settlements | | | | | | |
| F. Other Land | | | | | | |
| G. Other | | | | | | |
| **6. Waste** | | | | | | |
| A. Solid Waste Disposal on Land | | | | | | |
| B. Wastewater Handling | | | | | | |
| C. Waste Incineration | | | | | | |
| D. Other | | | | | | |
| **7. Other** | | | | | | |
| ***Memo Items:*** | | | | | | |
| **International Bunkers** | | | | | | |
| **Multilateral Operations** | | | | | | |
| **$CO_2$ Emissions from Biomass** | | | | | | |

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

# Annex B

## Expanded Energy Balance Sheets for 2010

## *Table B.1 Expanded Energy Balance Sheet 2010*

| 2010 Units = ktoe | NACE (Rev 2) | Coal | Bituminous Coal | Anthracite + Manufactured Ovoids | Coke | Lignite | Peat | Milled Peat | Sod Peat | Briquettes | Oil | Crude | Refinery Gas | Gasoline | Kerosene | Jet Kerosene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indigenous Production | | **0** | **0** | | | | **981** | 816 | 165 | | **0** | | | | | |
| Imports | | **956** | **914** | **32** | | 11 | **0** | | | | **8,912** | 3,066 | | 1,119 | 530 | 1,068 |
| Exports | | **7** | **0** | **7** | | 0 | **10** | | | 10 | **1,153** | | | 38 | 22 | 0 |
| Mar. Bunkers | | **0** | | | | | **0** | | | | **139** | | | | | |
| Stock Change | | **275** | **271** | 4 | | 0 | **-181** | -173 | -0 | -8 | **70** | -45 | | -14 | 13 | 4 |
| **Primary Energy Supply (incl non-energy)** | | **1,224** | **1,185** | **28** | **0** | **10** | **791** | **643** | **165** | **-18** | **7,690** | **3,021** | **0** | **1,067** | **521** | **1,072** |
| **Primary Energy Requirement (excl. non-energy)** | | **1,224** | **1,185** | **28** | **0** | **10** | **791** | **643** | **165** | **-18** | **7,364** | **3,021** | **0** | **1,067** | **521** | **1,072** |
| **Transformation Input** | | **868** | **868** | **0** | **0** | **0** | **605** | **605** | **0** | **0** | **3,158** | **3,021** | **7** | **0** | **0** | **0** |
| Public Thermal Power Plants | | **868** | 868 | | | | **481** | 481 | 0 | | **129** | | | | | |
| Combined Heat and Power Plants | | **0** | 0 | | | | **9** | 9 | | | **8** | | 7 | | | |
| Pumped Storage Consumption | | | | | | | | | | | | | | | | |
| Briquetting Plants | | **0** | | | | | **115** | 115 | | | **0** | | | | | |
| Oil Refineries & other energy sector | | **0** | | | | | **0** | | | | **3,021** | 3,021 | | | | |
| **Transformation Output** | | **0** | **0** | **0** | **0** | **0** | **105** | **0** | **0** | **105** | **3,032** | **0** | **86** | **503** | **221** | **0** |
| Public Thermal Power Plants | | **0** | | | | | **0** | | | | **0** | | | | | |
| Combined Heat and Power Plants - Electricity | | **0** | | | | | **0** | | | | **0** | | | | | |
| Combined Heat and Power Plants - Heat | | | | | | | | | | | | | | | | |
| Pumped Storage Generation | | | | | | | | | | | | | | | | |
| Briquetting Plants | | | | | | | **105** | | | 105 | **0** | | | | | |
| Oil Refineries | | | | | | | **0** | | | | **3,032** | | 86 | 503 | 221 | 0 |
| **Exchanges and transfers** | | **24** | -13 | 36 | 0 | 0 | **0** | 0 | 0 | 0 | **-17** | 0 | 0 | 3 | 283 | -282 |
| Electricity | | | | | | | | | | | | | | | | |
| Heat | | | | | | | | | | | | | | | | |
| Other | | **24** | -13 | 36 | | | | | | | **-17** | | | 3 | 283 | -282 |
| **Own Use and Distribution Losses** | | **0** | | | | | **23** | 23 | | | **113** | | 100 | | | |
| **Available Final Energy Consumption** | | **380** | **305** | **65** | **0** | **10** | **268** | **16** | **165** | **88** | **7,435** | **-0** | **-21** | **1,574** | **1,025** | **790** |
| **Non-Energy Consumption** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **326** | **0** | **0** | **0** | **0** | **0** |
| Final non-Energy Consumption (Feedstocks) | | 0 | | | | | 0 | | | | 326 | | | | | |
| **Total Final Energy Consumption** | | **365** | **288** | **67** | **0** | **10** | **254** | **0** | **165** | **88** | **7,214** | **0** | **0** | **1,505** | **1,123** | **787** |
| **Industry*** | | **103** | **103** | **0** | | | **0** | **0** | **0** | **0** | **769** | **0** | **0** | **0** | **112** | **0** |
| Non-Energy Mining | 05-09 | **0** | 0 | | | | **0** | | | | **70** | | | | 4 | |
| Food & beverages | 10-11 | **22** | 22 | | | | **0** | | | | **187** | | | | 66 | |
| Textiles and textile products | 13-14 | **0** | 0 | | | | **0** | | | | **4** | | | | 1 | |
| Wood and wood products | 16 | **0** | 0 | | | | **0** | | | | **4** | | | | 1 | |
| Pulp, paper, publishing and printing | 17-18 | **1** | 1 | | | | **0** | | | | **4** | | | | 1 | |
| Chemicals & man-made fibres | 20-21 | **0** | 0 | | | | **0** | | | | **42** | | | | 16 | |
| Rubber and plastic products | 22 | **0** | 0 | | | | **0** | | | | **10** | | | | 0 | |
| Other non-metallic mineral products | 23 | **77** | 77 | | | | **0** | | | | **127** | | | | 11 | |
| Basic metals and fabricated metal | 24-25 | **0** | 0 | | | | **0** | | | | **224** | | | | 0 | |
| Machinery and equipment n.e.c. | 28 | **0** | 0 | | | | **0** | | | | **6** | | | | 1 | |
| Electrical and optical equipment | 26-27 | **0** | 0 | | | | **0** | | | | **38** | | | | 0 | |
| Transport equipment manufacture | 29-30 | **0** | 0 | | | | **0** | | | | **5** | | | | 0 | |
| Other manufacturing | 31-33, 12, 15 & 19 | **4** | 4 | | | | **0** | | | 0 | **47** | | | | 12 | |
| **Transport** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **4,528** | **0** | **0** | **1,505** | **0** | **787** |
| Road Freight | | **0** | | | | | **0** | | | | **733** | | | | | |
| Road Private Car | | **0** | | | | | **0** | | | | **1,899** | | | 1,245 | | |
| Public Passenger Services | | **0** | | | | | **0** | | | | **187** | | | 40 | | |
| Rail | | **0** | | | | | **0** | | | | **40** | | | | | |
| Domestic Aviation | | **0** | | | | | **0** | | | | **14** | | | 1 | | 13 |
| International Aviation | | **0** | | | | | **0** | | | | **774** | | | | | 774 |
| Fuel Tourism | | **0** | | | | | **0** | | | | **299** | | | 118 | | |
| Navigation | | **0** | | | | | **0** | | | | **64** | | | | | |
| Unspecified | | **0** | | | | | **0** | | | | **518** | | | 101 | | |
| **Residential** | | **262** | **185** | 67 | | **10** | **254** | | **165** | **88** | **1,267** | | | **0** | **1,010** | |
| **Commercial/Public Services** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **402** | **0** | **0** | **0** | **0** | **0** |
| Commercial Services | | **0** | 0 | 0 | | 0 | **0** | | | | **260** | | | | 0 | |
| Public Services | | **0** | | | | | **0** | | 0 | 0 | **141** | | | | | |
| **Agricultural** | | **0** | **0** | | | | **0** | | | | **225** | | | **0** | **0** | |
| **Fisheries** | | **0** | | | | | **0** | | | | **25** | | | | | |
| **Statistical Difference** | | **15** | **17** | **-2** | **0** | **0** | **15** | **16** | **-0** | **-1** | **-106** | **-0** | **-21** | **69** | **-98** | **3** |

## *Table B.1 (continued) Expanded Energy Balance Sheet 2010*

| 2010 Units = ktoe | Fueloil | LPG | Gasoil / Diesel /DERV | Petroleum Coke | Naphtha | Bitumen | White Spirit | Lubricants | Natural Gas | Renewables | Hydro | Wind | Biomass & Renewable Waste | Landfill Gas | Biogas | Liquid Biofuel | Solar | Geothermal | Non-Renewable Waste | Electricity | Heat | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indigenous Production | | | | | | | | | **318** | **602** | 52 | 242 | 197 | 44 | 13 | 25 | 6 | 23 | 9 | | | 1,909 |
| Imports | 316 | 122 | 2,277 | 81 | 0 | 299 | 1 | 32 | **4,393** | **82** | | | 11 | | | 71 | | | | 65 | | 14,409 |
| Exports | 908 | 30 | 126 | 0 | 23 | 1 | 1 | 5 | **0** | **0** | | | 0 | | | 0 | | | | 25 | | 1,196 |
| Mar. Bunkers | 38 | | 100 | | | | | | | **0** | | | | | | | | | | | | 139 |
| Stock Change | 103 | 1 | -17 | 30 | -4 | 0 | 0 | 0 | **-7** | **-1** | | | 3 | | | -4 | | | | | | 157 |
| **Primary Energy Supply (incl non-energy** | **-528** | **93** | **2,033** | **111** | **-26** | **299** | **0** | **27** | **4,704** | 683 | **52** | **242** | **211** | **44** | **13** | **92** | **6** | **23** | **9** | **40** | **0** | **15,141** |
| **Primary Energy Requirement (excl. non** | **-528** | **93** | **2,033** | **111** | **-26** | **0** | **0** | **0** | **4,704** | 683 | **52** | **242** | **211** | **44** | **13** | **92** | **6** | **23** | **9** | **40** | **0** | **14,815** |
| **Transformation Input** | **103** | **0** | **26** | **0** | **0** | **0** | **0** | **0** | **3,027** | **77** | **0** | **0** | **28** | **44** | **5** | **0** | **0** | **0** | **0** | **41** | **0** | **7,775** |
| Public Thermal Power Plants | 103 | | 26 | | | | | | **2,768** | **65** | | | 20 | 44 | | | | | | | | 4,310 |
| Combined Heat and Power Plants | 0 | 0 | 0 | | | | | | **257** | **13** | | | 7 | | 5 | | | | | | | 286 |
| Pumped Storage Consumption | | | | | | | | | | | | | | | | | | | | 25 | | 25 |
| Briquetting Plants | | | | | | | | | | **0** | | | | | | | | | | | | 115 |
| Oil Refineries & other energy sector | | | | | | | | | **2** | **0** | | | | | | | | | | 16 | | 3,039 |
| **Transformation Output** | **950** | **64** | **1,178** | **0** | **29** | **0** | **0** | **0** | **0** | **27** | **0** | **0** | **10** | **16** | **2** | **0** | **0** | **0** | **0** | **2,143** | **0** | **5,308** |
| Public Thermal Power Plants | | | | | | | | | | **24** | | | 8 | 16 | | | | | | 1,960 | | 1,984 |
| Combined Heat and Power Plants - Electricity | | | | | | | | | | **3** | | | 2 | | 2 | | | | | 168 | | 172 |
| Combined Heat and Power Plants - Heat | | | | | | | | | | **0** | | | | | | | | | | | | 0 |
| Pumped Storage Generation | | | | | | | | | | | | | | | | | | | | 15 | | 15 |
| Briquetting Plants | | | | | | | | | | **0** | | | | | | | | | | | | 105 |
| Oil Refineries | 950 | 64 | 1,178 | | 29 | | | | | **0** | | | | | | | | | | | | 3,032 |
| **Exchanges and transfers** | 5 | 0 | -2 | -24 | 0 | 0 | 0 | 0 | **0** | **-321** | -52 | -242 | -10 | -16 | -2 | 0 | 0 | 0 | 0 | **321** | **0** | 7 |
| Electricity | | | | | | | | | | **-321** | -52 | -242 | -10 | -16 | -2 | | | | | **321** | | 0 |
| Heat | | | | | | | | | | | | | | | | | | | | | | 0 |
| Other | 5 | | -2 | -24 | | | | | | **0** | | | | | | | | | | | | 7 |
| **Own Use and Distribution Losses** | 9 | 3 | 1 | | | | | | **71** | **0** | | | | | | | | | | **282** | | 489 |
| **Available Final Energy Consumption** | **316** | **154** | **3,181** | **88** | **3** | **299** | **0** | **27** | **1,607** | **312** | **0** | **0** | **183** | **0** | **8** | **92** | **6** | **23** | **9** | **2,181** | **0** | **12,191** |
| **Non-Energy Consumption** | **0** | **0** | **0** | **0** | | **299** | **0** | **27** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **326** |
| Final non-Energy Consumption (Feedstocks) | | | | | | 299 | 0 | 27 | 0 | 0 | | | | | | | | | | | | 326 |
| **Total Final Energy Consumption** | **321** | **148** | **3,234** | **95** | **1** | **0** | **0** | **0** | **1,616** | **321** | **0** | **0** | **192** | **0** | **8** | **92** | **6** | **23** | **9** | **2,163** | **0** | **11,942** |
| **Industry*** | **311** | **103** | **159** | **82** | **1** | **0** | **0** | **0** | **467** | **152** | **0** | **0** | **148** | | **5** | **0** | **0** | **0** | **9** | **591** | **0** | **2,091** |
| Non-Energy Mining | 3 | 0 | 38 | 26 | | | | | 10 | **0** | | | | | | | | | | 42 | | 123 |
| Food & beverages | 56 | 29 | 36 | 0 | | | | | 88 | **40** | | | 36 | | 5 | | | | | 126 | | 463 |
| Textiles and textile products | 1 | 0 | 1 | 0 | | | | | 1 | **0** | | | | | | | | | | 8 | | 12 |
| Wood and wood products | 0 | 0 | 2 | 0 | | | | | 2 | **100** | | | 100 | | | | | | | 25 | | 131 |
| Pulp, paper, publishing and printing | 1 | 0 | 2 | 0 | | | | | 3 | **0** | | | | | | | | | | 14 | | 21 |
| Chemicals & man-made fibres | 13 | 3 | 10 | 0 | | | | | 54 | **0** | | | 0 | | | | | | | 107 | | 203 |
| Rubber and plastic products | 0 | 5 | 4 | 0 | | | | | 4 | **0** | | | | | | | | | | 26 | | 40 |
| Other non-metallic mineral products | 9 | 1 | 50 | 56 | | | | | 14 | **12** | | | 12 | | | | | | 9 | 37 | | 276 |
| Basic metals and fabricated metal | 216 | 5 | 3 | 0 | | | | | 177 | **0** | | | | | | | | | | 49 | | 450 |
| Machinery and equipment n.e.c. | 0 | 2 | 3 | 0 | | | | | 5 | **0** | | | | | | | | | | 15 | | 26 |
| Electrical and optical equipment | 0 | 35 | 2 | 0 | | | | | 103 | **0** | | | | | | | | | | 73 | | 214 |
| Transport equipment manufacture | 0 | 3 | 1 | 0 | | | | | 2 | **0** | | | | | | | | | | 12 | | 19 |
| Other manufacturing | 10 | 18 | 6 | 0 | 1 | | | | 5 | **0** | | | | | | | | | | 57 | | 114 |
| **Transport** | **0** | **1** | **2,236** | **0** | **0** | **0** | **0** | **0** | **0** | **92** | **0** | **0** | **0** | **0** | **0** | **92** | **0** | **0** | **0** | **4** | **0** | **4,624** |
| Road Freight | | | 733 | | | | | | | **0** | | | | | | | | | | | | 733 |
| Road Private Car | | 1 | 654 | | | | | | | **92** | | | | | | 92 | | | | | | 1,991 |
| Public Passenger Services | | | 146 | | | | | | | **0** | | | | | | | | | | | | 187 |
| Rail | | | 40 | | | | | | | **0** | | | | | | | | | | 4 | | 44 |
| Domestic Aviation | | | | | | | | | | **0** | | | | | | | | | | | | 14 |
| International Aviation | | | | | | | | | | **0** | | | | | | | | | | | | 774 |
| Fuel Tourism | | | 181 | | | | | | | **0** | | | | | | | | | | | | 299 |
| Navigation | | | 64 | | | | | | | **0** | | | | | | | | | | | | |
| Unspecified | 0 | | 417 | | | | | | | **0** | | | | | | | | | | | | 518 |
| **Residential** | **0** | **37** | **206** | **13** | | | | | **710** | **58** | | | **33** | | | | **5** | **20** | | **732** | | **3,281** |
| **Commercial/Public Services** | **10** | **8** | **384** | **0** | **0** | **0** | **0** | **0** | **440** | **18** | **0** | **0** | **12** | **0** | **3** | **0** | **0** | **2** | **0** | **789** | **0** | **1,648** |
| Commercial Services | 1 | 6 | 254 | 0 | | | | | **193** | **15** | | | 12 | | | | 0 | 2 | | 566 | | 1,033 |
| Public Services | 9 | 2 | 130 | | | | | | **247** | **3** | | | | | 3 | | | | | 223 | | 615 |
| **Agricultural** | | **0** | **225** | | | | | | **0** | **0** | | | | | | | | | | **48** | | **273** |
| **Fisheries** | | | 25 | | | | | | | **0** | | | | | | | | | | | | |
| **Statistical Difference** | **-5** | **5** | **-53** | **-7** | **2** | **0** | **0** | **0** | **-10** | **-9** | **0** | **0** | **-9** | **0** | **0** | **0** | **0** | **0** | **0** | **18** | **0** | **-77** |

# Annex C

## Calculation Sheets for Energy 2010

## Comparison of Reference and Sectoral Approach

## Time-Series of Implied Emission Factors in Categories 1.A.1 and 1.A.2

## *Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2010 (continued on following page)*

| | Sectoral Disaggregation of Fuel Combustion from National Energy Balance | | | Emission Factors $CO_2$ | Emission Factors $CH_4$ | Emission Factors $N_2O$ | Emissions $CO_2$ | Emissions $CH_4$ | Emissions $N_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| | **Sector/Fuel** | **kTOE** | **TJ** | **kg/TJ** | **kg/TJ** | **kg/TJ** | **Gg** | **Mg** | **Mg** |
| | **1A1a Public Electricity** | | | | | | | | |
| 1 | Coal | 867.50 | 36320.56 | 92990 | 0.7 | 0.5 | 3377.43 | 25.42 | 18.16 |
| 2 | Peat | 481.13 | 20144.16 | 114709 | 3.0 | 7.0 | 2310.72 | 60.43 | 141.01 |
| 3 | Fuel Oil and Gas Oil | 129.07 | 5403.82 | 78424 | 0.8 | 0.3 | 423.79 | 4.32 | 1.62 |
| 4 | Natural Gas | 2768.19 | 115898.69 | 57233 | 1.4 | 2.7 | 6633.19 | 166.98 | 313.65 |
| 5 | Biomass (LFG & Wood) | 64.53 | 2701.77 | 69167 | 4.2 | 4.3 | 186.87 | 11.23 | 11.52 |
| | **Public Electricity Total** | **4310.43** | **180469.00** | | | | **12745.14** | **268.39** | **485.95** |
| | | | | | | | | | |
| | **1A1b Refinery Fuel** | | | | | | | | |
| 6 | Refinery Gas | 107.10 | 4484.02 | 53513 | 1.0 | 0.1 | 239.95 | 4.48 | 0.45 |
| 7 | Fuel Oil | 8.92 | 373.44 | 120219 | 3.0 | 0.6 | 44.90 | 1.12 | 0.22 |
| 8 | LPG | 3.58 | 150.09 | 118388 | 1.0 | 0.1 | 17.77 | 0.15 | 0.02 |
| 9 | Gasoil/Diesel/DERV | 1.29 | 54.20 | 41053 | 3.0 | 0.6 | 2.23 | 0.16 | 0.03 |
| | **Refinery Total** | **120.90** | **5061.76** | | | | **304.84** | **5.92** | **0.72** |
| | | | | | | | | | |
| | **1A1c Manufacture of Briquettes** | | | | | | | | |
| 10 | Peat | **32.08** | **1342.98** | 89945 | 2.0 | 1.5 | **120.79** | **2.69** | **2.01** |
| | | | | | | | | | |
| | **1A2a-1A2f Industry Fuel** | | | | | | | | |
| 11 | Bituminous Coals | 103.31 | 4325.32 | 94600 | 10.0 | 1.5 | 409.18 | 43.25 | 6.49 |
| 12 | Briquettes | 0.00 | 0.00 | 98860 | 2.0 | 1.5 | 0.00 | 0.00 | 0.00 |
| 13 | Kerosene | 112.27 | 4700.46 | 71400 | 3.0 | 0.6 | 335.61 | 14.10 | 2.82 |
| 14 | Fuel Oil | 311.47 | 13040.52 | 76000 | 3.0 | 0.6 | 991.08 | 39.12 | 7.82 |
| 15 | LPG | 102.70 | 4300.03 | 63700 | 1.0 | 0.1 | 273.91 | 4.30 | 0.43 |
| 16 | Gasoil/Diesel/DERV | 159.40 | 6673.68 | 73300 | 3.0 | 0.6 | 489.18 | 20.02 | 4.00 |
| 17 | Pet Coke | 81.84 | 3426.32 | 93597 | 3.0 | 0.6 | 320.69 | 10.28 | 2.06 |
| 18 | Naphta | 1.05 | 44.00 | 73330 | 3.0 | 0.6 | 3.23 | 0.13 | 0.03 |
| 19 | Natural Gas | 705.34 | 29530.98 | 57098 | 1.0 | 0.1 | 1686.15 | 29.53 | 2.95 |
| 20 | Biomass (solid) | 147.92 | 6193.07 | 110000 | 30.0 | 4.0 | 681.24 | 185.79 | 24.77 |
| 21 | Biomass (gas) | 4.54 | 190.28 | 54600 | 1.0 | 0.1 | 10.39 | 0.19 | 0.02 |
| 22 | Non Renewable wastes | 8.55 | 358.00 | 46658 | 3.0 | 0.6 | 16.70 | 1.07 | 0.21 |
| | **Industry Total** | **1729.83** | **72424.64** | | | | **4525.74** | **347.80** | **51.61** |
| | | | | | | | | | |
| | **1A3a Aviation** | | | | | | | | |
| 23 | Civil Aviation Kerosene | 13.57 | 568.00 | 71298 | 1.4 | 2.7 | 40.50 | 0.77 | 1.52 |
| | | | | | | | | | |
| | **1A3b Road Transport Fuel** | | | | | | | | |
| 24 | Gasoline | 1503.55 | 62950.66 | 69960 | 11.8 | 1.86 | 4404.03 | 741.66 | 114.76 |
| 25 | Gasoil/Diesel/DERV | 2131.32 | 89234.23 | 73300 | 0.8 | 2.05 | 6540.87 | 68.47 | 177.44 |
| 26 | LPG | 2.21 | 92.64 | 63700 | 11.71 | 3.28 | 5.90 | 1.08 | 0.30 |
| 27 | Liquid Biofuels | 92.46 | 3870.99 | 70617 | 4.37 | 1.94 | 273.36 | 16.90 | 7.50 |
| | **Road Transport Total** | **3729.54** | **156148.53** | | | | **10950.80** | **828.12** | **300.01** |

***Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2010 (continued from previous page)***

| | Sectoral Disaggregation of Fuel Combustion from National Energy Balance | | | Emission Factors | | | Emissions | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ | $CH_4$ | $N_2O$ |
| | **Sector/Fuel** | **kTOE** | **TJ** | **kg/TJ** | **kg/TJ** | **kg/TJ** | **Gg** | **Mg** | **Mg** |
| | **1A3c-1A3e Other Transport Fuel** | | | | | | | | |
| 28 | Railway Diesel | 39.70 | 1662.37 | 73300 | 4.2 | 28.6 | 121.85 | 6.90 | 47.54 |
| 29 | Navigation Fuel Oil | 0.00 | 0.00 | 76000 | 7.0 | 2.0 | 0.00 | 0.00 | 0.00 |
| 30 | Navigation Gasoil | 64.47 | 2699.42 | 73300 | 7.0 | 2.0 | 197.87 | 18.90 | 5.40 |
| 31 | Gas Distribution Use (Natural Gas) | 68.85 | 2882.77 | 57098 | 5.0 | 2.0 | 164.60 | 14.41 | 5.77 |
| | **Other Transport Total** | **173.03** | **7244.56** | | | | **484.32** | **40.21** | **58.71** |
| | **1A4a Commercial/Institutional Fuel** | | | | | | | | |
| 32 | Bituminous Coal | 0.00 | 0.00 | 94600 | 10.0 | 1.5 | 0.00 | 0.00 | 0.00 |
| 33 | Anthracite + Manufactured Ovoids | 0.00 | 0.00 | 98260 | 10.0 | 1.5 | 0.00 | 0.00 | 0.00 |
| 34 | Lignite | 0.00 | 0.00 | 101200 | 10.0 | 1.5 | 0.00 | 0.00 | 0.00 |
| 35 | Briquettes | 0.00 | 0.00 | 98860 | 10.0 | 1.4 | 0.00 | 0.00 | 0.00 |
| 36 | Fuel Oil | 9.85 | 412.36 | 76000 | 10.0 | 0.6 | 31.34 | 4.12 | 0.25 |
| 37 | LPG | 7.76 | 325.06 | 63700 | 5.0 | 0.1 | 20.71 | 1.63 | 0.03 |
| 38 | Gasoil / Diesel/ DERV | 383.93 | 16074.48 | 73300 | 10.0 | 0.6 | 1178.26 | 160.74 | 9.64 |
| 39 | Natural Gas | 457.10 | 19138.03 | 57098 | 5.0 | 0.1 | 1092.74 | 95.69 | 1.91 |
| 40 | Biomass | 12.02 | 503.14 | 110000 | 300.0 | 4.0 | 55.35 | 150.94 | 2.01 |
| 41 | Biogas | 3.10 | 129.80 | 54600 | 5.0 | 0.1 | 7.09 | 0.65 | 0.01 |
| | **Commercial/Institutional Total** | **873.77** | **36582.87** | | | | **2323.04** | **413.77** | **13.86** |
| | **1A4b Residential Fuel** | | | | | | | | |
| 42 | Bituminous Coal | 184.93 | 7742.61 | 94600 | 300.0 | 1.5 | 732.45 | 2322.78 | 11.61 |
| 43 | Anthracite + Manufactured Ovoids | 66.57 | 2786.95 | 98260 | 300.0 | 1.5 | 273.85 | 836.08 | 4.18 |
| 44 | Lignite | 10.38 | 434.60 | 101200 | 300.0 | 1.5 | 43.98 | 130.38 | 0.65 |
| 45 | Sod Peat | 165.45 | 6927.16 | 104000 | 300.0 | 1.4 | 720.42 | 2078.15 | 9.70 |
| 46 | Briquettes | 88.09 | 3688.00 | 98860 | 300.0 | 1.4 | 364.60 | 1106.40 | 5.16 |
| 47 | Kerosene | 1010.42 | 42304.10 | 71400 | 10.0 | 0.6 | 3020.51 | 423.04 | 25.38 |
| 48 | LPG | 37.35 | 1563.58 | 63700 | 5.0 | 0.1 | 99.60 | 7.82 | 0.16 |
| 49 | Gasoil / Diesel/ DERV | 205.54 | 8605.53 | 73300 | 10.0 | 0.6 | 630.79 | 86.06 | 5.16 |
| 50 | Petroleum Coke | 13.28 | 556.12 | 93597 | 10.0 | 0.6 | 52.05 | 5.56 | 0.33 |
| 51 | Natural Gas | 709.73 | 29714.92 | 57098 | 5.0 | 0.1 | 1696.65 | 148.57 | 2.97 |
| 52 | Biomass | 32.51 | 1361.14 | 110000 | 300.0 | 4.0 | 149.73 | 408.34 | 5.44 |
| | **Residential Total** | **2524.24** | **105684.72** | | | | **7634.90** | **7553.19** | **70.76** |
| | **1A4c Agriculture/forestry/Fishing Fuel** | | | | | | | | |
| 53 | Gasoil | 250.01 | 10467.35 | 73300 | 9.2 | 23.5 | 767.26 | 96.59 | 245.60 |
| 54 | Biomass | 0.00 | 0.00 | 110000 | 300.0 | 4.0 | 0.00 | 0.00 | 0.00 |
| | **Agriculture Total** | **250.01** | **10467.35** | | | | **767.26** | **96.59** | **245.60** |
| | **Total Energy** | **13757.39** | **575994.40** | | | | **39897.33** | **9557.44** | **1230.76** |

### *Table C.2 Emissions from Fuel Combustion Allocated by IPCC Source Category*

| | GREENHOUSE GAS SOURCE AND SINK CATEGORIES | AGGREGATE ACTIVITY DATA | IMPLIED EMISSION FACTORS | | | EMISSIONS | | |
|---|---|---|---|---|---|---|---|---|
| | | Consumption (TJ) | $CO_2$ (t/TJ) | $CH_4$ (kg/TJ) | $N_2O$ (kg/TJ) | $CO_2$ | $CH_4$ (Gg) | $N_2O$ |
| **A** | **1.A.1. Energy Industries** | **186,873.7380** | | | | **13,170.7764** | **0.2770** | **0.4887** |
| B | Solid Fuels | 57,807.6980 | 100.4874 | 1.5317 | 2.7883 | 5,808.9478 | 0.0885 | 0.1612 |
| C | Liquid Fuels | 10,465.5775 | 69.6219 | 0.9785 | 0.2237 | 728.6336 | 0.0102 | 0.0023 |
| D | Gaseous Fuels | 115,898.6885 | 57.2327 | 1.4407 | 2.7062 | 6,633.1949 | 0.1670 | 0.3136 |
| E | Biomass | 2,701.7739 | 69.1672 | 4.1574 | 4.2630 | 186.8743 | 0.0112 | 0.0115 |
| **F** | **1.A.2 Manufacturing Industries and Construction** | **72,782.6486** | | | | **4,525.7356** | **0.3478** | **0.0516** |
| G | Solid Fuels | 4,325.3171 | 94.6000 | 10.0000 | 1.5000 | 409.1750 | 0.0433 | 0.0065 |
| H | Liquid Fuels | 32,184.9998 | 74.9947 | 2.7328 | 0.5332 | 2,413.7055 | 0.0880 | 0.0172 |
| I | Gaseous Fuels | 29,530.9758 | 57.0977 | 1.0000 | 0.1000 | 1,686.1512 | 0.0295 | 0.0030 |
| J | Biomass | 6,383.3519 | 108.3486 | 29.1356 | 3.8837 | 691.6273 | 0.1860 | 0.0248 |
| K | Other Fuels | 358.0040 | 46.6583 | 3.0000 | 0.6000 | 16.7039 | 0.0011 | 0.0002 |
| **L** | **1.A.3 Transport** | **163,961.0864** | | | | **11,475.6145** | **0.8691** | **0.3602** |
| M | Solid Fuels | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO | NE,NO |
| N | Liquid Fuels | 157,207.3177 | 71.9497 | 5.3292 | 2.2071 | 11,311.0147 | 0.8378 | 0.3470 |
| O | Gaseous Fuels | 2,882.7748 | 57.0977 | 5.0000 | 2.0000 | 164.5999 | 0.0144 | 0.0058 |
| P | Biomass | 3,870.9940 | 70.6171 | 4.3658 | 1.9376 | 273.3584 | 0.0169 | 0.0075 |
| **Q** | **1.A.4 Other Sectors** | **152,734.9355** | | | | **10,725.2021** | **8.0635** | **0.3302** |
| R | Solid Fuels | 21,579.3180 | 98.9511 | 300.0000 | 1.4508 | 2,135.2983 | 6.4738 | 0.0313 |
| S | Liquid Fuels | 80,308.5891 | 72.2278 | 9.7817 | 3.5682 | 5,800.5121 | 0.7856 | 0.2866 |
| T | Gaseous Fuels | 48,852.9487 | 57.0977 | 5.0000 | 0.1000 | 2,789.3918 | 0.2443 | 0.0049 |
| U | Biomass | 1,994.0797 | 106.3938 | 280.7975 | 3.7461 | 212.1578 | 0.5599 | 0.0075 |
| **V** | **1.A.5 Other *(Not specified elsewhere)* (6)** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **W** | **1.A. Fuel Combustion** | **576,352.4085** | | | | **39,897.3286** | **9.5574** | **1.2308** |
| | **Memo Items** | | | | | | | |
| X | Aviation Bunkers | 32,425.0349 | 71.4000 | 0.2536 | 2.3281 | 2,315.1475 | 0.0082 | 0.0755 |
| Y | Marine Bunkers | 5,806.7182 | 74.0483 | NE,NO | NE,NO | 429.9777 | NE,NO | NE,NO |
| Z | $CO_2$ from Biomass | 14,950.1995 | 91.2374 | | | 1,364.0178 | NA | NA |

***Table C.3 Correspondence between National Disaggregation of Sources and IPCC Combustion Source Categories***

| | IPCC Source Category/Fuel Groups from Table C.2 | National Disaggregated Sources from Table C.1 |
|---|---|---|
| **A** | **1.A.1 Energy Industries (A = B+C+D+E)** | |
| B | (a) Solid Fuels | 1+2+10 |
| C | (b) Liquid Fuels | 3+6+7+8+9 |
| D | (c) Gaseous Fuels | 4 |
| E | (d) Biomass | 5 |
| **F** | **1.A.2 Manufacturing Industries (F = G+H+I+J+K)** | |
| G | (a) Solid Fuels | 11+12 |
| H | (b) Liquid Fuels | 13+14+15+16+17+18 |
| I | (c) Gaseous Fuels | 19 |
| J | (d) Biomass | 20+21 |
| K | (e) Other Fuels | 22 |
| **L** | **1.A.3 Transport (L = M+N+O+P)** | |
| M | (a) Solid Fuels | NO |
| N | (b) Liquid Fuels | 23+24+25+26+28+29+30 |
| O | (c) Gaseous Fuels | 31 |
| P | (d) Biomass | 27 |
| **Q** | **1.A.4 Other Sectors (Q = R+S+T+U)** | |
| R | (a) Solid Fuels | 32+33+34+35+42+43+44+45+46 |
| S | (b) Liquid Fuels | 36+37+38+47+48+49+50+53 |
| T | (c) Gaseous Fuels | 39+51 |
| U | (d) Biomass | 40+41+52+54 |
| **V** | **1.A.5 Other** | **NO** |
| **W** | **1.A Fuel Combustion (W = A+F+L+Q+V)** | |

## *Table C.4 Emissions of $CO_2$ from the Reference Approach in 2010 [CRF 2010 Table 1.A(b)]*

| FUEL TYPES | | | Unit | Production | Imports | Exports | International bunkers | Stock change | Apparent consumption | Conversion factor (TJ/Unit) | NCV/ GCV[(1)] | Apparent consumption (TJ) | Carbon emission factor (t C/TJ) | Carbon content (Gg C) | Carbon stored (Gg C) | Net carbon emissions (Gg C) | Fraction of carbon oxidized | Actual $CO_2$ emissions (Gg $CO_2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liquid Fossil | Primary Fuels | Crude Oil | kt | NO | 2,998.374 | NO | | 44.354 | 2,954.019 | 42.814 | NCV | 126,473.981 | 20.000 | 2,529.480 | NA | 2,529.480 | 1.000 | 9,274.759 |
| | | Orimulsion | | NO | NO | NO | | NO | NO | 41.868 | NCV | NO | NO | NO | NO | NO | NO | NO |
| | | Natural Gas Liquids | kt | NO | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NA | NA,NO | NO | NA,NO |
| | Secondary Fuels | Gasoline | kt | | 1,050.846 | 35.489 | NO | 13.493 | 1,001.863 | 44.589 | NCV | 44,672.483 | 19.080 | 852.351 | NA | 852.351 | 1.000 | 3,125.287 |
| | | Jet Kerosene | kt | | 1,014.317 | NO | 735.269 | -3.434 | 282.483 | 44.100 | NCV | 12,457.374 | 19.473 | 242.582 | NA | 242.582 | 1.000 | 889.469 |
| | | Other Kerosene | kt | | 501.685 | 20.838 | NO | -12.564 | 493.411 | 44.196 | NCV | 21,806.745 | 19.473 | 424.636 | NA | 424.636 | 1.000 | 1,556.999 |
| | | Shale Oil | | | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| | | Gas / Diesel Oil | kt | | 2,201.149 | 122.162 | 96.918 | 16.558 | 1,965.512 | 43.308 | NCV | 85,122.970 | 19.991 | 1,701.685 | NA | 1,701.685 | 1.000 | 6,239.511 |
| | | Residual Fuel Oil | kt | | 320.759 | 921.470 | 39.028 | -104.078 | -535.661 | 41.236 | NCV | -22,088.426 | 20.727 | -457.831 | NA | -457.831 | 1.000 | -1,678.714 |
| | | Liquefied Petroleum Gas (LPG) | kt | | 107.908 | 26.512 | | -0.979 | 82.375 | 47.156 | NCV | 3,884.478 | 17.373 | 67.484 | NA | 67.484 | 1.000 | 247.441 |
| | | Ethane | | | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NA | NA,NO | NO | NA,NO |
| | | Naphtha | kt | | NO | 21.497 | | 3.608 | -25.104 | 44.003 | NCV | -1,104.677 | 20.000 | -22.094 | NO | -22.094 | 1.000 | -81.010 |
| | | Bitumen | kt | | 332.410 | 1.000 | | NO | 331.410 | 37.698 | NCV | 12,493.461 | 22.000 | 274.856 | 274.856 | 0.000 | 1.000 | 0.000 |
| | | Lubricants | kt | | 32.007 | 4.893 | NO | NO | 27.114 | 42.287 | NCV | 1,146.562 | 20.000 | 22.931 | 11.466 | 11.466 | 1.000 | 42.041 |
| | | Petroleum Coke | kt | | 106.209 | 0.325 | | -39.422 | 145.305 | 32.088 | NCV | 4,662.560 | 25.526 | 119.019 | NO | 119.019 | 1.000 | 436.402 |
| | | Refinery Feedstocks | kt | | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| | | Other Oil | | | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| Other Liquid Fossil | | | | | | | | | | | | 98.215 | | 1.964 | 1.964 | 0.000 | | 0.000 |
| Aviation Gasoline | | | kt | NO | NO | NO | NO | NO | NO | 44.589 | NCV | NO | 19.080 | NO | NO | NO | 1.000 | NO |
| Other non-specified | | | kt | NO | NO | NO | NO | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NA | NA,NO |
| White Spirit | | | kt | NO | 1.232 | -1.000 | NO | NO | 2.232 | 44.003 | NCV | 98.215 | 20.000 | 1.964 | 1.964 | 0.000 | 1.000 | 0.000 |
| Liquid Fossil Totals | | | | | | | | | | | | 289,625.726 | | 5,757.063 | 288.286 | 5,468.777 | | 20,052.184 |
| Solid Fossil | Primary Fuels | Anthracite [(2)] | kt | NO | 34.275 | 0.176 | | -7.437 | 41.537 | 27.842 | NCV | 1,156.468 | 26.798 | 30.991 | NO | 30.991 | 1.000 | 113.635 |
| | | Coking Coal | kt | NO | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NA | NA,NO | NO | NA,NO |
| | | Other Bituminous Coal | kt | NO | 1,539.007 | 12.758 | NO | -407.696 | 1,933.945 | 25.479 | NCV | 49,275.804 | 25.470 | 1,255.070 | NA | 1,255.070 | 1.000 | 4,601.924 |
| | | Sub-bituminous Coal | | NO | NO | NO | NO | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| | | Lignite | kt | NO | 22.288 | 0.666 | | -0.350 | 21.971 | 19.816 | NCV | 435.388 | 27.600 | 12.017 | NO | 12.017 | 1.000 | 44.061 |
| | | Oil Shale | | NO | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| | | Peat | kt | 4,463.263 | NO | NO | | 943.925 | 3,519.338 | 7.787 | NCV | 27,406.493 | 29.863 | 818.440 | NA | 818.440 | 1.000 | 3,000.947 |
| | Secondary Fuels | BKB[(3)] and Patent Fuel | kt | | NO | 22.820 | | 17.508 | -40.328 | 18.548 | NCV | -747.984 | 26.962 | -20.167 | NA | -20.167 | 1.000 | -73.946 |
| | | Coke Oven/Gas Coke | | | NO | NO | | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| Other Solid Fossil | | | | | | | | | | | | 6,925.352 | | 196.375 | NO | 196.375 | | 720.043 |
| Manufactured Ovoids | | | kt | NO | 11.583 | 8.834 | NO | 1.697 | 1.051 | 32.000 | NCV | 33.630 | 26.798 | 0.901 | NO | 0.901 | 1.000 | 3.304 |
| Other non-specified | | | | NO | NO | NO | NO | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| Sod Peat | | | kt | 528.000 | NO | NO | NO | 2.103 | 525.897 | 13.105 | NCV | 6,891.722 | 28.364 | 195.474 | NO | 195.474 | 1.000 | 716.738 |
| Solid Fossil Totals | | | | | | | | | | | | 84,451.522 | | 2,292.727 | NA,NO | 2,292.727 | | 8,406.664 |
| Gaseous Fossil | | Natural Gas (Dry) | TJ | 13,306.302 | 184,150.610 | NO | | 286.517 | 197,170.395 | 1.000 | NCV | 197,170.395 | 15.572 | 3,070.358 | NO | 3,070.358 | 1.000 | 11,257.979 |
| Other Gaseous Fossil | | | | | | | | | | | | NO | | NO | NO | NO | | NO |
| | Other non-specified | | | NO | NO | NO | NO | NO | NO | NO | NCV | NO | NO | NO | NO | NO | NO | NO |
| Gaseous Fossil Totals | | | | | | | | | | | | 197,170.395 | | 3,070.358 | NO | 3,070.358 | | 11,257.979 |
| **Total** | | | | | | | | | | | | 571,247.643 | | 11,120.148 | 288.286 | 10,831.862 | | 39,716.827 |
| Biomass total | | | | | | | | | | | | 13,010.949 | | 312.549 | NO | 312.549 | | 1,146.012 |
| | | Solid Biomass | TJ | 6,156.916 | 454.429 | 6.660 | | -134.670 | 6,739.355 | 1.000 | NCV | 6,739.355 | 30.000 | 202.181 | NO | 202.181 | 1.000 | 741.329 |
| | | Liquid Biomass | TJ | 2,655.008 | 1,376.417 | NO | | 157.166 | 3,874.259 | 1.000 | NCV | 3,874.259 | 19.229 | 74.498 | NO | 74.498 | 1.000 | 273.161 |
| | | Gas Biomass | TJ | 2,397.334 | NO | NO | | NO | 2,397.334 | 1.000 | NCV | 2,397.334 | 14.962 | 35.870 | NO | 35.870 | 1.000 | 131.523 |

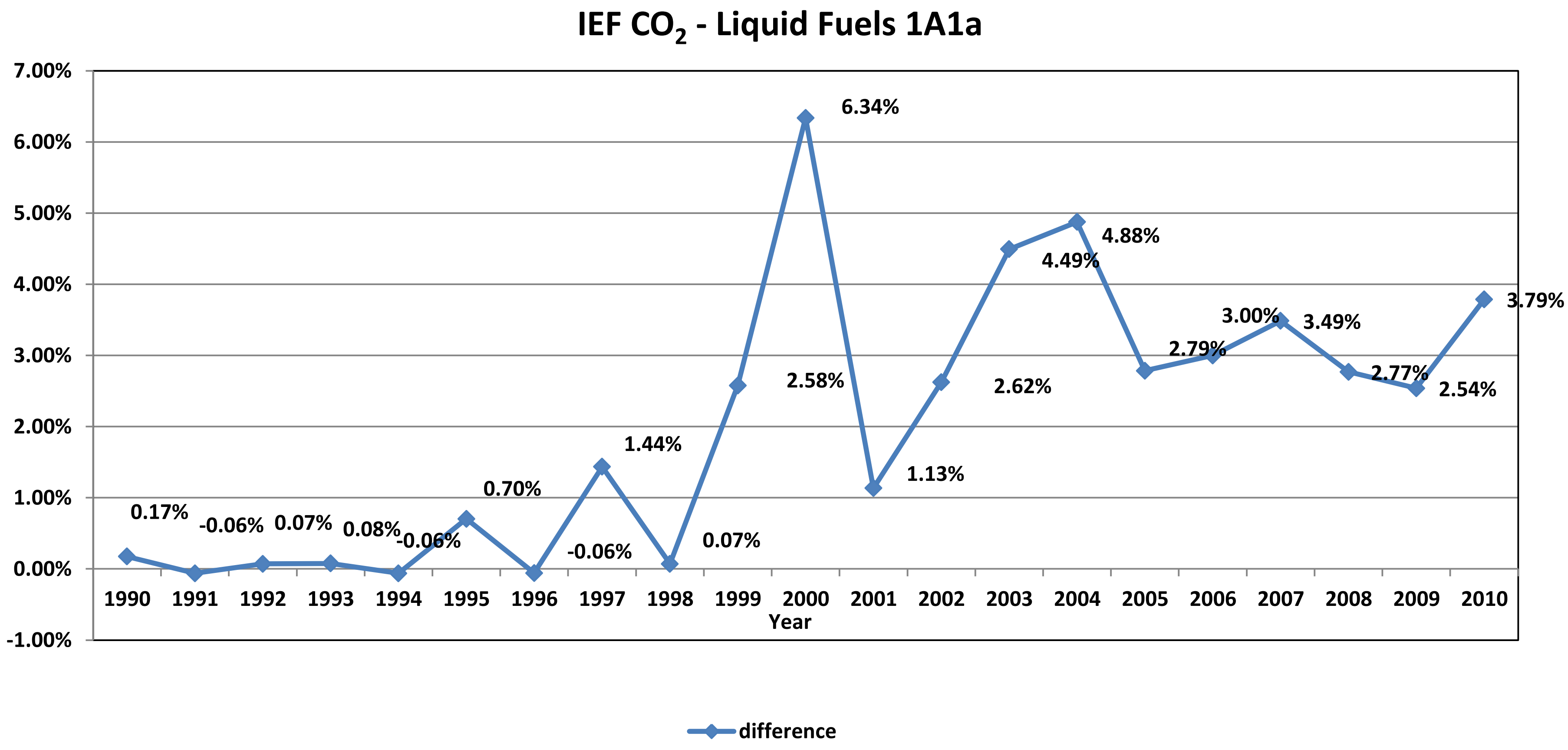
***Table C.5 Comparison of Results from Sectoral Approach and Reference Approach for 2010 (CRF 2010 Table 1.A(c)]***

| FUEL TYPES | REFERENCE APPROACH | | | SECTORAL APPROACH [(1)] | | DIFFERENCE [(2)] | |
|---|---|---|---|---|---|---|---|
| | Apparent energy consumption [(3)] (PJ) | Apparent energy consumption (excluding non-energy use and feedstocks) [(4)] (PJ) | $CO_2$ emissions (Gg) | Energy consumption (PJ) | $CO_2$ emissions (Gg) | Energy consumption (%) | $CO_2$ emissions (%) |
| Liquid Fuels (excluding international bunkers) | 289.626 | 276.977 | 20,052.184 | 280.166 | 20,253.867 | -1.139 | -0.996 |
| Solid Fuels (excluding international bunkers) [(5)] | 84.452 | 84.452 | 8,406.664 | 83.712 | 8,353.421 | 0.883 | 0.637 |
| Gaseous Fuels | 197.170 | 197.170 | 11,257.979 | 197.165 | 11,273.338 | 0.003 | -0.136 |
| Other [(5)] | 0.358 | 0.358 | 16.704 | 0.358 | 16.704 | 0.000 | 0.000 |
| ***Total*** [(5)] | ***571.606*** | ***558.957*** | ***39,733.531*** | ***561.402*** | ***39,897.330*** | ***-0.436*** | ***-0.411*** |

## *Table C.6 (a) Implied emission factors (IEFs) for $CO_2$ – Liquid Fuels in Sector 1.A.1.a*

| Energy (TJ) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | **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 | **Energy balance data** |
| **total** | **14282.09** | **23558.07** | **24139.52** | **23720.94** | **27252.93** | **25968.40** | **26162.15** | **33959.85** | **46295.57** | **58153.04** | **42984.49** | **51101.72** | **37259.30** | **25082.08** | **31847.00** | **32882.18** | **28440.12** | **16329.13** | **14644.96** | **8738.04** | **5403.82** | **Liquid Fuels CRFReporter** |
| **Emission Factors (t $CO_2$/TJ)** | | | | | | | | | | | | | | | | | | | | | | |
| Heavy Fuel Oil | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 76.00 | 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 | |
| **$CO_2$ Emissions National Approach Tier 1)** | | | | | | | | | | | | | | | | | | | | | | |
| Heavy Fuel Oil | 1062.40 | 1770.66 | 1808.27 | 1786.33 | 2011.98 | 1924.23 | 1958.70 | 2544.74 | 3472.38 | 4337.35 | 3174.66 | 3801.45 | 2769.17 | 1817.37 | 2295.30 | 2283.10 | 1989.76 | 1196.93 | 1078.26 | 637.08 | 327.42 | |
| 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 | |
| **total** | **1084.62** | **1789.71** | **1833.67** | **1802.21** | **2069.12** | **1971.84** | **1987.27** | **2579.66** | **3516.83** | **4416.71** | **3263.55** | **3880.81** | **2829.48** | **1903.08** | **2415.93** | **2491.37** | **2155.35** | **1239.45** | **1111.78** | **663.13** | **407.73** | |
| **IEF calculated** | **75.94** | **75.97** | **75.96** | **75.98** | **75.92** | **75.93** | **75.96** | **75.96** | **75.96** | **75.95** | **75.92** | **75.94** | **75.94** | **75.87** | **75.86** | **75.77** | **75.79** | **75.90** | **75.92** | **75.89** | **75.45** | IEF National Approach |
| $CO_2$ emissions from ETS (Tier 3 bottom up) | 1086.52 | 1788.62 | 1834.97 | 1803.59 | 2067.85 | 1985.81 | 1986.13 | 2617.23 | 3519.32 | 4533.60 | 3484.39 | 3925.34 | 2905.74 | 1992.62 | 2539.76 | 2562.77 | 2222.00 | 1284.23 | 1143.44 | 680.41 | 423.79 | **Gg $CO_2$ CRFReporter** |
| **difference** | **0.17%** | **-0.06%** | **0.07%** | **0.08%** | **-0.06%** | **0.70%** | **-0.06%** | **1.44%** | **0.07%** | **2.58%** | **6.34%** | **1.13%** | **2.62%** | **4.49%** | **4.88%** | **2.79%** | **3.00%** | **3.49%** | **2.77%** | **2.54%** | **3.79%** | |
| **IEF reported** | **76.08** | **75.92** | **76.02** | **76.03** | **75.88** | **76.47** | **75.92** | **77.07** | **76.02** | **77.96** | **81.06** | **76.81** | **77.99** | **79.44** | **79.75** | **77.94** | **78.13** | **78.65** | **78.08** | **77.87** | **78.42** | **IEF CRFReporter** |

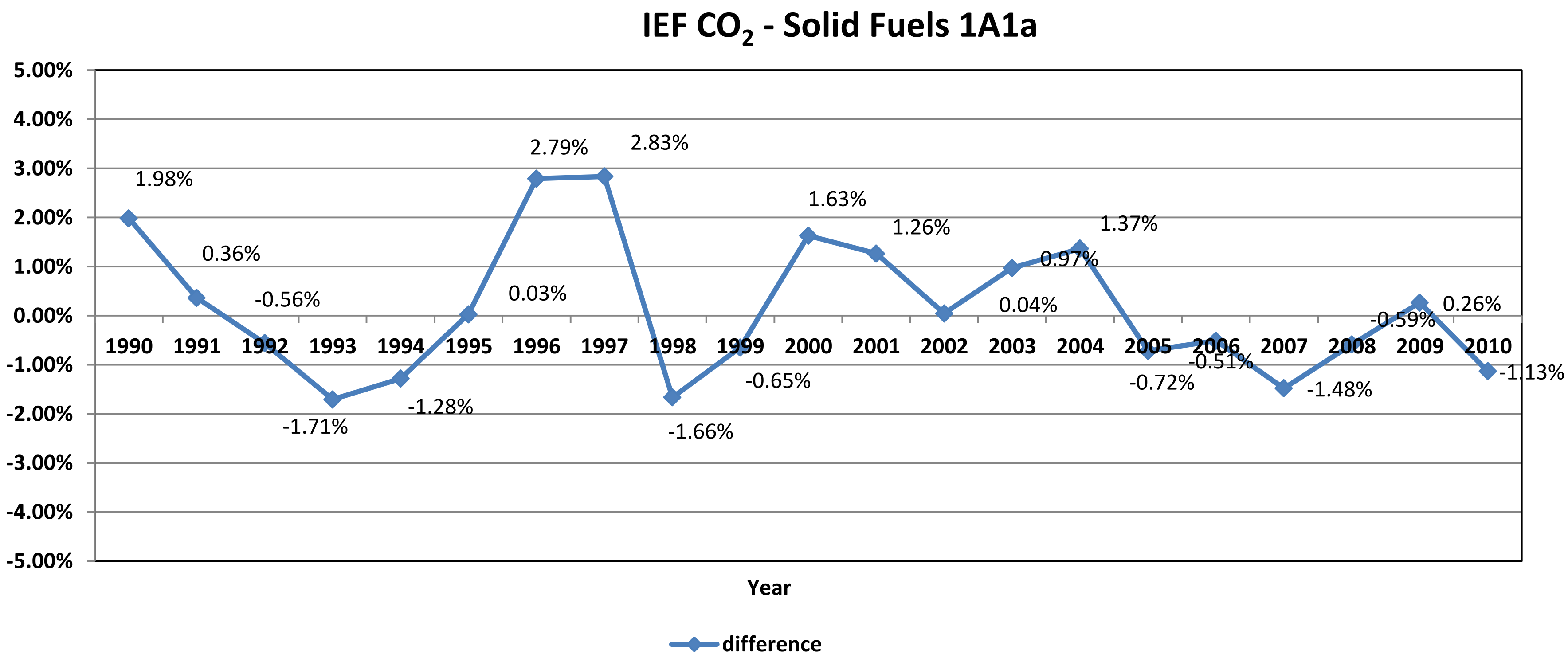
***Table C.6 (b) Implied emission factors (IEFs) for $CO_2$ – Liquid Fuels in Sector 1.A.1.a***



## *Table C.7 (a) Implied emission factors (IEFs) for $CO_2$ – Solid Fuels in Sector 1.A.1.a*

| Energy (TJ) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | **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 | **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 | **Energy balance data** |
| **total** | **76759.23** | **76731.10** | **84555.44** | **80477.79** | **82681.22** | **86285.00** | **85993.17** | **83428.49** | **82874.94** | **74651.99** | **79750.03** | **85842.71** | **83872.41** | **76405.67** | **70820.42** | **79795.64** | **69923.01** | **67856.14** | **65362.59** | **55758.40** | **56464.72** | **Solid Fuels CRFReporter** |
| **Emission Factors ($t\ CO_2/TJ$)** | | | | | | | | | | | | | | | | | | | | | | |
| Coal | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | 94.60 | |
| 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 | |
| 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 | |
| **$CO_2$ Emissions National Approach (Tier 1)** | | | | | | | | | | | | | | | | | | | | | | |
| Coal | 4916.56 | 4837.62 | 5514.00 | 5374.23 | 5538.35 | 5920.52 | 5881.99 | 5695.20 | 5787.13 | 5009.24 | 5650.32 | 5995.36 | 5803.08 | 5240.38 | 5392.54 | 5610.49 | 4820.15 | 4640.08 | 3926.44 | 3069.21 | 3435.93 | |
| 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 | |
| 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 | |
| **total** | **7752.52** | **7767.46** | **8524.86** | **8091.12** | **8310.56** | **8642.59** | **8609.98** | **8362.24** | **8280.63** | **7502.74** | **7952.79** | **8579.04** | **8393.92** | **7656.59** | **6981.48** | **7966.62** | **7001.71** | **6802.85** | **6669.98** | **5750.36** | **5752.50** | |
| **IEF calculated** | **101.00** | **101.23** | **100.82** | **100.54** | **100.51** | **100.16** | **100.12** | **100.23** | **99.92** | **100.50** | **99.72** | **99.94** | **100.08** | **100.21** | **98.58** | **99.84** | **100.13** | **100.25** | **102.05** | **103.13** | **101.88** | **IEF National Approach** |
| $CO_2$ emissions from ETS (Tier 3 bottom up) | 7909.31 | 7795.76 | 8477.38 | 7955.29 | 8205.33 | 8645.06 | 8857.12 | 8606.14 | 8145.16 | 7454.31 | 8084.48 | 8688.84 | 8397.65 | 7731.52 | 7078.28 | 7909.68 | 6966.22 | 6703.73 | 6630.99 | 5765.58 | 5688.15 | **Gg $CO_2$ CRFReporter** |
| **difference** | **1.98%** | **0.36%** | **-0.56%** | **-1.71%** | **-1.28%** | **0.03%** | **2.79%** | **2.83%** | **-1.66%** | **-0.65%** | **1.63%** | **1.26%** | **0.04%** | **0.97%** | **1.37%** | **-0.72%** | **-0.51%** | **-1.48%** | **-0.59%** | **0.26%** | **-1.13%** | |
| **IEF reported** | **103.04** | **101.60** | **100.26** | **98.85** | **99.24** | **100.19** | **103.00** | **103.16** | **98.28** | **99.85** | **101.37** | **101.22** | **100.12** | **101.19** | **99.95** | **99.12** | **99.63** | **98.79** | **101.45** | **103.40** | **100.74** | **IEF CRFReporter** |

***Table C.7 (b) Implied emission factors (IEFs) for $CO_2$ – Solid Fuels in Sector 1.A.1.a***



## *Table C.8 Implied emission factors (IEFs) for $CO_2$ – Liquid Fuels in Sector 1.A.2.f*

| Energy (TJ) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | **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 | **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 | **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 | 5351.13 | 5007.74 | 4714.96 | 4532.44 | **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 | **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 | **Energy balance data** |
| **total** | **10809.78** | **9898.20** | **9810.62** | **9728.91** | **11906.77** | **12640.08** | **10072.17** | **12303.07** | **12205.22** | **13110.97** | **15613.80** | **15746.06** | **16236.14** | **18216.57** | **19626.81** | **22948.82** | **20923.83** | **22649.49** | **20794.69** | **14025.92** | **13031.82** | **Energy balance data** |
| **Emission Factors ($t CO_2/TJ$)** | | | | | | | | | | | | | | | | | | | | | | |
| Kerosene | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | 71.40 | |
| 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 | |
| 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 | |
| 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 | |
| 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 | 94.18 | |
| 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 | |
| **$CO_2$ Emissions National Approach (Tier 1)** | | | | | | | | | | | | | | | | | | | | | | |
| Kerosene | 10.33 | 6.46 | 6.08 | 6.84 | 11.78 | 15.20 | 20.52 | 22.42 | 26.60 | 33.82 | 32.30 | 33.85 | 32.63 | 35.26 | 32.33 | 166.08 | 121.03 | 99.25 | 112.40 | 112.32 | 87.98 | |
| 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 | |
| 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 | |
| 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 | 392.24 | 367.07 | 345.61 | 332.23 | |
| 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 | 322.67 | |
| 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 | |
| **total** | **823.55** | **757.28** | **741.57** | **732.28** | **905.72** | **963.53** | **751.15** | **950.37** | **934.76** | **1004.65** | **1227.59** | **1250.02** | **1295.28** | **1466.99** | **1595.21** | **1862.79** | **1686.26** | **1846.60** | **1669.89** | **1093.30** | **1000.86** | |
| **IEF calculated** | **76.19** | **76.51** | **75.59** | **75.27** | **76.07** | **76.23** | **74.58** | **77.25** | **76.59** | **76.63** | **78.62** | **79.39** | **79.78** | **80.53** | **81.28** | **81.17** | **80.59** | **81.53** | **80.30** | **77.95** | **76.80** | **IEF National Approach** |
| $CO_2$ emissions | 823.55 | 757.28 | 741.57 | 732.28 | 905.72 | 963.53 | 751.15 | 950.37 | 934.76 | 1004.65 | 1227.59 | 1250.02 | 1295.28 | 1466.99 | 1595.21 | 1862.79 | 1686.26 | 1846.60 | 1669.89 | 1093.30 | 998.88 | **Gg $CO_2$ CRFReporter** |
| **difference** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **0.00%** | **-0.20%** | |
| **IEF reported** | **76.19** | **76.51** | **75.59** | **75.27** | **76.07** | **76.23** | **74.58** | **77.25** | **76.59** | **76.63** | **78.62** | **79.39** | **79.78** | **80.53** | **81.28** | **81.17** | **80.59** | **81.53** | **80.30** | **77.95** | **76.65** | **IEF CRFReporter** |
| **% Share of Fuels** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | |
| 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% | 6.14% | 7.57% | 11.22% | 9.46% | |
| 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% | 6.78% | 6.55% | 9.61% | 8.04% | |
| 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% | 15.02% | 17.51% | 15.28% | 21.09% | |
| 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% | 23.63% | 24.08% | 33.62% | 34.78% | |
| **Petroleum Coke** | **18.24%** | **20.15%** | **14.91%** | **13.66%** | **16.56%** | **17.35%** | **10.12%** | **22.33%** | **19.79%** | **19.94%** | **29.52%** | **33.52%** | **36.66%** | **41.71%** | **46.28%** | **41.33%** | **42.78%** | **48.25%** | **44.07%** | **29.97%** | **26.29%** | |
| 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% | |
| | 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 D

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

## Civil aviation data 1990-2010
## Vehicle population and kilometre data 1990-2010

*Table D.1 Number of Domestic LTOs by departure airport 1990-2010*

| Domestic LTOs No. | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ex Dublin | 7657 | 6944 | 6885 | 5921 | 6153 | 7235 | 7742 | 8134 | 8991 | 10183 | 11018 | 10947 | 10849 | 11261 | 12143 | 9976 | 10392 | 10803 | 9611 | 7844 | 6074 |
| ex Cork | 2872 | 2604 | 2582 | 2221 | 2307 | 2713 | 2903 | 3050 | 3372 | 3819 | 4132 | 4106 | 4069 | 4223 | 4438 | 3649 | 3721 | 4608 | 3919 | 2872 | 1861 |
| ex Shannon | 1737 | 1576 | 1562 | 1343 | 1396 | 1641 | 1757 | 1845 | 2040 | 2310 | 2500 | 2484 | 2462 | 2555 | 2865 | 2809 | 2892 | 2277 | 1897 | 1349 | 1077 |
| ex Galway | 1425 | 1293 | 1282 | 1102 | 1145 | 1347 | 1441 | 1514 | 1674 | 1895 | 2051 | 2038 | 2019 | 2096 | 2224 | 1631 | 1615 | 1815 | 1848 | 1563 | 1746 |
| ex Sligo | 620 | 562 | 557 | 479 | 498 | 586 | 627 | 658 | 728 | 824 | 892 | 886 | 878 | 912 | 946 | 759 | 748 | 754 | 785 | 741 | 678 |
| ex Donegal | 581 | 527 | 523 | 449 | 467 | 549 | 588 | 617 | 682 | 773 | 836 | 831 | 824 | 855 | 717 | 684 | 747 | 736 | 754 | 739 | 697 |
| ex Knock | 445 | 404 | 400 | 344 | 358 | 421 | 450 | 473 | 523 | 592 | 641 | 637 | 631 | 655 | 753 | 565 | 557 | 568 | 481 | 510 | 454 |
| ex Kerry | 1133 | 1027 | 1019 | 876 | 910 | 1070 | 1145 | 1203 | 1330 | 1506 | 1630 | 1620 | 1605 | 1666 | 1755 | 1477 | 1515 | 1506 | 1418 | 1170 | 1048 |
| ex Waterford | 236 | 214 | 213 | 183 | 190 | 223 | 239 | 251 | 278 | 314 | 340 | 338 | 335 | 348 | 254 | 181 | 191 | 279 | 456 | 231 | 472 |
| ex Other | 347 | 314 | 312 | 268 | 279 | 328 | 350 | 368 | 407 | 461 | 499 | 496 | 491 | 510 | 539 | 495 | 518 | 411 | 476 | 305 | 282 |
| **Total** | **17053** | **15465** | **15334** | **13187** | **13703** | **16113** | **17242** | **18115** | **20024** | **22679** | **24538** | **24381** | **24164** | **25080** | **26634** | **22226** | **22896** | **23757** | **21645** | **17324** | **14389** |

| Domestic LTOs (%) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ex Dublin | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 45% | 46% | 45% | 45% | 45% | 44% | 45% | 42% |
| ex Cork | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 17% | 16% | 16% | 19% | 18% | 17% | 13% |
| ex Shannon | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 11% | 13% | 13% | 10% | 9% | 8% | 7% |
| ex Galway | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 7% | 7% | 8% | 9% | 9% | 12% |
| ex Sligo | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 3% | 3% | 3% | 4% | 4% | 5% |
| ex Donegal | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 4% | 5% |
| ex Knock | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 2% | 2% | 2% | 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% |
| ex Waterford | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 2% | 1% | 3% |
| ex Other | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| **Total** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

*Table D.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 D.3 LTO emissions factors by aircraft type*

| Aircraft Type | kg of fuel per LTO | $CH_4$ kg/ LTO | $N_2O$ kg/ LTO |
|---|---|---|---|
| A30B | 1540.55 | 0.12 | 0.20 |
| A310 | 1540.55 | 0.63 | 0.20 |
| A320 | 802.33 | 0.06 | 0.10 |
| A321 | 802.33 | 0.14 | 0.10 |
| A332 | 2231.52 | 0.13 | 0.20 |
| A333 | 2231.52 | 0.13 | 0.20 |
| A343 | 2231.52 | 0.39 | 0.20 |
| AT43 | 115.20 | 0.02 | 0.02 |
| AT72 | 137.00 | 0.03 | 0.02 |
| ATP | 569.51 | 0.10 | 0.10 |
| B462 | 569.51 | 0.14 | 0.10 |
| B463 | 569.51 | 0.14 | 0.10 |
| B733 | 825.39 | 0.08 | 0.10 |
| B734 | 825.39 | 0.08 | 0.10 |
| B737 | 784.12 | 0.09 | 0.10 |
| B738 | 763.48 | 0.07 | 0.10 |
| B752 | 1253.00 | 0.02 | 0.10 |
| B762 | 1617.09 | 0.33 | 0.10 |
| B763 | 1617.09 | 0.12 | 0.20 |
| B764 | 1617.09 | 0.10 | 0.20 |
| BE20 | 51.80 | 0.06 | 0.01 |
| BE40 | 58.30 | 0.06 | 0.01 |
| CL30 | 569.51 | 0.10 | 0.10 |
| CL60 | 569.51 | 0.10 | 0.10 |
| DC10 | 2381.18 | 0.24 | 0.20 |
| GLF2 | 569.51 | 0.14 | 0.10 |
| GLF4 | 569.51 | 0.14 | 0.10 |
| GLF5 | 569.51 | 0.03 | 0.10 |
| H25B | 569.51 | 0.14 | 0.10 |
| LJ31 | 569.51 | 0.14 | 0.10 |
| LJ45 | 569.51 | 0.14 | 0.10 |
| LJ60 | 569.51 | 0.14 | 0.10 |
| MD11 | 1003.06 | 0.24 | 0.20 |
| MD82 | 1003.06 | 0.19 | 0.10 |
| MD83 | 1003.06 | 0.19 | 0.10 |
| T154 | 2190.00 | 7.59 | 0.20 |
| Other | 49.57 | 0.02 | 0.10 |

*Table D.4 Weighted Cruise fuel use per flight (IEF) by departure airport 1990-2010*

| kg Fuel | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **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 |
| **Total** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **454.5** | **402.0** | **433.5** | **492.9** | **451.1** | **467.0** | **485.6** | **440.6** |

*Table D.5 Vehicle numbers, by technology class 1990, 2000-2010*

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pass. Cars | Gasoline <1,4 l | PRE ECE | 12753 | 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 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/02 | 280562 | 8600 | 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 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/04 | 71416 | 271727 | 192288 | 157760 | 115198 | 87750 | 60785 | 44162 | 30208 | 21293 | 14731 | 7424 |
| Pass. Cars | Gasoline <1,4 l | Open Loop | 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 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 2 | 0 | 177840 | 305296 | 387716 | 380373 | 375274 | 368217 | 354676 | 340548 | 320459 | 312717 | 308269 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 3 | 0 | 0 | 0 | 0 | 81521 | 157601 | 236126 | 233047 | 230927 | 228512 | 213481 | 214849 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 86208 | 173076 | 258324 | 276615 | 214128 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 5 | 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 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PRE ECE | 4175 | 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 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/02 | 91854 | 3634 | 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 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/04 | 23381 | 115040 | 81171 | 67563 | 51553 | 39906 | 28597 | 21643 | 15689 | 11320 | 8970 | 4757 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | Open Loop | 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 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 2 | 0 | 75322 | 128876 | 166046 | 170224 | 170663 | 173229 | 173820 | 176876 | 170373 | 190406 | 197526 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 36482 | 71672 | 111086 | 114211 | 119940 | 121490 | 129983 | 137606 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42249 | 89894 | 137339 | 168424 | 137204 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Gasoline >2,0 l | PRE ECE | 291 | 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 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/02 | 6406 | 222 | 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 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/04 | 1631 | 7011 | 5493 | 6505 | 4895 | 4302 | 3304 | 2667 | 2114 | 1642 | 770 | 418 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 1 | 0 | 7640 | 8333 | 11445 | 11525 | 12378 | 12723 | 12195 | 12259 | 10743 | 5940 | 7504 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 2 | 0 | 4590 | 8722 | 15987 | 16164 | 18396 | 20016 | 21417 | 23834 | 24719 | 16354 | 17347 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 3465 | 7726 | 12835 | 14072 | 16162 | 17627 | 11164 | 12090 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5206 | 12113 | 19927 | 14466 | 12050 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Diesel <2,0 l | Conventional | 45976 | 60051 | 39587 | 31809 | 23614 | 18276 | 13201 | 10384 | 8432 | 6832 | 3105 | 1043 |
| Pass. Cars | Diesel <2,0 l | PC Euro 1 | 0 | 62255 | 58749 | 55242 | 55591 | 52592 | 50833 | 47487 | 48898 | 44687 | 23104 | 26595 |
| Pass. Cars | Diesel <2,0 l | PC Euro 2 | 0 | 37403 | 61483 | 77165 | 77970 | 78161 | 79970 | 83399 | 95064 | 102819 | 58346 | 70583 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pass. Cars | Diesel <2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 16711 | 32825 | 51284 | 54799 | 64463 | 73318 | 79799 | 97469 |
| Pass. Cars | Diesel <2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20271 | 48314 | 82883 | 155636 | 157793 |
| Pass. Cars | Diesel <2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Diesel >2,0 l | Conventional | 3207 | 8189 | 5398 | 4753 | 3844 | 3225 | 2515 | 1978 | 1210 | 922 | 771 | 3257 |
| Pass. Cars | Diesel >2,0 l | PC Euro 1 | 0 | 8489 | 8011 | 8255 | 9050 | 9281 | 9683 | 9045 | 7015 | 6030 | 5738 | 6550 |
| Pass. Cars | Diesel >2,0 l | PC Euro 2 | 0 | 5101 | 8385 | 11530 | 12693 | 13793 | 15233 | 15886 | 13638 | 13875 | 14490 | 17384 |
| Pass. Cars | Diesel >2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 2720 | 5793 | 9767 | 10438 | 9248 | 9894 | 19818 | 24006 |
| Pass. Cars | Diesel >2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3861 | 6932 | 11185 | 38652 | 38864 |
| Pass. Cars | Diesel >2,0 l | PC Euro 5 | 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 |
| Pass. Cars | LPG | Conventional | 3986 | 220 | 220 | 220 | 150 | 153 | 153 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | LPG | PC Euro 1 | 0 | 280 | 280 | 280 | 169 | 153 | 153 | 70 | 75 | 75 | 70 | 70 |
| Pass. Cars | LPG | PC Euro 2 | 0 | 216 | 216 | 216 | 169 | 153 | 153 | 85 | 80 | 80 | 85 | 85 |
| Pass. Cars | LPG | PC Euro 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 90 | 90 | 85 | 85 |
| Pass. Cars | LPG | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 90 | 90 | 90 | 90 |
| Pass. Cars | LPG | PC Euro 5 | 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 |
| Pass. Cars | Hybrid Gasoline <1,4 l | PC Euro 4 | 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 |
| Pass. Cars | Hybrid Gasoline >2,0 l | PC Euro 4 | 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 |
| LDV | Gasoline <3,5t | LD Euro 1 | 0 | 2845 | 3097 | 917 | 727 | 585 | 453 | 299 | 185 | 116 | 84 | 67 |
| LDV | Gasoline <3,5t | LD Euro 2 | 0 | 0 | 0 | 2123 | 1668 | 1374 | 1125 | 802 | 554 | 384 | 308 | 263 |
| LDV | Gasoline <3,5t | LD Euro 3 | 0 | 0 | 0 | 0 | 408 | 692 | 874 | 637 | 468 | 354 | 312 | 295 |
| LDV | Gasoline <3,5t | LD Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 284 | 421 | 485 | 535 | 548 |
| LDV | Gasoline <3,5t | LD Euro 5 | 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 |
| LDV | Diesel <3,5 t | Conventional | 57449 | 70983 | 62672 | 53848 | 53361 | 38845 | 31914 | 24683 | 19306 | 14838 | 11634 | 9485 |
| LDV | Diesel <3,5 t | LD Euro 1 | 0 | 81275 | 106574 | 38870 | 45653 | 38652 | 36684 | 33059 | 29333 | 24912 | 20424 | 17205 |
| LDV | Diesel <3,5 t | LD Euro 2 | 0 | 0 | 0 | 89942 | 104772 | 90837 | 91112 | 88497 | 87861 | 82717 | 74707 | 67526 |
| LDV | Diesel <3,5 t | LD Euro 3 | 0 | 0 | 0 | 0 | 25626 | 45804 | 70719 | 70282 | 74250 | 76253 | 75757 | 75665 |
| LDV | Diesel <3,5 t | LD Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31300 | 67027 | 104716 | 129528 | 140423 |
| LDV | Diesel <3,5 t | LD Euro 5 | 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 |
| HDT | Gasoline >3,5 t | Conventional | 651 | 193 | 167 | 140 | 119 | 102 | 87 | 71 | 54 | 44 | 42 | 38 |
| HDT | Rigid <=7,5 t | Conventional | 10195 | 3388 | 2608 | 2024 | 1503 | 1130 | 841 | 580 | 412 | 301 | 216 | 115 |
| HDT | Rigid <=7,5 t | HD Euro I | 0 | 3833 | 3467 | 3222 | 2955 | 2671 | 2353 | 1913 | 1579 | 1274 | 984 | 817 |
| HDT | Rigid <=7,5 t | HD Euro III | 0 | 2738 | 4034 | 5080 | 4717 | 4455 | 4243 | 3821 | 3597 | 3277 | 2795 | 2357 |
| HDT | Rigid <=7,5 t | HD Euro III | 0 | 0 | 0 | 0 | 1154 | 2247 | 3293 | 3034 | 3039 | 3021 | 2834 | 2641 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HDT | Rigid <=7,5 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1351 | 2744 | 4148 | 4845 | 4902 |
| HDT | Rigid <=7,5 t | HD Euro V | 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 |
| HDT | Rigid 7,5 - 12 t | Conventional | 7681 | 5326 | 3946 | 3048 | 2258 | 1687 | 1234 | 870 | 608 | 424 | 280 | 133 |
| HDT | Rigid 7,5 - 12 t | HD Euro I | 0 | 6031 | 5247 | 4852 | 4423 | 3968 | 3465 | 2884 | 2333 | 1796 | 1278 | 942 |
| HDT | Rigid 7,5 - 12 t | HD Euro III | 0 | 4308 | 6103 | 7651 | 7067 | 6471 | 6249 | 5753 | 5314 | 4619 | 3632 | 2719 |
| HDT | Rigid 7,5 - 12 t | HD Euro III | 0 | 0 | 0 | 0 | 1716 | 3266 | 4873 | 4560 | 4490 | 4258 | 3683 | 3047 |
| HDT | Rigid 7,5 - 12 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2046 | 4054 | 5847 | 6298 | 5654 |
| HDT | Rigid 7,5 - 12 t | HD Euro V | 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 |
| HDT | Rigid 12 - 14 t | Conventional | 990 | 1741 | 1405 | 1178 | 920 | 726 | 564 | 453 | 348 | 205 | 132 | 60 |
| HDT | Rigid 12 - 14 t | HD Euro I | 0 | 1972 | 1868 | 1876 | 1803 | 1708 | 1585 | 1501 | 1337 | 867 | 603 | 429 |
| HDT | Rigid 12 - 14 t | HD Euro III | 0 | 1409 | 2174 | 2958 | 2880 | 2851 | 2859 | 2994 | 3044 | 2230 | 1713 | 1237 |
| HDT | Rigid 12 - 14 t | HD Euro III | 0 | 0 | 0 | 0 | 700 | 1439 | 2229 | 2374 | 2572 | 2056 | 1737 | 1386 |
| HDT | Rigid 12 - 14 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1065 | 2323 | 2824 | 2970 | 2573 |
| HDT | Rigid 12 - 14 t | HD Euro V | 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 |
| HDT | Rigid 14 - 20 t | Conventional | 91 | 162 | 143 | 126 | 100 | 90 | 74 | 64 | 52 | 94 | 70 | 34 |
| HDT | Rigid 14 - 20 t | HD Euro I | 0 | 184 | 190 | 201 | 196 | 214 | 208 | 211 | 200 | 397 | 320 | 244 |
| HDT | Rigid 14 - 20 t | HD Euro III | 0 | 131 | 220 | 316 | 313 | 356 | 374 | 422 | 456 | 1020 | 910 | 705 |
| HDT | Rigid 14 - 20 t | HD Euro III | 0 | 0 | 0 | 0 | 77 | 180 | 291 | 335 | 385 | 940 | 923 | 790 |
| HDT | Rigid 14 - 20 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 149 | 346 | 1291 | 1578 | 1466 |
| HDT | Rigid 14 - 20 t | HD Euro V | 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 |
| HDT | Rigid 20 - 26 t | Conventional | 0 | 0 | 0 | 0 | 5 | 5 | 4 | 4 | 3 | 3 | 2 | 1 |
| HDT | Rigid 20 - 26 t | HD Euro I | 0 | 0 | 0 | 0 | 11 | 12 | 12 | 14 | 13 | 11 | 11 | 9 |
| HDT | Rigid 20 - 26 t | HD Euro III | 0 | 0 | 0 | 0 | 17 | 20 | 21 | 29 | 29 | 29 | 30 | 26 |
| HDT | Rigid 20 - 26 t | HD Euro III | 0 | 0 | 0 | 0 | 4 | 10 | 16 | 23 | 25 | 27 | 31 | 29 |
| HDT | Rigid 20 - 26 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 22 | 37 | 53 | 53 |
| HDT | Rigid 20 - 26 t | HD Euro V | 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 |
| HDT | Rigid 26 - 28 t | Conventional | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| HDT | Rigid 26 - 28 t | HD Euro I | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 1 |
| HDT | Rigid 26 - 28 t | HD Euro III | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 3 | 4 | 4 | 3 |
| HDT | Rigid 26 - 28 t | HD Euro III | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 4 | 4 | 3 |
| HDT | Rigid 26 - 28 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 8 | 6 |
| HDT | Rigid 26 - 28 t | HD Euro V | 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 |
| HDT | Rigid 28 - 32 t | Conventional | 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 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HDT | Rigid 28 - 32 t | HD Euro III | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 3 |
| HDT | Rigid 28 - 32 t | HD Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 4 | 3 |
| HDT | Rigid 28 - 32 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 |
| HDT | Rigid 28 - 32 t | HD Euro V | 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 |
| HDT | Rigid >32 t | Conventional | 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 |
| HDT | Rigid >32 t | HD Euro III | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 0 | 2 | 1 | 1 |
| HDT | Rigid >32 t | HD Euro III | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| HDT | Rigid >32 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 |
| HDT | Rigid >32 t | HD Euro V | 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 |
| HDT | Articulated 40 - 50 t | Conventional | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 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 |
| HDT | Articulated 40 - 50 t | HD Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| HDT | Articulated 40 - 50 t | HD Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| HDT | Articulated 40 - 50 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| HDT | Articulated 40 - 50 t | HD Euro V | 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 |
| HDT | Articulated 50 - 60 t | Conventional | 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 |
| HDT | Articulated 50 - 60 t | HD Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| HDT | Articulated 50 - 60 t | HD Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| HDT | Articulated 50 - 60 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| HDT | Articulated 50 - 60 t | HD Euro V | 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 |
| Buses | Urban Buses 15-18 t | Conventional | 1679 | 1239 | 1034 | 812 | 611 | 468 | 348 | 247 | 173 | 126 | 98 | 55 |
| Buses | Urban Buses 15-18 t | HD Euro I | 0 | 1521 | 1373 | 1294 | 1202 | 1106 | 974 | 814 | 663 | 533 | 445 | 388 |
| Buses | Urban Buses 15-18 t | HD Euro III | 0 | 997 | 1593 | 2044 | 1918 | 1845 | 1756 | 1625 | 1511 | 1371 | 1264 | 1121 |
| Buses | Urban Buses 15-18 t | HD Euro III | 0 | 0 | 0 | 0 | 469 | 931 | 1364 | 1290 | 1277 | 1264 | 1282 | 1256 |
| Buses | Urban Buses 15-18 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 575 | 1152 | 1736 | 2192 | 2331 |
| Buses | Urban Buses 15-18 t | HD Euro V | 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 |
| Buses | Coaches <=18 t | Conventional | 1678 | 1342 | 1050 | 813 | 605 | 467 | 348 | 247 | 173 | 126 | 98 | 55 |
| Buses | Coaches <=18 t | HD Euro I | 0 | 1521 | 1395 | 1296 | 1189 | 1103 | 974 | 814 | 663 | 533 | 445 | 388 |
| Buses | Coaches <=18 t | HD Euro III | 0 | 1081 | 1620 | 2047 | 1898 | 1841 | 1756 | 1625 | 1511 | 1371 | 1264 | 1121 |
| Buses | Coaches <=18 t | HD Euro III | 0 | 0 | 0 | 0 | 463 | 930 | 1364 | 1290 | 1277 | 1264 | 1282 | 1256 |
| Buses | Coaches <=18 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 576 | 1152 | 1737 | 2192 | 2331 |
| Buses | Coaches <=18 t | HD Euro V | 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 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mopeds | <50 $cm^3$ | Conventional | 0 | 7471 | 8716 | 9301 | 8530 | 8444 | 7395 | 4451 | 3443 | 2527 | 1987 | 1684 |
| Mopeds | <50 $cm^3$ | Mop - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1500 | 1475 | 1684 | 1988 | 1684 |
| Mopeds | <50 $cm^3$ | Mop - Euro II | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mopeds | <50 $cm^3$ | Mop - Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 2-stroke >50 $cm^3$ | Conventional | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke <250 $cm^3$ | Conventional | 19371 | 9447 | 10036 | 10292 | 9638 | 9535 | 8817 | 6605 | 5885 | 5561 | 4937 | 4397 |
| M.cycles | 4-stroke <250 $cm^3$ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1500 | 1962 | 2383 | 3291 | 3598 |
| M.cycles | 4-stroke <250 $cm^3$ | Mot - Euro II | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke <250 $cm^3$ | Mot - Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke 250 - 750 $cm^3$ | Conventional | 6457 | 8759 | 10736 | 11988 | 13481 | 15404 | 16778 | 14220 | 14959 | 15765 | 14691 | 13954 |
| M.cycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3000 | 4986 | 6756 | 9794 | 11416 |
| M.cycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro II | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke 250 - 750 $cm^3$ | Mot - Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke >750 $cm^3$ | Conventional | 0 | 1000 | 1150 | 1332 | 1498 | 1711 | 1864 | 1274 | 1662 | 1751 | 1633 | 1550 |
| M.cycles | 4-stroke >750 $cm^3$ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 750 | 554 | 751 | 1088 | 1269 |
| M.cycles | 4-stroke >750 $cm^3$ | Mot - Euro II | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke >750 $cm^3$ | Mot - Euro III | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table D.6 Vehicle kilometres, by technology class 1990, 2000-2010*

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pass. Cars | Gasoline <1,4 l | PRE ECE | 16791 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/00-01 | 16791 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/02 | 16791 | 20038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/03 | 16791 | 20038 | 20611 | 21594 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline <1,4 l | ECE 15/04 | 16791 | 20936 | 21479 | 21594 | 19581 | 19669 | 17698 | 17636 | 17513 | 17908 | 18171 | 17345 |
| Pass. Cars | Gasoline <1,4 l | Open Loop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 1 | 0 | 21036 | 21599 | 21594 | 20539 | 20138 | 20044 | 20084 | 19497 | 19102 | 19392 | 18494 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 2 | 0 | 21036 | 21599 | 21844 | 20539 | 21135 | 20643 | 20084 | 19497 | 19102 | 19392 | 18494 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 3 | 0 | 0 | 0 | 0 | 20539 | 21135 | 20643 | 20583 | 19497 | 19102 | 19392 | 18494 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20583 | 20993 | 19898 | 20192 | 19284 |
| Pass. Cars | Gasoline <1,4 l | PC Euro 5 | 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 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PRE ECE | 16791 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/00-01 | 16791 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/02 | 16791 | 22484 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/03 | 16791 | 22484 | 23076 | 21594 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | ECE 15/04 | 16791 | 23482 | 22577 | 21594 | 23024 | 20686 | 19645 | 18635 | 20445 | 20047 | 20342 | 19414 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | Open Loop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 1 | 0 | 23482 | 24543 | 23542 | 24481 | 21135 | 21142 | 21583 | 20445 | 20047 | 20342 | 19414 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 2 | 0 | 22983 | 24543 | 23542 | 24481 | 21634 | 21142 | 21583 | 20445 | 20296 | 20592 | 19644 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 24481 | 21634 | 21142 | 22082 | 20445 | 20396 | 20692 | 19744 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22582 | 21492 | 20396 | 20792 | 19854 |
| Pass. Cars | Gasoline 1,4 - 2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Gasoline >2,0 l | PRE ECE | 17229 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/00-01 | 17650 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/02 | 17650 | 23482 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/03 | 17650 | 23482 | 23575 | 23542 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | Gasoline >2,0 l | ECE 15/04 | 17229 | 23482 | 24543 | 23542 | 22435 | 21634 | 19645 | 18635 | 20494 | 20047 | 20342 | 19414 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 1 | 0 | 24421 | 24543 | 23542 | 24481 | 21634 | 21641 | 21583 | 20494 | 20047 | 20342 | 19414 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 2 | 0 | 23482 | 24543 | 23542 | 24481 | 21634 | 21641 | 21583 | 20494 | 20396 | 20692 | 19744 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 24481 | 21634 | 21641 | 22582 | 20494 | 20396 | 20692 | 19744 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22582 | 21492 | 21390 | 21663 | 20694 |
| Pass. Cars | Gasoline >2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Diesel <2,0 l | Conventional | 29942 | 33134 | 35105 | 34496 | 29940 | 30305 | 30201 | 29863 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel <2,0 l | PC Euro 1 | 0 | 33134 | 35105 | 34496 | 31949 | 31010 | 32228 | 29863 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel <2,0 l | PC Euro 2 | 0 | 33134 | 35105 | 34496 | 31949 | 32017 | 33241 | 30365 | 28845 | 28843 | 27034 | 25500 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pass. Cars | Diesel <2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 31949 | 32973 | 33241 | 31871 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel <2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31871 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel <2,0 l | PC Euro 5 | 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 |
| Pass. Cars | Diesel >2,0 l | Conventional | 28382 | 33134 | 35105 | 35515 | 31949 | 31010 | 30201 | 29863 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel >2,0 l | PC Euro 1 | 0 | 33134 | 35105 | 35515 | 31949 | 32017 | 32228 | 29863 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel >2,0 l | PC Euro 2 | 0 | 33134 | 35105 | 35515 | 31949 | 32973 | 33241 | 29863 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel >2,0 l | PC Euro 3 | 0 | 0 | 0 | 0 | 31949 | 32973 | 33241 | 31871 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel >2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32874 | 28845 | 28843 | 27034 | 25500 |
| Pass. Cars | Diesel >2,0 l | PC Euro 5 | 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 |
| Pass. Cars | LPG | Conventional | 48231 | 57336 | 48445 | 34821 | 44482 | 40067 | 36888 | 0 | 0 | 0 | 0 | 0 |
| Pass. Cars | LPG | PC Euro 1 | 0 | 57336 | 48445 | 34821 | 44982 | 41975 | 36888 | 51514 | 50288 | 49424 | 59175 | 59177 |
| Pass. Cars | LPG | PC Euro 2 | 0 | 57336 | 48445 | 34821 | 44982 | 41975 | 36888 | 51514 | 50288 | 49424 | 59175 | 59177 |
| Pass. Cars | LPG | PC Euro 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51514 | 50288 | 49424 | 59175 | 59177 |
| Pass. Cars | LPG | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51514 | 50288 | 49424 | 59175 | 59177 |
| Pass. Cars | LPG | PC Euro 5 | 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 |
| Pass. Cars | Hybrid Gasoline <1,4 l | PC Euro 4 | 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 |
| Pass. Cars | Hybrid Gasoline >2,0 l | PC Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LDV | Gasoline <3,5t | Conventional | 32497 | 44988 | 44176 | 45136 | 46008 | 43269 | 44220 | 44164 | 42136 | 41040 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 1 | 0 | 55082 | 56113 | 45136 | 45060 | 43269 | 44220 | 44164 | 42136 | 41040 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 2 | 0 | 0 | 0 | 45385 | 45060 | 43269 | 44220 | 44164 | 42136 | 41040 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 3 | 0 | 0 | 0 | 0 | 45060 | 43269 | 44220 | 44164 | 42136 | 41040 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44164 | 42136 | 41040 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41625 | 39568 |
| LDV | Gasoline <3,5t | LD Euro 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LDV | Diesel <3,5 t | Conventional | 35879 | 54188 | 63732 | 62911 | 54947 | 56985 | 59489 | 59224 | 57790 | 57727 | 55082 | 51731 |
| LDV | Diesel <3,5 t | LD Euro 1 | 0 | 55671 | 63732 | 63675 | 54947 | 59502 | 59489 | 59224 | 58944 | 57727 | 55082 | 51731 |
| LDV | Diesel <3,5 t | LD Euro 2 | 0 | 0 | 0 | 63675 | 55459 | 59502 | 59996 | 60730 | 58944 | 57727 | 55082 | 51731 |
| LDV | Diesel <3,5 t | LD Euro 3 | 0 | 0 | 0 | 0 | 55459 | 59502 | 59996 | 60730 | 58944 | 57727 | 55082 | 51731 |
| LDV | Diesel <3,5 t | LD Euro 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60730 | 58944 | 57927 | 55082 | 51731 |
| LDV | Diesel <3,5 t | LD Euro 5 | 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 |
| HDT | Gasoline >3,5 t | Conventional | 41867 | 37455 | 37633 | 37669 | 37499 | 37654 | 37646 | 37453 | 39074 | 38945 | 39144 | 37122 |
| HDT | Rigid <=7,5 t | Conventional | 57877 | 66258 | 60201 | 60924 | 51943 | 55022 | 58982 | 37843 | 59777 | 59130 | 59799 | 56045 |
| HDT | Rigid <=7,5 t | HD Euro I | 0 | 66258 | 60201 | 60924 | 51943 | 57036 | 58982 | 58722 | 59777 | 59130 | 59799 | 56045 |
| HDT | Rigid <=7,5 t | HD Euro III | 0 | 66258 | 60201 | 60924 | 51943 | 57036 | 58982 | 72173 | 59777 | 59130 | 59799 | 56045 |
| HDT | Rigid <=7,5 t | HD Euro III | 0 | 0 | 0 | 0 | 51943 | 57036 | 58982 | 72173 | 59777 | 59130 | 59799 | 56045 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HDT | Rigid <=7,5 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 59777 | 59130 | 59799 | 56045 |
| HDT | Rigid <=7,5 t | HD Euro V | 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 |
| HDT | Rigid 7,5 - 12 t | Conventional | 58777 | 66258 | 75290 | 77123 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 7,5 - 12 t | HD Euro I | 0 | 66258 | 75290 | 77123 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 7,5 - 12 t | HD Euro III | 0 | 66258 | 75290 | 77123 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 7,5 - 12 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 7,5 - 12 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 7,5 - 12 t | HD Euro V | 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 |
| HDT | Rigid 12 - 14 t | Conventional | 57878 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 12 - 14 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 12 - 14 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 12 - 14 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 12 - 14 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 12 - 14 t | HD Euro V | 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 |
| HDT | Rigid 14 - 20 t | Conventional | 57877 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 14 - 20 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 14 - 20 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 14 - 20 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 14 - 20 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 14 - 20 t | HD Euro V | 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 |
| HDT | Rigid 20 - 26 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 20 - 26 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 20 - 26 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 20 - 26 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 20 - 26 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 20 - 26 t | HD Euro V | 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 |
| HDT | Rigid 26 - 28 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 26 - 28 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 26 - 28 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 26 - 28 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 26 - 28 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 26 - 28 t | HD Euro V | 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 |
| HDT | Rigid 28 - 32 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 28 - 32 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HDT | Rigid 28 - 32 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 28 - 32 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 28 - 32 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid 28 - 32 t | HD Euro V | 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 |
| HDT | Rigid >32 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid >32 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid >32 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid >32 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid >32 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Rigid >32 t | HD Euro V | 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 |
| HDT | Articulated 40 - 50 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 40 - 50 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 40 - 50 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 40 - 50 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 40 - 50 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 40 - 50 t | HD Euro V | 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 |
| HDT | Articulated 50 - 60 t | Conventional | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 50 - 60 t | HD Euro I | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72613 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 50 - 60 t | HD Euro III | 0 | 66258 | 72292 | 75085 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 50 - 60 t | HD Euro III | 0 | 0 | 0 | 0 | 69927 | 71987 | 72563 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 50 - 60 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72173 | 71736 | 71006 | 71801 | 67404 |
| HDT | Articulated 50 - 60 t | HD Euro V | 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 |
| Buses | Urban Buses 15 - 18 t | Conventional | 44439 | 56825 | 59236 | 60883 | 59930 | 65040 | 70536 | 71170 | 71234 | 70405 | 71198 | 66453 |
| Buses | Urban Buses 15 - 18 t | HD Euro I | 0 | 56825 | 59236 | 60883 | 59930 | 65040 | 70536 | 71170 | 71234 | 70405 | 71198 | 66453 |
| Buses | Urban Buses 15 - 18 t | HD Euro III | 0 | 56825 | 59236 | 60883 | 59930 | 65040 | 70536 | 71170 | 71234 | 70405 | 71198 | 66453 |
| Buses | Urban Buses 15 - 18 t | HD Euro III | 0 | 0 | 0 | 0 | 59930 | 65040 | 70536 | 71170 | 71234 | 70405 | 71198 | 66453 |
| Buses | Urban Buses 15 - 18 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71170 | 71234 | 70405 | 71198 | 66453 |
| Buses | Urban Buses 15 - 18 t | HD Euro V | 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 |
| Buses | Coaches <=18 t | Conventional | 42211 | 72878 | 77220 | 76104 | 59930 | 74000 | 74589 | 73679 | 73743 | 72860 | 73687 | 68755 |
| Buses | Coaches <=18 t | HD Euro I | 0 | 72878 | 77220 | 76104 | 59930 | 74000 | 74589 | 73679 | 73743 | 72860 | 73687 | 68755 |
| Buses | Coaches <=18 t | HD Euro III | 0 | 72878 | 77220 | 76104 | 59930 | 74000 | 74589 | 73679 | 73743 | 72860 | 73687 | 68755 |
| Buses | Coaches <=18 t | HD Euro III | 0 | 0 | 0 | 0 | 59930 | 74000 | 74589 | 73679 | 73743 | 72860 | 73687 | 68755 |
| Buses | Coaches <=18 t | HD Euro IV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 73679 | 73743 | 72860 | 73687 | 68755 |
| Buses | Coaches <=18 t | HD Euro V | 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 |

| Sector | Subsector | Technology | 1990 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mopeds | <50 cm³ | Conventional | 0 | 14987 | 14984 | 14993 | 14981 | 14981 | 12486 | 12490 | 12466 | 12436 | 12507 | 11886 |
| Mopeds | <50 cm³ | Mop - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12490 | 12466 | 12436 | 12507 | 11886 |
| Mopeds | <50 cm³ | Mop - Euro II | 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 |
| M.cycles | 2-stroke >50 cm³ | Conventional | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| M.cycles | 4-stroke <250 cm³ | Conventional | 12452 | 19982 | 20477 | 20490 | 20473 | 20473 | 20477 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke <250 cm³ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke <250 cm³ | Mot - Euro II | 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 |
| M.cycles | 4-stroke 250 - 750 cm³ | Conventional | 12452 | 19982 | 20477 | 20490 | 20473 | 20473 | 20477 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke 250 - 750 cm³ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke 250 - 750 cm³ | Mot - Euro II | 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 |
| M.cycles | 4-stroke >750 cm³ | Conventional | 0 | 19982 | 20477 | 20490 | 20473 | 20473 | 20477 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke >750 cm³ | Mot - Euro I | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20483 | 20445 | 19600 | 19712 | 18739 |
| M.cycles | 4-stroke >750 cm³ | Mot - Euro II | 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 |

# Annex E

# Industrial Processes

## Cement production (IPCC sector 2.A.1)

## Limestone and Dolomite Use (IPCC sector 2.A.3)

## Glass Production (IPCC sector 2.A.7)

## Bricks and Tiles (IPCC sector 2.A.7)

***Table E.1 Cement production 1990-2010***

***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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Clinker production (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Cement Plant 1 | 925 | 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 |
| Cement Plant 2 | 685 | 613 | 608 | 584 | 660 | 680 | 667 | 770 | 776 | 799 | 908 | 915 | 902 | 905 | 977 | 957 | 900 | 934 | 902 | 501 | 362 |
| 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 |
| Cement Plant 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 381 | 411 | 547 | 608 | 609 | 557 | 441 | 367 |
| **Total** | **1,610** | **1,424** | **1,371** | **1,328** | **1,565** | **1,601** | **1,792** | **2,087** | **1,930** | **2,125** | **3,109** | **3,386** | **3,413** | **3,967** | **4,283** | **4,400** | **4,400** | **4,441** | **3,893** | **2,438** | **2,053** |
| **Emission Factor t $CO_2$/t Clinker Produced** | | | | | | | | | | | | | | | | | | | | | |
| Cement Plant 1 | 0.546 | 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 |
| 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 |
| 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 |
| 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 |
| **IEF t $CO_2$/t Clinker** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.549** | **0.547** | **0.547** | **0.545** | **0.536** | **0.536** | **0.536** | **0.534** | **0.535** | **0.541** | **0.544** | **0.538** |
| **Emissions $CO_2$ (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Cement Plant 1 | 505 | 443 | 417 | 406 | 494 | 503 | 614 | 719 | 630 | 724 | 764 | 798 | 810 | 836 | 853 | 894 | 894 | 900 | 763 | 379 | 309 |
| Cement Plant 2 | 379 | 339 | 336 | 323 | 365 | 376 | 369 | 426 | 429 | 442 | 502 | 506 | 499 | 487 | 506 | 510 | 481 | 500 | 491 | 272 | 193 |
| Cement Plant 3 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 435 | 547 | 550 | 604 | 654 | 658 | 651 | 652 | 555 | 441 | 411 |
| Cement Plant 4 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 200 | 282 | 295 | 321 | 322 | 298 | 235 | 192 |
| **Total** | **884** | **782** | **753** | **729** | **859** | **879** | **983** | **1,145** | **1,059** | **1,166** | **1,701** | **1,851** | **1,860** | **2,127** | **2,295** | **2,357** | **2,348** | **2,374** | **2,107** | **1,327** | **1,105** |

### *Table E.2 Limestone and Dolomite Use 1990-2010*

### *Activity data and emission factors*

| IPCC Sector 2A3 Limestone and Dolomite | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Limestone use (tonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Power plant 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 9,929.00 | 4,673.00 | 5,132.60 | 7,749.00 | 8,323.00 | 5,281.00 | 4,755.00 | 4,810.10 | 2,197.04 | 2,318.30 |
| Power plant 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 89.64 | 960.00 | 1,353.21 | 80.08 |
| Brick Manufacturer | 343.16 | 308.85 | 291.68 | 240.22 | 291.68 | 411.80 | 377.47 | 549.06 | 523.32 | 574.79 | 406.00 | 389.50 | 303.40 | 316.50 | 293.00 | 289.00 | 552.00 | 442.00 | 394.40 | NO | NO |
| Tile manufacturer | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 34.72 | 31.01 | 31.30 | NO | NO |
| Sugar processing | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | 1,216.00 | 178.00 | NO | NO | NO | NO |
| **Total** | **343.16** | **308.85** | **291.68** | **240.22** | **291.68** | **411.80** | **377.47** | **549.06** | **523.32** | **574.79** | **406.00** | **10,318.50** | **4,976.40** | **5,449.10** | **8,042.00** | **9,828.00** | **6,045.72** | **5,317.65** | **6,195.80** | **3,550.25** | **2,398.38** |
| **Emission Factor t $CO_2$/t Limestone Use** | | | | | | | | | | | | | | | | | | | | | |
| Power plant 1 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 0.436 | 0.436 | 0.436 | 0.441 | 0.436 | 0.436 | 0.436 | 0.436 | 0.430 | 0.430 |
| 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 |
| 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 |
| 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 |
| 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 |
| **IEF t $CO_2$/t Limestone Use** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.440** | **0.436** | **0.436** | **0.436** | **0.441** | **0.437** | **0.437** | **0.436** | **0.437** | **0.434** | **0.430** |
| **Emissions $CO_2$ (tonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Power plant 1 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 4,331.00 | 2,038.00 | 2,239.00 | 3,420.00 | 3,630.00 | 2,303.31 | 2,073.89 | 2,097.92 | 944.50 | 996.63 |
| Power plant 2 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 39.44 | 422.40 | 595.41 | 35.24 |
| Brick Manufacturer | 150.99 | 135.89 | 128.34 | 105.69 | 128.34 | 181.19 | 166.09 | 241.58 | 230.26 | 252.91 | 178.64 | 171.38 | 133.50 | 139.26 | 128.92 | 127.00 | 243.00 | 194.48 | 173.54 | NO | NO |
| Tile manufacturer | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 15.34 | 13.29 | 13.62 | NO | NO |
| Sugar processing | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | 535.00 | 78.00 | NO | NO | NO | NO |
| **Total** | **150.99** | **135.89** | **128.34** | **105.69** | **128.34** | **181.19** | **166.09** | **241.58** | **230.26** | **252.91** | **178.64** | **4,502.38** | **2,171.50** | **2,378.26** | **3,548.92** | **4,292.00** | **2,639.65** | **2,321.11** | **2,707.48** | **1,539.92** | **1,031.87** |

*Table E.3 Glass production 1990-2010*

*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Carbonate use (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Glass plant 1 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.412 | 0.363 | 0.438 | 0.438 | 0.328 | NO | NO | NO | NO | NO |
| 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 |
| 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 |
| Glass w ool | 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 |
| **Total** | **63.878** | **63.852** | **63.260** | **63.812** | **63.994** | **63.707** | **63.423** | **63.794** | **63.360** | **63.781** | **63.742** | **62.758** | **31.964** | **1.612** | **1.727** | **1.428** | **1.409** | **1.299** | **0.882** | **0.063** | **NO** |
| **Emission Factor t $CO_2$/t Carbonate Use** | | | | | | | | | | | | | | | | | | | | | |
| Glass plant 1 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | NA | NA | NA | NA | NA |
| 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 |
| 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 |
| Glass w ool | 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 |
| **IEF t $CO_2$/t Carbonate Use** | **0.209** | **0.204** | **0.199** | **0.196** | **0.192** | **0.188** | **0.183** | **0.180** | **0.174** | **0.172** | **0.168** | **0.162** | **0.161** | **0.343** | **0.336** | **0.337** | **0.345** | **0.350** | **0.348** | **0.275** | **NA** |
| **Emissions $CO_2$ (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Glass plant 1 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.113 | 0.100 | 0.120 | 0.120 | 0.090 | NO | NO | NO | NO | NO |
| 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 |
| 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 |
| Glass w ool | 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 |
| **Total** | **13.325** | **13.056** | **12.587** | **12.520** | **12.307** | **11.966** | **11.625** | **11.465** | **11.049** | **10.957** | **10.714** | **10.136** | **5.131** | **0.553** | **0.580** | **0.481** | **0.487** | **0.455** | **0.307** | **0.017** | **NO** |

*Table E.4 Bricks and tiles 1990-2010*

*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Raw material use (clays, shale, bricks and flues) (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Fireclay plant 1 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 30.750 | 32.638 | 35.591 | 37.169 | 41.206 | 34.319 | 33.807 | 16.524 | 2.733 | 0.168 |
| Brick Manufacturer 1 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 40.000 | 43.144 | 44.542 | 45.898 | 46.124 | 47.581 | 46.060 | 47.712 | 45.065 | 26.223 | 13.617 | 15.657 |
| Brick Manufacturer 2 | 39.641 | 35.677 | 33.694 | 27.749 | 33.694 | 47.569 | 43.605 | 63.425 | 60.452 | 66.398 | 65.897 | 63.158 | 49.232 | 51.352 | 48.461 | 52.222 | 48.298 | 38.389 | 20.875 | NO | NO |
| Tile manufacturer | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 18.826 | 21.218 | 19.711 | 19.162 | NO | NO |
| **Total** | **110.391** | **106.427** | **104.444** | **98.499** | **104.444** | **118.319** | **114.355** | **134.175** | **131.202** | **137.148** | **139.791** | **138.450** | **127.768** | **133.067** | **133.211** | **158.314** | **151.548** | **136.972** | **82.784** | **16.350** | **15.826** |
| **Emission Factor t $CO_2$/t Raw Material Use** | | | | | | | | | | | | | | | | | | | | | |
| Fireclay plant 1 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.036 | 0.046 | 0.045 | 0.048 | 0.046 | 0.048 | 0.048 | 0.048 | 0.055 | 0.056 |
| 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 |
| 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 |
| 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 |
| **IEF t $CO_2$/t Raw Material Use** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.046** | **0.044** | **0.046** | **0.046** | **0.047** | **0.047** | **0.049** | **0.050** | **0.048** | **0.033** | **0.027** |
| **Emissions $CO_2$ (kilotonnes)** | | | | | | | | | | | | | | | | | | | | | |
| Fireclay plant 1 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.394 | 1.104 | 1.506 | 1.598 | 1.790 | 1.883 | 1.655 | 1.630 | 0.801 | 0.151 | 0.009 |
| Brick Manufacturer 1 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.760 | 1.898 | 1.960 | 2.019 | 2.029 | 2.093 | 2.026 | 2.099 | 1.983 | 0.892 | 0.380 | 0.411 |
| Brick Manufacturer 2 | 1.921 | 1.729 | 1.633 | 1.345 | 1.633 | 2.306 | 2.114 | 3.074 | 2.930 | 3.218 | 3.194 | 3.061 | 2.386 | 2.489 | 2.349 | 2.529 | 2.342 | 1.860 | 1.013 | NO | NO |
| Tile manufacturer | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 0.969 | 1.304 | 1.359 | 1.291 | NO | NO |
| **Total** | **5.075** | **4.883** | **4.787** | **4.498** | **4.787** | **5.459** | **5.267** | **6.228** | **6.084** | **6.372** | **6.486** | **6.125** | **5.912** | **6.116** | **6.232** | **7.407** | **7.400** | **6.831** | **3.997** | **0.531** | **0.420** |

# Annex F

## Agriculture

## Animal Populations

## Methane Emission Factors for Enteric Fermentation and Manure Management

## Input Parameters used for the Calculation of Nitrous Oxide Emissions from Agricultural Soils

## Allocation of animal wastes to AWMS

## Nitrogen Excretion values used in Submission 2012

## *Table F.1 Animal Populations 1990-2010*

| 1000 head | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Cattle** | 6,821.80 | 6,921.45 | 6,973.40 | 6,959.30 | 6,965.20 | 7,008.75 | 7,282.30 | 7,490.95 | 7,592.10 | 7,347.55 | 7,011.95 | 7,022.30 | 6,960.80 | 6,971.30 | 6,972.70 | 6,951.21 | 6,925.32 | 6,826.98 | 6,827.54 | 6,813.03 | 6,508.15 |
| **Dairy Cows** | 1,340.95 | 1,309.40 | 1,262.05 | 1,255.90 | 1,246.80 | 1,238.50 | 1,241.00 | 1,226.55 | 1,216.30 | 1,187.20 | 1,165.15 | 1,165.25 | 1,146.40 | 1,145.65 | 1,138.95 | 1,025.47 | 1,053.75 | 1,053.56 | 1,059.64 | 1,059.53 | 1,059.74 |
| **All Other Cattle** | 5,480.85 | 5,612.05 | 5,711.35 | 5,703.40 | 5,718.40 | 5,770.25 | 6,041.30 | 6,264.40 | 6,375.80 | 6,160.35 | 5,846.80 | 5,857.05 | 5,814.40 | 5,825.65 | 5,833.75 | 5,925.74 | 5,871.58 | 5,773.42 | 5,767.90 | 5,753.50 | 5,448.41 |
| Other Cows | 730.35 | 800.65 | 902.90 | 958.15 | 989.85 | 1,021.85 | 1,098.05 | 1,182.85 | 1,222.05 | 1,192.05 | 1,171.10 | 1,178.25 | 1,152.50 | 1,165.75 | 1,178.95 | 1,121.21 | 1,170.78 | 1,185.03 | 1,197.55 | 1,169.33 | 1,103.72 |
| Dairy Heifers | 171.95 | 155.90 | 186.60 | 190.80 | 206.65 | 229.75 | 237.60 | 243.95 | 226.30 | 212.00 | 204.70 | 202.25 | 223.25 | 220.70 | 233.80 | 214.09 | 204.08 | 196.53 | 194.74 | 196.09 | 214.89 |
| Other Heifers | 79.95 | 70.90 | 105.90 | 116.45 | 104.35 | 123.20 | 133.90 | 148.75 | 127.75 | 120.85 | 132.75 | 140.15 | 142.40 | 138.95 | 141.60 | 190.64 | 192.91 | 211.86 | 180.02 | 155.73 | 154.09 |
| Cattle < 1 yrs | 1,716.10 | 1,764.60 | 1,694.50 | 1,737.50 | 1,736.20 | 1,746.00 | 1,852.10 | 1,938.20 | 1,965.10 | 1,820.60 | 1,751.90 | 1,824.40 | 1,799.30 | 1,761.20 | 1,771.40 | 1,962.37 | 1,952.82 | 1,941.12 | 1,959.25 | 1,889.05 | 1,761.25 |
| Cattle < 1 yrs - male | 903.20 | 918.70 | 888.90 | 913.80 | 903.80 | 915.30 | 974.30 | 1,023.00 | 1,054.80 | 965.10 | 919.40 | 955.20 | 953.10 | 922.10 | 929.80 | 957.54 | 951.11 | 947.09 | 969.35 | 918.23 | 826.66 |
| Cattle < 1 yrs - female | 812.90 | 845.90 | 805.60 | 823.70 | 832.40 | 830.70 | 877.80 | 915.20 | 910.30 | 855.50 | 832.50 | 869.20 | 846.20 | 839.10 | 841.60 | 1,004.84 | 1,001.72 | 994.03 | 989.90 | 970.83 | 934.59 |
| Cattle 1 - 2 yrs | 1,663.10 | 1,692.00 | 1,637.70 | 1,587.00 | 1,585.70 | 1,586.10 | 1,639.40 | 1,717.00 | 1,782.60 | 1,706.10 | 1,517.10 | 1,515.00 | 1,593.20 | 1,577.20 | 1,534.80 | 1,642.50 | 1,505.75 | 1,466.33 | 1,495.93 | 1,541.54 | 1,407.45 |
| Cattle 1 - 2 yrs - male | 985.80 | 981.10 | 981.60 | 957.50 | 952.00 | 964.40 | 996.20 | 1,054.70 | 1,085.60 | 1,039.00 | 912.40 | 913.30 | 991.80 | 983.30 | 949.80 | 972.12 | 845.19 | 817.95 | 832.19 | 851.39 | 760.26 |
| Cattle 1 - 2 yrs - female | 677.30 | 710.90 | 656.10 | 629.50 | 633.70 | 621.70 | 643.20 | 662.30 | 697.00 | 667.10 | 604.70 | 601.70 | 601.40 | 593.90 | 585.00 | 670.38 | 660.56 | 648.38 | 663.74 | 690.15 | 647.19 |
| Cattle > 2 yrs | 1,092.60 | 1,098.80 | 1,151.80 | 1,077.90 | 1,057.80 | 1,022.90 | 1,036.20 | 985.80 | 1,002.10 | 1,057.70 | 1,016.30 | 941.10 | 844.70 | 901.50 | 910.60 | 733.79 | 781.79 | 715.26 | 686.59 | 749.72 | 759.76 |
| Cattle > 2 yrs - male | 826.40 | 797.50 | 829.60 | 773.20 | 739.80 | 711.60 | 732.20 | 690.20 | 708.10 | 736.70 | 721.60 | 642.10 | 560.40 | 598.70 | 605.40 | 536.83 | 565.14 | 509.70 | 475.82 | 501.16 | 506.17 |
| Cattle > 2 yrs - female | 266.20 | 301.30 | 322.20 | 304.70 | 318.00 | 311.30 | 304.00 | 295.60 | 294.00 | 321.00 | 294.70 | 299.00 | 284.30 | 302.80 | 305.20 | 196.96 | 216.65 | 205.56 | 210.78 | 248.56 | 253.60 |
| Bulls | 26.80 | 29.20 | 31.95 | 35.60 | 37.85 | 40.45 | 44.05 | 47.85 | 49.90 | 51.05 | 52.95 | 55.90 | 59.05 | 60.35 | 62.60 | 61.15 | 63.44 | 57.30 | 53.82 | 52.03 | 47.26 |
| **Total Sheep** | 8,020.98 | 8,483.60 | 8,735.75 | 8,977.17 | 8,559.06 | 8,363.78 | 8,329.04 | 8,050.87 | 8,572.21 | 8,547.20 | 7,957.34 | 7,454.74 | 6,682.41 | 6,480.70 | 6,703.38 | 6,431.32 | 6,187.15 | 5,655.52 | 5,105.41 | 4,726.98 | 4,314.84 |
| Ewes Lowland | 2,396.60 | 2,542.51 | 2,621.99 | 2,576.42 | 2,511.11 | 2,426.96 | 2,369.07 | 2,389.75 | 3,056.41 | 2,936.15 | 2,814.25 | 2,704.28 | 2,637.25 | 2,552.34 | 2,463.83 | 2,626.72 | 2,414.32 | 2,206.80 | 2,056.56 | 1,928.16 | 1,903.96 |
| Ewes Upland | 1,960.85 | 2,080.24 | 2,145.26 | 2,107.98 | 2,054.54 | 1,985.69 | 1,938.33 | 1,955.25 | 1,309.89 | 1,258.35 | 1,206.11 | 1,158.98 | 1,130.25 | 1,093.86 | 1,055.93 | 656.68 | 603.58 | 551.70 | 514.14 | 482.04 | 475.99 |
| Rams lowland | 64.27 | 67.40 | 69.55 | 68.78 | 67.13 | 66.00 | 62.23 | 63.53 | 80.99 | 79.28 | 77.46 | 74.59 | 73.26 | 71.65 | 70.00 | 77.00 | 74.16 | 68.60 | 62.96 | 57.80 | 58.40 |
| Rams upland | 52.58 | 55.15 | 56.90 | 56.27 | 54.92 | 54.00 | 50.92 | 51.98 | 34.71 | 33.98 | 33.20 | 31.97 | 31.40 | 30.71 | 30.00 | 19.25 | 18.54 | 17.15 | 15.74 | 14.45 | 14.60 |
| Other Sheep>1 - lowland | 164.11 | 96.14 | 88.74 | 98.57 | 107.17 | 112.93 | 105.70 | 118.46 | 171.64 | 152.84 | 143.32 | 127.54 | 129.12 | 144.02 | 139.61 | 124.10 | 122.21 | 109.44 | 112.28 | 102.68 | 102.68 |
| **Total Pigs** | 134.27 | 78.66 | 72.61 | 80.65 | 87.69 | 92.40 | 86.48 | 96.92 | 73.56 | 65.50 | 61.42 | 54.66 | 55.34 | 61.72 | 59.83 | 31.03 | 30.55 | 27.36 | 28.07 | 25.67 | 25.67 |
| Lambs - lowland | 1,786.57 | 1,959.93 | 2,024.39 | 2,193.68 | 2,022.08 | 1,994.19 | 2,043.97 | 1,856.25 | 2,691.50 | 2,814.77 | 2,535.12 | 2,311.92 | 1,838.06 | 1,768.49 | 2,018.93 | 2,317.23 | 2,339.03 | 2,139.58 | 1,852.53 | 1,692.94 | 1,386.84 |
| Lambs - upland | 1,461.74 | 1,603.58 | 1,656.32 | 1,794.83 | 1,654.43 | 1,631.61 | 1,672.34 | 1,518.75 | 1,153.50 | 1,206.33 | 1,086.48 | 990.82 | 787.74 | 757.92 | 865.26 | 579.31 | 584.76 | 534.89 | 463.13 | 423.24 | 346.71 |
| Pigs | 1,221.60 | 1,324.60 | 1,404.25 | 1,504.45 | 1,514.35 | 1,546.30 | 1,642.80 | 1,708.30 | 1,809.75 | 1,774.95 | 1,726.80 | 1,760.40 | 1,790.80 | 1,728.65 | 1,703.75 | 1,679.20 | 1,631.60 | 1,544.10 | 1,486.45 | 1,443.65 | 1,509.35 |
| Gilts in Pig | 21.10 | 21.85 | 25.45 | 23.20 | 21.65 | 23.70 | 24.50 | 26.85 | 25.60 | 24.85 | 21.25 | 22.65 | 20.05 | 20.00 | 21.55 | 19.75 | 21.65 | 21.45 | 21.20 | 20.35 | 19.30 |
| Gilts not yet Served | 12.10 | 13.90 | 14.55 | 14.35 | 14.70 | 17.55 | 16.85 | 17.70 | 18.70 | 16.20 | 17.85 | 18.95 | 19.55 | 17.80 | 19.00 | 19.55 | 18.65 | 16.10 | 15.80 | 17.30 | 14.70 |
| Sows in Pig | 83.45 | 90.25 | 96.15 | 100.75 | 99.40 | 100.30 | 103.20 | 107.95 | 109.10 | 108.60 | 109.65 | 107.30 | 110.00 | 103.95 | 102.25 | 99.80 | 96.40 | 95.55 | 91.15 | 88.60 | 91.90 |
| Other Sows for Breeding | 30.50 | 31.20 | 33.10 | 32.75 | 30.00 | 30.90 | 35.80 | 37.05 | 38.00 | 37.70 | 32.00 | 36.50 | 32.85 | 32.30 | 30.40 | 33.60 | 30.50 | 28.00 | 25.10 | 26.55 | 28.80 |
| **Total Poultry** | 6.25 | 6.65 | 6.55 | 6.35 | 5.65 | 5.30 | 5.10 | 5.10 | 4.75 | 4.20 | 4.00 | 3.55 | 3.30 | 3.00 | 2.75 | 2.45 | 1.95 | 1.70 | 1.50 | 1.60 | 1.55 |
| Pigs 20 Kg + | 749.20 | 802.65 | 836.50 | 904.95 | 917.65 | 951.90 | 1,015.80 | 1,063.90 | 1,144.35 | 1,094.15 | 1,037.90 | 1,036.20 | 1,061.95 | 1,043.20 | 1,027.80 | 1,010.30 | 1,033.95 | 938.50 | 932.00 | 910.95 | 953.40 |
| Pigs Under 20 Kg | 319.00 | 358.10 | 391.95 | 422.10 | 425.30 | 416.65 | 441.55 | 449.75 | 469.25 | 489.25 | 504.15 | 535.25 | 543.10 | 508.40 | 500.00 | 493.75 | 428.50 | 442.80 | 399.70 | 378.30 | 399.70 |
| Poultry | 11,412.83 | 12,338.21 | 12,913.07 | 12,712.41 | 13,674.55 | 14,078.45 | 15,015.62 | 15,189.04 | 15,326.96 | 15,130.48 | 15,320.50 | 15,663.15 | 15,182.57 | 15,787.87 | 16,742.78 | 16,042.15 | 15,426.25 | 14,946.44 | 15,699.31 | 16,198.17 | 16,248.17 |
| Layer | 1,868.25 | 1,800.00 | 2,231.00 | 1,831.50 | 1,730.00 | 1,370.50 | 1,701.00 | 1,580.00 | 1,558.50 | 1,537.00 | 1,572.00 | 1,676.00 | 1,613.00 | 1,906.60 | 1,906.27 | 1,950.00 | 1,970.00 | 1,900.00 | 1,980.00 | 1,995.00 | 1,995.00 |
| Broiler | 8,035.13 | 8,904.90 | 9,066.82 | 9,522.47 | 10,392.54 | 11,092.18 | 11,729.88 | 12,096.34 | 12,286.79 | 12,200.11 | 12,426.10 | 12,628.89 | 12,321.96 | 12,672.21 | 13,375.11 | 12,817.66 | 12,359.60 | 12,149.49 | 13,067.24 | 13,790.00 | 13,840.00 |
| Turkey | 1,509.45 | 1,633.30 | 1,615.26 | 1,358.44 | 1,552.01 | 1,615.77 | 1,584.74 | 1,512.70 | 1,481.67 | 1,393.37 | 1,322.41 | 1,358.26 | 1,247.60 | 1,209.06 | 1,461.40 | 1,274.49 | 1,096.65 | 896.95 | 652.06 | 413.17 | 413.17 |
| **Horses** | 61.60 | 63.10 | 65.10 | 66.20 | 67.00 | 68.00 | 69.90 | 71.90 | 72.80 | 75.50 | 69.90 | 71.00 | 72.60 | 70.40 | 72.80 | 79.90 | 86.60 | 89.20 | 98.70 | 98.10 | 98.10 |
| **Mules** | 8.30 | 7.30 | 8.00 | 8.50 | 7.80 | 7.00 | 7.60 | 7.10 | 7.50 | 7.30 | 5.00 | 4.90 | 4.70 | 5.80 | 5.70 | 6.00 | 7.00 | 7.20 | 8.80 | 8.80 | 8.80 |
| **Goats** | 17.40 | 17.40 | 17.80 | 17.60 | 16.10 | 15.60 | 14.90 | 15.20 | 15.10 | 13.50 | 8.10 | 7.80 | 7.70 | 7.60 | 7.50 | 7.30 | 6.70 | 7.30 | 8.90 | 10.10 | 10.10 |
| **Fertiliser (1000's kg/N)** | 379,311.00 | 370,121.00 | 358,302.00 | 377,985.00 | 404,811.00 | 428,826.00 | 416,918.00 | 380,350.00 | 431,999.00 | 442,916.00 | 407,598.00 | 368,667.00 | 363,513.00 | 388,080.00 | 362,525.00 | 352,165.00 | 342,137.00 | 321,553.00 | 308,960.00 | 306,806.00 | 362,395.00 |

*Table F.2 $CH_4$ Emission Factors for Enteric Fermentation (kg/head/year)*

| Animal Category | Animal Liveweight (kg) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle** | | | | | | | | | | | | | | | | | | | | | | |
| 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 | 112.09 |
| 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 | 73.34 |
| 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 |
| 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 |
| 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 |
| 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 | 29.68 |
| 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 | 59.06 |
| > 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 | 39.48 |
| 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 | 27.70 | 27.63 | 27.01 |
| 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 |
| > 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 |
| **Sheep** | | | | | | | | | | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| **Horses** | | 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 |
| **Mules** | | 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 |
| **Goats** | | 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 |
| **Pigs** | **59.26** | | | | | | | | | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| **Poultry** | **2.18** | 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 F.3 $CH_4$ Emission Factors for Manure Management (kg/head/year)*

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle** | | | | | | | | | | | | | | | | | | | | | |
| 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 | 20.75 |
| 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 | 13.96 |
| 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 |
| 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 |
| 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 |
| 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 | 8.27 |
| 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 | 14.07 |
| > 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 |
| 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 | 7.91 | 7.90 | 7.87 |
| 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 |
| > 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 |
| **Sheep** | | | | | | | | | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| **Horses** | 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 |
| **Mules** | 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 |
| **Goats** | 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 |
| **Pigs** | | | | | | | | | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| **Poultry** | | | | | | | | | | | | | | | | | | | | | |
| 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 |
| 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 |
| 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 |

* Note: This value is low because this category of animal only live part of their third year.

*Table F.4.1 Allocation of Animal Wastes to Animal Waste Management Systems – Cattle*

| Cattle | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Number of days housed** | | | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 118 | 117 | 117 | 117 | 117 |
| Suckler Cows | 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 |
| Other Heifer | 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 | 222 | 223 | 225 |
| Oneto2yrs | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 154 | 156 | 156 | 155 | 156 | 157 | 158 |
| Over2yrs | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 25 | 29 | 28 | 31 | 23 | 26 | 26 |
| Bulls | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 156 | 154 | 156 | 156 | 155 | 156 | 157 | 158 |
| **Number of days grazing** | | | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 248 | 248 | 248 | 248 |
| Suckler Cows | 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 |
| Other Heifer | 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 | 143 | 142 | 140 |
| Oneto2yrs | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 211 | 209 | 209 | 210 | 209 | 208 | 207 |
| Over2yrs | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 342 | 340 | 336 | 337 | 334 | 342 | 339 | 339 |
| Bulls | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 211 | 209 | 209 | 210 | 209 | 208 | 207 |
| **Proportion to each AWMS** | | | | | | | | | | | | | | | | | | | | | |
| **Liquid** | | | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 0.32 | 0.32 | 0.32 | 0.32 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.30 | 0.30 | 0.30 | 0.30 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| 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 |
| 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 |
| 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 |
| 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 | 0.41 | 0.42 | 0.42 |
| Oneto2yrs | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| 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 | 0.04 | 0.04 | 0.04 |
| 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 |
| **Solid** | | | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 | 0.03 | 0.03 |
| Bulls | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| **Pasture** | | | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 0.66 | 0.66 | 0.66 | 0.66 | 0.67 | 0.67 | 0.67 | 0.67 | 0.68 | 0.68 | 0.68 | 0.68 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 |
| 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 |
| 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 |
| 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 |
| 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 | 0.38 |
| Oneto2yrs | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.58 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 | 0.57 |
| 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 | 0.94 | 0.93 | 0.93 |
| 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 |

*Table F.4.2 Allocation of Animal Wastes to Animal Waste Management Systems – Other Livestock*

| Animal Catgeory | Days housed | % housed | % outwintered | Housing Type | | Proportion to each AWMS | | |
|---|---|---|---|---|---|---|---|---|
| | | | | % Slurry based | % Straw based | Liquid | Solid | Pasture |
| **Sheep** | | | | | | | | |
| Lowland Ewes | 61.00 | 47.07 | 52.93 | 0.00 | 100.00 | 0.00 | 0.08 | 0.92 |
| Upland Ewes | 85.00 | 44.34 | 55.66 | 0.00 | 100.00 | NA | 0.10 | 0.90 |
| Rams | 85.00 | 22.34 | 77.66 | 0.00 | 100.00 | NA | 0.05 | 0.95 |
| Lambs | 58.00 | 16.88 | 83.12 | 0.00 | 100.00 | NA | 0.03 | 0.97 |
| Other sheep | 61.00 | 47.07 | 52.93 | 0.00 | 100.00 | NA | 0.08 | 0.92 |
| **Pigs** | | | | | | | | |
| Gilts in pig | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Gilts not yet served | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Sows in pig | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Other sows for breeding | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Boars | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Pigs < 20 kg | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| Pigs > 20 kg | 365.00 | 100.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 | 0.00 |
| **Poultry** | | | | | | | | |
| Layers | 365.00 | 88.00 | 12.00 | 84.20 | 15.80 | 0.74 | 0.14 | 0.12 |
| Broilers | 365.00 | 100.00 | 0.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 |
| Turkeys | 365.00 | 100.00 | 0.00 | 0.00 | 100.00 | 0.00 | 1.00 | 0.00 |
| **Horses** | 143.00 | 100.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.39 | 0.61 |
| **Mules and Asses** | 143.00 | 100.00 | 0.00 | 0.00 | 100.00 | 0.00 | 0.39 | 0.61 |
| **Goats** | 0.00 | 0.00 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |

*Table F.5.1 Revised Nitrogen excretion values for Livestock in Submission 2012*

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **N excretion (kg/head/year)** | **Revised 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 | 101.89 |
| 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 F.5.2 Nitrogen excretion values for Livestock in previous Submissions*

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N excretion values used in previous submissions | | | | | | | | | | | | | | | | | | | |
| Dairy Cows | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 | 85.00 |
| Suckler Cows | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 |
| Dairy Heifer | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 |
| Other Heifer | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 |
| Under1yr | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 | 24.00 |
| One to 2yrs | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 |
| Over 2yrs | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 |
| Bulls | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 | 65.00 |
| Ewes Lowland | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| Ewes Upland | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| 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 |
| 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 |
| Other Sheep>1 - lowland | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 |
| Other Sheep>1 - upland | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 | 5.30 |
| Lambs - lowland | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Lambs - upland | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| Laying hen per bird place | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 | 0.56 |
| Broiler per bird place | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| Turkey per bird place | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 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 |
| 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 |
| Goats | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |

*Table F.6 Input Parameters for the calculation of $N_2O$ Emissions from Agricultural Soils*

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Frac_{GASF}$ | 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 |
| $Frac_{GRAZ}$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $Frac_{GASM1}$ | 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 | 0.359 |
| $Frac_{GASM2}$ | 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 |
| $Frac_{GASM}$ | 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 |
| $F_{BN}$ | 0.010 | 0.009 | 0.009 | 0.017 | 0.017 | 0.013 | 0.014 | 0.013 | 0.022 | 0.012 | 0.005 | 0.006 | 0.005 | 0.009 | 0.010 | 0.013 | 0.013 | 0.009 | 0.007 | 0.015 | 0.017 |
| $Frac_{LEACH}$ | 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 |
| $F_{SN}$ (tonnes/year) | 368,663 | 359,336 | 346,225 | 367,122 | 393,812 | 418,564 | 406,692 | 370,788 | 421,025 | 431,229 | 397,104 | 359,131 | 354,236 | 378,766 | 354,310 | 344,517 | 334,296 | 314,906 | 301,205 | 297,394 | 351,805 |
| $F_{AM}$ (tonnes/year) | 107,842 | 109,769 | 110,508 | 111,048 | 111,621 | 112,893 | 117,309 | 121,605 | 123,434 | 118,830 | 113,612 | 114,759 | 115,201 | 114,627 | 114,907 | 116,025 | 114,686 | 113,396 | 113,556 | 112,757 | 109,238 |
| $F_S$ (tonnes/year) | 105.527 | 106.126 | 106.993 | 107.583 | 107.938 | 97.136 | 92.189 | 255.082 | 364.974 | 568.682 | 741.352 | 932.714 | 1,103.564 | 1,228.756 | 1,687.586 | 1,839.495 | 1,913.307 | 1,952.212 | 1,990.756 | 2,028.262 | 2,065.185 |
| $F_{CR}$ (tonnes/year) | 19,692 | 19,001 | 19,335 | 16,199 | 17,934 | 19,439 | 20,849 | 19,969 | 19,917 | 21,127 | 21,683 | 19,743 | 17,757 | 19,963 | 23,569 | 17,959 | 10,551 | 10,244 | 11,362 | 10,478 | 10,792 |

*Table F.7 Nitrogen application to agricultural soils from sewage sludge 1990-2010*

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N applied (kg/year) | 105,527 | 106,126 | 106,993 | 107,583 | 107,938 | 97,136 | 92,189 | 255,082 | 364,974 | 568,682 | 741,352 | 932,714 | 1,103,564 | 1,228,756 | 1,687,586 | 1,839,495 | 1,913,307 | 1,952,212 | 1,990,756 | 2,028,262 | 2,065,185 |

# Annex G

## Activity Data and Carbon Stock Change Estimates for LULUCF Category 5.A Forest Land

***Table G.1 Activity Data and Carbon Stock Change Estimates for LULUCF Category 5.A Forest Land***

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Affor | Refor | Felling | Unclass | Forest cover (excl unclass) | Defor (since 1990) | Total Forest | Harvest volume | Harvest carbon | C stock young forest | C stock mature forest | Total biomass C stock | Biomass CSC | 5 A.1 CSC | 5 A.2 CSC | 5 A.2.1 CSC | 5 A.2.2 CSC | 5 A.2.3 CSC | 5 A.2.4 CSC | 5 A.2.5 CSC |
| | kha | kha | kha | kha | kha | kha | kha | $1000m^3$ | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C | Gg C |
| **1990** | 15.817 | 3.882 | 4.203 | 110.915 | 370.180 | 0.021 | 481.074 | 1676.00 | 508.83 | 1939.42 | 13946.97 | 15886.39 | 216.99 | 272.38 | -55.39 | -5.54 | -16.62 | -31.57 | 0.00 | -1.66 |
| **1991** | 19.147 | 4.203 | 4.063 | 126.493 | 373.749 | 0.021 | 500.201 | 1769.00 | 537.07 | 1939.42 | 14258.27 | 16113.56 | 227.17 | 311.30 | -84.13 | -8.41 | -25.24 | -47.96 | 0.00 | -2.52 |
| **1992** | 16.699 | 4.063 | 4.621 | 140.688 | 376.253 | 0.021 | 516.879 | 2083.07 | 632.42 | 1855.29 | 14495.16 | 16298.91 | 185.35 | 236.88 | -51.54 | -5.15 | -15.46 | -29.38 | 0.00 | -1.55 |
| **1993** | 15.998 | 4.621 | 4.816 | 151.985 | 380.954 | 0.021 | 532.857 | 2100.14 | 637.60 | 1803.75 | 14729.43 | 16507.76 | 208.85 | 234.27 | -25.42 | -2.54 | -7.63 | -14.49 | 0.00 | -0.76 |
| **1994** | 19.459 | 4.816 | 5.447 | 165.792 | 386.606 | 0.021 | 552.295 | 2286.91 | 694.30 | 1778.33 | 14886.93 | 16707.20 | 199.45 | 157.50 | 41.94 | 4.19 | 12.58 | 23.91 | 0.00 | 1.26 |
| **1995** | 23.710 | 5.447 | 6.203 | 180.777 | 395.331 | 0.333 | 575.672 | 2382.36 | 723.28 | 1820.28 | 15003.51 | 16926.21 | 219.00 | 116.59 | 102.42 | 10.24 | 30.73 | 58.38 | 0.00 | 3.07 |
| **1996** | 20.981 | 6.711 | 7.090 | 190.089 | 407.000 | 0.333 | 596.319 | 2464.93 | 748.35 | 1922.69 | 15097.58 | 17145.00 | 218.79 | 94.06 | 124.73 | 12.47 | 37.42 | 71.10 | 0.00 | 3.74 |
| **1997** | 11.434 | 7.655 | 7.185 | 189.009 | 419.514 | 0.333 | 607.420 | 2322.49 | 705.10 | 2047.42 | 15161.90 | 17395.75 | 250.75 | 64.32 | 186.43 | 18.64 | 55.93 | 106.26 | 0.00 | 5.59 |
| **1998** | 12.928 | 7.494 | 7.924 | 186.511 | 434.940 | 0.333 | 620.015 | 2638.02 | 800.90 | 2233.85 | 15298.06 | 17677.58 | 281.83 | 136.15 | 145.68 | 14.57 | 43.70 | 83.03 | 0.00 | 4.37 |
| **1999** | 12.668 | 8.137 | 7.747 | 186.164 | 447.955 | 0.333 | 632.350 | 2777.07 | 843.11 | 2379.53 | 15452.66 | 17972.83 | 295.25 | 154.60 | 140.65 | 14.06 | 42.19 | 80.17 | 0.00 | 4.22 |
| **2000** | 15.695 | 9.421 | 8.677 | 189.917 | 459.897 | 0.857 | 647.187 | 3008.45 | 913.36 | 2520.17 | 15488.37 | 18237.86 | 265.03 | 35.71 | 229.32 | 22.93 | 68.80 | 130.71 | 0.00 | 6.88 |
| **2001** | 15.465 | 9.139 | 9.132 | 190.239 | 475.040 | 0.857 | 661.795 | 2836.00 | 861.00 | 2749.49 | 15499.29 | 18548.39 | 310.53 | 10.92 | 299.61 | 29.96 | 89.88 | 170.78 | 0.00 | 8.99 |
| **2002** | 15.054 | 9.771 | 10.286 | 186.422 | 493.911 | 0.857 | 675.992 | 2910.71 | 883.69 | 3049.11 | 15587.43 | 18886.56 | 338.17 | 88.14 | 250.03 | 25.00 | 75.01 | 142.52 | 0.00 | 7.50 |
| **2003** | 9.097 | 10.516 | 9.289 | 177.116 | 512.314 | 0.857 | 684.232 | 3000.00 | 910.79 | 3299.13 | 15917.72 | 19310.33 | 423.77 | 330.29 | 93.48 | 9.35 | 28.04 | 53.28 | 0.00 | 2.80 |
| **2004** | 9.739 | 10.699 | 9.828 | 177.594 | 521.575 | 0.857 | 693.114 | 2846.49 | 864.19 | 3392.62 | 16110.80 | 19628.94 | 318.60 | 193.08 | 125.52 | 12.55 | 37.66 | 71.55 | 0.00 | 3.77 |
| **2005** | 10.096 | 8.382 | 9.781 | 177.049 | 532.216 | 0.857 | 702.353 | 2942.00 | 893.19 | 3518.14 | 16334.70 | 19981.18 | 352.24 | 223.90 | 128.34 | 12.83 | 38.50 | 73.15 | 0.00 | 3.85 |
| **2006** | 8.037 | 7.144 | 9.811 | 174.092 | 543.210 | 0.374 | 710.015 | 2967.78 | 901.01 | 3646.48 | 16555.60 | 20352.91 | 371.73 | 220.90 | 150.83 | 15.08 | 45.25 | 85.97 | 0.00 | 4.52 |
| **2007** | 7.175 | 7.194 | 8.832 | 164.983 | 559.494 | 0.339 | 716.852 | 2980.82 | 904.97 | 3797.31 | 16935.25 | 20855.54 | 502.64 | 379.65 | 122.98 | 12.30 | 36.89 | 70.10 | 0.00 | 3.69 |
| **2008** | 6.249 | 6.206 | 6.279 | 152.907 | 577.819 | 0.295 | 722.806 | 2226.00 | 675.81 | 3920.29 | 17553.47 | 21531.61 | 676.06 | 618.22 | 57.84 | 5.78 | 17.35 | 32.97 | 0.00 | 1.74 |
| **2009** | 6.648 | 4.902 | 8.431 | 143.161 | 594.213 | 0.198 | 729.256 | 2582.98 | 784.19 | 3978.13 | 18231.54 | 22105.48 | 573.87 | 678.07 | -104.20 | -10.42 | -31.26 | -59.39 | 0.00 | -3.13 |
| **2010** | 8.314 | 8.705 | 7.711 | 139.573 | 606.115 | 0.124 | 737.446 | 2879.80 | 874.30 | 3873.94 | 18909.56 | 22678.45 | 572.97 | 678.02 | -105.04 | -10.50 | -31.51 | -59.88 | 0.00 | -3.15 |

**N** Biomass Carbon stock change (572.97 Gg C in 2010) after harvest (corresponding to difference between carbon stocks of 22,678.45 Gg in 2010 and 22,105.48 Gg in 2009)

**P** Carbon stock change for young forests, column K (corresponding in 2010 to difference between carbon stocks of 3,873.94 Gg in 2010 and 3,978.13 Gg in 2009)

**Q, R, S, T, U** The total carbon stock change for 5.A.2 (column P) is split as Cropland (Q) – 10.50; Grassland (R) – 31.51; Wetland (S) – 59.88; Settlements (T) – 0.00; Other Land (U) – 3.15

# CARBWARE MODEL

## DETERMINATION OF TIME-SERIES FOREST AREAS USING 1995 BASE YEAR DATA

The assumptions use to assign areas to the three different categories were:

1. Afforested and reforested areas 7 years and over, defined as cleared/unclassified in FIPS move each year into the young crops category. Areas were derived from Coillte felling and Forest Service planting records.
2. Five percent of the young crop category moves each year into the mature category. This means that there is a full turn-over of these crops every 20 years.
3. Mature crops are clearfelled and these areas come back to the cleared/unclassified category.
4. For the purposes of the model clearfell is defined as Coillte felling plus an arbitrary 200 ha of private felling.
5. The reforestation is derived from the clearfell area of the previous year.
6. The process works forward or back from FIPS base year 1995.

### YOUNG CROPS

*General rule for years before 1995:*
Current year = (Current year+1) ha. - (afforestation [current year + 1 - minimum age for young trees] + reforestation [current year + 1 - minimum age for young trees])*(Category % related to planting) + (Current year+ 1)*Accretion Rate

Example: 1993 ha. = 1994 ha. - (afforestation 1987 + reforestation 1987)*species % + 1994 ha.*0.05
Example: 1994 ha. = 1995 ha. - (afforestation 1988 + reforestation 1988)*species % + 1995 ha.*0.05

1995 ha. = FIPS ha. For 1995 for a given category

*General rule for years after 1995:*
Current year = (Current year -1) ha. + (afforestation [current year - minimum age for young trees] + reforestation [current year - minimum age for young trees])*(Category % related to planting) - (Current year - 1)*Accretion Rate

Example: 1996 ha. = 1995 ha. + (afforestation 1989 + reforestation 1989)*species % - 1995 ha.*0.05
Example: 1997 ha. = 1996 ha. + (afforestation 1990 + reforestation 1990)*species % - 1996 ha.*0.05

### MATURE CROPS

*General Rule for years before 1995:*
Current Year = (Current Year + 1)ha - ([Current Year + 1] Young Trees)ha*(Accretion Rate)+ ([Current Year + 1 Felling]ha * [Category % in Felling])

Example: 1993 ha. = 1994 ha. - 1994 'young' ha * 0.5 + 1994 Felling ha * Category % in Felling
Example: 1994 ha. = 1995 ha. - 1995 'young' ha. * 0.5 + 1995 Felling ha * Category % in Felling

1995 ha. = FIPS ha. For 1995 for a given category

*General Rule for years after 1995:*
Current Year = (Current Year - 1)ha + ([Current Year - 1] Young Trees)ha*(Accretion Rate) - ([Current Year Felling]ha * [Category % in Felling])
Example: 1996 ha. = 1995 ha. + 1995 'young' ha. * 0.5 - 1996 Felling ha * Category % in Felling
Example: 1997 ha. = 1996 ha. + 1996 'young' ha. * 0.5 - 1997 Felling ha * Category % in Felling

### CLEARED/UNCLASSIFIED AREAS

The category cleared/unclassified represents total identified forest area by Forest Service less covered forest as located by remote sensing and classified in FIPS. This would include felled areas in which forest cover had not been established, recent plantings not yet classified and other productive unforested sites. This category is assumed not to store carbon.

*General Rule for years before 1995:*

Current Year= (Current Year + 1 ha) - Afforestation[Current Year +1] - Felling[Current Year + 1] + ([Current Year + 1 - minimum age for young trees]Afforestation) + ([Current Year + 1 - minimum age for young trees]Reforestation)

Example:
1994 ha. = 1995 ha. - 1995 Afforestation -1995 Felling + 1988 Afforestation + 1988 Reforestation
*General Rule for years after 1995:*
Current Year= (Current Year - 1 ha) + Afforestation[Current Year)+ Felling[Current Year) - ([Current Year - minimum age for young trees]Afforestation) - ([Current Year - minimum age for young trees]Reforestation)

Example:
1996 ha. = 1995 ha. + 1996 Afforestation +1996 Felling - 1989 Afforestation - 1989 Reforestation

<u>The minimum age for young trees</u> is7 in all examples:

<u>Accretion rate</u> represents the movement of young categories into mature categories on the basis that a given percentage per annum reaches a given age. For example here (minimum age of 7 years assumed for young plantations and 25 years for mature plantations) the percentage is calculated as [1/(25-7)] or 0.056%.

## Derivation of Historic deforestation areas for LULCF and KP_LULUCF

Lack of a method to record historic 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 available data sources available to transparently report historic deforestation. However, both methods are severely flawed and not in accordance with GPG because these do not <u>accurately</u> represent forest areas changes, which are <u>consistent</u> with the forest definition (minimum area of 0.1 ha).

### 1) Tracking deforestation using CORINE Land cover (CLC) data sets (GPG approach 3)

The reporting of LUC matricides in Chapter 7 have and deforestation areas since 1990 (KP_CRF, Chapter 11) has been estimated using CLC 1990-2000 and CLC 2000-2006.

*Background information*
Coordination of Information on the Environment, CORINE, is an EU initiative established in 1985. The CORINE methodology for indicating Change in Land Cover (CLC) between 1990 and 2006 is complex (CEC 1993). Computer aided visual interpretation of satellite images (Büttner et al. 2004) was applied in the process of updating the 1990 European Land Cover to 2000 (±1 year) and the Land Cover change detection for the interval of 1990–2000, and 2000-2006 using Landsat MSS and TM satellite images. The smallest unit identified in CLC 2000 is 25 ha, and the minimum width of a linear feature is 100 m. Changes detected in the CORINE CLC were incorporated in CORINE 2000/6 only if the final CORINE polygon met the minimum mapping unit criterion of 25 ha. This means that a newly afforested area can only be detected by CORINE if it is larger than 25 ha<u>. 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).</u>

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% 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, CLC324, 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. <u>CLC324 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.</u> 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) and

**b.** aggregation of classified categories, which may not reflect forest area change. This may be particularly relevant for CLC 234 (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 (Ch 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).

*Methodology*
Despite the abovementioned inappropriateness of CLC for reporting areas under LULUCF in a consistent, representative and accurate manner, this methodology is the only data currently available to track historic land use change (see Ch 7).

For this excise were extracted CLC coded 311, 312 and 313 to represent forest land area that were present in 1990, but were converted to land cover other that forest in the 2000 and 2006 time series. The resulting polygons were then interested 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

### 2) Sampling approach: NFI grid points and aerial photography (modified GPG approach 3)

This 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 2km) sample weighting factor used to derive total areas statistics in 400ha (i.e. 1 sample point represents 400ha). 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 4000 ha with a lower and upper confidence limit of 945 and 7055 ha, respectively. This represents a sampling error of 76 %.
- 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 KP-GPG. 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.

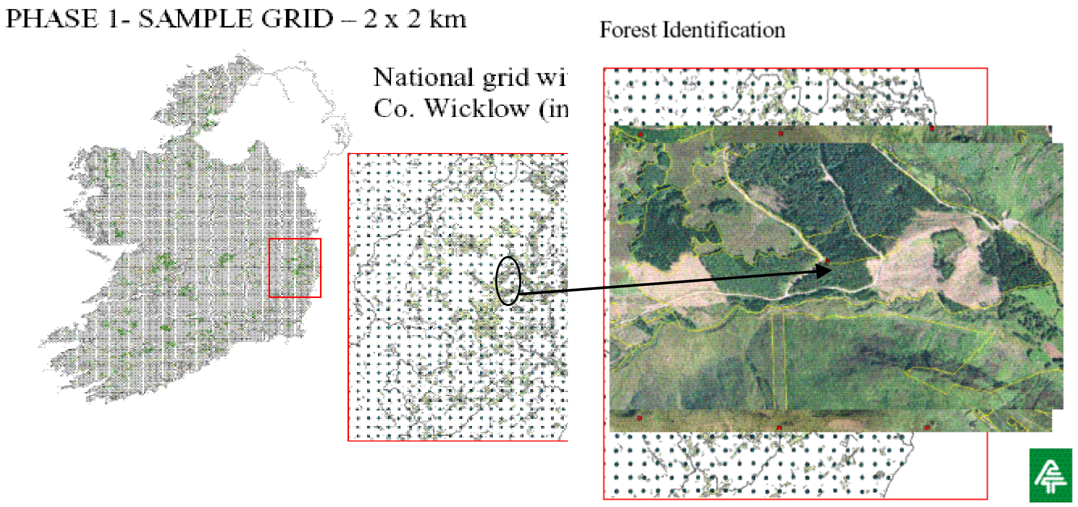



***Figure 1: The NFI systematic sample approach used to classify land use for each permanent sample plot (PSP)***

The use of the NFI stratified sample 2x2km grid of PSP described in Ch 11. Assessment of ca.18000 point intersects with aerial photographs form 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 1 shows 2 examples of the GIS analysis and photo interpretation.

*Figure 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*

**Conversion to Wetlands**

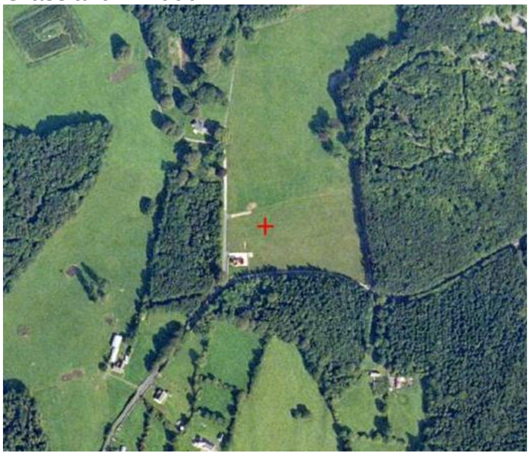
Young forest in 2000

EU peat restoration in 2006

**Conversion to Grassland**

Mature forest in 2000

Grassland in 2006



**Conversion to Development**

Young forest in 2000

Mushroom factory in 2006

Assessments of deforestation from 1995 to 2000 were based on a GIS intersection of the 18000 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 3), see database for detailed information.

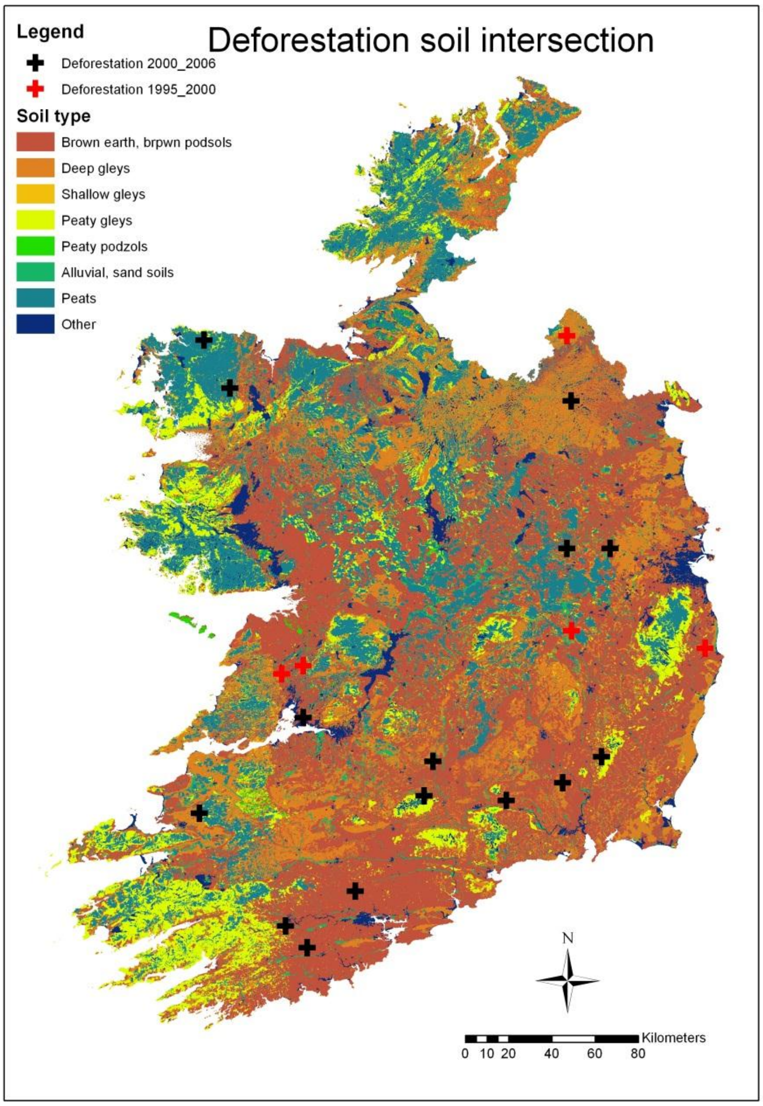



***Figure 3: The Irish soils map showing intersection with NFI PSP plots determined to be deforested between 1995 and 2006***

### 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 1).

***Table 1 The new deforestation, land use change and soil type matrix***

| Period | Source | Land use | Soil category | Area (ha) per year | % for period |
|---|---|---|---|---|---|
| **1990-1994** | **CLC1990-2000** | | | **20.6**[7] | **100** |
| | | Grassland | Mineral | 2.5 | 12.2 |
| | | Grassland | Peat | | |
| | | Grassland | Peaty mineral | 5.7 | 27.9 |
| | | Settlement | Mineral | 10.2 | 49.4 |
| | | Settlement | Peat | | |
| | | Settlement | Peaty mineral | | |
| | | Wetland | Mineral | | |
| | | Wetland | Peat | | |
| | | Wetland | Peaty mineral | | |
| | | Other | Mineral | 2.2 | 10.5 |
| | | Other | Peat | | |
| | | Other | Peaty mineral | | |
| | | | | | |
| **1995-1999** | **NFI-FIPs 95** | | | **333.3**[8] | **100** |
| | | Grassland | Mineral | 266.7 | 80 |
| | | Grassland | Peat | | |
| | | Grassland | Peaty mineral | | |
| | | Settlement | Mineral | | |
| | | Settlement | Peat | | |
| | | Settlement | Peaty mineral | | |
| | | Wetland | Mineral | | |
| | | Wetland | Peat | | |
| | | Wetland | Peaty mineral | | |
| | | Other | Mineral | 66.6 | 20 |
| | | | | | |
| **2000-2005** | **NFI-2000-2006** | | | **857.1**[9] | **100** |
| | | 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 |

[7] The CLC 1990-1994 area was calculated using the values show in table 1a to be, where annual deforestation

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

[8] NFI 1995-1999 area was calculated using the values show in table 2a to be, where the annual deforested

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

[9] NFI 2000-2005 area was calculated using the values show in table 2b to be, where the annual deforested

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

| | | | | | |
|---|---|---|---|---|---|
| | | Wetland | Peaty mineral | | 0 |
| | | Other | Mineral | 57.4 | 6.7 |
| | | Other | Peat | 57.4 | 6.7 |
| | | Other | Peaty mineral | | 0 |
| | | | | | |
| **2006** | **Felling licence and land taken out** | | | **376.44** | **100** |
| | 242.34+134.1 | Grassland | Mineral | 5.3 | 1.4 |
| | (LFL+LTO)[10] | Grassland | Peat | | 0 |
| | | Grassland | Peaty mineral | 19.7 | 5.2 |
| | | Settlement | Mineral | 17.1 | 4.5 |
| | | Settlement | Peat | | 0 |
| | | Settlement | Peaty mineral | 0.6 | 0.2 |
| | | Wetland | Mineral | | 0 |
| | | Wetland | Peat | 299.9 | 79.7 |
| | | Wetland | Peaty mineral | 30.8 | 8.2 |
| | | Other | Mineral | 3.1 | 0.8 |
| | | Other | Peat | | 0 |
| | | Other | Peaty mineral | | 0 |
| | | | | | |
| **2007** | **Felling licence and land taken out** | | | **338.7** | **100** |
| | 174.83+163.9 | Grassland | Mineral | 0.6 | 0.2 |
| | (LFL+LTO)[4] | Grassland | Peat | 14.5 | 4.3 |
| | | Grassland | Peaty mineral | | 0 |
| | | Settlement | Mineral | 4.7 | 1.4 |
| | | Settlement | Peat | 0.8 | 0.3 |
| | | Settlement | Peaty mineral | | 0 |
| | | Wetland | Mineral | | 0 |
| | | Wetland | Peat | 297.2 | 87.7 |
| | | Wetland | Peaty mineral | | 0 |
| | | Other | Mineral | 8.6 | 2.5 |
| | | Other | Peat | 12.4 | 3.6 |
| | | Other | Peaty mineral | | |
| | | | | | |
| **2008** | **Felling licence and land taken out** | | | **294.5** | **100** |
| | 26.42+268 | Grassland | Mineral | 80.2 | 27.2 |
| | (LFL+LTO)[4] | Grassland | Peat | 0.04 | 0.01 |
| | | Grassland | Peaty mineral | | 0 |
| | | Settlement | Mineral | 66.4 | 22.6 |
| | | Settlement | Peat | | 0 |
| | | Settlement | Peaty mineral | | 0 |
| | | Wetland | Mineral | | 0 |
| | | Wetland | Peat | 24.5 | 8.3 |
| | | Wetland | Peaty mineral | 21.2 | 7.2 |
| | | Other | Mineral | 100.9 | 34.3 |
| | | Other | Peat | | 0 |
| | | Other | Peaty mineral | 1.1 | 0.4 |
| | | | | | |
| **2009** | **Felling licence and land taken out** | | | **196.9** | **100** |
| | 49.9+147 | Grassland | Mineral | 5.1 | 2.6 |
| | (LFL+LTO)[4] | Grassland | Peat | | |
| | | Grassland | Peaty mineral | | |
| | | Settlement | Mineral | 15.4 | 7.8 |
| | | Settlement | Peat | 1.5 | 0.7 |
| | | Settlement | Peaty mineral | 1.5 | 0.8 |
| | | Wetland | Mineral | | 0 |
| | | Wetland | Peat | | 0 |

[10] LFL is areas from limited felling licence records and LTO is the areas from lands taken out

| | | | | | |
|---|---|---|---|---|---|
| | | Wetland | Peaty mineral | | 0 |
| | | Other | Mineral | 121.1 | 61.5 |
| | | Other | Peat | 19.9 | 10.1 |
| | | Other | Peaty mineral | 32.4 | 16.4 |
| | | | | | |
| | | | | | |
| **2010** | **Felling licence and land taken out** | | | **124** | **100** |
| | 26+98 | Grassland | Mineral | 39.7 | 39.1 |
| | (LFL+LTO)[4] | Grassland | Peat | | |
| | | Grassland | Peaty mineral | | |
| | | Settlement | Mineral | 7.9 | 6.3 |
| | | Settlement | Peat | | 0.7 |
| | | Settlement | Peaty mineral | 47.2 | 37.9 |
| | | Wetland | Mineral | | 0 |
| | | Wetland | Peat | 0.5 | 0.4 |
| | | Wetland | Peaty mineral | | 0 |
| | | Other | Mineral | 18.5 | 14.8 |
| | | Other | Peat | 4.5 | 3.6 |
| | | Other | Peaty mineral | 6.1 | 6.9 |
| | | | | | |
| | | | | | |

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# Annex H

## Summary of Parameter Input Values to Estimate Methane Generation using 2006 IPCC Guidelines Model

*Table H.1 Summary of Parameter Input Values to Estimate Methane Generation using 2006 IPCC Guidelines Model*

| Model Run | Reference | Number of Sites | Active Period | Status in 2010 | MSW Total (t) | MSW 2010 (t) | [a]DOC Fraction | $DOC_f$ | [b]Decay Rate k | [c]MCF |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | From 1969 | 13 | 1956-2010 | Open | 7,067,653 | 175,653 | 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 | 1972-2010 | Open | 6,782,647 | 229,759 | 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 | - | 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 | - | 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 | - | 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 | Arthurstown | 1 | 1997-2010 | Open | 4,790,944 | 191,553 | 0.15, 0.40, 0.43, 0.24 | 0.75 | 0.20, 0.07, 0.04, 0.07, 0.10 | 1.0 |
| 7 | Dunsink | 1 | 1976-2001 | Closed | 4,812,569 | - | 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 | Balleally | 1 | 1971-2010 | Open | 3,537,809 | 52,052, | 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 | Kinsale Road | 1 | 1965-2009 | Closed | 2,675,434 | - | 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 | KTK | 1 | 1999-2010 | Open | 1,933,739 | 1,720 | 0.15, 0.40, 0.43, 0.24 | 0.75 | 0.20, 0.07, 0.04, 0.07, 0.10 | 1.0 |
| 11 | New Sites | 10 | 1995-2010 | Open | 6,778,683 | 826,115 | 0.15, 0.40, 0.43, 0.24 | 0.60 | 0.20, 0.07, 0.04, 0.07, 0.10 | 1.0 |
| 12 | Town Dumps | ~250 | 1956-1998 | Closed | 15,372,064 | - | 0.15, 0.40, 0.43, 0.24 | 0.60 | 0.20, 0.07, 0.04, 0.07, 0.10 | 0.4 |
| 13 | Sewage Sludge | 1 | 1995-2010 | Open | 312,150 | 2,121 | 0.05 | 0.60 | 0.20 | 0.8,1.0 |
| 14 | Street Cleanings | 1 | 1990-2010 | Open | 1,087,722 | 18,713 | 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 H.2 Time Series of Solid Waste Disposal and Composition 1990-2010*

| Year | Pop | MSW Prod Rate kg/cap/day | MSW Managed tonnes | MSW to SWDS % | MSW to SWDS tonnes | Street Cleansing 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[a] tonnes | MSW Other tonnes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 3,505,800 | 1.4 | 2,037,978 | 0.92 | 1,878,358 | 46,959 | 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 | 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 | 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 | 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 | 33.0% | 30.0% | 5.2% | 2.7% | 0.0% | 29.1% | 666,215 | 606,484 | 104,253 | 55,151 | | 586,492 |
| 1995 | 3,601,300 | 1.4 | 2,067,106 | 0.92 | 1,905,206 | 46,791 | 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 | 2,469,888 | 0.92 | 2,266,842 | 58,194 | 31.8% | 30.9% | 4.3% | 1.0% | 1.0% | 33.6% | 738,510 | 719,521 | 99,249 | 23,990 | 22,451 | 780,178 |
| 1997 | 3,664,300 | 1.5 | 2,538,442 | 0.91 | 2,319,897 | 69,596 | 30.0% | 31.4% | 3.6% | 1.1% | 1.0% | 35.3% | 717,856 | 751,077 | 87,196 | 25,892 | 22,741 | 843,596 |
| 1998 | 3,703,100 | 1.5 | 2,323,692 | 0.91 | 2,114,605 | 80,999 | 28.5% | 31.9% | 3.1% | 1.1% | 0.9% | 37.2% | 625,701 | 699,309 | 68,358 | 24,822 | 20,514 | 815,764 |
| 1999 | 3,741,600 | 1.7 | 2,039,195 | 0.90 | 1,826,474 | 80,156 | 29.0% | 31.6% | 2.6% | 1.3% | 1.0% | 37.6% | 553,258 | 602,804 | 49,395 | 24,317 | 18,908 | 716,811 |
| 2000 | 3,789,500 | 1.8 | 2,395,557 | 0.88 | 2,111,319 | 79,312 | 27.0% | 33.7% | 1.8% | 1.4% | 1.1% | 37.7% | 591,233 | 737,643 | 40,153 | 31,436 | 23,231 | 825,799 |
| 2001 | 3,847,200 | 1.9 | 2,558,726 | 0.87 | 2,218,447 | 78,469 | 27.6% | 33.2% | 1.2% | 1.6% | 1.1% | 37.9% | 632,855 | 763,143 | 26,486 | 36,527 | 25,853 | 870,915 |
| 2002 | 3,917,200 | 1.9 | 2,684,314 | 0.79 | 2,128,259 | 65,573 | 28.5% | 32.1% | 0.9% | 1.6% | 1.2% | 38.3% | 626,094 | 704,055 | 19,424 | 35,626 | 27,064 | 840,432 |
| 2003 | 3,978,900 | 2.0 | 2,717,740 | 0.72 | 1,946,012 | 71,779 | 27.5% | 32.4% | 0.8% | 1.6% | 1.2% | 38.0% | 554,187 | 653,847 | 15,811 | 32,473 | 24,430 | 766,526 |
| 2004 | 4,043,800 | 2.0 | 2,823,173 | 0.66 | 1,875,428 | 26,344 | 33.9% | 27.7% | 1.0% | 4.4% | 3.6% | 30.2% | 645,648 | 526,192 | 18,107 | 82,845 | 68,759 | 575,013 |
| 2005 | 4,130,700 | 2.0 | 2,875,399 | 0.65 | 1,880,955 | 23,875 | 33.8% | 27.6% | 0.9% | 4.4% | 3.5% | 30.6% | 643,995 | 525,176 | 17,651 | 83,235 | 67,385 | 582,179 |
| 2006 | 4,239,848 | 2.2 | 3,202,322 | 0.64 | 2,045,788 | 30,366 | 34.5% | 26.4% | 0.9% | 4.5% | 3.8% | 30.7% | 716,385 | 547,100 | 19,510 | 93,751 | 78,400 | 637,952 |
| 2007 | 4,339,000 | 2.1 | 3,316,376 | 0.63 | 2,104,800 | 70,334 | 40.4% | 21.4% | 1.5% | 6.9% | 4.5% | 27.8% | 879,361 | 466,316 | 33,264 | 149,983 | 98,660 | 605,600 |
| 2008 | 4,422,100 | 2.0 | 3,182,048 | 0.62 | 1,987,575 | 24,969 | 34.5% | 24.2% | 1.5% | 6.5% | 5.0% | 31.0% | 694,156 | 486,831 | 30,588 | 131,127 | 100,014 | 623,042 |
| 2009 | 4,459,300 | 1.8 | 2,895,940 | 0.61 | 1,767,004 | 26,701 | 36.3% | 21.9% | 1.5% | 6.4% | 5.0% | 31.5% | 650,264 | 392,399 | 26,993 | 115,379 | 89,644 | 564,176 |
| 2010 | 4,470,700 | 1.7 | 2,548,148 | 0.58 | 1,476,852 | 18,713 | 35.1% | 21.3% | 1.0% | 6.3% | 5.0% | 31.5% | 525,488 | 318,638 | 14,365 | 93,943 | 74,918 | 470,576 |

[a] Nappies are assumed to be included in the textiles proportion during the period 1990-1995 inclusive.

# Annex I

## Ireland's Response to the Recommendations in the UNFCCC Review of Ireland's 2010 Inventory Submission

| **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 CO2, N2O and CH4 emissions from the use of solid fuels in navigation and CO2 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 report4, 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 CO2, CH4 and N2O 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 N2O emissions from industrial, domestic and commercial wastewater, and the ERT recommends that Ireland provide estimates of N2O 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 N2O 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 CO2 emissions from asphalt roofing, road paving with asphalt, and food and drink, N2O emissions from the use of N2O from anaesthesia, and N2O 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. | |

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| 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 CO2 eq in CRF table 5(IV) but as 376.77 Gg CO2 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 | (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. CH4 and N2O 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; CO2 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 CO2 EFs in manufacturing industries and construction were reported as CORINAIR ("CR") in the NIR but as "CS" in the CRF tables.<br>(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. | 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. |

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| 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 CO2 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 | (47) In 2008, CO2 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 CO2 emissions are below 2 per cent.<br>(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. | The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011.<br>The inventory agency will work with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012. | |

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| 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 – CO2 | 53 | Ireland uses CO2 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 CO2 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 CH4 and N2O emissions was based on the energy balance data presented in the CRF tables. This means that the data basis for estimating and reporting CO2 and non-CO2 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 CH4 and N2O are not underestimated, while CO2 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.<br>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 – CO2, CH4 and N2O | 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.<br>The inventory agency has plans to improve reporting of domestic aviation in Submission 2012. | Chapter 3, section 3.2.1.3 and 3.8. |

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| Energy | Non-key categories: Road transportation: all fuels – $CH_4$ and $N_2O$ | 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 – $CO_2$, $CH_4$ and $N_2O$ | 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.<br>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 – $CO_2$, $CH_4$ and $N_2O$ | 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.<br>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: $CO_2$ emissions from asphalt roofing, road paving with asphalt, and food and drink; and $N_2O$ emissions from the use of $N_2O$ 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 $SF_6$ emissions from sporting goods (consumption of halocarbons and $SF_6$) are reported as “NE”. Actual emissions are reported for 2008, while the Party stated in the NIR that the use of $SF_6$ 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 emissions. | Notation keys have been corrected in the CRF Submission for 2011. | |

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| IP and Solvent and other product use | Sector overview | 63, 64 | (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.<br>(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. | 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.<br>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. | |

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| 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.<br>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. | | |

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| Agriculture | Key categories: Enteric Fermantation | 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 Fermantation | 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). |

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| Agriculture | Key categories: Manure management – $CH_4$ and $N_2O$ (80, 81,82) | 80, 81, 82 | (80) During the centralized review, the ERT identified potential problems with the $CH_4$ IEF for dairy cattle: (a) the value reported in CRF table 4.B(a) is 20.7 kg $CH_4$/head/year, but the ERT estimated it to be equal to 27 kg $CH_4$/head/year using the values provided by Ireland for the following parameters: $CH_4$ 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 $CH_4$ 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 $N_2O$ emissions from manure management (liquid (40.6 per cent), solid storage (2.7 per cent) and pasture range and paddock (56.7 per cent)).<br>(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 $CH_4$ and $N_2O$ 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.<br>(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: $CH_4$ and $N_2O$ emissions from manure management; $N_2O$ emissions from pasture range and paddock; and $N_2O$ 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. | Additional QA\QC was undertaken for Submission 2011. | Chapter 6, section 6.7. |
| Agriculture | Key categories: Direct soil emissions – $N_2O$ | 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.<br>The inventory agency will consider separate reporting of sewage sludge in Submission 2012. | |

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| Agriculture | Key categories: Indirect soil emissions – N2O | 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 ($Frac_{LEACH}$) 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 this country specific fraction is provided in NIR 2011. | Chapter 6, section 6.5.3. |
| Agriculture | Key categories: Indirect soil emissions – N2O | 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 (NH3) and nitrogen oxide (NOX) 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.<br>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 CO2, CH4 and N2O 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. |

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| 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. | |

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| 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 a afforesation 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 |

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| LULUCF | Non key categories: Grassland remaining grassland – $CO_2$ | 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 $CO_2$ 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. $N_2O$ 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. $N_2O$ 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 – $CH_4$ | 103 | In the NIR, Ireland provides detailed information on the calculations and parameters applied to estimate $CH_4$ 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 – $CH_4$ | 104 | Ireland has recalculated the $CH_4$ recovery estimates from solid waste disposal on land based on a detailed study prepared by Fehily Timony Consultants. This study quantified the $CH_4$ recovered through landfill gas flaring for all years since the practice was introduced and validated the $CH_4$ 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 – $CH_4$ | 106 | Ireland has reported $CH_4$ 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. |

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| Waste | Non-key categories: Waste incineration – CO2 and N2O | 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 – CO2 (110) and Deforestation – CO2 (112) | 109, 110, 112 | (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.<br>(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.<br>(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. | 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 – CO2 | 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 settlements. | Additional information is provided in NIR 2011. | Chapter 11, sections |

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| 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 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. |

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| Conclusions and recommendations | | 141 | 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:<br>(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);<br>(b) Improve the transparency of the reporting on the national system by including more detailed information on the archiving system;<br>(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;<br>(d) Improve the uncertainty analysis with the consideration of a higher level of disaggregation for the LULUCF sector;<br>(e) Improve completeness of the inventory, in particular by estimating the remaining emissions reported as "NE" (see paragraph 13 above);<br>(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;<br>(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;<br>(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). | See above. | |

# Annex J

## Allometric Equations for Biomass

## Growth Models and Pre-processing Functions for CARBWARE v5

***Table J.1: Allometric equations used to calculate biomass component for individual trees (kg d.wt tree$^{-1}$).***

Similar species are grouped into 6 different cohorts based on available research information (Spruces, Pines, Larches, Other conifers, fast growing broadleaves and slow growing broadleaves). Abbreviations: AB-above ground, TB-total biomass, BB-below ground, FB-foliage, SB-stem (i.e. timber >7cm diameter), $L_{HR}$= lop and top from harvest residues, DBH diameter at breast height (1.3 m) in cm, H –height in m.

| Eq | Function | Range | Equation | Coefficients | | | | $r^2$ | RMSE | Slope | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | a | b | c | d | | | | |
| Spruce | | | | | | | | | | | |
| 1 | AB | H>4.5m | $a \times DBH^b + c \times H^d$ | 0.23 | 2.12 | 5 x $10^{-7}$ | 4.99 | 0.91 | 0.29 | 1.01 | i, ii |
| 2 | AB | H<4.5m | $a \times H^b \times c$ | 1.32 | 1.7 | 1.38 | | 0.86 | 0.2 | 1.1 | i, ii |
| 3 | TB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 1.02 | 1.033 | | | 0.91 | 0.08 | 1.03 | ii, iii |
| 4 | BB | | TB-AB | | | | | | | | |
| 5 | FB | | $AB \times a + b \times \exp[-c \times AB]$ | 0.025 | 0.089 | 0.003 | | 0.68 | 3.4 | 0.98 | i, ii |
| 6 | SB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 0.405 | 1.09 | | | 0.99 | 2.99 | 1.03 | ii, iii |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |
| Pines | | | | | | | | | | | |
| 8 | AB | H>3.8m | $a \times DBH^b + c \times H^d$ | 0.07 | 2.42 | 0.039 | 2.51 | 0.93 | 0.13 | 0.94 | ii, iii |
| 9 | AB | H<3.8m | $a \times H^b$ | 0.12 | 3.91 | | | 0.95 | 0.74 | 0.95 | i, ii |
| 10 | TB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 1.15 | 1.01 | | | 0.96 | 0.4 | 1.01 | ii, iii |
| 4 | BB | | TB-AB | | | | | | | | |
| 5 | FB | | $AB \times a + b \times \exp[-c \times AB]$ | 0.025 | 0.089 | 0.003 | | 0.68 | 3.4 | 0.98 | i, ii |
| 11 | SB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 0.71 | 1.005 | | | 0.97 | 0.27 | 0.96 | ii, iii |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |
| Larch | | | | | | | | | | | |
| 12 | AB | H>2m | $a \times DBH^b + c \times H^d$ | 0.11 | 2.31 | 0.001 | 3.29 | 0.94 | 0.27 | 0.94 | ii, iii |
| 13 | AB | H<2m | $a \times H^b$ | 0.03 | 1.91 | | | 0.67 | 0.44 | 1.2 | i, ii |
| 14 | TB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 1.43 | 0.98 | | | 0.99 | 0.25 | 0.99 | ii, iii |
| 4 | BB | | TB-AB | | | | | | | | |

| Eq | Function | Range | Equation | Coefficients | | | | $r^2$ | RMSE | Slope | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | a | b | c | d | | | | |
| 5 | FB | | $AB \times a + b \times \exp[-c \times AB]$ | 0.025 | 0.089 | 0.003 | | 0.68 | 3.4 | 0.98 | i, ii |
| 15 | SB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 0.903 | 0.972 | | | 0.98 | 0.28 | 0.96 | ii, iii |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |
| Other conifers | | | | | | | | | | | |
| 16 | AB | H>3.8m | $a \times DBH^b + c \times H^d$ | 0.022 | 2.73 | 0.19 | 2.06 | 0.96 | 0.46 | 1.008 | ii, iii |
| 17 | AB | H<3.8m | $a \times H^b \times c$ | 0.005 | 1.58 | 1.12 | | 0.86 | 0.28 | 1.02 | i, ii |
| 18 | TB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 1.59 | 0.96 | | | 0.99 | 0.28 | 1.005 | ii, iii |
| 4 | BB | | TB-AB | | | | | | | | |
| 5 | FB | | $AB \times a + b \times \exp[-c \times AB]$ | 0.025 | 0.089 | 0.003 | | 0.68 | 3.4 | 0.98 | i, ii |
| 19 | SB | | $\exp[Ln(a) + b \times Ln(AG)]$ | 0.89 | 0.96 | | | 0.98 | 0.57 | 1.055 | ii, iii |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |
| Slow growing broadleaves | | | | | | | | | | | |
| 20 | AB | H>3.0m | $a + \left[\frac{b \times DBH^c}{DBH^c + 246872}\right]$ | 0.08 | 25000 | 2.5 | 246872 | | | | iv |
| 21 | AB | H<3.0m | $a \times H^b$ | 0.031 | 1.72 | | | 0.84 | 0.88 | 0.91 | i, ii |
| 22 | BB | | $\exp(-a + Ln(DBH) + b)$ | 1.509 | 0.284 | | | | | | iv |
| 23 | FB | DBH>10cm | $a \times (DBH \times 10)^b$ | 0.009 | 1.47 | | | 0.96 | | | v |
| 24 | FB | DBH<10cm | $AB \times 0.3$ | | | | | 0.78 | 1.2 | 0.79 | i, ii |
| 25 | SB | DBH>19cm | $a \times (DBH \times 10)^b$ | 0.0002 | 2.5 | | | 0.97 | | | v |
| 26 | SB | DBH<9cm | $\frac{AB + BB}{1.4}$ | | | | | | | | BEF |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |
| Slow growing broadleaves | | | | | | | | | | | |
| 20 | AB | H>3.0m | $a + \left[\frac{b \times DBH^c}{DBH^c + 246872}\right]$ | 0.06 | 25000 | 2.5 | 246872 | | | | iv |

| Eq | Function | Range | Equation | Coefficients | | | | $r^2$ | RMSE | Slope | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | a | b | c | d | | | | |
| 21 | AB | H<3.0m | $a \times H^b$ | 0.031 | 1.72 | | | 0.84 | 0.88 | 0.91 | i, ii |
| 22 | BB | | $\exp\left(-a + Ln(DBH) + b\right)$ | 1.509 | 0.284 | | | | | | iv |
| 27 | FB | DBH>3cm | $a + b \times DBH^c$ | 0.375 | 0.0024 | 2.517 | | 0.90 | | | vi |
| 28 | FB | DBH<3cm | $AB \times 0.3$ | | | | | 0.78 | 1.2 | 0.79 | i, ii |
| 29 | SB | DBH>35cm | $a \times DBH^b$ | 0.0001 | 2.535 | | | 0.97 | | | v |
| 30 | SB | DBH<9cm | $\frac{AB + BB}{1.4}$ | | | | | | | | BEF, vii |
| 7 | $L_{HR}$ | | AB-SB | | | | | | | | |

**i** National research harvested tree database (COFORD funded project CARBiFOR)
**ii** Black et al., Biomass equations for modelling C dynamics in Irish forests (in prep)
**iii** Forest Research pulled tree database (Brice Nicholl, NRS, Forest Research, UK)
**iv** Brown S (2002) . Measuring carbon in forests: current status and future challenges. Environmental Pollution 116: 363-372.
**v** Johansson, T. Dry matter amounts and increment in 21-to 91-year-old common alder and grey alder some practical implicatons. Canadian Journal of Forest Research 29 1679-1690.
**vi** Bartelink, H.H., Allometric relationship for biomass and leaf area of beech (Fagus sylvatica L). Annals of Forest Science, 1997. 54: p. 39-50.
**vii** Black K., Tobin B., Saiz G., Byrne K. & Osborne B. (2004). Improved estimates of biomass expansion factors for Sitka spruce. Irish Forestry 61:50-65.

## Annex J.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.

### J.1-A: Pre-processing functions

**Height-Diameter And Crown Ratio Modelling For Six Species Cohorts**.

It is common among forestry datasets that tree height (H) or crown ratio (CR) is not measured on every tree. This creates interest in estimating the height of such trees.

A common forest inventory approach used to derive missing H and CR values involves the use of single parameter (DBH) models based on species and plot specific predictions (NFI, 2007; Wykoff et al., 1982). However, is has been suggested that these Chapman-Richards functions, or derivations thereof, are problematic because the function approaches the asymptote too rapidly, particularly when there is a weak relationship between DBH and H in larger trees. In addition, individual plot DBH-H data is sometimes too sparse to parameterise plot specific functions. Generalised DBH-H functions avoid the need to parameterise relationship for every stand. Since the relationship between DBH and H is influenced by the relative competitive position of trees within a stand and management interventions, site-level stand-density information is often incorporated (Temesgen and Gadow, 2004). Taking their results as a starting point, we address here several issues that arise in the context of our modelling dataset. These include the application of nonlinear mixed effects models which successfully borrow strength across all permanent plots, thereby facilitating imputation in plots where data is sparse or unevenly distributed. The permanent sample plot data, taken from a range of spacing and thinning experiments, used in this study is well suited, albeit not arising by design, to evaluate these stand-density parameters to describe variations in H and CR across different silvicultural conditions.

**Materials and methods**

***Data***

Data used were obtained from Coillte Teoranta's (the Irish Forestry Board state commercial forestry company) permanent sample plot record system. The dataset contains records from many silvicultural and thinning trials established during the period 1963 to 2001. The trials were initially established as replicated experimental designs with repeated measurements typically undertaken every five years. The dataset is described in Broad and Lynch (2007).

### ***Incorporating competition covariates***

The modelling here follows Temesgen and Gadow (2004) who based their work on Yang et al. (1978) and incorporated competition covariates into the Yang/Weibull function (Table 1, Model 2).We evaluate that model and also use test for differences between management regimes conditional on the DBH-H model by incorporating dummy indicator variables in the linear regression models of the model parameters. Our aim in this section was to test if the inclusion of certain covariates, typically relating to the competition in a forest stand/plot, improved the baseline DBH-H model (Table G.2.1, Model 1). We also investigated whether the model was improved by including random effects on the level of the plot (Table G.2.1, Model 3).

The competition covariates are plot basal area (BA, $m^2$ $ha^{-1}$), basal area in larger trees (BAL, $m^2$ $ha^{-1}$) which is the integral of the empirical frequency distribution of the BA variable from the subject tree to the largest diameter tree in the plot and plot density (DENS, trees $ha^{-1}$). Models were fitted in NLMixed procedure in SAS using the Trust-Region algorithm. Grids were specified as starting values for parameters where sensible.

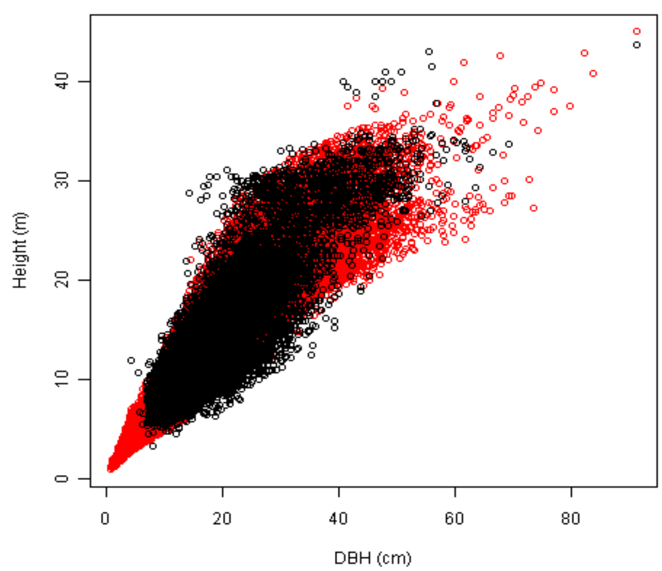


***Figure J.1-A.1. Model 2 Height estimates (red) and actual heights (black).***
The estimates presented here depict a "cloud" because they are conditioned on covariates that vary between trees (BAL) and plots (Density, Basal Area) and over time (BAL, Density, BA).

***Table J.1-A.1***

| | Model | -2l | BIC |
|---|---|---|---|
| 1 | $H = a(1-\exp(b.DBH^{c}))$ | 65185 | 65223 |
| 2 | $H = (a_1 + a_2 BAL + a_3 BA)(1-\exp(b.DBH^{(c_1-c_2 BAL)}))$ | 58341 | 58417 |
| 3 | $H = (Ui + a_1 + a_2 BAL + a_3 DENS + a_4 BA)(1-\exp(b.DBH^{(c_1-c_2 BAL)}))$ | 44980 | 45034 |

***Table J.1-A.2 Likelihood statistics for different forms of the DBH-H model.***

Model 2 is the model used in CARBWARE for the 6 different cohorts. If dependent variables had no significant influence on the H model prediction, these variables were excluded from the model.

| Cohort | Model (2 variation) | a1 | a2 | a3 | b | c1 | c2 |
|---|---|---|---|---|---|---|---|
| Spruce | $H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(b.DBH^{(c_1 - c_2 BAL)}))$ | 33.69 | -0.274 | 0.1603 | 0.024 | 0.8846 | 0.0064 |
| Pine | $H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.BAL))$ | 16.905 | 0.083 | 0.0803 | 0.042 | | |
| Larch | $H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.BAL))$ | 32.59 | 0.1052 | 0.1229 | 0.023 | | |
| Conifers | $H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.DBH^{c_1}))$ | 23.226 | 0.1381 | 0.0703 | 0.027 | 1.1021 | |
| FGB | $H = (a_1 + a_2 BAL + a_3 BA)(1 - \exp(-b.DBH))$ | 14.661 | 0.1167 | 0.0187 | 0.076 | | |
| SGB | $H = (a_1 + a_2 BAL)(1 - \exp(-b.DBH^{c}))$ | 29.677 | 0.1034 | | 0.044 | 0.7813 | |

**BAL** is the sum of the basal area of all individual trees larger than the subject tree ($m^2$ per ha)
**BA** is the basal area of all trees in the plot (normalised to a ha)
**DBH** is the diameter at breast height (cm)

***Table J.1-A.3. CR models used in CARBWARE for the 6 different cohorts.***

If dependent variables had no significant influence on the H model prediction, these variables were excluded from the model.

The CR model takes the form of:

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

where $lCR$ is derived from the non linear equations, which may vary for different cohorts.

| Cohort | Model (*lCR* variations) | a1 | a2 | a3 | a4 | a5 | b | c |
|---|---|---|---|---|---|---|---|---|
| Spruce | $lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + a_5 \left[\frac{H}{BAL}\right] + bDBH^c$ | 4.8705 | -0.017 | -0.397 | -0.119 | -0.296 | 0.0003 | 2 |
| Pine | $lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + bDBH^c$ | 3.8478 | -0.024 | -0.213 | -0.137 | | 0.0002 | 2 |
| Larch | $lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H$ | 5.8306 | -0.018 | -0.794 | -0.039 | | | |
| Conifers | $lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + bDBH^c$ | 4.1759 | -0.019 | -0.394 | -0.965 | | 0.0004 | 2 |
| FGB | $lCR = (a_1 + a_2 BAL + a_3 Ln(CCF) + a_4 H + a_5 \left[\frac{H}{DBH}\right] + bDBH^c$ | 2.4539 | -0.009 | -0.145 | -0.045 | -0.591 | 0.0001 | 2 |
| SGB | $lCR = (a_1 + a_2 BAL + a_3 H + a_5 \left[\frac{H}{BAL}\right]$ | 1.477 | -0.005 | -0.017 | -0.578 | | | |

**BAL** is the sum of the basal area of all individual trees larger than the subject tree ($m^2$ per ha)

**CCF** is the crown competition factor, which is a measure of the crown areas of the subject tree relative to a open grown tree that would not be subjected to crown competition (taken from Hassenhaur, see section B of this appendix)

**DBH** is the diameter at breast height (cm)

**H** is height (m) form actual or predicted H estimates (Table J.1-A.2)

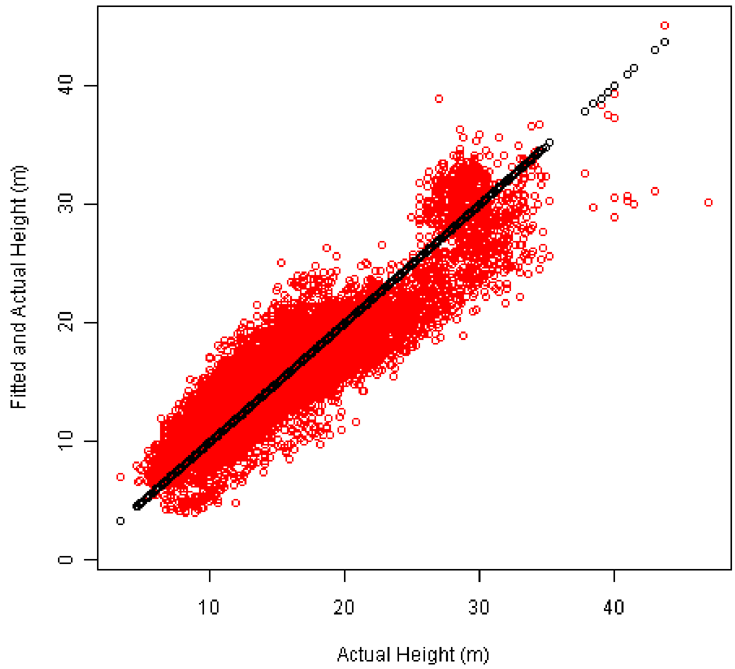


*Figure J.1-A.2. Fitted and actual height plotted (all cohorts model 2) against actual height.*

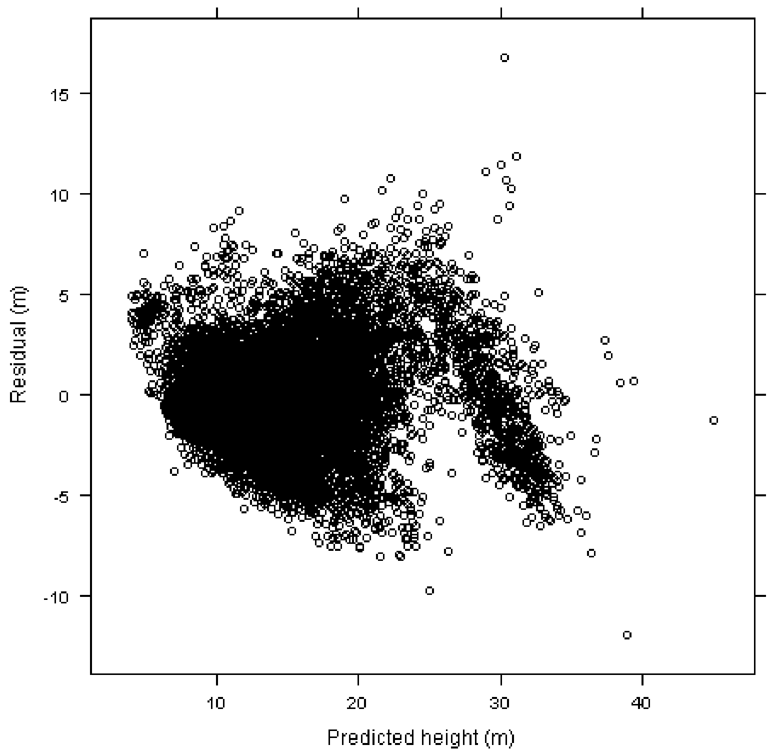


*Figure J.1-A.3. Raw residuals from the fitted model plotted against the fitted height value.*

### ***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.

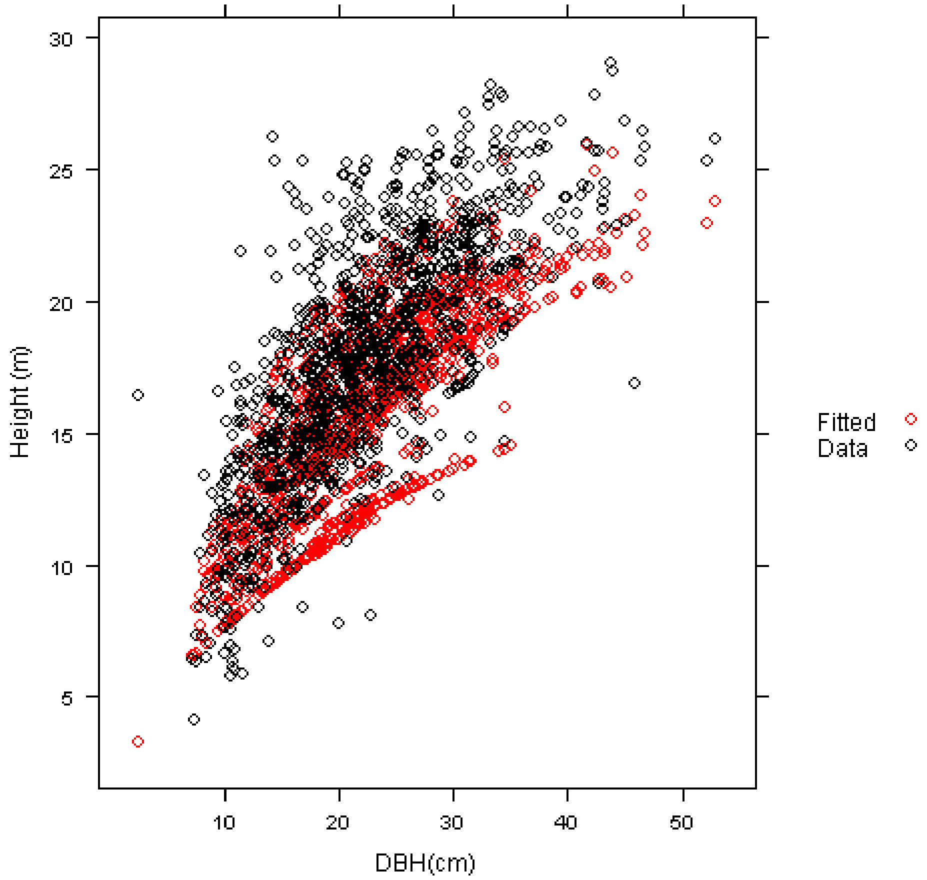


***Figure J.1-A.4. Estimated and observed validation heights versus DBH.***

### ***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 J.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.

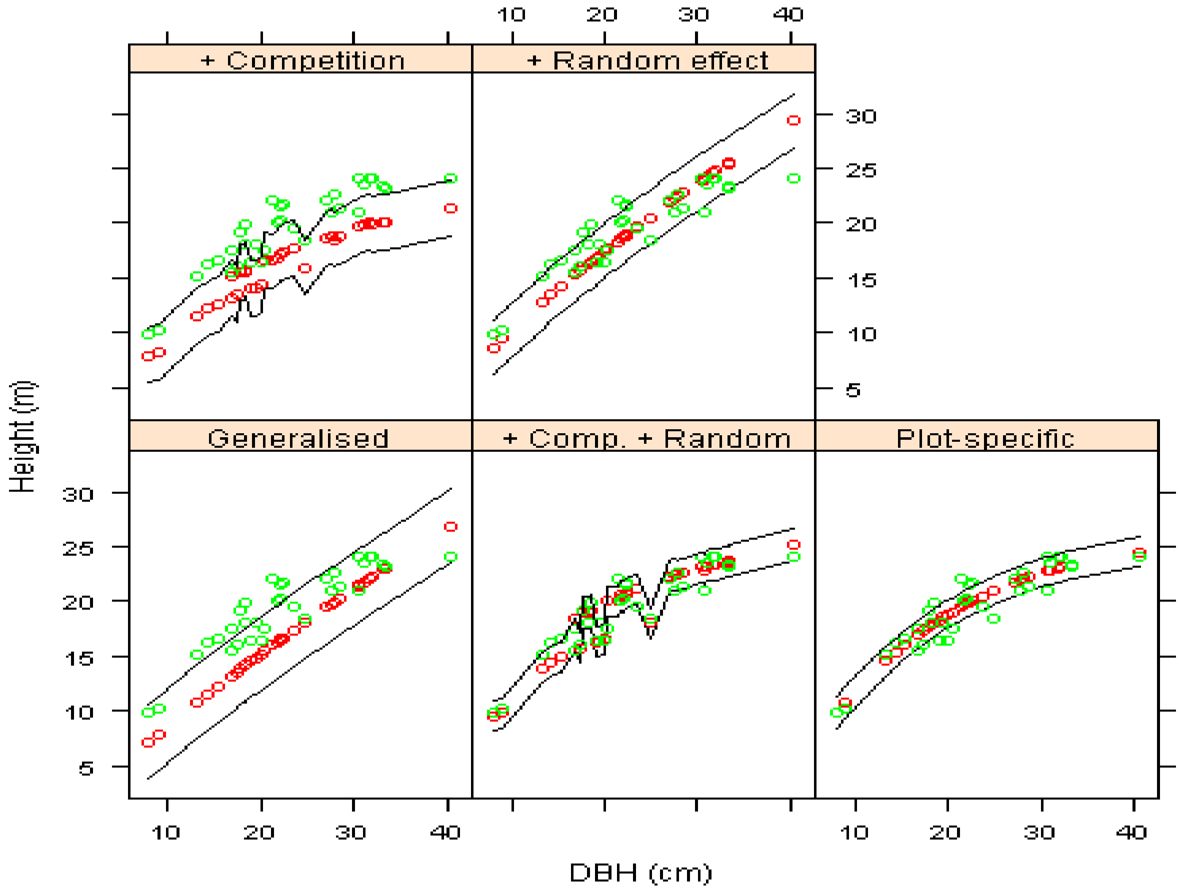


***Figure J.1-A.5. Model predictions for a single plot with various models, all based on the Yang/Weibull funtion (cf. Table J.1-A.1).***

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 J.1-A.1), *Random* denotes a plot-specific random asymptote (cf. Model 3, Table J.1-A.1), *Generalised* denotes parameters are estimated from the entire dataset. The smallest standard error of prediction is associated with the *Plot-specific* model, followed by the + *Comp.* + *Random* model. Average s.e.p. for these models are 1.39 and 1.25 respectively.

### *Thinning effects*

All observations in the dataset were categorised by us as “thinned” or “non-thinned” depending on the general management regime for the plot. We estimated the following model to test for a residual thinning effect, having conditioned on other effects. :

$$H = (U_i + a + a_1 BAL + a_2 DENS + a_3 BA + a_4 I(Thinned))(1 - \exp(b.DBH^{(c_1 - c_2 BAL)}))$$

where I(*Thinned*) is an indicator function valued 1 if the plot was thinned and 0 otherwise. The BIC of this model was 45037, and the Wald test for the $a_4$ parameter (p = 0.08) indicated that the thinning effect was not statistically significant at the 5% level. The $a_4$ estimate was greater than zero, perhaps reflecting the longer tail in the height distribution for trees in thinned plots (Figure J.1-A.6).

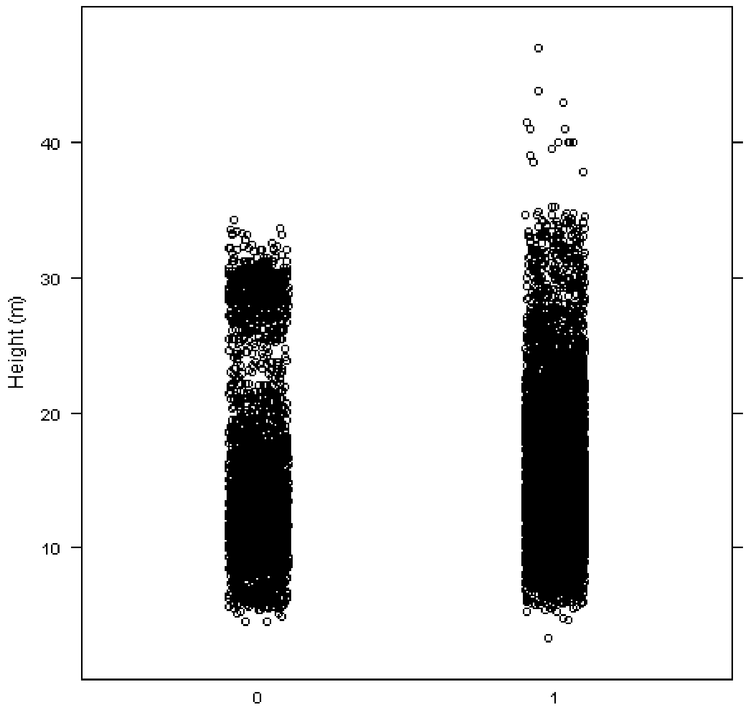


***Figure J.1-A.6. Strip-plot of Heights in the calibration dataset.***
1 = Thinned, 0 = Unthinned.

### *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 J.2.2).

### *References*

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Temesgen, H. and von Gadow, K. (2004) Generalized height-diameter models : An application for major tree species in complex stands of interior British Columbia. European Journal of Forest Research. 123 : 45-51

Yang, R.C., Kozak, A., and Smith, J.H.G. (1978) The potential of Weibull-type functions as flexible growth curves. Canadian Journal of Forest Research, 8 : 424 - 431

Zeide, Boris (1993) Analysis of growth equations. Forest Science

## J.1-B: Growth Modelling

### (a) Modelling diameter increments in Irish Forests

#### Introduction

The modelling approach adapted in this version of CARBWARE v5 is the use of diameter increment models for all trees with a DBH greater that 5cm. This model in a distance independent individual tree growth model parameterised on Coillte permanent plot data recorded every 4 to 6 year since 1954 to 2003. These include pure and mixed species stands at establishment planting densities of 5000 to 1000 trees per ha and with different thinning treatments. The advantage of using a single tree growth model and the nature of the parameterisation data set is that different silvicultural regimes and species mixtures can be handled by one generalised modelling framework. In addition, the application data set, i.e. the data from which models will be run, does not contain explicit complete longitudinal data representing stand variable, which are used in conventional growth models.

#### Data operations

Two datasets are referred to, Coillte permanent sample plot (PSP) and NFI. Some of the data operations referred to below differ between these because the former has complete enumeration on a plot and is longitudinal, the latter samples from the plot and is cross-sectional.

In general, the modelling framework that we base our work on, PrognAus (see various references below), informed the types of data operations required. The framework involves, using their terminology, site, competition and size variables. Our focus was on the latter variables, and site or plot effects were accounted for using mixed model methods, whereby plot or site effects are random, blocking, effects, rather than effects whose levels have physical dimension. In any case, site or plot effects are not a feature of the growth simulator. Furthermore, incomplete enumeration of certain independent variables meant that random effects were difficult to estimate because of the sparse data. We can illustrate that elsewhere but such detail is not relevant to the CARBWARE software manual.

The variables described here are those that feature in the diameter increment model that we aim towards calibrating:

$$Dinc(cm) = \exp(a_0 + a_1 \ln DBH + a_2 DBH^2 + a_{3.} \ln CR + a_{4.} \ln CCF + a_5.BAL)$$

See Table G.4 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 J.1-B.1. Explanation of some symbols used in the text.***

| Variable | Formula | Scale of measurement |
|---|---|---|
| CR | Crown length/height | Range (0,1) |
| DBH | Diameter at 1.3 m | Cm |
| Crown competition factor (CCF) | The "open-grown" (e.g. if every tree had zero competitors) crown area of all trees in a plot expressed as a percentage of plot area. | Percent |
| BAL | A function for each plot that takes as its argument any tree's rank in the diameter distribution ordered from smallest to largest and returns the combined basal area of all trees with higher rank. | $M^2$ $ha^{-1}$ |
| BA | Plot basal area. | $M^2$ $ha^{-1}$ |
| Annualised diameter increment (Dinc) | (DBH(t+1)-DBH(t))/([t+1] – [t]). DBH(t) stands for "DBH on the occasion of the $t^{th}$ measurement". Since measurment intervals vary, this implies that [t +1] – [t] = 1 is not necessarily true, hence the use of the term "annualised". | cm |

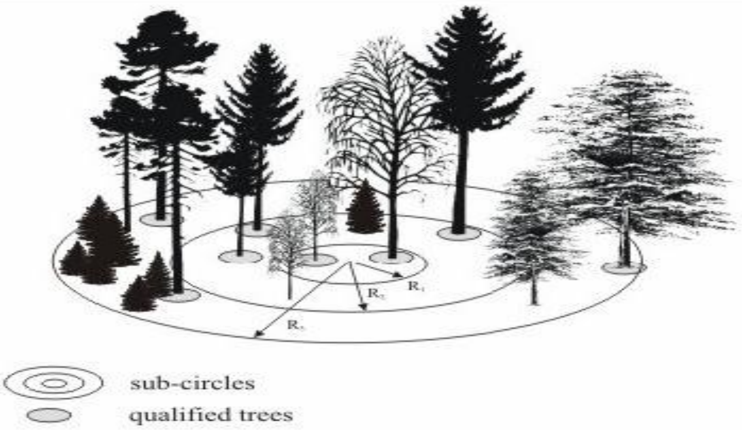
.

*Open-grown crown width* (cw), is an intermediary variable in the calculation CCF. We estimated *cw* using equations derived by Hasenauer (1997). These equations return open-grown crown width in *metres*. Hasenauer (1997) derived species-specific equations that we apply in approximation to cohorts,

| | |
|---|---|
| **Spruce** | : $cw = \exp(-\mathbf{0.3232})*((DBH)^{0.6441})$ |
| **Other conifers** | : $cw = \exp(\mathbf{0.092})*((DBH)^{0.538})$ |
| **Pine** | : $cw = \exp(-\mathbf{0.1797})*((DBH)^{0.6267})$ |
| **Larch** | : $cw = \exp(-\mathbf{0.3396})*((DBH)^{0.6823})$ |
| **Slow-growing broadleaves** | : $cw = \exp(-\mathbf{0.3973})*((DBH)^{0.7328})$ |

**Fast-growing broadleaves** : $cw = \exp(0.1366)*((DBH)^{0.6183})$
(where a circumflex denotes exponentiation.)

Open grown crown area ($m^2$) = $(0.25)*(3.141593*cw^2)$
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 J.1-B.1 for an explanation.




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

***Figure J.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.

$$Dinc = \exp(a_0 + a_1 \ln DBH + a_2 DBH\hat{}^2 + a_3 . \ln CR + a_4 . \ln CCF + a_5 . BAL) + e$$

Where $a_i$, i = 1…5 are coefficients and *e* is a residual that was autocorrelated between measurements on the same tree and independent otherwise. The fitting was done in the Glimmix procedure in SAS, and the model is a GLM with Gaussian variance function and a log link. This is slightly different from Monserud and Sterba (1997), who log-transformed the response, where we log-transform the expected value of *Dinc*, and didn't model autocorrelation.

Where fitting was unsatisfactory, i.e. because of parameter instability or data sparseness, a submodel was selected. A criterion of model selection was that the parameters should be qualitatively similar to those estimated by Monserud and Sterba (1997). In this respect, the fitting of the increment models is better described as model calibration than model selection.

The parameters for the fitted models were:

**FGB**
E(Dinc) = EXP(-2.8528 + LN(DBH)*1.1729 - 0.00012*DBH$^2$ + LN(CR)*0.8241 - 0.000015*CCF)
**Larch**
E(Dinc) = EXP(-2.2969 + LN(DBH)*0.6338 - 0.00096*CCF)
**OC**
E(Dinc) = EXP(-1.4191 + LN(DBH)*0.554 - 0.00025*DBH$^2$ + LN(CR)*0.5549 - 0.00052*CCF - 0.00646*BAL)
**Pine**
E(Dinc) = EXP(-1.3466 + LN(DBH)*0.741 - 0.001*DBH$^2$ + LN(CR)*0.998 - 0.00066*CCF - 0.00417*BAL)
**SGB**
E(Dinc) = EXP(-2.5897 + LN(DBH)*0.7534 - 0.00068*DBH^$^2$ - 0.0006*CCF - 0.00979*BAL)
**Spruce**
E(Dinc) = EXP(-1.8628 + LN(DBH)*0.9456 - 0.0005*DBH$^2$ + LN(CR)*1.1639 - 0.000638*CCF-0.00273*BAL)

***Uncertainty:***
In this section we look at various measures of the performance for the different models discussed above. The performance measures quoted give rough ideas about how the models perform. It should be noted that performance can be improved somewhat by including plot and site effects but since these are problematic for extrapolation from PSP to NFI, they were omitted from the Dinc model. They were also omitted from within NFI imputation models, by which we mean imputation models calibrated on NFI data, for similar considerations. They were not omitted from PSP-specific models.

We looked at the performance of the various models – DBH-H, CR, Dinc – for the two datasets. Some measures we could have used, that are used by Thurig et al (2005), for example, are *accuracy, precision,* and *excess error,* calculated as follows.

**Accuracy** : ((Σ(**pred**icted-**obs**erved)/n)*100)/m. Where *m* is E(obs), and *n* is the number of observations.
**Precision** : SD(pred-obs)
**Empirical Excess error** (%): ((1-Sec)/Sei)*100. Where *Sec* is the *precision* of the calibration data, and *Sei* the *precision* of the independent data.
**Theoretical Excess error** : (1/n)[Σ($pred_{(-1)}$-obs)$^2$- Σ(pred-obs)$^2$ ]. Where pred(-1) is the leave one out prediction error

Note that *empirical excess error* is only viable when doing external validation.

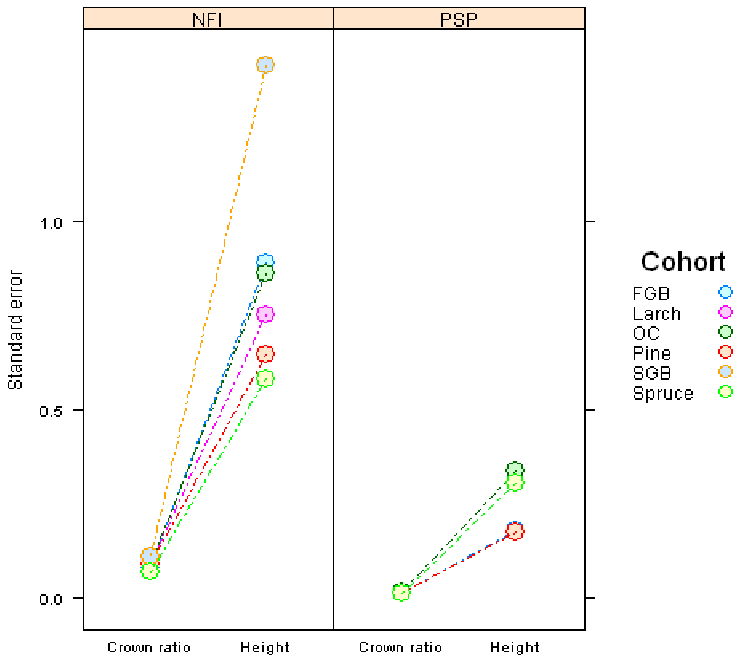
Temesgen and von Gadow (2004), for example, use *root mean squared error* (RMSE) and Bias to evaluate their models.

**Bias** : (Σ(pred-obs)/n)
**RMSE** : √( Σ(pred-obs)$^2$/n-p). Where *p* is the number of parameters in the model.

Another measure is *mean absolute error* (MAE).

**MAE** : Σ |pred-obs|/n

A certain amount of model selection was done, as noted above, when fitting the models to the data in the first place. This ensures that the fitted models are the most parsimonious to minimise residual error. However, model performance is best evaluated by external validation or, failing that, some cross-validation. We conduct leave-k-out cross validation on the Dinc calibration data. *MAE* and *RMSE* are calculated for each cross-validation dataset replicate. External validation data was only available for the PSP DBH-H model, and that is discussed in another document.



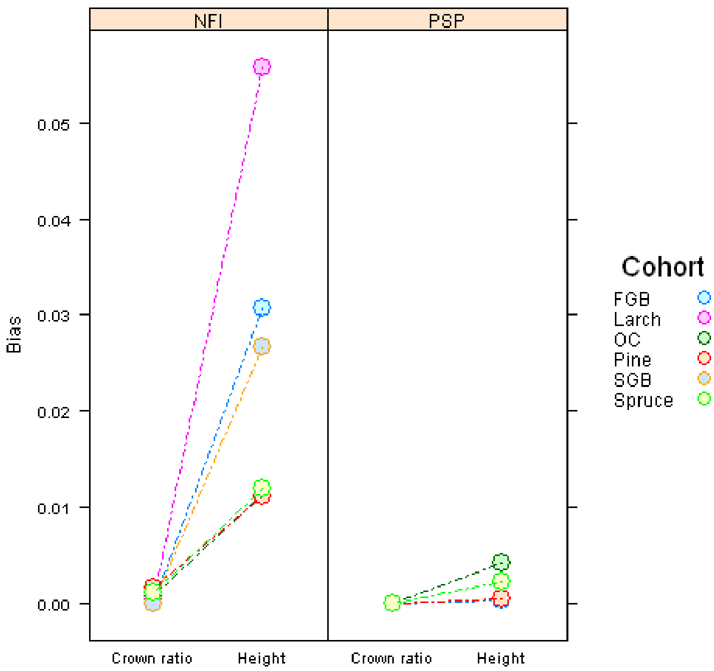



***Figure J.1-B.2. Within-sample Precision (upper panel) and Bias (lower panel) for imputation.***
Values are plotted for each dataset, for cohorts, and for models of Height and Crown ratio.

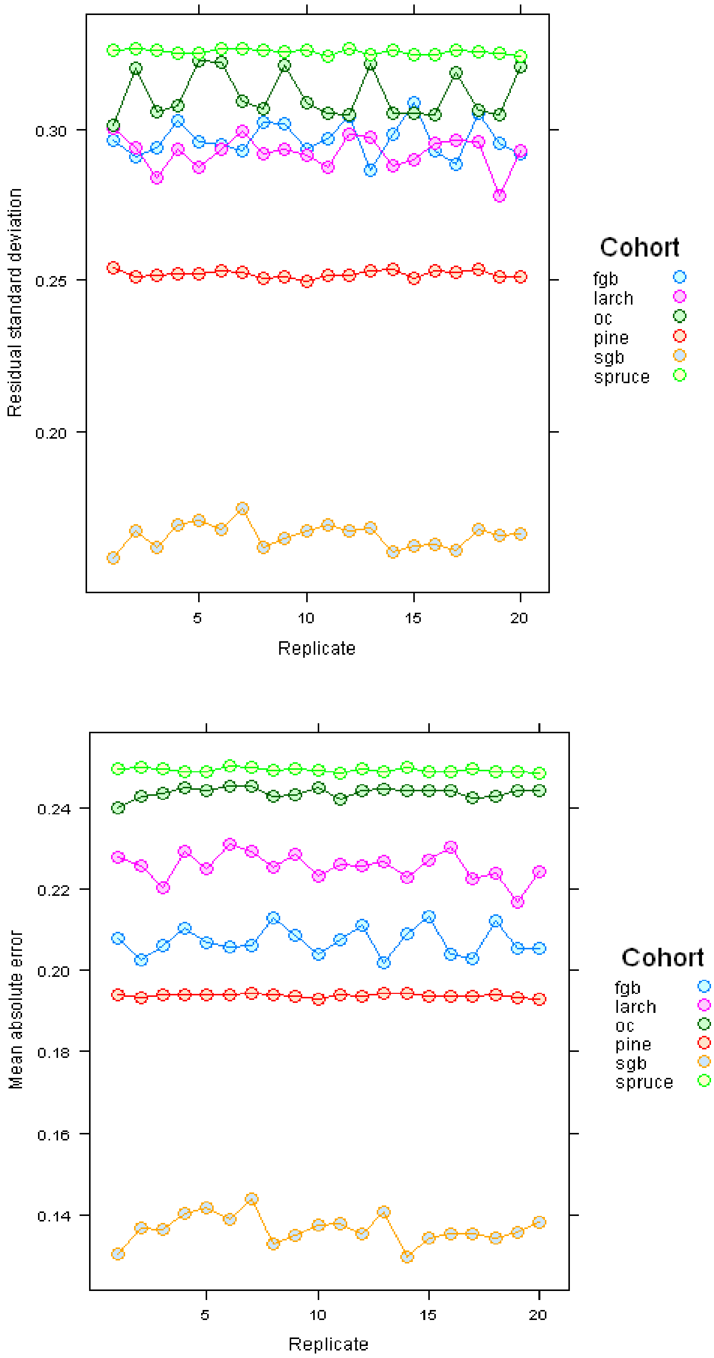



***Figure J.1-B.3. Leave k-out cross validation results, precision (top) and mean absolute error (bottom) for the Dinc model.***
The probability of inclusion in the validation dataset is 0.33. 20 cross-validation replicates are displayed.

## Discussion and conclusions

The lines joining the points in Figure J.1-B.2 are only included to facilitate a comparison between panels. The interpolating lines in Figure J.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 J.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 J.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).

***References***

Robert A. Monserud, Hubert Sterba (1999) Modeling individual tree mortality for Austrian forest species. Forest Ecology and Management 113:109-123
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## (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).

$$xHinc_{i,j}^{n+1} = \frac{a_1}{1+\exp(-1\times\left[\frac{age^n - a_2}{a_3}\right])} \quad \text{.......................................................(1)}$$

where, *xH* is mean height of all trees in the NFI plot for the $_i$th species and $_j$th H index ratio at the determined age (n+1). The age of the forest (n) is obtained from the NFI stand attribute data. The partial coefficients (*a*) for each species and productivity class and goodness of f Once the new mean tree H ($xH_n$+$xHinc_{n+1}$) is computed, the individual tree H is recalculated based on a scaling function:

$$H_{n+1} = \frac{H_n}{xH_n} \times H_n \quad \text{.......................................................(2)}$$

where, $H_{n+1}$ is the individual H of the tree in the plot in the year following the NFI , $H_n$ is the individual H in the year the last NFI was completed (2005), and $xH_n$ is the mean H of trees in the plot in the year the last NFI was completed.

The Productivity class (H over age) categories were defined to match conventional yield class productivity indices (YC*eq*) as described by (Christy and Edwards, 1981). This was derived by comparison of Chapman Richard outputs from each H index ratio (HI) with static age-H tables at ca. 10 to 20 year old crops.

$$YCeq = HI = \min, \{YCH_{ij} - xH_{ij}\}^2$$

where, YC *eq* is the *HI* equivalent to YC at the lowest least-squares different between the yield table H values (*YCH*) and the predicted mean height (*x*H see equation 1) for the *i*th cohort and *j*th HI.

***Selection of tree for H increment model***

All trees with no measurable DBH are selected for growth increment using the H model. The CARBWARE model also selects eligible trees to be grown using the H growth model based on cohort-specific threshold DBH values (Table J.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 J.1-B.2). If a tree has a larger corresponding DBH than the threshold value, it is grown using the DBH increment model.

***Table J.1-B.2. Threshold minimum DBH values suitable for use din DBH increment model and corresponding cut-off H values used for H growth in small trees***

| Cohort | DBH threshold (cm) | Corresponding H (m) |
|---|---|---|
| Spruce | 4 | 2.7 |
| Pine | 4 | 5.1 |
| Larch | 2 | 3.6 |
| Other conifers | 4 | 3.1 |
| Slow growing Broadleaves (SGB) | 2 | 4.2 |
| Fast growing Broadleaves (FGB) | 2 | 3.2 |

***Datasets and measure of goodness of fit***

We used both the Coillte PSP and NFI individual tree data base to develop H-age curves (range 0.1 to 12 m). Data operations were concerned with assembling datasets of the variables used in the H model, insofar as was feasible.

We looked at the performance of the various models –H-Age for different cohort for the combined datasets. Some measures we could have used, that are used by Thurig et al (2005), for example, are *accuracy, precision,* and *excess error,* calculated as follows.

**Accuracy** : ((Σ(**pred**icted-**obs**erved)/n)*100)/m. Where *m* is E(obs), and *n* is the number of observations.
**Precision** : SD(pred-obs)
Empirical Excess error measures could not be performed because there was no external validation data set (Thirig et al., 2005).
**Bias** : (Σ(pred-obs)/n)
**RMSE** : √( Σ(pred-obs) $^{2}$/n-p). Where *p* is the number of parameters in the model.

**Results**

**Fitted model parameters**

Table J.1-B.3 shows the partial coefficients for each species and productivity class for the Chapman-Richards H-Age functions.

***Table J.1-B3. Spruce cohort***

| HI range | YCeq | | | | Precision | RMSE | Bias |
|---|---|---|---|---|---|---|---|
| | | $a_1$ | $a_2$ | $a_3$ | | | |
| >1.2 | >24 | 1.02 | 5.59 | 2.04 | 1.8 | 4.69 | 0.32 |
| 1-1.2 | 24 | 1.05 | 7.05 | 2.32 | 1.42 | 4.23 | -0.23 |
| 0.8-1 | 22 | 0.76 | 5.98 | 1.63 | 1.33 | 3.21 | 0.11 |
| 0.6-0.8 | 20 | 0.66 | 5.51 | 1.33 | 0.66 | 2.55 | 0.56 |
| 0.5-0.6 | 18 | 0.57 | 5.26 | 1.12 | 0.89 | 1.69 | 0.45 |
| 0.4-0.5 | 16 | 0.53 | 5.35 | 1.47 | 1.11 | 3.66 | 0.32 |
| 0.3-0.4 | 14 | 0.48 | 5.32 | 0.54 | 0.74 | 3.54 | 0.62 |
| 0.2-0.3 | 12 | 0.44 | 6.59 | 2.20 | 1.53 | 4.53 | 0.24 |
| 0.1-0.2 | 10 | 0.35 | 6.93 | 2.27 | 0.69 | 1.77 | -0.43 |
| <0.1 | <10 | 0.28 | 8.02 | 0.35 | 1.9 | 4.23 | -0.7 |

## Annex J.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.

## J.2-A: Mortality models

**Introduction**

In the general context of forest growth models, and at the most basic level, the tree mortality module's role at each iteration is to classify a particular tree in the dataset as being either dead or alive. This paper approaches this problem in the context of an individual-tree model of mortality that is both age- and distance-independent. The specific modelling framework within which the mortality module will be applied, is a framework similar to the PrognAus framework, with the goal of estimating annual forest dynamics for Ireland.

***Literature review***

There are two areas of interest for the literature context of this paper: *tree-mortality* modelling, and *threshold-based* classification. (Note that this paper is not focussed on a survival analysis, as one might perhaps expect, because such models are time-dependent.)

1. *Mortality modelling* in Forest Succession.

Wunder et al. [2006a] compared the use of classical stress-thresholds in mortality modules of forest succession (\gap") models. They conclude that logistica1 regression-based models are superior to stress-threshold models with regard to predicting time of tree death.

Baesens et al. [2003] review threshold-based classifiers in the context of credit-scoring. They examine logistic regression, discriminant analysis, k-nearest neighbour, neural networks and decision trees, advanced kernel-based classification algorithms such as support vector machines and least-squares support vector machines (LS-SVM). They assess performance using the classification accuracy and the area under the receiver operating characteristic curve. They found that both the LS-SVM and neural network classifiers yield a very good performance, but also simple classifiers such as logistic regression and linear discriminant analysis perform very well for credit scoring.

Bigler and Bugmann [2004] introduced a new approach to modelling tree mortality based on different growth patterns of entire tree-ring series. They were interested in predicting time of tree death. In their study, dendrochronological data from *Picea abies* (Norway spruce) in the Swiss Alps were used to calibrate mortality models using logistic regression. They introduced a mortality threshold and classified a tree as dead if its modelled mortality probability curve plotted over time went above that threshold. They ignored autocorrelation at the modelling stage, and applied a jackknife method to correct for the resulting biased variance estimates. They found that the most reliable models were those that included relative growth rate and a short-term growth trend as explanatory variables.

Focussing on the role played by life-history strategies in determining tree mortality Wunder et al. [2008] investigated whether the relationship between growth and mortality divers among tree species and site conditions. This carries on from Monserud [1976] who showed that reduced growth generally accompanies a higher mortality risk. For each of nine species, they modelled mortality probablity as a function of relative basal area increment, tree size and site. They selected the species-specific model with the highest goodness-of-fit and calculated the area under the receiver operating characteristic curve and calibration measures. The discriminatory power as measured by AUC ranged from 0.62 to 0.87. They found that most growth-mortality relationships differed among species and sites, i.e. there is no universal growth-mortality relationship.

It has been noted that a lack of long-term growth/mortality data has made it difficult to evaluate the performance of mortality models. Wunder et al. [2006b] adopt a “virtual ecology" approach to this problem, simulating forests with either of two a priori specified growth-mortality relationships. They simulate different sampling regimes in these virtual forests, thereby generating virtual tree-ring data, forest inventory data, or a combination of both. They compare eight existing or newly developed models of different structural flexibility by their ability to model the growth-mortality relationship in the simulated data, and quantify the deviation from the *a priori* specified growth-mortality relationships with the Kullback-Leibler distance. Of the models they evaluated, the highest accuracies were obtained with tree-ring based models, which required only small (approx. 60) numbers of dead trees. For larger sample sizes (approx 500 dead trees) forest inventory based models were also seen to be accurate. They also showed that exible statistical approaches were superior to less flexible models only for large sample sizes (totally 2000 trees) and that the additional use of Bayesian statistics, model accuracies only when model flexibility was constrained. They also provided guidelines for sufficient sampling schemes in real forests.

In the PrognAus framework, Monserud and Sterba [1999] modelled mortality in Austrian forests for six major species based on 5-year re-measurements of the permanent plot network of the Austrian National Forest Inventory. Their general results, varying slightly between species, was that inverse of tree diameter, crown ratio and BAL were respectively the three most closely correlated factors in their model with 5-year mortality rates. They compared mortality rates across tree diameter class, thereby identifying a classic U-shape in mortality rates as diameter class increased. They modelled mortality rates rather than individual tree mortality probability, and validated the model with the chi-square statistic calculated between observed and estimated. Because the explanatory variables in their model were measured on the scale of the individual tree, they were able to calculate the classification success rate using the complement of the overall proportion of mortality (i.e., approximately 93%, although it is not clear from the text) as the threshold. On this basis, their model correctly classified between 81 and 92%, of live trees, and between 25 and 44%, of dead trees. However, their treatment of the threshold is very brief, and may not be a typical interpretation, e.g. in their interpretation, a tree is classified as dead if the threshold exceeds the modelled probability. Also, they derive a total correct classification accuracy of 86%.

***Materials and Methods***

We fitted logistic regression models to the growth dataset. We investigated model performance in the case of separate models for each cohort. (Principal issue here was the lack of data for some cohorts). The response variable was a binary indicator of mortality (arbitrarily, 1 = tree dead at time of DBH measurement, 0 = tree alive). We only included trees whose cause of death was natural mortality, e.g. such causes as windblown, diseased, were excluded. Explanatory variables were as such that were selected by Monserud and Sterba [1999] {DBH and transformations thereof, CR, BAL, CCF}, but we also investigated relative growth indicators that Bigler and Bugmann [2004] noted as being useful correlates. Site and plot effects were modelled as random, and consecutive observations on the same tree were modelled as being correlated. Conditional on this correlation structure the fixed effects parameters were selected by backward selection starting with the candidate set of covariates just listed.

Models were fitted by maximum likelihood and individual fixed effects were identified as non-significant on the basis of asymptotic Wald-tests. This was done for each cohort separately. Performance of candidate models was then evaluated by cross-validation and external validation (comparing fitted to observed mortality in NFI dataset) and with threshold-based classification tools like the ROC and ROL curves and related measures and hypothesis tests. Cross-validation was done on a leave-k out basis, where the data \left-out" was selected at random. Up to twenty independent cross-validation runs were performed, and up to 33% of the data was left-out as cross-validation data for each run.

Other performance measures were consulted, and the ROC convex hull played a role in our chosen classifier. We used threshold-averaging to investigate the performance of the classifier in cross-validation and bootstrap scenarios. We derived confidence bands for the ROC curve of the chosen classifier following the approach of Macskassy et al. [2005]. (Note, the authors have also developed techniques for point interval estimation also, the reference appearing in that paper.)

***Performance measures in ROC space and their role in uncertainty analysis***

The AUC of the ROC curve is the estimated probability that the classifier will give a higher score to positive cases than negative cases. (In our application, the estimated probability of mortality is higher for dead trees than live trees.) We envisage that an uncertainty analysis of the forest growth model of which the mortality classifier is a component part could utilise this probability and its standard error in monte-carlo simulation assessments of overall uncertainty and sensitivity.

The AUC is equivalent to the Mann-Whitney U-statistic, and methods for comparing AUCs have been developed as a result, e.g. Heagerty et al. [2000]. The principal complicating factor here is the underlying correlation structure of the comparison, which can be influenced by details pertaining to the derivation of the classification forecasts, the setup of the calibration datasets, or whether the forecasts are clustered in some way, e.g. DeLong et al. [1988], Obuchowski [1997], Heagerty et al. [2000], Mason and Graham [2002].

The convex hull of a classifier, or group of classifiers, in ROC space, can be seen as the optimal attainable classification performance. Fawcett [2006] notes that candidate classifiers that do not attain the convex hull can be discarded, on the grounds that a better classifier in ROC space exists. He suggests a method for interpolating between candidate classifiers to better approach the limit of performance estimated by the convex hull based on mis-classification costs and the prior class distribution.

When comparing ROC curves, per se, a complicating factor when it is of interest to compare different classifiers crops up if the classifiers in question are of a different \class", e.g. a probabilistic classifier versus a discrete classifier, or, more generally, comparisons across model classes, whose scoring systems are incommensurate Fawcett [2006].

***Datasets***

*Permanent Sample Plot*

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

Although there are several categories of disease or mortality causes in the PSP database {including, Windblown, Uprooted, Diseased, Broken and Dead}, we modelled only the binary response Dead/Alive for the initial model. In this way, after derived variables { basal area, plot density, etc. {were calculated, only data points that could be classified as Dead/Alive, were kept in the calibration dataset

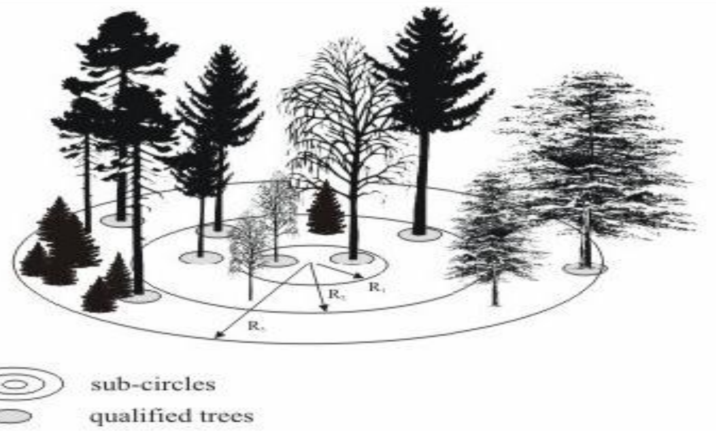
*National Forest Inventory Plot data*

We validated the ROC curve for the chosen model on the NFI data. In the NFI sample, the probability that a tree's status as dead or alive will be recorded { more generally, the probability that any feature of the tree is measured { is a function of its diameter class at the time of survey, and its distance from the centre of the plot. The expansion factor concept is a weight that varies between each tree in the dataset that estimates the prior probability of the tree's inclusion in the dataset. Figure J.2-A.1 shows that trees of three diameter classes are only recorded if they are observed within a certain distance from the plot centre. The expansion factor we use, and that used by the NFI, assumes a random distribution for tree diameter in the plot. Because of that assumption, the weight assigned to a tree in the ith diameter class is:

$$\frac{R_3^2}{R_i^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

where Ri denotes the radius of the concentric circle associated with the ith diameter class.

In practice, the expansion factor, or weight, is used to estimate plot-level features, e.g. basal area. In such calculations, we estimate the number of trees of the ith diameter class that were not included in the sample by $\frac{R_3^2}{R_i^2}$ * ni, where ni is the number of trees of the ith class




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

***Figure J.2-A.1. The NFI concentric-plot sampling schema.***

that are included in the sample. The expansion factor therefore defines the relationship between each included tree and the estimated number of trees of the same class that were not included (Equation 2).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where $n_{ij}$ _ $EF_{ij}$ is the product of the expansion factor for the *j* th tree in the *I* th class, and $\check{N}_{ij}$ is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 2 is the representative tree number. With minor and obvious changes to the equation, we can calculate other tree-level estimates, including representative basal area, and individual-tree estimates can be aggregated for the entire plot to give plot-level estimates, including representative density.

The question to address in the current paper is whether we can arrive at a sensible definition of representative mortality. At issue is how to derive a binary individual-tree-level mortality rule based on information in the NFI dataset, given the fact that there is missing information due to the sampling scheme. With this in mind, Figure J.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 J.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 J.2-A.2, at least for the cohorts with enough observations, suggests a way to make the operation of a binary mortality rule more accurate in the context of the NFI sampling scheme. The basic idea would be to use the column heights as weights in a finite mixture function whose components would be the outcome of the mortality rule. Rather than reducing the expansion factor by one unit when death is predicted (which, we can show, can lead to an unrealistically height global mortality rate), the actual reduction would be a function of the weight for the given diameter class. This method could be stochastic or deterministic. Other information might be used to inform the values of the weights, including a forester's rule of thumb about global mortality (i.e., _ 6%), or information from the NFI or a meta-analysis.

A similar approach would be to mix the outcome of the mortality rule with the diameter class mortality weights. It might be possible to iteratively tune the weights and/or the rule's cut-off parameter.

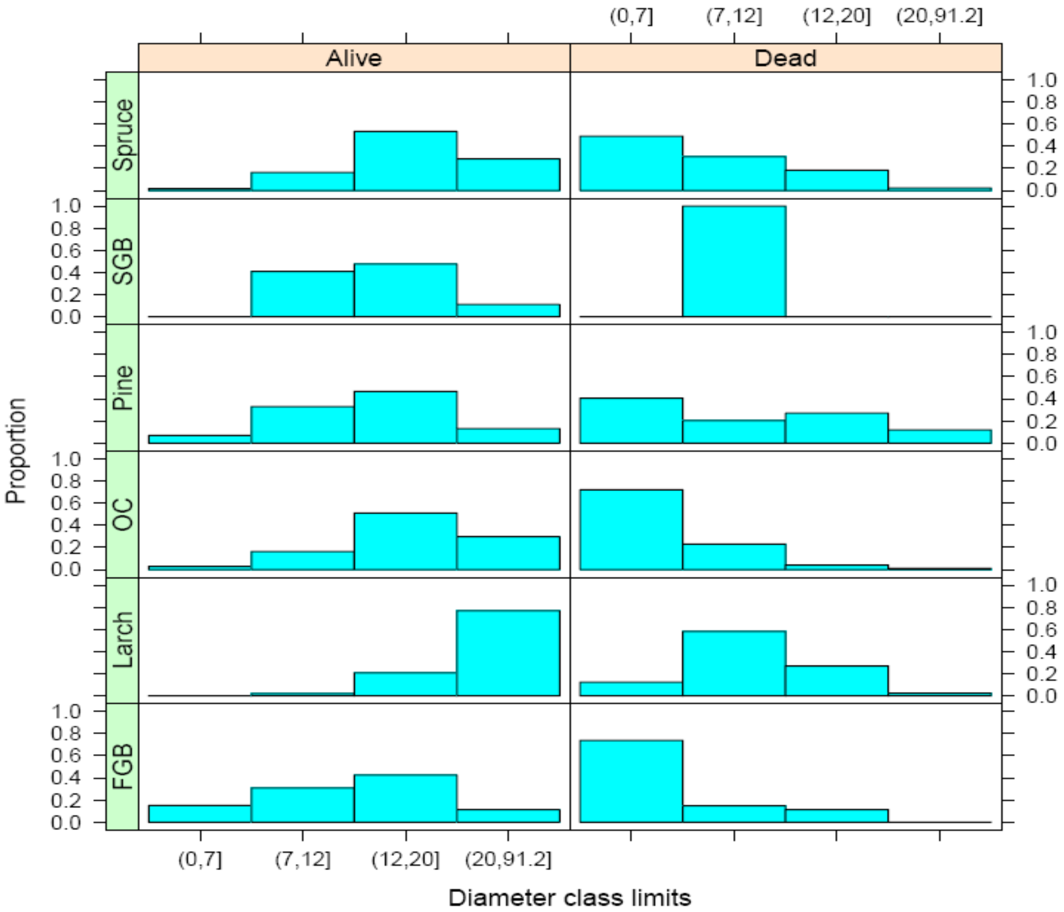



*Figure J.2-A.2 The empirical distribution in the PSP dataset of diameter classes of dead/alive trees classified by cohorts.*

### ***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

RelDiamInc $\left( \frac{growth(t-t-1)}{DBH(t)} \right)$

Part of the reason for looking at this model was that it was not subject to additional uncertainty due to imputation of missing X data, as would have been the case with the model put forward by Monserud and Sterba [1999], which also conditioned mortality on CR, a variable that was not measured on every tree in our dataset.

There are several points of interest to the results of this model fitting:

1. The characteristics of the parameters.
2. The cross-validation exercise.
3. The out-of-sample/deployment performance. E.g. how well the model described NFI mortality.

### ***Estimated parameters Candidate Model 1 (Used in CARBWARE models)***

The fitted parameters and their standard errors are presented in Table J.2-A.1. We supply parameter estimates for cohort-wise fits and the fit to the entire dataset, with no cohort-effect parameter.

***Table J.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.

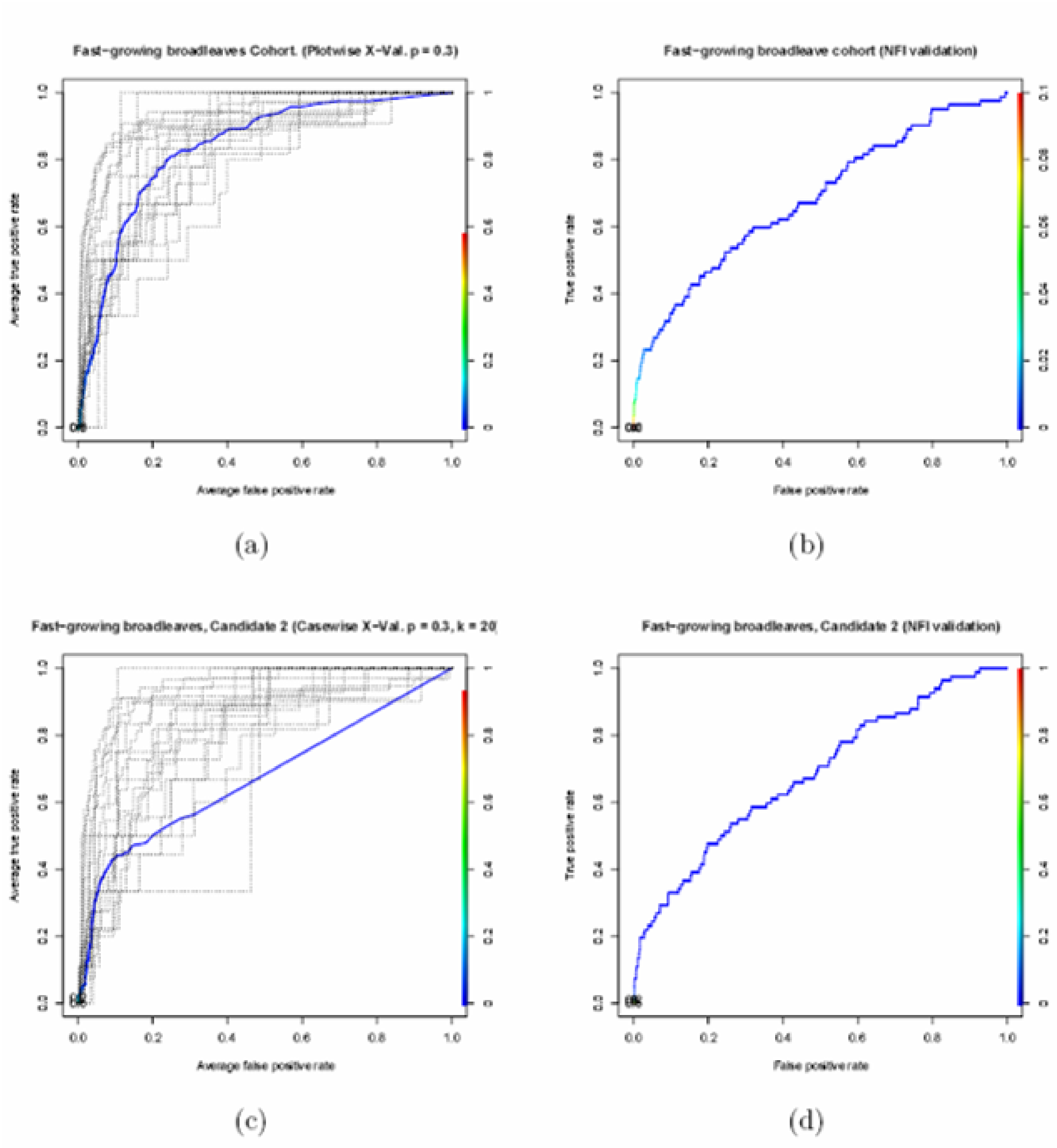



***Figure J.2-A.3. The Receiver operating characteristic curve for Candidate model 1 (panels (a),(b)) and model 2 (panel (c),(d)) in the Fast-growing broadleaves cohort.***

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 J.2-A.3). The cross-validation and deployment performance plots are presented pair-wise in the Figures below.
In all cased model candidate outperformed candidate based on false positives and fit. For example we show the results for Fast growing cohorts in Figure J.2-A.3
Note that Slow-growing broadleaves cohort did not have enough data for the cross-validation to be feasible, so 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 J.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.

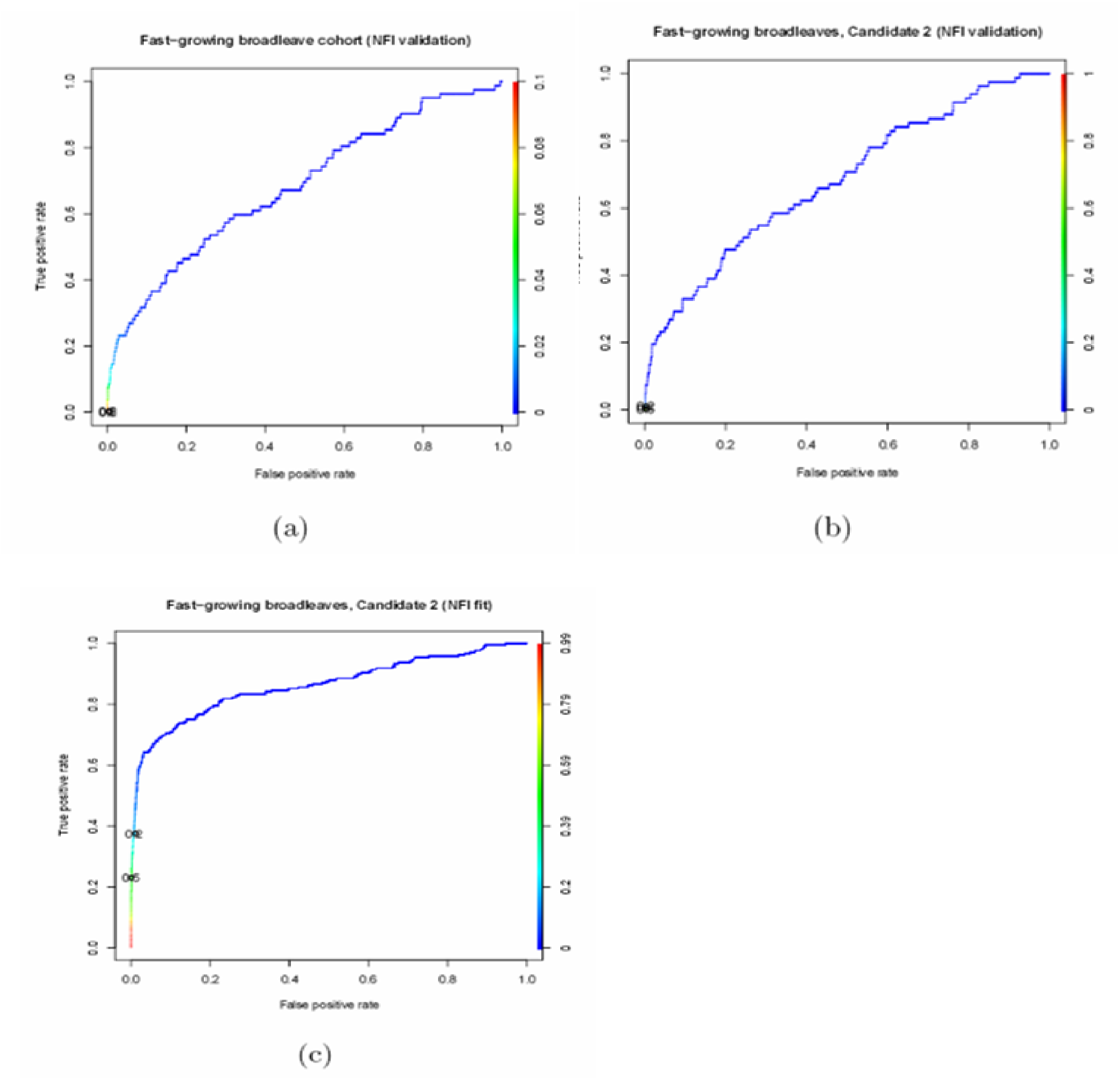



***Figure J.2-A.4. The Receiver operating characteristic curve for Fast-growing broadleaves cohort Candidate models 1 and 2 fitted on PSP, and for the NFI-fitted model.***

### *The selected CARBWARE models based on NFI data fits*

**Fast-growing broadleaves cohort**

$$Pmort = IL(12.93 + 0.068 \times BAL - 2.868 \times CR - 0.962 \times DBH - 72.28 \times \frac{1}{DBH} + 0.009 \times DBH^2$$

**Larch cohort**

$$Pmort = IL(-4.9266 + 0.04273 \times DBH)$$

**Other conifers**

$$Pmort = IL(-4.5226 + 0.067 \times BAL - 6.05 \times CR + 0.066 \times DBH)$$ **Pine cohort**

$$Pmort = IL(2.395 + 0.0408 \times BAL - 3.0036 \times CR - 0.2263 \times DBH - 24.21 \times \frac{1}{DBH})$$

**Slow growing broadleaves**

$$Pmort = IL(15.78 + 0.0109 \times BAL - 2.2807 \times CR - 0.771 \times DBH - 94.002 \times \frac{1}{DBH} + 0.00449 \times DBH^2$$

**Spruce cohort**

$$Pmort = IL(6.8976 + 0.0912 \times BAL - 21.3795 \times CR - 0.8287 \times DBH - 49.15 \times \frac{1}{DBH} + 0.008 \times DBH^2$$

Where (0 < Pmort < 1) is the probability the tree is dead. We map then this estimated probabiilty onto the binary (Dead, Alive) outcome using a cutoff, which may differ between cohorts. More details on this is give elsewhere. IL(.) is the inverse logit, e.g. IL(x) = exp(x)/(1+exp(x)).

***Choosing the operational cut-off***

To identify a cut-off level to use for the mortality probability estimate, we plotted the True positive rate (TPR) and (FPR) on the same axis versus the cut-off (e.g. Figure J.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 J.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 J.2-A.2 Formulae for some standard performance measures used in the text.***

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.

| Performance Measure | Formula |
|---|---|
| Accuracy | $\frac{TP+TN}{TP+FP+TN+FN}$ |
| Rate of positive predictions | $\frac{TP+FP}{TP+FP+TN+FN}$ |
| Correlation Coefficient | $\frac{(TP.TN)-(FP.FN)}{\sqrt{(TP+FN).(TN+FP).(TP+FP).(TN+FN)}}$ |

Figures J.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 G.9 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 J.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 formulas are given in Table G.8. These measures and others are described in Sing et al. [2005].

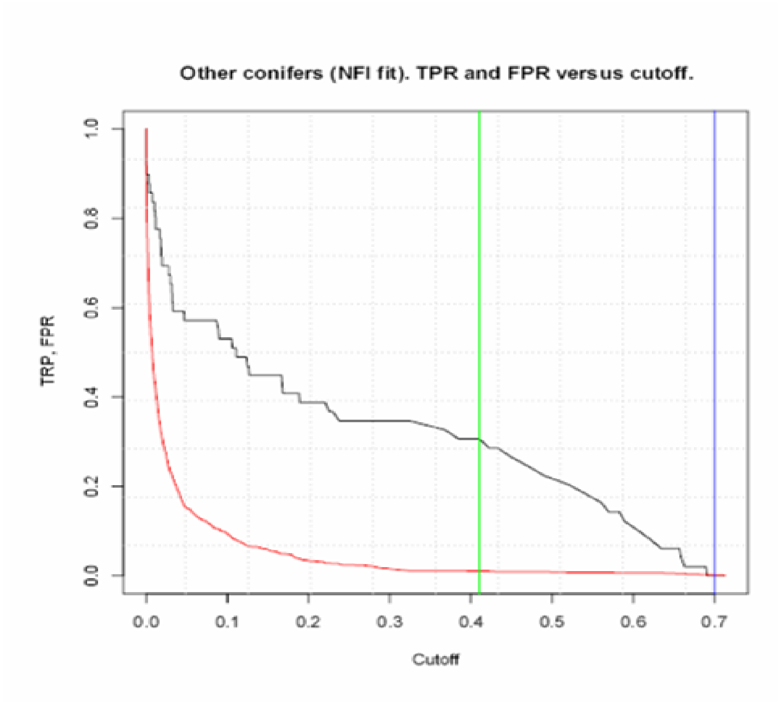



***Figure J.2-A.5 TPR (Black) and FPR (Red) versus cut-off for Fast-growing broadleaves.***
The vertical green line shows the cut-of where FPR < 0.01, the blue vertical line shows the cut-off where FPR< 0.001.

### *Discussion*

In binary classification, a common approach is to visualise the parameterised curve described by plotting two performance measures as a parametric curve parameterised by the threshold value. Comparing models based on classification and mis-classification rate (precision, recall, etc.) make more sense when there is some hierarchy of misclassification errors. That is, that we can quantify the relative importance of gains from correct classification and losses from incorrect classification. Such a loss function is particularly useful when the number of objects to be classified is not equal, because then the trade-off curves are much more likely to be nonlinear and the concept of trade-off between competing performance measures is not easy to understand. The problem is how to specify losses/gains, in other words, how to quantify Trade-off, how to measure gains and losses in the same units so a net trade-off can be calculated. Otherwise, it is not always clear, even for commonly presented parameterised curves, in what sense the trade-off is occurring, particularly when a “good" classifier, e.g. one that exhibits desirable tendencies in threshold-space, can *a priori* exhibit a number of different “shapes" when presented as a “trade-off" curve.

For example, the class ROC trade-off curve has *a priori* a sense in which a classifier is good or bad. This is when the majority of the ROC curve lies below the line of equality. However, the precision-recall curve is not so easily understood. We know that the best classifier from a group is the one with the largest area between the curve and the line of equality. However, because the value of the precision at zero threshold is a function of the number of objects in each class to be classified, it is possible to have a “good" classifier for which that area is zero. However, such a classifier is probably not statistically better than the naive, 50:50 classifier. We propose that for a classifier to be demonstrably better than the naive classifier, it should at the minimum describe a positive region between the curve and the line of equality. We conclude that the precision-recall curve does not describe a trade-off, and that in fact, a trade-off should have a point of equilibrium and the gains and losses should be incurred when the threshold moves from that point in either direction. In other words, the gains and losses as quantified by the two performance measures should be negatively correlated, for the parameterised graph to truly describe a trade-off. The precision-recall performance measures, for example, are positively correlated (both have TP in the numerator), and so their parameterised curve representation does not describe a true trade-off situation in every region of threshold space. If we overlay the two graphs with precision and recall on the y and y' axes, and threshold on the x axis, we can see more clearly where a true trade-off may occur. It is likely that should a true trade-off occur, that the region between the parameterised curve and the line of equality will have to be positive. As external corroboration, DeLong et al. [1988] note that the cost or loss function is essential to deciding the optimal cutpoint/threshold for a ROC curve. In summary, there are therefore two issues: comparing classifiers and, given a classifier, choosing a cut-off point.

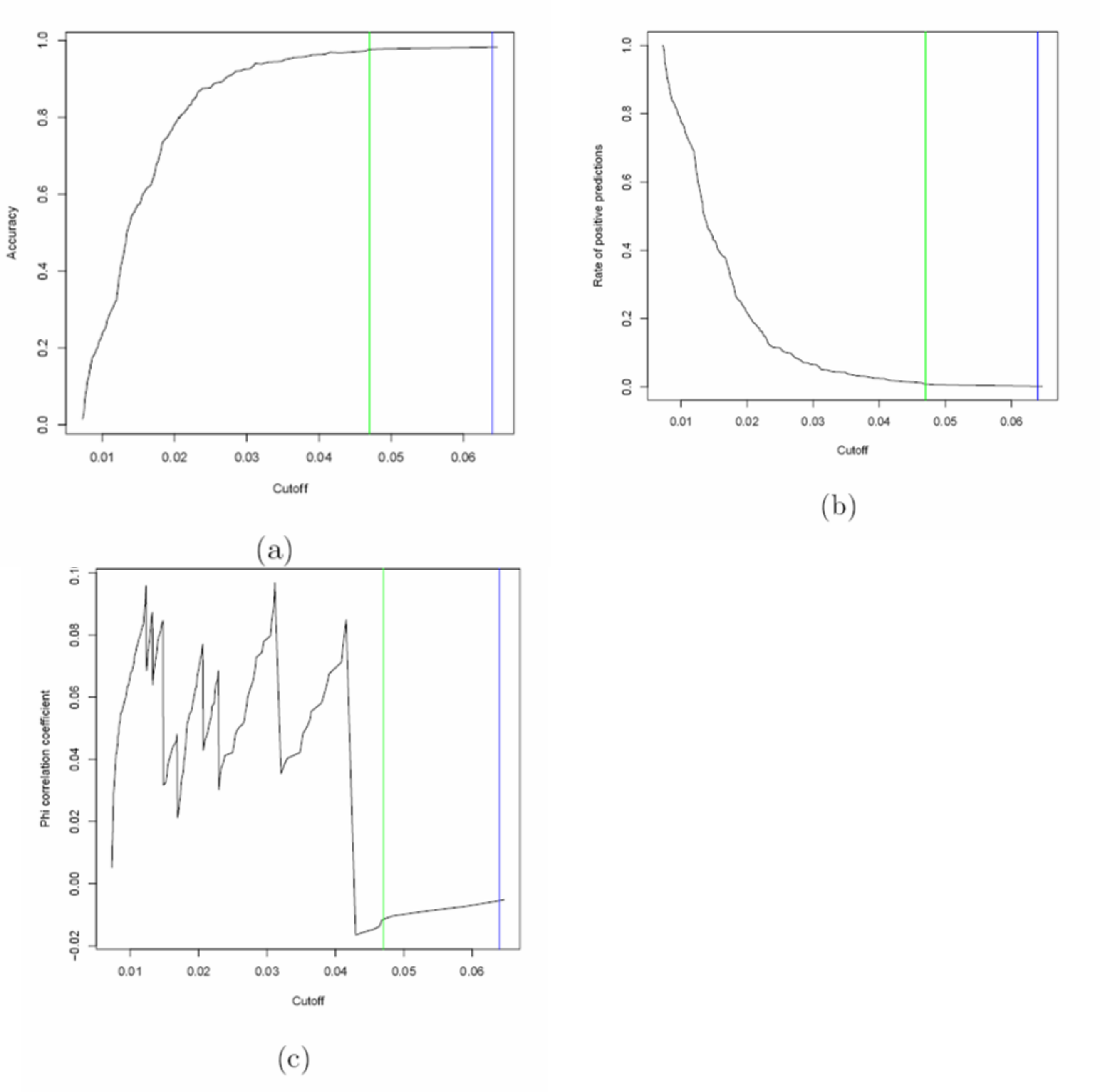



***Figure J.2-A.6 Illustrating some other performance measures of the NFI-calibrated model for the Larch cohort across the cut-off range and in particular the 0.01 (green vertical) and 0.001(blue vertical) cut-off points.***

This latter can only be done in conjunction with some kind of loss function describing costs of the different types of classification error. The kind of classifier we are using, based on multiple correlation/regression, and therefore wholly empirical, is easier to select than other types of classifier. We can use model selection criteria based on correlation/regression, or minimization of errors, or some other abstract modelling concepts. Then, the classifier selected, we can choose the cut-off. In what we call mechanistic classifiers, such as described in Martin-Davila et al. [2005], where the classifier is predicated first and foremost on an understood pathway, not naive correlation, the threshold has a physical dimension, and the choice of cut-off has a defined purpose in a physical system. Note that a logistic regression with a single explanatory variable can be made to fit such a schema. In fact, it might be possible to define a convex hull of the multiple explanatory variables to take the place of single-variable classifier in that schema. Also, some variables might be better at defining the threshold than others and this can also be examined. A convex hull defined by cut-off points in each explanatory variable might be envisaged to play the role of a kind of “syncretized" cut-off point. In such an instance, it would be relevant to assess the cross-correlations among the explanatory variables.

### *Conclusions*

We set out to determine a logistic regression model of mortality that could be used to describe mortality in the NFI data. This was the ultimate goal of the model. We investigated the possibility of calibrating this model on the permanent sample plot longitudinal data but found that we could improve the result be simply calibrating the parameters on the NFI data alone. In the absence of a mis-classification cost function we chose the cut-off for transforming predictions on the logit scale to the binary (dead, alive) scale based on the false positive rate (the rate at which the model predicted mortality incorrectly). Specifically, we chose the cut-off to keep this as small as reasonably possible.

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## J.2-B: Other modifications in the growth simulator

### Thinning/Harvest

We assume that all thinning occur randomly. Random thinning can be implemented on an individual plot level. The CARBWARE user sets a basal area (BA) to be removes as stipulated in the harvest activity data (in the '**Eventstable**') so thinning of trees are selected at random from the plot until this target BA is achieved. The thinned or harvested trees in a given plot are removed from the growth database and populated in a modifier table within the CarwKP_08 database. These data are then called up in the allocation module (Annex G2 and NIR section 11.2.3).

Although it is common practice that clear felled stands are replanted within 2 years, the CARBWARE model does no re-populate clear felled plots due to uncertainty of re-establishment success and species choice. This is a conservative approach and is consistent with the rules applied, which differentiate between deforestation and clear fell with re-establishment (NIR section 11.4.2)

# Annex K

# Standard Electronic Format (SEF) 2011

# 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: | 2012 |
| Reported year: | 2011 |
| Commitment period: | 1 |
| Completeness check: | YES |
| Consistency check: | YES |
| File locked: | YES |
| Lock timestamp: | 06/01/2012 11:13 |
| Submission version number: | 1 |
| Submission type: | Official |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

## Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

| Account type | Unit type | | | | | |
|---|---|---|---|---|---|---|
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| Party holding accounts | 253149685 | NO | NO | NO | NO | NO |
| Entity holding accounts | 21225739 | 722440 | NO | 6387753 | 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 | 490 | NO | NO | 2059 | NO | NO |
| Retirement account | 36660229 | NO | NO | 936835 | NO | NO |
| tCER replacement account for expiry | NO | NO | NO | NO | NO | |
| lCER replacement account for expiry | NO | NO | NO | NO | | |
| lCER replacement account for reversal of storage | NO | NO | NO | NO | | NO |
| lCER replacement account for non-submission of certification report | NO | NO | NO | NO | | NO |
| **Total** | 311036143 | 722440 | NO | 7326647 | NO | NO |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

## Table 2 (a). Annual internal transactions

| Transaction type | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Article 6 issuance and conversion** | | | | | | | | | | | | |
| Party-verified projects | | NO | | | | | NO | | NO | | | |
| Independently verifed projects | | NO | | | | | NO | | NO | | | |
| **Article 3.3 and 3.4 issuance or cancellation** | | | | | | | | | | | | |
| 3.3 Afforestation and reforestation | | | NO | | | | NO | NO | NO | NO | | |
| 3.3 Deforestation | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Forest management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Cropland management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Grazing land management | | | NO | | | | NO | NO | NO | NO | | |
| 3.4 Revegetation | | | NO | | | | NO | NO | NO | NO | | |
| **Article 12 afforestation and reforestation** | | | | | | | | | | | | |
| Replacement of expired tCERs | | | | | | | NO | NO | NO | NO | NO | |
| Replacement of expired lCERs | | | | | | | NO | NO | NO | NO | | |
| Replacement for reversal of storage | | | | | | | NO | NO | NO | NO | | NO |
| Replacement for non-submission of certification report | | | | | | | NO | NO | NO | NO | | NO |
| **Other cancellation** | | | | | | | 245 | NO | NO | NO | NO | NO |
| **Sub-total** | | NO | NO | | | | 245 | NO | NO | NO | NO | NO |

| Transaction type | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Retirement** | 16230638 | 394883 | NO | 730497 | NO | NO |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

Add registry Delete registry

## Table 2 (b). Annual external transactions

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Transfers and acquisitions** | | | | | | | | | | | | |
| AT | 10000 | NO | NO | NO | NO | NO | NO | NO | NO | 240493 | NO | NO |
| CZ | 800 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| FR | 248400 | NO | NO | 13361 | NO | NO | 1009361 | NO | NO | NO | NO | NO |
| DE | 93500 | NO | NO | 110550 | NO | NO | 1223215 | NO | NO | 313000 | NO | NO |
| IT | NO | NO | NO | NO | NO | NO | NO | NO | NO | 700000 | NO | NO |
| JP | NO | NO | NO | NO | NO | NO | NO | NO | NO | 2231370 | NO | NO |
| NL | 15000 | 2957 | NO | 1171898 | NO | NO | 17525 | NO | NO | NO | NO | NO |
| PT | 1470000 | NO | NO | NO | NO | NO | 25000 | NO | NO | 595000 | NO | NO |
| SK | 262500 | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| ES | 1221300 | NO | NO | 475000 | NO | NO | 497000 | NO | NO | 1013813 | NO | NO |
| SE | 71500 | NO | NO | 580607 | NO | NO | NO | NO | NO | NO | NO | NO |
| CH | NO | NO | NO | 1663889 | NO | NO | NO | NO | NO | 1631665 | NO | NO |
| GB | 2167581 | 234338 | NO | 9931683 | NO | NO | 15232152 | 435000 | NO | 3740189 | NO | NO |
| **Sub-total** | 5560581 | 237295 | NO | 13946988 | NO | NO | 18004253 | 435000 | NO | 10465530 | NO | NO |

### Additional information

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Independently verified ERUs | | | | | | | | NO | | | | |

## Table 2 (c). Total annual transactions

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total (Sum of tables 2a and 2b)** | 5560581 | 237295 | NO | 13946988 | NO | NO | 18004498 | 435000 | NO | 10465530 | NO | NO |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

## Table 3. Expiry, cancellation and replacement

| Transaction or event type | Expiry, cancellation and requirement to replace | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| **Temporary CERs (tCERS)** | | | | | | | | |
| Expired in retirement and replacement accounts | NO | | | | | | | |
| Replacement of expired tCERs | | | NO | NO | NO | NO | NO | |
| Expired in holding accounts | NO | | | | | | | |
| Cancellation of tCERs expired in holding accounts | NO | | | | | | | |
| **Long-term CERs (lCERs)** | | | | | | | | |
| Expired in retirement and replacement accounts | | NO | | | | | | |
| Replacement of expired lCERs | | | NO | NO | NO | NO | | |
| Expired in holding accounts | | NO | | | | | | |
| Cancellation of lCERs expired in holding accounts | | NO | | | | | | |
| Subject to replacement for reversal of storage | | NO | | | | | | |
| Replacement for reversal of storage | | | NO | NO | NO | NO | | NO |
| Subject to replacement for non-submission of certification report | | NO | | | | | | |
| Replacement for non-submission of certification report | | | NO | NO | NO | NO | | NO |
| **Total** | | | NO | NO | NO | NO | NO | NO |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

## Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

| Account type | Unit type | | | | | |
|---|---|---|---|---|---|---|
| | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| Party holding accounts | 231112024 | NO | NO | NO | NO | NO |
| Entity holding accounts | 14588845 | 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 | |
| lCER replacement account for expiry | NO | NO | NO | NO | | |
| lCER replacement account for reversal of storage | NO | NO | NO | NO | | NO |
| lCER replacement account for non-submission of certification report | NO | NO | NO | NO | | NO |
| **Total** | 298592471 | 524735 | NO | 10808105 | NO | NO |

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| **Starting values** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| Issuance pursuant to Article 3.7 and 3.8 | 314184272 | | | | | | | | | | | |
| Non-compliance cancellation | | | | | | | NO | NO | NO | NO | | |
| Carry-over | NO | NO | | NO | | | | | | | | |
| **Sub-total** | 314184272 | NO | | NO | | | NO | NO | NO | NO | | |
| **Annual transactions** | | | | | | | | | | | | |
| Year 0 (2007) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 1 (2008) | 2029090 | NO | NO | 3778980 | NO | NO | 1245569 | NO | NO | 108000 | NO | NO |
| Year 2 (2009) | 3237702 | NO | NO | 9285054 | NO | NO | 3269878 | NO | NO | 5762220 | NO | NO |
| Year 3 (2010) | 5439324 | 722440 | NO | 9241948 | NO | NO | 9339288 | NO | NO | 9111174 | NO | NO |
| Year 4 (2011) | 5560581 | 237295 | NO | 13946988 | NO | NO | 18004498 | 435000 | NO | 10465530 | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | 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 |
| **Sub-total** | 16266697 | 959735 | NO | 36252970 | NO | NO | 31859233 | 435000 | NO | 25446924 | NO | NO |
| **Total** | 330450969 | 959735 | NO | 36252970 | NO | NO | 31859233 | 435000 | NO | 25446924 | NO | NO |

**Table 5 (b). Summary information on replacement**

| | Requirement for replacement | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | **tCERs** | **lCERs** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| **Previous CPs** | | | NO | NO | NO | NO | NO | NO |
| Year 1 (2008) | | NO | NO | NO | NO | NO | NO | NO |
| Year 2 (2009) | | NO | NO | NO | NO | NO | NO | NO |
| Year 3 (2010) | | NO | NO | NO | NO | NO | NO | NO |
| Year 4 (2011) | | NO | NO | NO | NO | NO | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 6 (2013) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 7 (2014) | NO | NO | NO | NO | NO | NO | NO | NO |
| Year 8 (2015) | NO | NO | NO | NO | NO | NO | NO | NO |
| **Total** | NO | NO | NO | NO | NO | NO | NO | NO |

**Table 5 (c). Summary information on retirement**

| | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| **Year** | **AAUs** | **ERUs** | **RMUs** | **CERs** | **tCERs** | **lCERs** |
| Year 1 (2008) | NO | NO | NO | NO | NO | NO |
| Year 2 (2009) | 19668515 | NO | NO | 713192 | NO | NO |
| Year 3 (2010) | 16991714 | NO | NO | 223643 | NO | NO |
| Year 4 (2011) | 16230638 | 394883 | NO | 730497 | NO | NO |
| Year 5 (2012) | NO | NO | NO | NO | NO | NO |
| Year 6 (2013) | NO | NO | NO | NO | NO | NO |
| Year 7 (2014) | NO | NO | NO | NO | NO | NO |
| Year 8 (2015) | NO | NO | NO | NO | NO | NO |
| **Total** | 52890867 | 394883 | NO | 1667332 | NO | NO |

| | |
|---|---|
| Party | Ireland |
| Submission year | 2012 |
| Reported year | 2011 |
| Commitment period | 1 |

Add transaction | Delete transaction | No corrective transaction

**Table 6 (a). Memo item: Corrective transactions relating to additions and subtractions**

| | Additions | | | | | | Subtractions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit type | | | | | | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | | | | | | | |

Add transaction | Delete transaction | No corrective transaction

**Table 6 (b). Memo item: Corrective transactions relating to replacement**

| | Requirement for replacement | | Replacement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unit type | | Unit type | | | | | |
| | tCERs | lCERs | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | | | |

Add transaction | Delete transaction | No corrective transaction

**Table 6 (c). Memo item: Corrective transactions relating to retirement**

| | Retirement | | | | | |
|---|---|---|---|---|---|---|
| | Unit type | | | | | |
| | AAUs | ERUs | RMUs | CERs | tCERs | lCERs |
| | | | | | | |

# Appendix 1
# Standard Independent Assessment Report
# (Electronic Appendix)