IRELAND

NATIONAL INVENTORY REPORT 2011

GREENHOUSE GAS EMISSIONS 1990 - 2009
REPORTED TO THE UNITED NATIONS
FRAMEWORK CONVENTION
ON CLIMATE CHANGE

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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.

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EXECUTIVE SUMMARY

ES.1 Background

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 ongoing technical review of submissions from Annex I Parties.

The present report constitutes Irelands NIR for 2011 and refers to the inventory time-series for the years 1990-2009 under the Convention. Ireland's submission under the UNFCCC in 2011 is also its submission under the Kyoto Protocol, with 2009 being the second 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 ongoing improvements, in addition to the 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). 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 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 and 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 2011 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 as they address the challenges to comply with Ireland's commitments under the Kyoto Protocol. 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, the preparation of the Government's annual carbon budget 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 percent above base year emissions. The baseline emissions total for Ireland is calculated as the sum of CO_2, CH_4 and N_2O emissions in 1990 and the contribution from fluorinated gases in 1995. The baseline value was established at 55.607 Mt CO_2eq and results in total allowable emissions of 314.184272 Mt CO_2eq in the commitment period, which equates to the average of 62.837 Mt CO_2eq per annum. This value remains fixed for the commitment period even though methodological improvements may change the estimates of emissions in the base year. Compliance with the Kyoto Protocol limit is achieved by ensuring that Ireland's total emissions in the period 2008-2012, adjusted for any offsets from activities under Article 3.3 and the surrender of any purchased Kyoto Protocol credits, are below 314.184272 Mt CO_2eq at the end of the five-year period.

ES.2 Emissions Trends and Key Categories

In 2009, total emissions of greenhouse gases (excluding the *LULUCF* sector) in Ireland were 62,368.67 Gigagrams (Gg) CO_2 equivalent, which is 13.8 percent higher than emissions in 1990. The total for 2009 is 10.5 percent lower than the level of 69,671.57 Gg CO_2 equivalent in 2001 when emissions reached a maximum following a period of unprecedented economic growth. The *Energy* sector accounted for 66.5 percent of total emissions in 2009, *Agriculture* contributed 28.0 percent while a further 3.4 percent emanated from *Industrial Processes* and 2.0 percent was due to *Waste*. Emissions of CO_2 accounted for 68.0 percent of the national total in 2009, with CH_4 and N_2O contributing 19.5 percent and 11.5 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for 1.0 percent of total emissions in 2009.

Tier 1 level assessment of emission source categories (ranking on the basis of their contribution to total emissions) taken at the level at which they could be targeted on an individual basis identified 23 key categories in 2009 (excluding the *LULUCF* sector). There were 14 key categories of CO_2, accounting for 67.0 percent of total emissions. There were five key categories of CH_4, three key categories of N_2O and 1 key category of HFC in level assessment, which accounted for 17.4 percent, 10.1 percent and 0.8 percent 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 23 key categories identified by level assessment in 2009 and for two-thirds (64.9) percent of total emissions. The top ten key categories contributed 73.3 percent of total emissions in 2009 with emissions of CO_2 from the combustion of petrol and diesel by road traffic being the single largest source, accounting for 20.2 percent 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 6.2 percent in the 2009 inventory (excluding the LULUCF sector) and a trend uncertainty of 3.0 percent for the period 1990 to 2009. 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 68 percent of emissions contributed by CO_2 are estimated to have an uncertainty of 1.2 percent. Emissions of N_2O from the agriculture sector account for over 94 percent of the level uncertainty in the 2009 inventory. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2009 is negligible (0.2 percent) because they account for only 1 percent of total emissions.

Ireland has reported net greenhouse gas removals amounting to 5,564.19 Gg CO_2 eq. for 2008 and 2009 under Article 3.3 of the Kyoto Protocol in respect of 271.38 ha of lands subject to afforestation since 1990 while there were net emissions of 59.35 Gg CO_2 for a deforested area of 8.12 ha for the same 2 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 2009. 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 2011 submission and the latest inventories for the years 1990-2009 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 2009. The largest increase took place in transport with an increase of 155.5 percent on 1990 levels, while there were increases of 15.1 percent and 14.8 percent 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 9.2 percent below 1990 levels in 2009. As the emissions from energy increased, the contribution of agriculture to the total decreased from 35.1 percent in 1990 to 28.0 percent in 2009. 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 1990-2009 are included in the submission.

The emissions of most of the indirect gases have decreased substantially in the period 1990-2009 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 2009 in Ireland are of the order of 82.2 percent in the case of SO_2, 62.8 percent for CO and 40.8 percent for NMVOC and 28.9 percent for NO_X.

PART I

ANNUAL INVENTORY SUBMISSION 2011

Chapter One

Introduction

1.1 Background and Context

1.1.1 Reporting Requirements under the UNFCCC

Under Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), hereafter referred to as the Convention, Annex I Parties must 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 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 needed by expert review teams to assess the transparency, completeness and overall quality of the inventories as part of the ongoing review process for the submissions from Annex I Parties.

The present report constitutes Irelands NIR for 2011 and refers to the inventory time-series for the years 1990-2009 under the Convention. Ireland's submission under the UNFCCC in 2011 is also its submission under the Kyoto Protocol, with 2009 being the second 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 ongoing improvements, in addition to the 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). 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. 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. This NIR is designed to capture the cyclical nature of the reporting process and to clarify 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, the preparation of the Government's annual carbon budget 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.

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 ongoing 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 2011 is also its submission under the Kyoto Protocol.

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

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. 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 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

The reporting of greenhouse gas emissions under the Convention is done with reference to the 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 CRF and it assigns all potential sources of emission and removals making up 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 is extended to accommodate the reporting of emissions and removals under Articles 3.3 and 3.4 of the Kyoto Protocol 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. Much reference is made throughout this report to the IPCC reporting format when describing source category coverage, methods, emissions and key categories. 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

Under Section 52 of the Environmental Protection Agency Act of 1992 (DOE, 1992), 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 55 of 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. 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 Heritage and Local Government (DEHLG) 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 Agency's Office of Climate, Licensing and Resource Use (OCLR) currently compiles the national greenhouse gas emission inventories on behalf of DEHLG for submission 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.

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. Established institutional arrangements directed towards national inventory reporting and involving the EPA, DEHLG and other stakeholders are reorganised, extended and legally consolidated across all participating institutions to strengthen inventory capacity within the EPA, ensuring that more formal and comprehensive mechanisms of data collection and processing are established and maintained for long term implementation. 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 stipulating 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 obtains considerable supplementary information from other teams in OCLR and the Office of Environmental Enforcement within the EPA. These sources include Annual Environmental Reports (AER) submitted by licensed companies and the National Waste Database. 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 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 (CCER) 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 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 Emissions Trading Unit (ETU) in the Climate Change and Environmental Research Unit (CCER) forms part of OCLR and is a key component of the national system. Information submitted by participants in the European Union Emissions Trading Scheme (ETS) under Directive 2003/87/EC (EP and CEU, 2003) is managed by the ETU and is available to the inventory team in OCLR. 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 17,215 Gg in 2009, accounting for 27.6 percent of total greenhouse gas emissions. 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 formal mechanisms together with the QA/QC procedures are fully operational since becoming established in the 2007 reporting cycle. The EPA Office of Climate, Licensing and Resource Use is the inventory agency and the EPA is also designated as the single national entity with overall responsibility for the annual greenhouse gas inventory. 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. As a formal management system, the national system aims for continuous improvement to increase the quality and robustness of the national atmospheric inventory over time.

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, Fisheries and Food	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
COFORD (National Forest Research Institute)	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 (II) NFI database	30 September 2007, 2012	LULUCF and Article 3.3 activities
**Coillte	GIS data base of intersected of NFI permanent sample plot points (Coillte-NFI plots) with sub-compartment and management unit data.	30 September	LULUCF and Article 3.3 activities

[1]ETS – Emissions Trading Scheme
*These bodies have MOUs with SEI rather than with OCLR
**These bodies have MOUs with COFORD rather than with OCLR

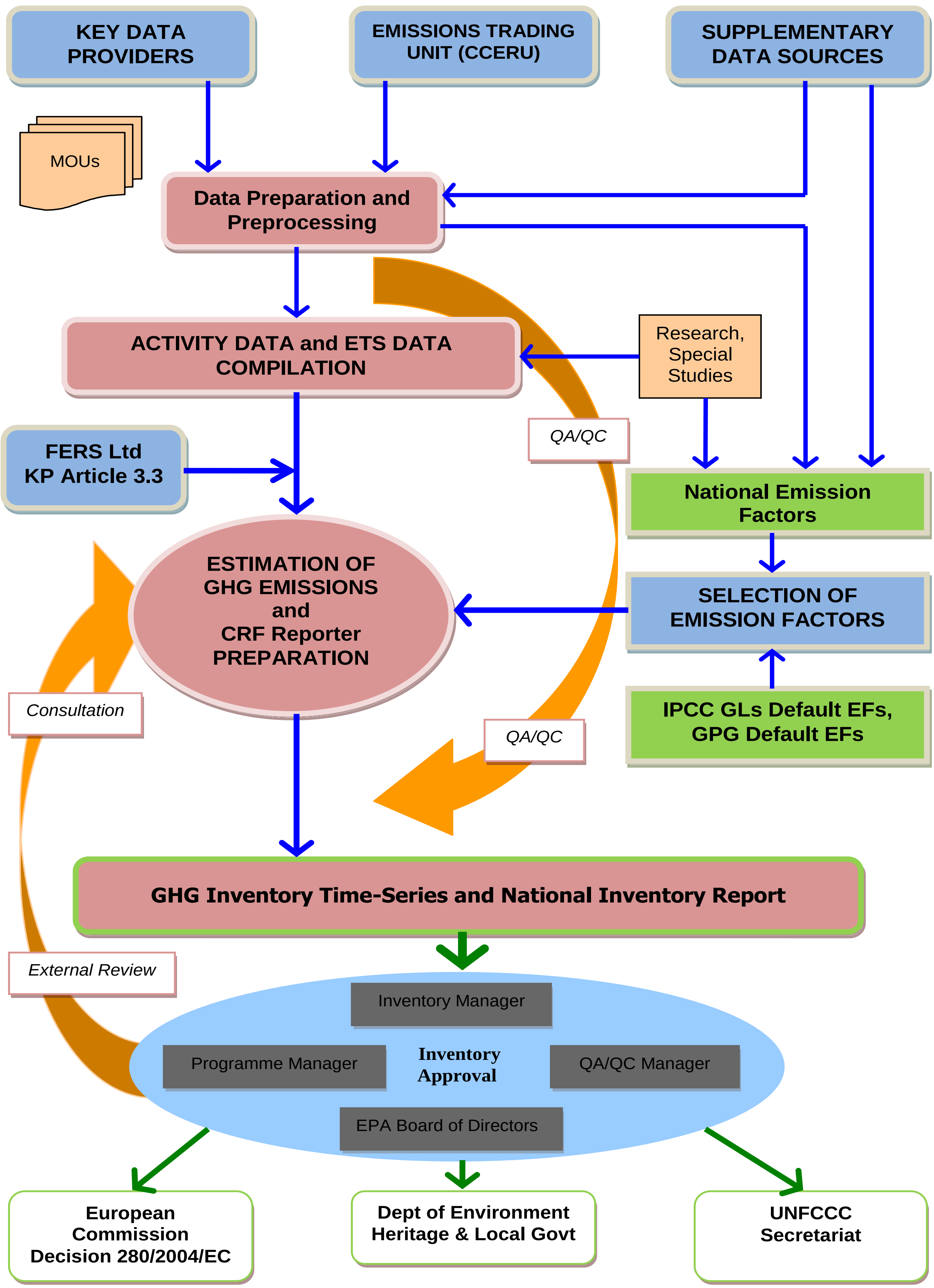


Figure 1.1. National Inventory System Overview

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 through the April submission to the UNFCCC secretariat. Planning largely involves the internal identification of improvements to be undertaken by way of revised methodologies and updated activity data or emission factors and 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, which are not handled by the OCLR inventory team and for which new information is becoming available on a continuous basis 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. The target date for the first release of the latest annual inventory at national level is Autumn of the following year.

1.2.3 Overview of Inventory Preparation and Management

The OCLR of the EPA performs the role of inventory agency and prepares the GHG inventory for all IPCC sectors except LULUCF through the system described above and using the data sources listed in Table 1.1. 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 COFORD, the Council for Forest Research and Development, and are delivered to the inventory agency under a Memorandum of Understanding between COFORD 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 COFORD and the research fellows include the completed CRF tables and draft NIR sections for their respective areas of responsibility.

This first version of the latest annual inventory produced in Autumn of the following year is then 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 consequent on the receipt of updated or outstanding information nationally, accounting for any observations or amendments following initial assessment at EU level of the 15 January submission by Member States to the European Commission and the completion of the National Inventory Report in order to comply with the 15 March deadline for the delivery of the complete and final inventory submission 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, which 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. 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.

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.

The transparency, robustness and accessibility of the data within the electronic filing structures were assessed in 2010 by Aether, an external consultant. The system was found to be very well organised.

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. 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. 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, the General Soil Map of Ireland, which are supported by statistical information from Bord na Mona and the National Roads Authority.

The static national model, CARBWARE, used for many years to estimate emissions and removals for forest lands for Convention reporting has been extensively developed to a dynamic version to provide the necessary estimates for Article 3.3 activities under the Kyoto Protocol. This work has been undertaken by FERs, the consultants working to COFORD, which supplies the Article 3.3 results to OCLR under an agreed MOU (Table 1.1). Secondary MOUs between COFORD 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 and FIPS and soils maps, supported by the Grants and Premiums Administration System (GPAS) and felling license records, using complex pre-processing functions, growth models, allometric equations and pool allocation and transfers to produce the results required for Article 3.3 activities.

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 in emission inventories 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 to the QA/QC system and guidance on the application of the plan and procedures. 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 so that the international requirements under the Kyoto Protocol and Decision 280/2004/EC are met. The manual provides guidance and templates for appropriate quality checking, documentation and traceability, the selection of source data and calculation methodologies and peer and expert review of inventory data and outlines the annual requirements for continuous improvement for the inventory.

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 1990-2009. More than 80 percent 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. 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 and 1.A.4, 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.

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.

Ireland relies on the simplified IPCC Tier 1 methodologies and default emission factors available 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.

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.

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 2009 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 being developed in Ireland during the 1990s, it was quickly established that CO_2 emissions from fuel combustion made by far the largest contribution 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 good first 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 and those for 1990 and 2009 are shown in Table 1.4 and Table 1.5, respectively. It can be seen that there are six highly significant key categories of emissions in Ireland in 2009. They are the CO_2 combustion sources *in 1.A.3 Transport, 1.A.1 Energy Industries, 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 categories accounted for 85.3 percent and 89.5 percent of total emissions in 1990 and 2009, respectively. In the case of 2009 emissions, two additional Level 2 source categories are needed to reach the cumulative 95 percent threshold that defines a key category. The increase in the contribution of CO_2 emissions from category *1.A.3 Transport* from 9.2 percent in 1990 to 20.8 percent in 2009 is notable, along with the corresponding reductions in the contributions from the two categories 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, the CO_2 removals in 5.A Forest Land become a key category in 1990 and 2009.

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	20.36	20.36
1.A.4	Other Sectors(Comm/Resid/Agric)	CO2	10,052.71	18.34	38.71
4.A	Enteric Fermentation	CH4	9,493.58	17.32	56.03
4.D.	Agricultural Soils	N2O	7,061.91	12.89	68.92
1.A.3	Transport	CO2	5,039.39	9.20	78.11
1.A.2.	Manufacturing Industries and	CO2	3,943.24	7.20	85.31
4.B	Manure Management	CH4	2,331.21	4.25	89.56
6.A	Solid Waste Disposal on land	CH4	1,173.05	2.14	91.70
2.B.2	Nitric Acid Production	N2O	1,035.40	1.89	93.59
2.B.1	Ammonia Production	CO2	990.23	1.81	95.40

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

Table 1.3. Key Categories at IPCC Level 2 in 2009

IPCC Level 2	Source Category	GHG	Emissions in 2009 Gg CO_2 eq	2009 Level Assessment %	Cumulative Total of Level %
1.A.3	Transport	CO2	12,976.90	20.81	20.81
1.A.1.	Energy Industries	CO2	12,926.12	20.73	41.53
1.A.4	Other Sectors(Comm/Resid/Agric)	CO2	10,428.42	16.72	58.25
4.A	Enteric Fermentation	CH4	8,679.83	13.92	72.17
4.D.	Agricultural Soils	N2O	6,286.89	10.08	82.25
1.A.2.	Manufacturing Industries and	CO2	4,525.21	7.26	89.51
4.B	Manure Management	CH4	2,133.72	3.42	92.93
2.A.1	Cement Production	CO2	1,326.78	2.13	95.05

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, T3	T1, 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	T1, 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	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	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	CS: Country specific
T2: IPCC Tier 2 or equivalent	CR: CORINAIR
T3: IPCC Tier 3 or equivalent	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	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 methods 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, which 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 2009 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. There is insufficient information available on uncertainties to allow for analysis using the Tier 2 methods. Results for Tier 1 trend assessment for 2009 are shown in Table 1.8.

The results of the level assessment for 2009 excluding LULUCF categories may be summarised as follows:

- (i) level assessment identifies 23 key categories;
- (ii) there are 14 key categories of CO_2 in level assessment, accounting for 67.0 percent of total emissions;
- (iii) there are five key categories of CH_4 and three key categories of N_2O in level assessment, which account for 17.4 percent and 10.1 percent, respectively, of total emissions;
- (iv) *Energy* accounts for 13 key categories, *Agriculture* for seven while *Industrial Processes* contributes two and *Waste* contributes one;
- (v) trend assessment identifies 22 key categories, all of which are key categories for level assessment;
- (vi) there are 13 key categories of CO_2 in trend assessment, accounting for 80.3 percent of the total trend;
- (vii) there are five key categories of CH_4 and three key categories of N_2O in trend assessment, which account for 8.4 percent and 5.4 percent, respectively, of the total trend.

The list of key categories given by level assessment in 2009 is very similar to that for 1990 but 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 2009. The top ten key categories contributed 70.3 and 73.3 percent, of total emissions in 1990 and 2009, respectively. The emissions of CO_2 from fuel combustion in *1.A.1 Energy Industries* and from the use of petrol and diesel by road traffic (1.A.3.b) were the largest source categories of greenhouse gas emissions in Ireland in 2009, accounting for 20.7 and 20.2 percent of the total, respectively. The CO_2 removals in category *5.A.1 Forest Land Remaining Forest Land* and the CO_2 emissions in *5.C.1 Grassland Remaining Grassland* 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 2009 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 percent of the total inventory uncertainty and that 95 percent 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 percent 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 excluding LULUCF indicate that 15 of the 25 key categories in 2009 each accounted for less than 3 percent of the total emissions and that only five key categories contributed more than 5 percent 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 60.6 percent of total emissions in 2009. 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 15 in Table 1.7), making up a further 14.0 percent 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 used the 2006 reporting cycle to begin implementation of the new approach to QA/QC developed for the national system and its application was completed and consolidated in delivering the submissions up to 2009. 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 2011 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 Agriculture was performed by a technical inspector in the Department of Agriculture, Fisheries and Food using the new calculation files with a view to assessing the consistency of the time series which had been subject to considerable improvement and recalculation in the 2006 reporting cycle to account for higher tier methods for enteric fermentation in cattle and advice from the Department on various aspects of input data and calculation parameters. As there have been no further changes to the methodologies in agriculture the detailed external review has not been repeated. However, the inventory agency continues to work closely with the Department and seeks advice and guidance from experts in Teagasc, an Agency of the Department of Agriculture, Fisheries and Food, who developed the improved methods in relation to technical inventory matters that may arise. The ETS returns to the Agency's Office of Climate, Licensing and Resource Use (OCLR) provide for the complete coverage of CO_2 estimates for 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 ongoing 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.

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 2009 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 2009 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 and 1.A.3, as shown on Table 1.9. Slightly higher uncertainty levels are used for energy activity data in sub-categories under 1.A.2 and 1.A.4, 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 percent 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 percent 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 percent. Following the opinion of national agriculture experts, a value of 15 percent has been adopted for these emissions considering that Ireland's Tier 2 method is very detailed and uses 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 percent and 10 percent 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 2009 inventory under the Convention (Table 1.9) gives an overall uncertainty of 7.8 percent in total emissions and a trend uncertainty of 4.4 percent for the period 1990 to 2009. These relatively low estimates are determined largely by the low uncertainties in the estimate of CO_2 emissions, which accounts for 67 percent of total Irish emissions in 2009 and which are estimated to have a level uncertainty of 4.5 percent. When CH_4 is included, bringing the proportion of total emissions up to 87 percent, the total uncertainty estimate is 4.9 percent, 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 2009 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 percent of total emissions in Ireland.

The overall uncertainly of the inventory in 2009 is estimated at 7.8 percent which is showing an increasing trend over the last number of years. The corresponding values in 2008 and 2007 were 6.4 and 5.95 percent, respectively. The reason for the increase from 2007 to 2008 is due to applying a consistent disaggregation within the uncertainty analysis for CO_2 emissions from fuel combustion and including emissions of CH_4 and N_2O in the sectors *Energy Industries, Manufacturing Industries and Construction, Transport and Other*. Whereas the reason for the increase in uncertainty between 2008 and 2009 is for the most part due to increased uncertainty in the LULUCF sector as a result of a larger differential between 1990 and 2009 emissions as reported in this submission compared to the differential between 1990 and 2008 as reported in the previous NIR. The overall trend uncertainty decreased in 2009 when compared to 2008 to a value of 4.44 percent compared to 4.74 percent.

The overall uncertainty estimate for Article 3.3 activities in 2009 is 23.2 percent, which is determined largely by an uncertainty of 22.7 percent 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 2009 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 1990-2008 to bring them fully into line with that for 2009, 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 Column J %
1	1.A.1.	Energy Industries - Solid Fuels	CO2	8009.44		8009.44	14.10	14.10
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94		5606.94	9.87	23.96
3	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH4	5546.60		5546.60	9.76	33.72
4	1.A.3.b.	Road Transport - Liquid Fuels	CO2	4700.93		4700.93	8.27	42.00
5	4.D.2.	Agricultural Soils - Pasture, Range & Paddock	N2O	2908.95		2908.95	5.12	47.12
6	4.A.1.	Enteric Fermentation - Dairy Cattle	CH4	2875.65		2875.65	5.06	52.18
7	4.D.1.	Agricultural Soils - Direct Soil Emissions	N2O	2819.95		2819.95	4.96	57.14
8	1.A.2.	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.87		2198.87	3.87	61.01
9	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO2	1976.61		1976.61	3.48	64.49
10	1.A.1.	Energy Industries - Gaseous Fuels	CO2	1880.66		1880.66	3.31	67.80
11	4.D.3.	Agricultural Soils - Indirect Emissions	N2O	1333.01		1333.01	2.35	70.14
12	1.A.1.	Energy Industries - Liquid Fuels	CO2	1268.51		1268.51	2.23	72.38
13	4.B.1.	Manure Management - Non-Dairy cattle	CH4	1261.42		1261.42	2.22	74.60
14	1.A.4.b	Residential - Liquid Fuels	CO2	1177.48		1177.48	2.07	76.67
15	6.A.	Waste - Solid Waste Disposal on land	CH4	1173.05		1173.05	2.06	78.73
16	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2		-1165.11	1165.11	2.05	80.78
17	2.B.	Chemical Industry	N2O	1035.40		1035.40	1.82	82.60
18	4.A.3.	Enteric Fermentation - Sheep	CH4	1032.48		1032.48	1.82	84.42
19	2.B.	Chemical Industry	CO2	990.23		990.23	1.74	86.16
20	2.A.1.	Cement Production	CO2	884.00		884.00	1.56	87.72
21	1.A.2.	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.14		873.14	1.54	89.26
22	1.A.2.	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24		871.24	1.53	90.79
23	1.A.4.c.	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	660.30		660.30	1.16	91.95
24	5.C.1	LULUCF - Grassland Remaining Grassland	CO2		621.96	621.96	1.09	93.05
25	4.B.1.	Manure Management - Dairy Cattle	CH4	612.63		612.63	1.08	94.12
26	1.A.4.b	Residential - Solid Fuels	CH4	356.29		356.29	0.63	94.75
27	4.B.8.	Manure Management - Pigs	CH4	323.83		323.83	0.57	95.32

Table 1.7. Key Category Level Assessment 2009

2009 Rank	IPCC Sub-Category	Emission Source/Activity	Direct GHG	2009 Estimate Emission exclud. LULUCF Gg CO2 eq	2009 Estimate LULUCF Gg CO2 eq	2009 Estimate Absolute Value Gg CO2 eq	2009 Level Assessment with LULUCF %	Cumulative Total %
1	1.A.3.b.	Road Transport - Liquid Fuels	CO2	12601.61		12601.61	18.85	18.85
2	1.A.1.	Energy Industries - Gaseous Fuels	CO2	6020.33		6020.33	9.01	27.86
3	1.A.1.	Energy Industries - Solid Fuels	CO2	5910.47		5910.47	8.84	36.70
4	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH4	5541.73		5541.73	8.29	44.99
5	1.A.4.b	Residential - Liquid Fuels	CO2	3634.97		3634.97	5.44	50.43
6	5.A.1	LULUCF - Forest land Remaining Forest Land	CO2		-2988.58	2988.58	4.47	54.90
7	4.D.2.	Agricultural Soils - Pasture, Range & Paddock	N2O	2718.65		2718.65	4.07	58.97
8	4.A.1.	Enteric Fermentation - Dairy Cattle	CH4	2494.66		2494.66	3.73	62.70
9	4.D.1.	Agricultural Soils - Direct Soil Emissions	N2O	2342.03		2342.03	3.50	66.20
10	1.A.2.	Manufacturing Industries & Construction - Liquid Fuels	CO2	2240.26		2240.26	3.35	69.55
11	1.A.4.b	Residential - Solid Fuels	CO2	2190.05		2190.05	3.28	72.83
12	1.A.2.	Manufacturing Industries & Construction - Gaseous Fuels	CO2	1810.27		1810.27	2.71	75.54
13	1.A.4.b	Residential - Gaseous Fuels	CO2	1491.41		1491.41	2.23	77.77
14	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO2	1414.57		1414.57	2.12	79.88
15	2.A.1.	Cement Production	CO2	1326.78		1326.78	1.98	81.87
16	4.D.3.	Agricultural Soils - Indirect Emissions	N2O	1226.22		1226.22	1.83	83.70
17	4.B.1.	Manure Management - Non-Dairy Cattle	CH4	1132.81		1132.81	1.69	85.40
18	6.A.	Waste - Solid Waste Disposal on land	CH4	1081.98		1081.98	1.62	87.02
19	1.A.4.a.	Commercial/Institutional - Gaseous Fuels	CO2	1048.31		1048.31	1.57	88.58
20	1.A.1.	Energy Industries - Liquid Fuels	CO2	995.32		995.32	1.49	90.07
21	1.A.4.c.	Agriculture/Forestry/Fisheries - Liquid Fuels	CO2	649.11		649.11	0.97	91.04
22	4.A.3.	Enteric Fermentation - Sheep	CH4	588.89		588.89	0.88	91.93
23	5.C.1	LULUCF - Grassland Remaining Grassland	CO2		535.16	535.16	0.80	92.73
24	2.F.	Consumption of F Gas & SF6	HFC	500.92		500.92	0.75	93.48
25	1.A.2.	Manufacturing Industries & Construction - Solid Fuels	CO2	474.67		474.67	0.71	94.19
26	4.B.1.	Manure Management - Dairy Cattle	CH4	473.57		473.57	0.71	94.89
27	4.B.8.	Manure Management - Pigs	CH4	404.99		404.99	0.61	95.50

Table 1.8. Key Category Trend Assessment 2009 (excluding LULUCF)

Rank	IPCC Sub-Category	Emission Source/Activity	Direct GHG	1990 Emissions exc LULUCF Gg CO2 eq	2009 Emissions exc LULUCF Gg CO2 eq	2009 Level Assessment %	2009 Trend Assessment	Contribution to Trend %	Cumulative Total Contribution %
1	1.A.3.b.	Road Transport - Liquid Fuels	CO2	4700.93	12601.61	20.21	10.22	22.39	22.39
2	1.A.4.b	Residential - Solid Fuels	CO2	5606.94	2190.05	3.51	5.90	12.94	35.34
3	1.A.1.	Energy Industries - Gaseous Fuels	CO2	1880.66	6020.33	9.65	5.47	11.98	47.32
4	1.A.1.	Energy Industries - Solid Fuels	CO2	8009.44	5910.47	9.48	4.52	9.90	57.22
5	1.A.4.b	Residential - Liquid Fuels	CO2	1177.48	3634.97	5.83	3.23	7.09	64.31
6	1.A.4.b	Residential - Gaseous Fuels	CO2	269.73	1491.41	2.39	1.67	3.66	67.96
7	4.D.1.	Agricultural Soils - Direct Soil Emissions	N2O	2819.95	2342.03	3.76	1.22	2.68	70.64
8	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO2	1976.61	1414.57	2.27	1.18	2.58	73.22
9	1.A.2.	Manufacturing Industries & Construction - Gaseous Fuels	CO2	873.14	1810.27	2.90	1.15	2.52	75.74
10	1.A.4.a.	Commercial/Institutional - Gaseous Fuels	CO2	223.37	1048.31	1.68	1.12	2.45	78.19
11	4.A.1.	Enteric Fermentation - Dairy Cattle	CH4	2875.65	2494.66	4.00	1.10	2.40	80.60
12	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH4	5546.60	5541.73	8.89	1.09	2.38	82.98
13	4.D.2.	Agricultural Soils - Pasture, Range & Paddock	N2O	2908.95	2718.65	4.36	0.83	1.83	84.81
14	4.A.3.	Enteric Fermentation - Sheep	CH4	1032.48	588.89	0.94	0.83	1.81	86.62
15	1.A.2.	Manufacturing Industries & Construction - Solid Fuels	CO2	871.24	474.67	0.76	0.73	1.60	88.21
16	2.F.	Consumption of F Gas & SF6	HFC	0.69	500.92	0.80	0.70	1.54	89.76
17	1.A.1.	Energy Industries - Liquid Fuels	CO2	1268.51	995.32	1.60	0.63	1.38	91.14
18	2.A.1.	Cement Production	CO2	884.00	1326.78	2.13	0.45	0.99	92.13
19	4.B.1.	Manure Management - Non-Dairy cattle	CH4	1261.42	1132.81	1.82	0.43	0.94	93.07
20	4.D.3.	Agricultural Soils - Indirect Emissions	N2O	1333.01	1226.22	1.97	0.41	0.90	93.97
21	1.A.4.b	Residential - Solid Fuels	CH4	356.29	139.36	0.22	0.37	0.82	94.79
22	1.A.2.	Manufacturing Industries & Construction - Liquid Fuels	CO2	2198.87	2240.26	3.59	0.37	0.81	95.60

Table 1.9 Tier 1 Uncertainty Estimates 2009 (continued on following pages)

IPCC Source Category		Gas	Emissions in 1990	Emissions in 2009	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2009	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_2eq	**Gg CO_2eq**	**%**	**%**	**%**	**%**		**%**	**%**	**%**	**%**	**%**	
1A1	Energy-Liquid	CO2	1268.511	995.318	1.0	2.5	2.69	0.04	0.00	-0.01	0.02	0.03	-0.02	0.03	0.00
1A1	Energy-Solid	CO2	8009.444	5910.469	1.0	5.0	5.10	0.50	0.23	-0.05	0.11	0.15	-0.27	0.31	0.10
1A1	Energy-Gas	CO2	1880.660	6020.329	1.0	2.5	2.69	0.27	0.07	0.07	0.11	0.16	0.18	0.24	0.06
1A2	Industry-Liquid exc Pet Coke	CO2	2198.825	2240.211	10.0	2.5	10.31	0.38	0.14	0.00	0.04	0.58	-0.01	0.58	0.34
1A2	Industry-Coal	CO2	871.235	445.378	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	CO2	0.042	0.050	5.0	5.0	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A2	Industry-Gas	CO2	873.141	1810.271	2.5	2.5	3.54	0.11	0.01	0.02	0.03	0.12	0.04	0.12	0.02
1A3	Transport-Oil	CO2	4977.350	12826.345	1.0	2.5	2.69	0.57	0.31	0.13	0.24	0.33	0.34	0.47	0.23
1A3	Transport-Gas	CO2	62.043	150.559	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	CO2	1976.608	1414.567	10.0	5.0	11.18	0.26	0.06	-0.01	0.03	0.37	-0.07	0.38	0.14
1A4	Comm-Coal	CO2	2.556	0.000	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	CO2	135.732	0.000	10.0	20.0	22.36	0.00	0.00	0.00	0.00	0.00	-0.06	0.06	0.00
1A4	Comm-Gas	CO2	223.370	1048.312	2.5	2.5	3.54	0.06	0.00	0.01	0.02	0.07	0.04	0.08	0.01
1A4	Res-Liquid	CO2	1101.795	3531.459	10.0	5.0	11.18	0.66	0.40	0.04	0.07	0.92	0.21	0.95	0.89
1A4	Res-Coal	CO2	2483.566	1029.192	5.0	10.0	11.18	0.19	0.03	-0.03	0.02	0.13	-0.32	0.35	0.12
1A4	Res-Petcoke	CO2	75.684	103.509	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	CO2	3123.373	1160.860	10.0	20.0	22.36	0.43	0.17	-0.04	0.02	0.30	-0.85	0.90	0.81
1A4	Res-Gas	CO2	269.730	1491.410	2.5	2.5	3.54	0.09	0.01	0.02	0.03	0.10	0.05	0.11	0.01
1A4	Agric Liquid	CO2	660.295	649.108	10.0	5.0	11.18	0.12	0.01	0.00	0.01	0.17	-0.01	0.17	0.03
2A1	Cement Production	CO2	884.000	1326.776	1.5	1.5	2.12	0.05	0.00	0.01	0.02	0.05	0.01	0.05	0.00
2A2	Lime Production	CO2	214.077	156.404	5.0	5.0	7.07	0.02	0.00	0.00	0.00	0.02	-0.01	0.02	0.00
2A3	Limestone and Dolomite Use	CO2	0.151	1.540	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	CO2	0.097	0.054	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	CO2	13.325	0.017	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	CO2	5.075	0.531	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	CO2	990.233	0.000	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	CO2	80.028	71.797	30.0	5.0	30.41	0.04	0.00	0.00	0.00	0.06	0.00	0.06	0.00
	LULUCF exc Liming	CO2	-935.336	-2522.836	30.0	100.0	104.40	-4.38	19.17	-0.03	-0.05	-1.97	-2.74	3.38	11.40
	LULUCF Liming	CO2	355.036	307.322	5.0	5.0	7.07	0.04	0.00	0.00	0.01	0.04	-0.01	0.04	0.00
	Total CO2		**31800.646**	**40168.952**	**0.67**			**4.54**	**20.63**					**3.77**	**14.18**

IPCC Source Category		Gas	Emissions in 1990	Emissions in 2009	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2009	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_2eq	**Gg CO_2eq**	**%**	**%**	**%**	**%**		**%**	**%**	**%**	**%**	**%**	
1A1	Energy-Liquid	CH4	0.326	0.290	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	CH4	2.360	2.078	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	CH4	2.879	4.201	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	CH4	0.000	0.000	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	CH4	1.728	1.767	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	CH4	0.000	0.000	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	CH4	1.934	0.984	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	CH4	36.166	20.621	1.0	50.0	50.01	0.02	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
1A3	Transport-Gas	CH4	0.119	0.277	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	CH4	5.586	4.023	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	CH4	0.006	0.000	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	CH4	0.281	0.000	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	CH4	0.427	1.930	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	CH4	2.954	10.151	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	CH4	165.065	67.696	5.0	50.0	50.25	0.06	0.00	0.00	0.00	0.01	-0.11	0.11	0.01
1A4	Res-Petcoke	CH4	0.170	0.232	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	CH4	191.225	71.666	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	CH4	0.516	2.746	2.5	50.0	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4	Agric Liquid	CH4	0.896	0.881	10.0	50.0	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Biomass	CH4	12.119	12.041	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	CH4	131.262	35.390	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	CH4	2875.646	2494.665	1.0	15.0	15.03	0.62	0.39	-0.01	0.05	0.07	-0.19	0.20	0.04
4A	Ent Ferm Other Cattle	CH4	5546.601	5541.732	1.0	15.0	15.03	1.38	1.92	-0.01	0.10	0.14	-0.17	0.22	0.05
4A	Ent Ferm Other Livestock	CH4	1071.336	643.433	1.0	30.0	30.02	0.32	0.10	-0.01	0.01	0.02	-0.30	0.30	0.09
4B	Manure Mgt Dairy Cattle	CH4	612.627	473.566	1.0	15.0	15.03	0.12	0.01	0.00	0.01	0.01	-0.06	0.06	0.00
4B	Manure Mgt Other Cattle	CH4	1261.422	1132.809	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	CH4	457.158	527.350	1.0	30.0	30.02	0.26	0.07	0.00	0.01	0.01	0.01	0.02	0.00
5	LULUCF	CH4	1.124	0.394	30.0	70.0	76.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6A	Solid Wasteabc	CH4	1173.049	1081.982	34.6	34.6	48.99	0.88	0.78	0.00	0.02	0.98	-0.14	0.99	0.97
6B	Wastewater Handling	CH4	14.728	15.733	10.0	30.0	31.62	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total CH4		**13569.707**	**12148.637**				**1.83**	**3.36**					**1.09**	**1.20**
	Cumulative CO2 and CH4		**45370.354**	**52317.589**	**0.87**			**4.90**	**23.99**					**3.92**	**15.37**

	IPCC Source Category	Gas	Emissions in 1990	Emissions in 2009	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2009	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_2eq	**Gg CO_2eq**	**%**	**%**	**%**	**%**		**%**	**%**	**%**	**%**	**%**	
1A1	Energy-Liquid	N2O	1.522	1.121	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	N2O	62.220	57.493	1.0	50.0	50.01	0.05	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A1	Energy-Gas	N2O	10.624	78.329	1.0	50.0	50.01	0.07	0.00	0.00	0.00	0.00	0.06	0.06	0.00
1A2	Industry-Liquid exc Pet Coke	N2O	0.000	0.000	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	N2O	0.000	0.000	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	N2O	0.000	0.000	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	N2O	5.021	5.151	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	N2O	58.508	121.923	1.0	25.0	25.02	0.05	0.00	0.00	0.00	0.00	0.03	0.03	0.00
1A3	Transport-Gas	N2O	0.700	1.637	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	N2O	4.924	3.542	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	N2O	0.013	0.000	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	N2O	0.581	0.000	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	N2O	0.126	0.570	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	N2O	2.435	8.848	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	N2O	12.183	4.997	5.0	50.0	50.25	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A4	Res-Petcoke	N2O	0.150	0.206	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	N2O	13.173	4.937	10.0	50.0	50.99	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A4	Res-Gas	N2O	0.152	0.811	2.5	50.0	50.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4	Agric Liquid	N2O	72.047	70.826	10.0	50.0	50.99	0.06	0.00	0.00	0.00	0.02	-0.01	0.02	0.00
	Biomass	N2O	6.602	6.240	10.0	50.0	50.99	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2B	Nitric Acid	N2O	1035.400	0.000	1.0	10.0	10.05	0.00	0.00	-0.02	0.00	0.00	-0.21	0.21	0.04
4B	Liquid Systemd	N2O	52.481	53.899	11.2	100.0	100.63	0.09	0.01	0.00	0.00	0.02	-0.01	0.02	0.00
4B	Solid Storage and Dry Lotd	N2O	295.380	310.781	11.2	100.0	100.63	0.52	0.27	0.00	0.01	0.09	-0.03	0.10	0.01
4D	Direct Soil Emissionsd	N2O	2819.949	2342.028	11.2	100.0	100.63	3.92	15.35	-0.01	0.04	0.68	-1.45	1.60	2.57
4D	Pasture Range and Paddockd	N2O	2908.950	2718.646	11.2	100.0	100.63	4.55	20.68	-0.01	0.05	0.79	-0.94	1.23	1.51
4D	Indirect Emissionsd	N2O	1333.006	1226.220	11.2	50.0	51.24	1.04	1.09	0.00	0.02	0.36	-0.23	0.43	0.18
5	LULUCF	N2O	14.165	42.061	30.0	100.0	104.40	0.07	0.01	0.00	0.00	0.03	0.05	0.06	0.00
6B	Wastewater Handling	N2O	113.999	144.878	10.0	10.0	14.14	0.03	0.00	0.00	0.00	0.04	0.00	0.04	0.00
	Total N2O		**8824.313**	**7205.143**				**6.12**	**37.42**					**2.08**	**4.32**
	Cumulative CO2, CH4, N2O		**54194.666**	**59522.732**				**7.84**	**61.41**					**4.44**	**19.69**
2F	Halocarbons & SF6	HFC	0.693	500.925	20.0	10.0	22.36	0.18	0.03	0.01	0.01	0.26	0.09	0.27	0.08
2F	Halocarbons & SF6	PFC	0.093	65.570	10.0	2.5	10.31	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
2F	Halocarbons & SF6	SF6	35.405	65.300	15.0	5.0	15.81	0.02	0.00	0.00	0.00	0.03	0.00	0.03	0.00
	Total HFC, PFC & SF6		**36.191**	**631.795**				**0.18**	**0.03**					**0.28**	**0.08**
	Total all gases		**54230.857**	**60154.528**					**61.44**						**19.77**
					Overall Uncertainty in Emissions			**7.84**				**Trend Uncertainty**		**4.45**	

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 0.3195

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

Table 2.1 shows the trends in emissions of the six greenhouse gases in Ireland over the period 1990-2009. The estimates reported here show some changes on those reported in the 2010 submission, which reflect recalculations that are fully described in subsequent chapters. The trends in the principal emission components as CO_2 equivalents within the six IPCC sectors are shown on Figure 2.3 through Figure 2.11. Total emissions of the six greenhouse gases in Ireland (excluding net emissions from *Land Use Land Use Change and Forestry*) increased steadily from 54,801.12 Gg CO_2 equivalent in 1990 to 69,671.57 Gg CO_2 equivalent in 2001 and then decreased slightly to 67,655.14 Gg CO_2 equivalent in 2004. Total emissions increased again in 2005 to 69,192.73 Gg CO_2 equivalent and then decreased for the last four consecutive years including a sudden much bigger decrease from 67,791.32 Gg CO_2 equivalent in 2008 to the current level of 62,368.67 Gg CO_2 equivalent in 2009. Total emissions in 2009 were 13.8 per cent higher than in 1990 and 10.5 per cent lower than the peak level in 2001. The estimated total for 2009 is 5,422.65 Gg CO_2 equivalent and 8.0 per cent lower than that for 2008. The percentage inter annual trend in total national GHG emissions for all years from 1990 to 2009 is shown in figure 2.1.

In 2009, the *Energy* sector accounted for 66.5 per cent of total emissions, *Agriculture* contributed 28.0 per cent while a further 3.4 per cent emanated from *Industrial Processes* and 2.0 per cent was due to *Waste*. The *Energy* and *Industrial Processes* sectors account for the bulk of the CO_2 emissions, CH_4 emissions are produced mainly in the *Agriculture* and *Waste* sectors and most of the N_2O emissions are generated in *Agriculture*.

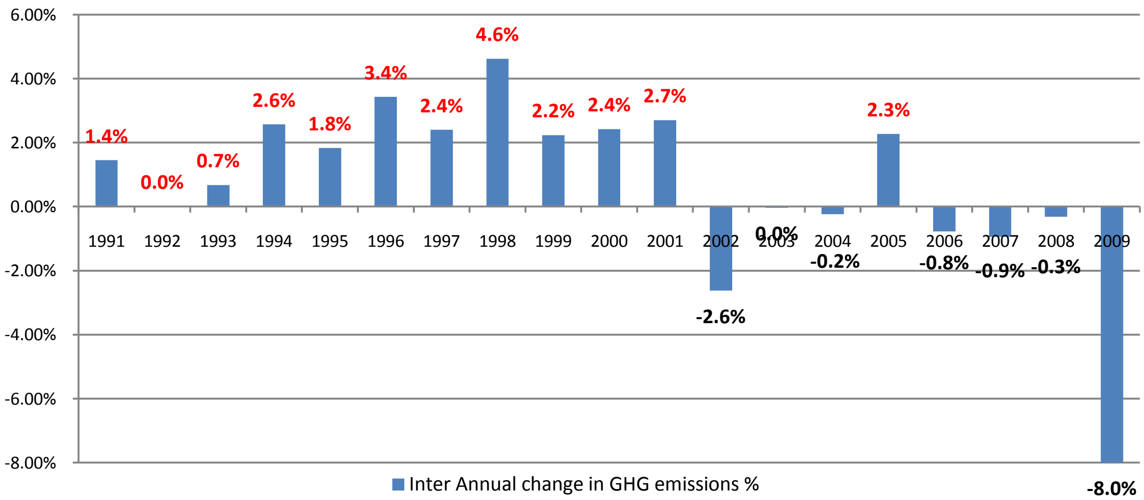


Figure 2.1 Percentage inter annual change in total GHG emissions 1990-2009

The large increase in emissions during the period 1990-2001 was clearly driven by the growth in CO_2 emissions from energy use. The increase in CO_2 from energy use amounted to 45.1 per cent over these 12 years. The bulk of this increase occurred in the years between 1994 and 2001, during which Ireland experienced a period of unprecedented economic growth, and energy CO_2 emissions over these 8 years grew by an average of 4.3 per cent annually. The rate of economic growth slowed down from 2000 to 2004, which together with the closure of ammonia and nitric acid production plants and continued decline in cattle populations and fertilizer use, resulted in some reduction in the emission levels in 2002 - 2004. The increase in 2005 was due largely to increased emissions from road transport and from electricity generation where two new peat-fired stations entered service. The recent declining trend between 2005 and 2009 can be largely attributed to decreases in the agriculture and waste sectors and in 2008 to reduced emissions from mineral products in the industrial processes sector. The single largest decrease in emissions occurred in 2009 when emissions decreased by 8.0 per cent due to the economic crisis. In addition, the sustained increase in transport emissions, the major contributor to the trend, came to an end in 2008 and in 2009 decreased to the level pre 2006.

Table 2.1. Greenhouse Gas Emissions 1990-2009 (Gg CO_2 equivalent)

(a) Emissions by Gas

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**

Table 2.1 contd. Greenhouse Gas Emissions 1990- 2009 (Gg CO_2 equivalent)

(b) Emissions by IPCC Source Category

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 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**

2.2 Trends by Gas

Emissions of CO_2 accounted for 68.0 per cent of the total (excluding LULUCF) of 62,368.67 Gg CO_2 equivalent in 2009, with CH_4 and N_2O contributing 19.5 per cent and 11.5 per cent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for approximately 1 per cent of total emissions in 2009. In 1990 emissions of CO_2, CH_4, N_2O and the combined emissions of HFCs, PFCs and SF_6 accounted for 59.1, 24.8, 16.1 and less than 0.1 per cent, respectively of total emissions of 54,801.12 Gg CO_2 equivalents.

Emissions of CO_2 increased from 32,380.95 Gg in 1990 to 42,413.76 Gg in 2009, which equates to an increase of 31.0 per cent. The main driver behind this increase in emissions is fuel combustion in *1.A.3 Transport* and *1.A.1 Energy Industries*. Over this period emissions of CO_2 from transport sources, which in Ireland are largely accounted for by road traffic, increased by 157.5 per cent. This trend is exaggerated somewhat in later years (1997 to 2009) by so-called fuel-tourism whereby approximately 14.5 per cent of automotive fuel (9.5 per cent of petrol and 19.5 per cent of diesel) sold in Ireland in these years is used in vehicles in the UK and other countries. The fuel tourism estimates for 2009 were 4.2 per cent for petrol and 1.9 per cent for diesel. Over the time-series, emissions of CO_2 from energy industries increased by 15.8 per cent, further adding to the trend. In addition, even though Ireland has only a small number of energy intensive industries and CO_2 emissions from combustion in the industrial sector *1.A.2 Manufacturing Industries and Construction* accounted for only 10.7 per cent of total CO_2 emissions in 2009, these emissions increased by 14.8 per cent between 1990 and 2009.

Methane is the second most significant contributor to greenhouse gas emissions in Ireland after CO_2, due mainly to large populations of cattle. In 2009 emissions of CH_4 were 12,151.87 Gg CO_2 equivalent, indicating a decrease of 10.5 per cent on the 1990 level of 13,570.19 Gg CO_2 equivalent. Emissions of CH_4 increased progressively from 1990, reaching a peak in 1998 of 14,361.63 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 2009 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 2001-2009 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.* Another significant source of methane emissions is from landfill gas in category *6.A Solid Waste Disposal on Land*. CH_4 emissions from this category decreased by 7.8 per cent from 1,173.05 Gg CO_2 equivalent in 1990 to 1,081.98 Gg CO_2 equivalent in 2009 as a result of improved management of landfill facilities and increased recovery of landfill gas.

Emissions of N_2O decreased by 18.6 per cent from their 1990 level of 8,813.80 Gg CO_2 equivalent in 1990 to 7,171.24 Gg CO_2 equivalent in 2009. Similar to CH_4, emissions of N_2O increased during the 1990s to reach peak level of 9,630.98 Gg CO_2 equivalent in 1999 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 the closure of Irelands only nitric acid plant in 2002 and reductions in synthetic fertilizer use and organic nitrogen applications on land as a result of the effect of CAP reform on animal numbers.

Emissions of the F-gases (HFCs, PFCs and SF_6) were 631.80 Gg CO_2 equivalent in 2009 compared to 36.19 Gg CO_2 equivalent in 1990, a 17.5-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 this increase has been the growth in HFC emissions in *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 0.69 Gg CO_2 equivalent in 1990 reaching a peak of 520.88 Gg CO_2 equivalent in 2008 and decreased to 500.92 Gg CO_2 equivalent in 2009. HFC emissions contributed 79.3 per cent to total F-gas emissions in 2009.

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. As a result, the downward trend in PFC emissions between 2000 and 2009 may continue into the future. Total emissions of PFCs in 2009 are 65.57 Gg CO_2 equivalent, contributing 10.3% to total F-gas emissions.

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 65.30 Gg CO_2 equivalent in 1990 and 2009, respectively. However, emissions of SF_6 at 132.10 Gg CO_2 equivalent peaked in 1997 following a steady increase in emissions from 1990 onwards. This 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 clearly seen that the largest contribution is from the *Energy* sector, which in 2009 contributes 66.5 per cent of total greenhouse gas emissions (excluding *LULUCF*). The second largest sector is *Agriculture*, which accounted for 28.0 per cent of total emissions in 2009. Emissions from *Industrial Processes, Solvent and Other Product Use* and *Waste* accounted for 3.4 per cent, 0.1 per cent and 2.0 per cent, respectively of total emissions in 2009. 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 33.8 per cent from 31,006.21 Gg CO_2 equivalent in 1990 to 41,472.03 Gg CO_2 equivalent in 2009. The increase occurred during the 1990s, driven by major increases in emissions from *1.A.1 Energy Industries* and *1.A.3 Transport*, and emissions are comparatively stable between 2001 and 2008, with a major decrease of 9.5 per cent between 2008 and 2009. *1.A.1 Energy Industries* accounted for 20.5 per cent and 21.0 per cent of total national greenhouse gas emissions in 1990 and 2009, respectively. Total greenhouse gas emissions from this sub-category increased by 54.5 per cent from 11,238.54 Gg in 1990 to 17,364.19 Gg 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 15,383.33 Gg CO_2 equivalent in 2004. Emissions subsequently increased in 2005 to 15,771.30 Gg CO_2 equivalent as levels of peat use returned to former levels with the entry into service of two new power plants. Emissions in 2006 decreased to 15,027.01 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 (14,533.81 Gg CO_2 equivalent) are largely as a result of the displacement of oil by natural gas. In 2008, emissions increased by 0.7 per cent or 106.89 Gg to 14,640.70 Gg CO_2 equivalent and then decreased in 2009 by 10.7 per cent to 13,071.58 Gg CO_2 equivalent in line with a similar drop in demand for electricity due to the economic crisis. Overall drivers and trends in emissions from the *Energy* sector are presented in Figure 2.2 and Figure 2.3.

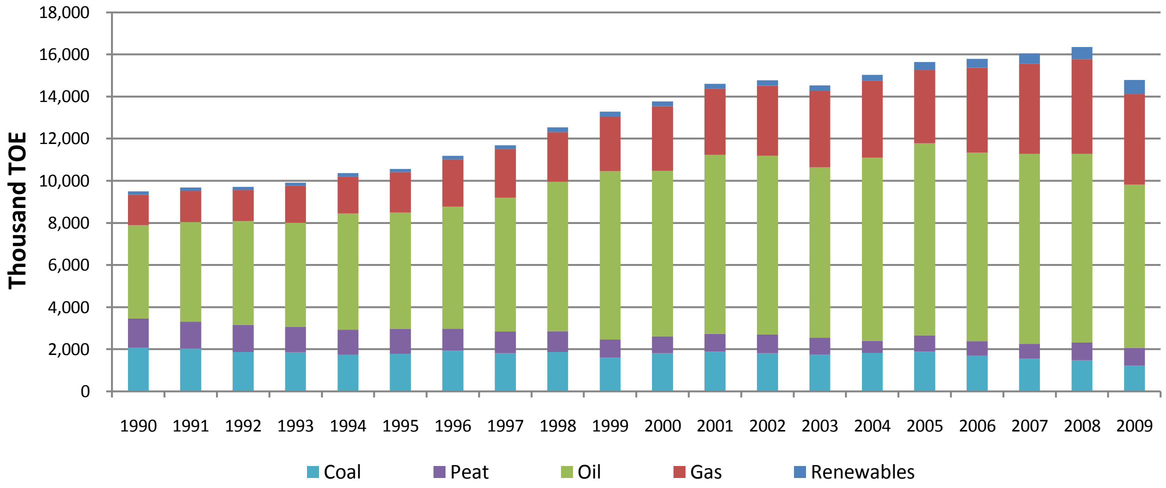


Figure 2.2 Total Primary Energy Requirement (TPER) 1990-2009

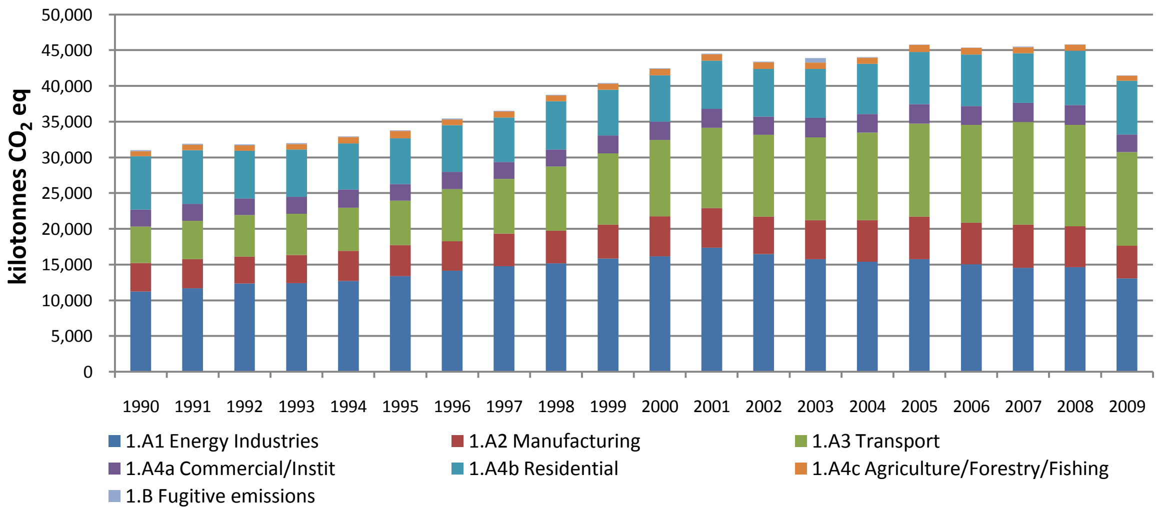


Figure 2.3 Trend in Emissions from Energy 1990-2009

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 and 7.3 per cent of total national greenhouse gas emissions in 1990 and 2009, 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* increased by 155.5 per cent from 5,134.89 Gg CO_2 equivalent in 1990 to 13,121.36 Gg CO_2 equivalent in 2009. This is largely accounted for by a 166.4 per cent increase in road transport associated 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 3.1 per cent of automotive fuels (4.2 per cent of petrol and 1.9 per cent of diesel) in 2009. 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. Even though emissions from civil aviation have more than doubled from 1990 to 2009, their overall effect on emission trends is negligible given their small share of total transport emissions.

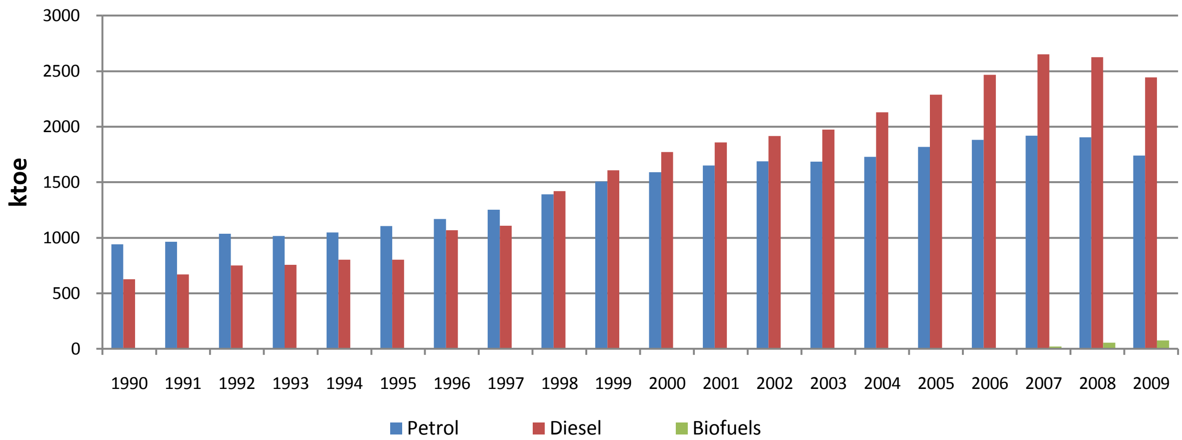


Figure 2.4 Fuel use in Road Transport 1990-2009

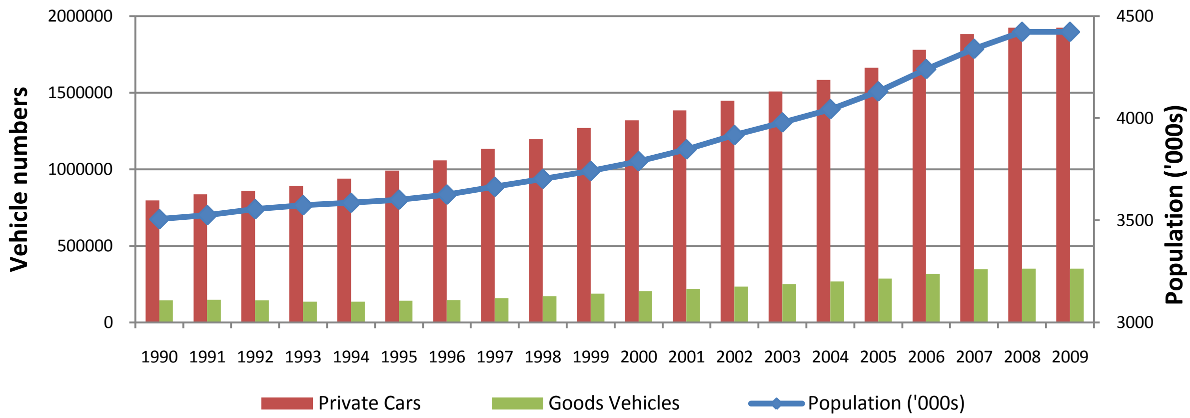


Figure 2.5 Vehicle numbers and Census of Population 1990-2009

Emissions from category *1.A.4 Other Sectors* increased by 1.5 per cent from 10,539.72 Gg CO_2 equivalent in 1990 to 10,695.95 Gg CO_2 equivalent in 2009. Emissions from the Commercial (1.A.4 a), and Residential (1.A.4 b) sub-categories increased by 5.4, 0.6 respectively and in Agriculture (1.A.4 c) decreased by 1.7 per cent. Although residential fossil fuel consumption increased by 27.1 per cent from 1990 to 2009 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 which has resulted in a stabilisation of emissions from this sector over the period 1990-2009. Emissions of CO_2 from coal and peat use in the residential sector decreased by 60.9 per cent between 1990 and 2009 while those from oil and natural gas more than tripled over the same 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 3.4 per cent in 2009. Total emissions from the sector were 3,178.55 Gg CO_2 equivalent in 1990 and 2,117.12 Gg CO_2 equivalent in 2009. This is a decrease of 33.4 per cent in emissions over the time series. Overall trends in emissions from *Industrial Processes* are presented in Figure 2.6.

In the early 1990's the contribution of *2.B Chemical Industry* to overall sectoral (sector 2) emissions was on average 64.0 per cent. By the late 1990's this proportion had fallen to approximately 50.3 per cent 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, which are reported under *2.A Mineral Products,* increased by 92.4 per cent. 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. However, the recent economic crisis has seen a 42.4 per cent decline in emissions from sector *2.A Mineral Products* from 2,580.43 Gg CO_2 equivalent in 2007 to 1,485.32 Gg CO_2 equivalent in 2009.

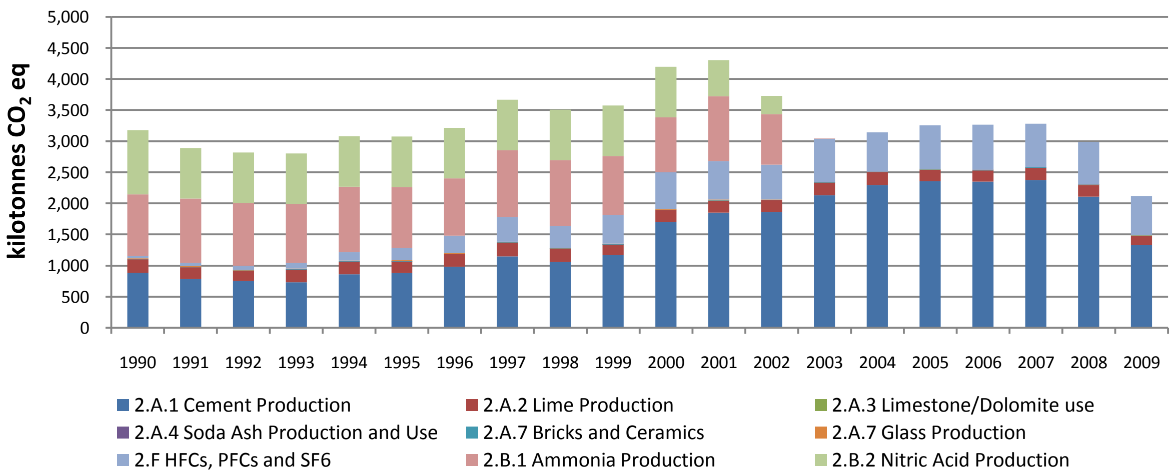


Figure 2.6 Trend in Emissions from Industrial Processes 1990-2009

The closure of Ireland's ammonia and nitric acid plants in 2003 and 2002, respectively significantly changed the level of process emissions in Ireland. As a result CO_2 emissions from cement manufacture (2.A.1) became the major component and these emissions increased steadily during the period of economic growth up to 2007, the year when they reached a peak at 72.4 per cent share of total sectoral emissions. Emissions from cement manufacture decreased in line with the economic downturn since 2007, accounting for 70.5 and 62.7 per cent of total emissions from *Industrial Processes* in 2008 and 2009, 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,* which collectively accounted for 7.5 per cent of total sectoral emissions in 2009. 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 631.80 Gg CO_2 equivalent in 2009, compared to 36.19 Gg CO_2 equivalent in 1990. This represents a 17.5 -fold increase over the time series with the result that the contribution of this category to the sectoral total for Industrial Processes increased to 29.8 per cent in 2009 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* 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 71.80 Gg CO_2 equivalent in 2009. The largest contributor to overall emissions in this sector is *3.D Other,* largely represented by domestic use of solvents, which accounts for approximately 50 per cent of total sectoral emissions in any one year. The contribution of sub-category *3.A Paint Application* to overall emissions from the sector has grown from 26.6 per cent in 1990 to 27.1 per cent in 2009 as a result of increasing paint sales. However, the market share of water-based paints, which have a lower VOC content, is increasing in response to market forces and Directive 2004/42/EC. 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 over all emissions in the sector in 2009. Emissions from both sub-categories show downward trends over the time-series 1990-2009. A graphical representation of the trends in emissions from *Solvent and Other Product Use* is presented in Figure 2.7.

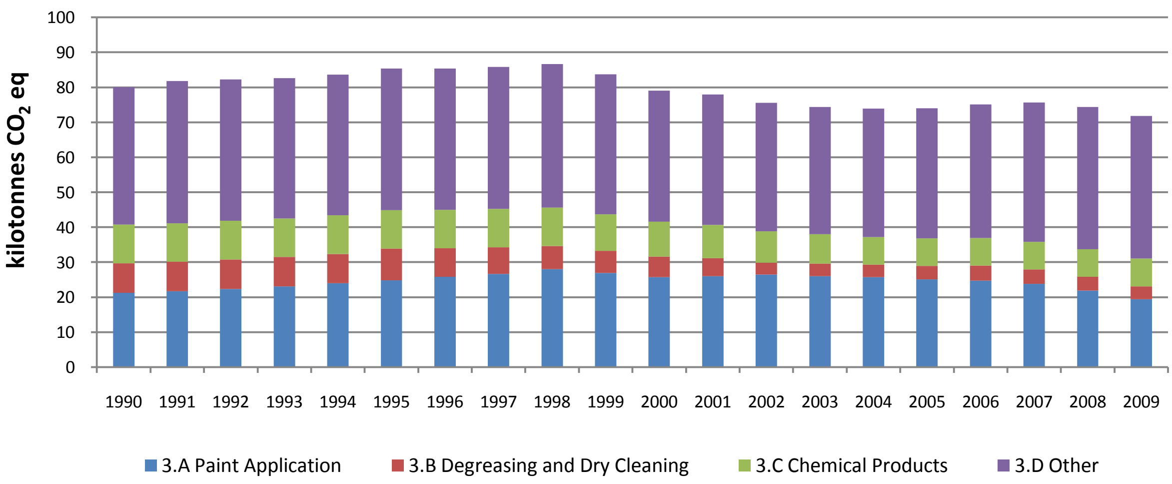


Figure 2.7 Trend in Emissions from Solvents and Other Product Use 1990-2009

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 19,253.54 Gg CO_2 equivalent in 1990 and 17,491.31 Gg CO_2 equivalent in 2009, a reduction of 9.4 per cent. Total emissions from the *Agriculture* sector increased by 9.5 per cent in the period 1990-1998, reflecting an increase in animal numbers and increased synthetic nitrogen use on farms. Following this peak in emission levels of 21,097.26 in 1998, the annual emissions from the sector decreased by 17.1 per cent to those in 2009 as a result of reductions in animal numbers and synthetic nitrogen fertilizer 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 11,843.77 Gg CO_2 equivalent in 1990. This increased by 7.9 per cent to reach 12,781.89 Gg CO_2 equivalent in 1998 and subsequently decreased by 15.2 per cent to 10,839.73 Gg CO_2 equivalent in 2009. Cattle account for 89.0 per cent of annual CH_4 emissions in Irish agriculture.

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 fertilizer and animal manures, which produces the bulk of N_2O emissions. Nitrous oxide emissions in the sector increased from 7,409.77 Gg CO_2 equivalent in 1990 by 12.5 per cent in the period 1990-1999 with emissions in 1999 totalling 8,333.45 Gg CO_2 equivalent. Nitrous oxide emissions totalling 6,651.57 CO_2 equivalent in 2009 represent a reduction of 20.2 per cent on the 1999 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.

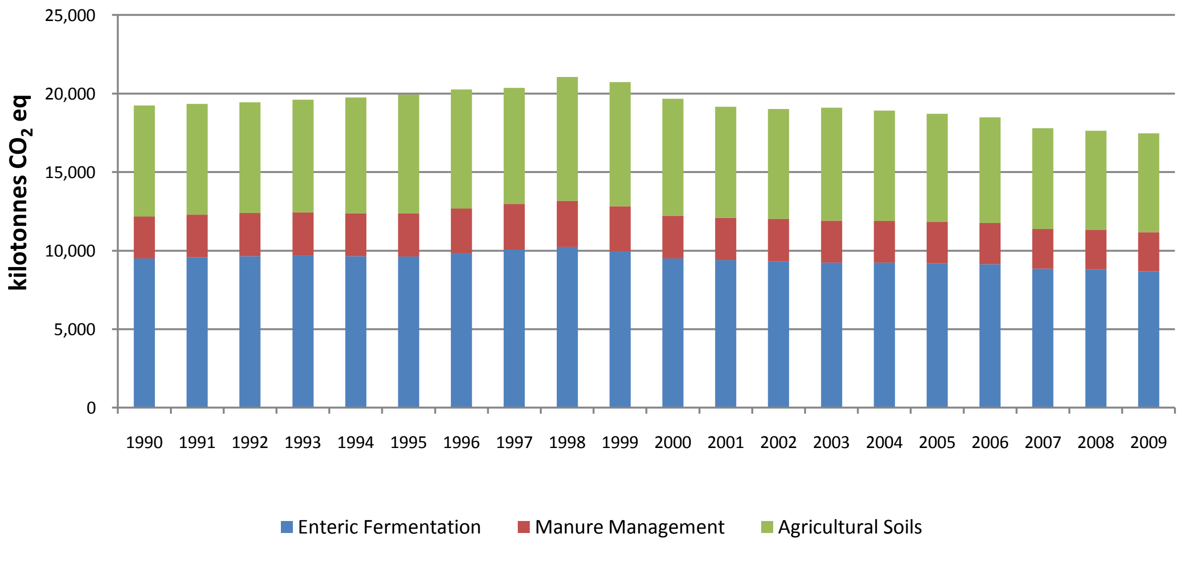


Figure 2.8 Trend in Emissions from Agriculture 1990-2009

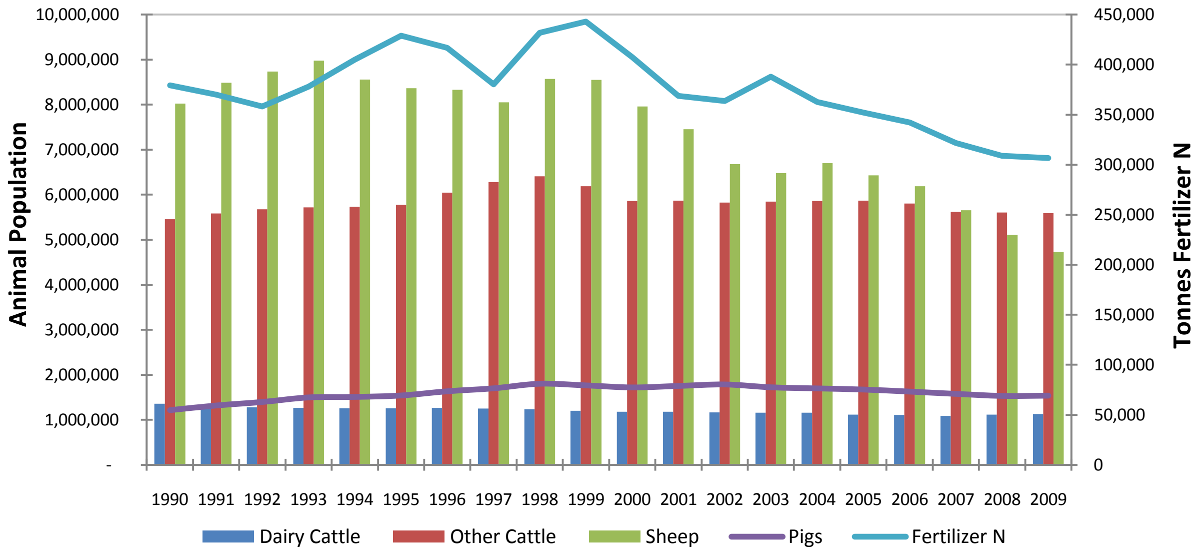


Figure 2.9 Principal Drivers of Emissions from Agriculture 1990-2009

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 and it has identified a number of land-use categories that are important in terms of either emissions or removals of CO_2. This sector is a net sink of carbon emissions in all years from 1990 to 2009 (Table 2.1 and Figure 2.10). The size of this sink 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. 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- 2009.

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 unimportant 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.

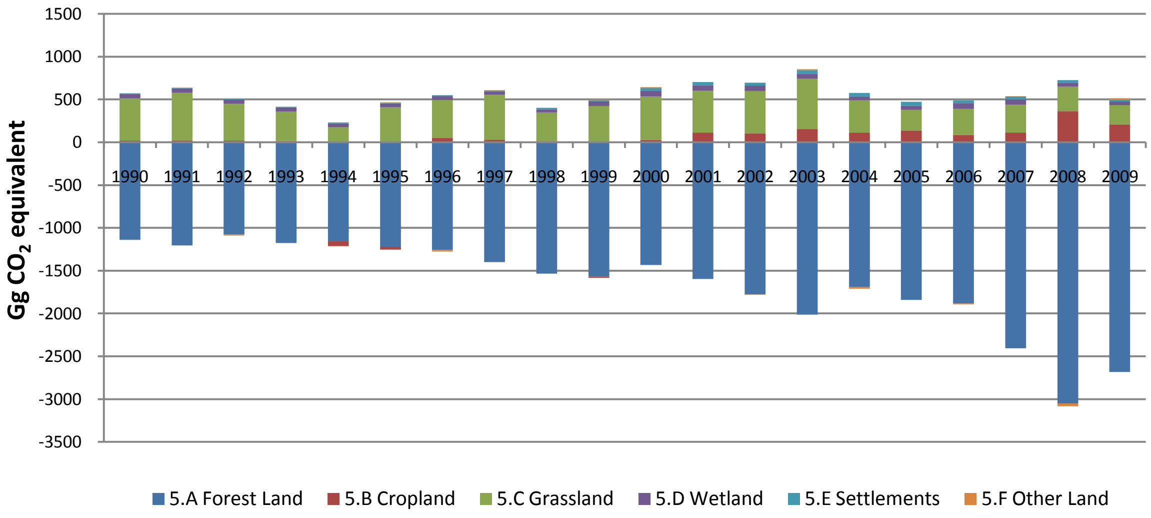


Figure 2.10 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2009

2.3.6 Trends in Waste (IPCC Sector 6)

The *Waste* sector remains an important source of CH_4 emissions (Figure 2.11) due to the continued dominance of landfills as a means of solid waste disposal in Ireland. Emissions from the waste sector decreased by 4.5 per cent from 1,301.78 Gg CO_2 equivalent in 1990 to 1,242.59 Gg CO_2 equivalent in 2009. 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 27.2 per cent 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% between 2008 and 2009 to 1.7 million tonnes. The proportion of organic materials in MSW has decreased from 40 per cent in 1990 to 35 per cent in 2009. The proportions of paper and textiles changed from 30.0 per cent and 10.0 per cent, respectively in 1990 to 21.4 per cent and 6.4 per cent, respectively in 2009, 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 58.3 per cent in 2009, up from 9.1 per cent in 1996. Emissions of CH_4 and N_2O from *6.B Wastewater Handling* accounted for 128.73 Gg CO_2 equivalent in 1990 and 160.61 Gg CO_2 equivalent in 2009, which equates to 9.9 and 12.9 per cent of total emissions from the waste sector, respectively. The contribution of this sub-category to overall sectoral trends is negligible.

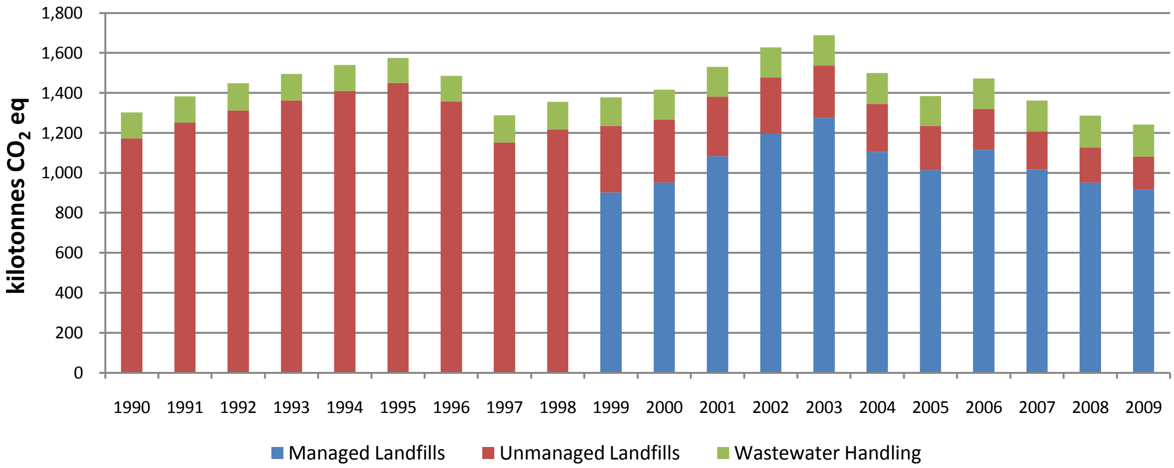


Figure 2.11 Trend in Emissions from Waste 1990-2009

2.4 Emissions of Indirect Greenhouse Gases

The total emissions of SO_2, NO_X, NMVOC and CO for the years 1990 to 2009 are summarised in Table 2.2. 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 (82.1 per cent) and CO (62.3 per cent). Significant reductions have also taken place in NMVOC emissions (40.7 per cent) and emissions of NO_X in 2009 were 28.1 per cent lower than those in 1990.

Total SO_2 emissions decreased by 82.1 per cent, from 182,530 tonnes in 1990 to 32,700 tonnes in 2009, reflecting reductions in the sulphur content of fuels, fuel switching and use of abatement technologies. Power stations remain the principal source of SO_2 emissions, contributing 48.0 per cent of the total in 2009. Combustion sources in the industrial (1.A.2) and together commercial/residential (1.A.4.a, 1.A.4.b) sectors largely account for the remainder of emissions, with contributions of 14.7 per cent and 31.0 per cent, respectively in 2009. 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 47.3 per cent of the total in 2009. The power generation sector is the other main source of NO_X emissions, accounting for 14.7 per cent of emissions in 2009. The reductions in NO_X emissions given by catalytic converters in cars and heavy-duty vehicles have only become apparent in recent years, as the technology has been offset by large increases in vehicle numbers 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 64.4 per cent of the 2009 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 petrol 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 1990-2009 (Tonnes)

	SO_2	NO_X	NMVOC	CO
1990	182,530	125,625	87,995	419,594
1991	180,908	127,481	88,944	417,257
1992	169,427	136,256	89,112	404,809
1993	160,399	125,994	85,814	370,910
1994	175,258	124,815	84,121	347,474
1995	161,123	126,792	81,147	316,318
1996	149,033	131,126	85,317	322,981
1997	166,485	131,269	84,617	307,995
1998	177,827	136,182	86,140	318,085
1999	158,959	136,492	79,016	283,478
2000	139,748	137,959	73,432	255,724
2001	134,410	139,847	71,403	244,950
2002	101,452	130,334	66,843	225,694
2003	79,294	126,185	64,281	213,997
2004	71,898	125,750	61,339	203,911
2005	71,189	127,052	59,699	193,757
2006	60,745	122,425	58,414	184,556
2007	55,121	121,168	56,948	173,748
2008	45,256	112,327	55,182	165,416
2009	32,700	90,275	52,222	158,311

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 2009 remain largely as described in the 2010 NIR. As for all years since 2005, CO_2 estimates reported under the ETS for 2009 are used to achieve complete bottom-up results in respect of some important sub-categories in this sector for the 2009 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 of GHG emissions in Ireland in 2009, with CO_2 emissions making up 98.5 percent of the total for the sector. The categories 1.A.1 Energy Industries and 1.A.3 Transport are the principal sources, each contributing about 32 percent to the sector total. Category 1.A.4 is also a significant source of emissions, contributing 26 percent in 2009 while 1.A.2 Manufacturing Industries and Construction accounted for approximately 11 percent of the total. Fugitive GHG emissions are insignificant in this sector.

Table B.1 of Annex B shows the national energy balance sheets for 2009, 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 2009 example indicates the same form of expanded balance sheet as previously used for all years from 1990 to 2008. The improved 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 1990-2009 underlies the estimates of emissions for *Energy* in this submission.

Following the methods decision tree of the IPCC good practice guidance for combustion sources, the information in Table 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 2009 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	NO	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 2009. The CO_2 emissions are relatively easy to quantify 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 spreadsheet given in Table C.1 of Annex C shows how the emissions from combustion sources are computed for the year 2009 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 percent of the total in 2009. 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 2009.

The annual returns to the EPA's Climate Change and Environmental Research Unit (CCERU) 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 percent) of fuel carbon may remain unoxidised 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 unoxidised 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 2009 under Directive 2003/87/EC were used to report the complete CO_2 inventory for category 1.A.1. The emissions data from a total of 22 individual installations – 19 electricity generating stations in 1.A.1(a), one oil refinery in 1.A.1(b) and two peat briquetting plants under 1.A.1(c) – are the basis for compiling the results in this important category. In each of the three sub-categories, the verified CO_2 estimates reported by the ETS participants were used directly and the corresponding fuel use as given in the national energy balance was used to estimate CH_4 and N_2O emissions using the appropriate IPCC emission factors mentioned in the previous section.

The CO_2 emissions for sub-category 1.A.1(a) obtained from AEIRs are estimated by ETS operators using IPCC 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 2009 are aggregated to report the CO_2 emissions for this category.

The AEIR reports not only include detailed information on the fuel consumption, and emissions of CO_2 from each installation, but also indicate the ETS tier that has been used to calculate the activity data, net calorific value, emission factor and oxidation factor (the ETS tiers differ from the IPCC tier system).

For primary fuels, plant under 1A1a all report using tier 4 for activity data, and all except two use tier 3 for both net calorific value and emission factors. The tier ratings are lower for the minor fuel types, but the majority of plant under 1A1a report using tier 4 for activity data, and tiers 2a and 3 for both net calorific value and emission factors for minor fuels.

These detailed data allow a thorough understanding of the quality of the data provided through the EU ETS, and demonstrate that the data is of high accuracy and precision. 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, which is the EPA in Ireland, 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 clearly 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 may be 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 using the appropriate IPCC emission factors, 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 intends to meet with SEAI in the spring of 2011 to resolve any issues regarding the national energy balance pending the outcome of the latest UNFCCC review. 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 1990-2009, which account for more than 95 percent of the total for category 1.A.1. The emissions from this category in 2009 show a substantial decrease on the 2008 emissions, reflecting the impact of the recent economic downturn in Ireland. Reductions are primarily from coal and oil, but gas also makes a significant contribution to the reduction.

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 and fuel amounts in the national energy balance. 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 2009 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 and fuel amounts in the national energy balance. Milled peat is the principal fuel concerned in 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 2009 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.

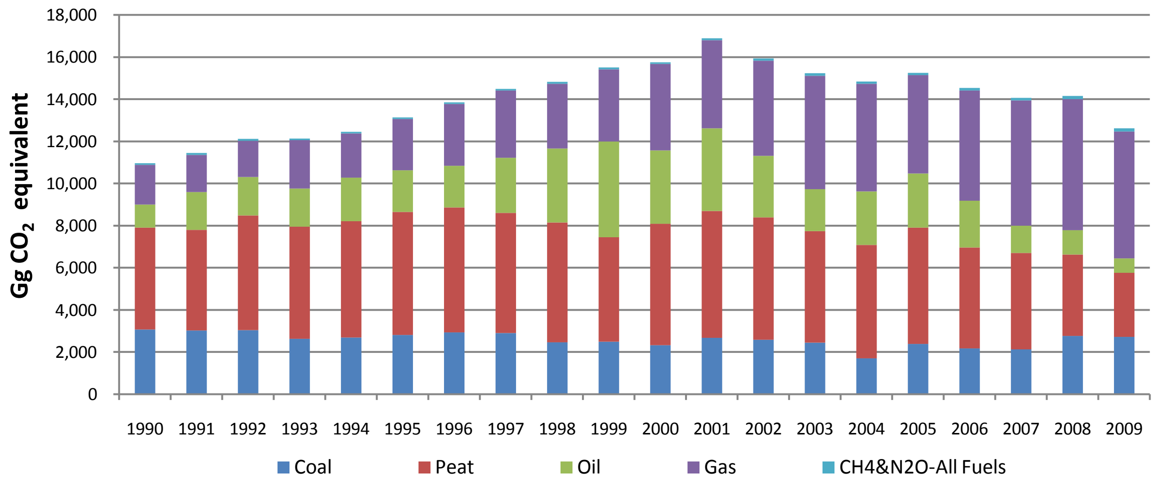


Figure 3.1 Emissions from 1.A.1(a) Public Electricity and Heat 1990-2009

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. In the past, allocation to the lower level was often based on poor information, which resulted in outlier implied emission factors for some of the fuels in sub-categories 1.A.2(a) through 1.A.2(f).

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.1 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 provided from the ETS on fuel data have been used to develop an annual country-specific CO_2 emission factor for petroleum coke since 2005. Petroleum coke is used in sub-categories 1.A.2.b, 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 most recent five years of yearly specific emission factors is applied to years prior to 2005, 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 80.1 t CO_2/TJ. However the implied emission factor in 2009 is 73.2 t CO_2/TJ reflecting the very small quantities of petroleum coke consumed. In 1.A.2(f), the implied emission factor for liquid fuels increases from 76.2 t CO_2/TJ in 1990 to 82.4 t CO_2/TJ in 2007, but then decreases substantially to 78.5 t CO_2/TJ in 2009 reflecting the decline in petroleum coke use in cement production. See Table C.8 of Annex C for further details.

Figure 3.2 shows the trend in emissions from 1.A.2 Manufacturing Industries and Construction over the period 1990-2009. The emissions from this category in 2009 show a 20.4 percent decrease on the 2008 emissions, reflecting the impact of the recent economic downturn in Ireland. Reductions are primarily from sub-categories 1.A.2 (b) and 1.A.2 (f) with annual decreases of 18.3 and 29.9 percent respectively.

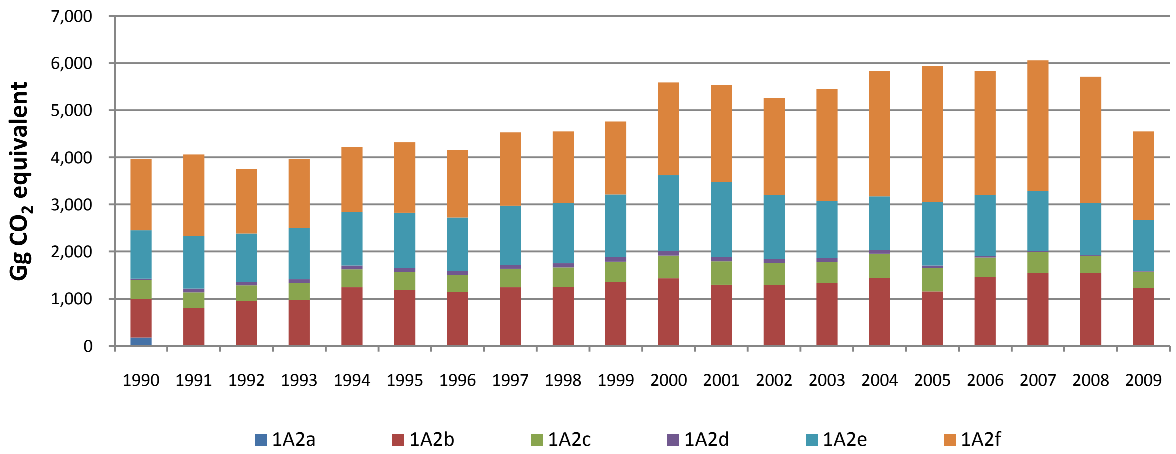


Figure 3.2 Emissions from 1.A.2 Manufacturing Industries and Construction 1990-2009

3.2.1.3 Transport (1.A.3)

The fuel consumption within Ireland associated with sub-category 1.A.3 (a) Civil Aviation is calculated from the number of annual landing and take-off (LTO) cycles for domestic air travel provided by airport authorities, the fuel consumption rates given by the IPCC good practice guidance appropriate to the type of aircraft concerned (Table 2.10, GPG Appendix 2.5A.1) and the length of the flights within Ireland. This approach is used for consistency with other years even though the expanded and updated energy balance sheets record the amount of fuel used in domestic air transport.

New, and more detailed, data on emissions from 1.A.3 (a) Civil Aviation is expected to become available in the near future through Eurocontrol. The expectation is that these estimates will be calculated at a Tier 2 level, and will be fully consistent across European countries. The inventory agency plan to incorporate these new emissions estimates into the national inventory and expect the data to be available in time for inclusion in the 2012 inventory submission. It is expected that this will allow emissions from jet kerosene and aviation gasoline to be reported separately.

Emissions of CO_2 reported under 1.A.3 (b) Road Transportation are computed from the amounts of petrol and diesel 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 some of the 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 first time (version 6.1 being used previously), and gives rise to significant recalculations for CH_4 and N_2O emissions for all years. The decreases that arise from using version 4v.8.0 of the COPERT model are caused by the use of updated emission factors for all fuel types. Tables 3.4 and 3.5 show the impact of recalculations for CH_4 and N_2O respectively. 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. For quality assurance purposes, the total fuel used in the COPERT model is balanced with the total fuel reported in the national energy balance. The difference between statistical and calculated fuel amounts in the COPERT model in < 0.1 percent.

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 2009 emission factors have been converted to national average values per fuel type for the purpose of Table C.1 in Annex C. To aid transparency, the national road vehicle fleet is given in Annex D, Table D.1 for 1990 and 2000 to 2009, presented by vehicle class and technology. Table D.2 in Annex D provides the vehicle kilometres for 1990 and 2000 to 2009 split by the same vehicle classes and technologies.

Road traffic is an important source of N_2O from fuel combustion and from 1990-2007 emissions have increased in line with the increasing share of catalyst-controlled vehicles in the national fleet. The last two years, 2008 and 2009, emissions of N_2O have decreased. This is primarily due to a decrease in consumption of petrol, but also because emission factors for petrol vehicles have decreased substantially, reflecting the improved control of N_2O emissions in more modern vehicles.

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 2010 national energy balance contains no breakdown of activity data for Navigation 1.A.3 (d). The inventory agency has reported emissions from this category as “included elsewhere (IE)” in this submission. The inventory agency will work together with SEAI to resolve this issue during the meeting referred to in Section 3.2.1.1 above and will revise the time series accordingly in future submissions.

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 3.3 shows the trend in emissions from 1.A.3 Transport over the period 1990-2009. Road transport accounts for 97 percent of the sectoral emissions in 2009. Transport emissions increased for all years up until 2007 and declined by 0.9 percent and 7.7 percent in 2008 and 2009 respectively, reflecting the impact of the recent economic downturn in Ireland.

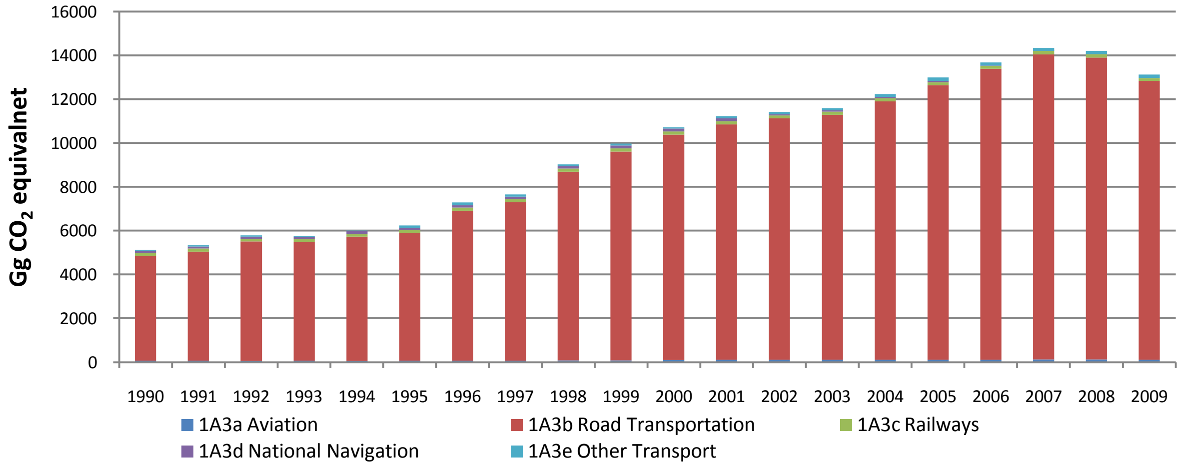


Figure 3.3 Emissions from 1.A.3 Transport 1990-2009

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, agriculture and forestry sectors. The residential sub-category 1.A.4(b) 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 1990-2009. 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 emissions relatively constant up to 2007. However, the benefits from fuel switching have been fully realised since 2007 and the emissions from oil and gas are increasing in line with higher overall fuel consumption resulting from greater housing stock and population. The emissions in the residential sub-category increased by 8.7 percent from 2007 to 2008 as a result of a colder than normal winter months. In 2009, emissions decreased by only 0.6 percent with similar degree heating days as in 2008. In 2009 decreases in emissions from 1.A.4(a) Commercial and Institutional, and 1.A.4(c) Agriculture reflect the impact of the economic downturn.

Table B.2 of Annex B 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. Consequently, a split based on information from agricultural experts (10 percent stationary sources and 90 percent 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.

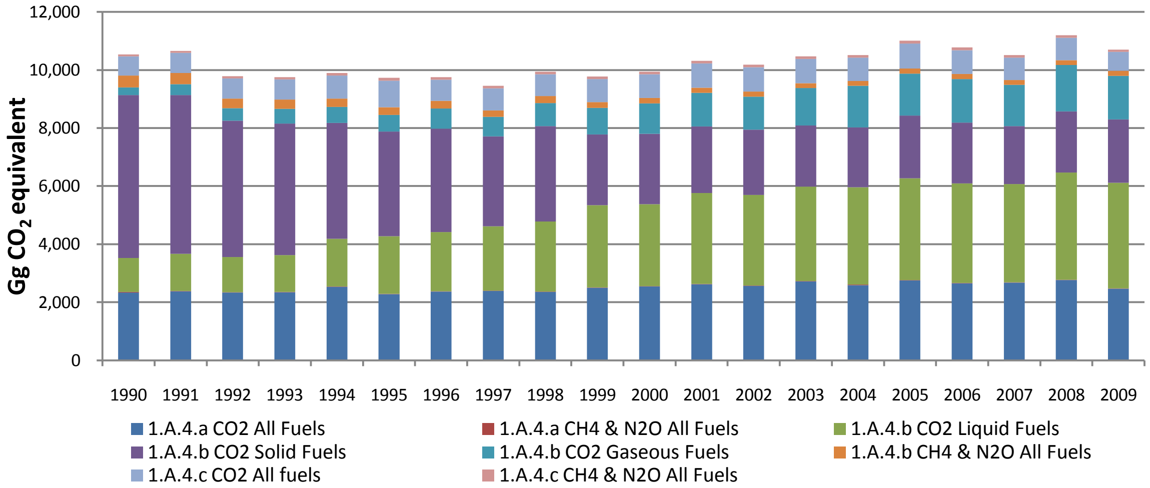


Figure 3.4 Emissions from 1.A.4 Other Sectors 1990-2009

3.2.2 Fugitive Emissions (1.B)

Ireland has no coal or oil production industries and therefore fugitive emissions of greenhouse gases are limited to those associated with natural gas production and distribution and fugitive losses of methane at Ireland's single refinery. 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 percent 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 1990-2009 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 2009.

Ireland's single oil refinery is a small hydroskimming refinery. In this submission fugitive losses of methane from oil refining and storage (1.B.2.a iv) are estimated for the first time for all years from 1990 to 2009. Estimates are based on default emission factors from Table 1-58 of the Revised 1996 IPCC Guidelines. Emission factors of 90 kg of CH_4 per petajoule of oil refined and 20 kg of CH_4 per petajoule of oil stored have been applied for all years from 1990 to 2009 based on the oil refinery throughput in Ireland's energy balance.

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 2009 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. However, the IPCC default value of 0.50 and 1.0 are now used for the proportion of carbon stored in lubricants and bitumen respectively. White spirit is also included under non-energy fuel use, but it is assumed that the carbon is completely released to air, and hence is included CRF table 1.A(d). 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 percent 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 2009 are very minor, indicating that in the Reference Approach energy use and CO_2 emissions were 1.48 percent and 0.67 percent lower than in the Sectoral Approach. The emissions from solid fuels are marginally higher in the Reference Approach while the emissions from liquid and gaseous fuels are marginally higher in the Sectoral Approach.

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 and international aviation in the national energy balance is achieved on the basis of particular tax and excise rates applicable to the sale of such fuels. The approach used to estimate fuel consumption in domestic civil aviation by the inventory agency is described in section 3.2.1.3 above and gives a result for 2009 close to that in the energy balance. This fuel amount is deducted from the value given in the energy balance sheet for kerosene use in air transport to obtain an estimate of international aviation bunker fuel consumption. In 2009, the amount of fuel allocated to domestic aviation was 4.4 percent 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 2009 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 that still persist between the energy amounts reported by SEAI and that supplied for particular sub-categories and fuels.

The incorporation of the ETS data in the *Energy* sector for the last several submissions is again considered an important step towards improved reliability and accuracy of the estimates for categories 1.A.1 and 1.A.2. Thorough checking of this input is achieved in collaboration with colleagues in the Climate Change and Environmental Research Unit (CCERU) of the EPA, which acts as the Competent Authority for the ETS in Ireland. Following receipt of the raw ETS data from CCERU, 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 CCERU 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.

3.7 Recalculations in Energy

Recalculations have been undertaken in the *Energy* sector for the years 1990-2008 to account for the following improvements:

- Minor revisions to fuel allocations within category 1.A.2 Manufacturing and construction, are documented in detail in Chapter 10;
- Minor revisions to the CO_2 emissions factors for natural gas and petroleum coke in category 1.A.2 Manufacturing and construction, are documented in detail in Chapter 10;
- The use of COPERT 4v.8.0, which has replaced COPERT 4v.6.1 (used for the previous submission). This new version of COPERT includes substantially revised emission factors for CH_4 and N_2O;
- Minor revisions to the CO_2 emissions factors for natural gas and petroleum coke in category 1.A.4 Other, are documented in detail in Chapter 10;
- New estimates for fugitive CH_4 emissions from oil refining/storage (1.B.2.a iv) for all years from 1990-2008.

The results of the recalculations are given by category and gas in Tables 3.2, 3.3, 3.4 and 3.5. The effect of using the most up to date version of COPERT is to substantially reduce the emissions for both CH_4 and N_2O from road transport. Recalculations reduce emissions in the early years of the time series by approximately 25 percent, and 17 percent in 2006 for both CH_4 and N_2O. By 2008, the impact of the recalculation is to reduce the N_2O emissions estimate by some 26 percent, but only 15 percent for CH_4. However, because emissions from the 1.A.3(b) Road Transportation are dominated by emissions of CO_2, the overall impact on the sectoral total is relatively small.

3.8 Planned Improvements in Energy

The changes referred to above for 2009 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 percent 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. However a number of improvements are planned following recommendations from the latest review.

New, and more detailed, data is expected to become available on emissions from 1.A.3 (a) Civil Aviation. The inventory agency will incorporate these improved estimates into the national inventory (see comments in section 3.2.1.3). The agency also intends to provide estimates of emissions for national navigation (1.A.3 d) in the transport sector in future inventory submissions as outlined in section 3.2.1.3.

Table 3.2. 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
											Estimates in 2010 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	15027.01	14533.81	14640.70
1.A.2.	Manuf Ind and Constn	3,958.61	4,059.53	3,752.46	3,965.61	4,216.66	4,318.06	4,151.43	4,529.84	4,549.76	4,760.65	5,588.18	5,533.10	5,254.81	5,261.81	5,647.60	5,743.38	5625.66	5872.85	5548.23
1.A.3.	Transport	5,160.32	5,366.33	5,817.25	5,790.22	6,037.13	6,272.02	7,332.73	7,690.71	9,068.62	10,028.18	10,766.26	11,279.71	11,471.12	11,644.17	12,272.39	13,031.89	13719.23	14376.11	14254.98
1.A.4.	Other Sectors	10,539.74	10,660.76	9,785.97	9,756.59	9,893.27	9,726.26	9,750.23	9,453.18	9,938.37	9,768.94	9,943.70	10,313.22	10,187.18	10,474.14	10,512.74	11,006.18	10774.32	10507.82	11198.31
1.B.	Fugitive Emissions	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	127.63	85.05	147.74	68.95	626.26	65.95	56.58	46.86	59.58	51.25
1	Total	31,028.31	31,913.00	31,842.14	32,012.77	32,981.77	33,831.92	35,465.07	36,561.54	38,816.08	40,507.68	42,523.67	44,637.96	43,435.36	43,767.69	43,882.01	45,609.32	45,193.07	45350.17	45693.47
											Recalculated 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
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
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
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
1.B.	Fugitive Emissions	131.26	127.55	123.01	121.95	118.17	114.40	110.30	105.78	92.39	127.91	85.38	148.07	69.26	626.58	66.24	56.90	47.17	59.92	51.57
1	Total	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
											Percentage Change in Total Emissions due to Recalculations									
1.A.1.	Energy Industries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.2.	Manuf Ind and Constn	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.06	0.05	0.05	0.06	3.54	3.29	3.40	3.58	3.15	2.93
1.A.3.	Transport	-0.49	-0.49	-0.49	-0.52	-0.54	-0.56	-0.53	-0.55	-0.54	-0.49	-0.46	-0.45	-0.43	-0.40	-0.35	-0.31	-0.27	-0.30	-0.33
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.	Fugitive Emissions	0.14	0.14	0.16	0.15	0.19	0.19	0.19	0.27	0.32	0.22	0.38	0.22	0.46	0.05	0.44	0.58	0.66	0.56	0.62
1	Total	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10	-0.11	-0.12	-0.11	-0.11	-0.11	-0.10	0.32	0.33	0.34	0.36	0.32	0.25

Table 3.3. 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
Estimates in 2010 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	14906.98	14406.63	14495.44
1.A.2.	Manuf Ind and Constn	3,940.06	4,040.80	3,736.50	3,948.80	4,199.98	4,300.79	4,133.25	4,511.14	4,529.83	4,740.32	5,564.42	5,508.27	5,230.92	5,238.16	5,621.59	5,713.95	5597.90	5845.47	5522.95
1.A.3.	Transport	5,039.39	5,242.11	5,685.51	5,646.50	5,880.60	6,106.55	7,144.84	7,482.38	8,826.58	9,783.77	10,512.66	11,017.18	11,215.64	11,396.54	12,027.84	12,792.15	13483.34	14143.78	14061.80
1.A.4.	Other Sectors	10,052.73	10,179.97	9,363.69	9,342.70	9,505.48	9,353.20	9,396.55	9,128.37	9,600.49	9,481.33	9,653.55	10,029.60	9,906.01	10,200.37	10,245.76	10,724.73	10501.67	10244.92	10923.78
1.B.	Fugitive Emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.27	0.00	56.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0000
1	Total	30,190.80	31,080.22	31,065.44	31,235.60	32,220.34	33,078.01	34,706.49	35,814.76	38,037.43	39,776.66	41,781.01	43,877.66	42,697.91	42,478.50	43,178.69	44,888.13	44,489.90	44,640.80	45,003.97
Recalculated 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
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
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
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
1.B.	Fugitive Emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.27	0.00	56.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0000
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	39,779.51	41,784.02	43,880.60	42,700.89	42,663.65	43,363.27	45,082.28	44,690.04	44,824.81	45,160.89
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	0.00	0.00	0.00	0.00	0.00
1.A.2.	Manuf Ind and Constn	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.06	0.06	0.05	0.06	3.54	3.28	3.40	3.58	3.15	2.92
1.A.3.	Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.	Fugitive Emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	Total	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.44	0.43	0.43	0.45	0.41	0.35

Table 3.4. 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
	Estimates in 2010 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
1.A.2.	Manuf Ind and Constn	5.60	5.65	4.74	5.01	4.85	5.03	5.40	5.49	5.92	6.00	7.04	7.41	7.16	7.07	7.88	9.00	8.59	8.45	7.80
1.A.3.	Transport	47.69	49.22	53.15	48.15	46.21	49.86	51.45	49.71	51.06	49.56	45.01	42.85	38.39	35.71	33.37	31.35	29.67	28.12	26.90
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
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
1	Total	568.84	558.18	501.83	488.28	447.34	422.06	420.41	384.72	385.56	329.92	322.50	320.02	289.47	835.41	269.62	266.52	250.05	257.16	257.27
	Recalculated 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
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
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
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
1.B.	Fugitive Emissions	131.26	127.55	123.01	121.95	118.17	114.40	110.30	105.78	92.39	89.64	85.38	92.03	69.26	626.58	66.24	56.90	47.17	59.92	51.57
1	Total	557.62	546.56	489.28	476.89	436.44	410.10	408.04	372.90	373.36	318.63	312.83	311.13	281.91	829.09	264.08	261.75	245.82	253.42	253.87
	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	0.00	0.00	0.00	0.00	0.00
1.A.2.	Manuf Ind and Constn	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	5.76	5.15	4.74	5.12	4.78	4.53
1.A.3.	Transport	-23.91	-23.96	-23.97	-24.04	-24.09	-24.45	-24.46	-24.37	-24.49	-23.34	-22.22	-21.52	-20.54	-19.72	-18.69	-17.60	-16.78	-15.93	-15.13
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.	Fugitive Emissions	0.14	0.14	0.16	0.15	0.19	0.19	0.19	0.27	0.32	0.31	0.38	0.36	0.46	0.05	0.44	0.58	0.66	0.56	0.62
1	Total	-1.97	-2.08	-2.50	-2.33	-2.44	-2.84	-2.94	-3.07	-3.17	-3.42	-3.00	-2.78	-2.61	-0.76	-2.06	-1.79	-1.69	-1.45	-1.32

Table 3.5. 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
		Estimates in 2010 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
1.A.2.	Manuf Ind and Constn	12.95	13.08	11.23	11.80	11.84	12.24	12.78	13.21	14.01	14.33	16.72	17.42	16.73	16.58	18.14	20.43	19.16	18.93	17.48
1.A.3.	Transport	73.25	75.00	78.59	95.56	110.31	115.62	136.45	158.63	190.97	194.85	208.60	219.68	217.10	211.92	211.19	208.39	206.22	204.20	166.28
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
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
1	Total	268.66	274.61	274.87	288.89	314.09	331.85	338.17	362.06	393.10	401.09	420.17	440.28	447.98	453.78	433.70	454.68	453.13	452.20	432.23
		Recalculated 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
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
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
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
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
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
		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	0.00	0.00	0.00	0.00	0.00
1.A.2.	Manuf Ind and Constn	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.05	5.45	4.97	4.63	5.09	4.73	4.49
1.A.3.	Transport	-19.17	-19.33	-20.05	-19.24	-19.19	-19.62	-19.10	-18.98	-18.93	-19.16	-19.13	-18.88	-18.89	-18.64	-17.20	-16.51	-15.73	-18.75	-22.95
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.B.	Fugitive Emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
1	Total	-5.22	-5.28	-5.73	-6.36	-6.74	-6.83	-7.70	-8.31	-9.19	-9.31	-9.50	-9.42	-9.15	-8.50	-8.17	-7.36	-6.94	-8.27	-8.65

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. The four industrial sources that have been covered in the past, mainly due to their emissions of CO_2, 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. A small amount of limestone is used to abate SO_2 emissions in peat-fired electricity generating stations and limestone is also used by a number of companies as a raw material and thus 2*.A.3 Limestone and Dolomite Use* is a relevant activity in Ireland. *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 1990-2009.

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 ETS. The category-level emission factors indicated by this information are used together with the best available production data to obtain the emissions estimates for other years.

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. Both potential and actual emissions of the 21 individual substances concerned (Table A.1, Annex A) should be reported for source category *2.F Consumption of Halocarbons and* SF_6 while actual emissions only are required in other source categories (*2.C Metal Production* and *2.E Production of Halocarbons and* SF_6). 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. 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 1990-2009 for the relevant sources in Ireland. They indicate contributions of 5.8 percent and 3.4 percent to total national emissions in 1990 and 2009, 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. However, since 2006, emissions from air conditioning and refrigeration have been decreasing, as has mobile air conditioning from 2008. This results in a relatively constant total HFC emission from 2006 onwards.

Emissions of PFC arise solely from semiconductor manufacture where they are used as "chamber clean" gases. Emissions continue to follow the downward trend post 2000, which has been evident in previous submissions. 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 where it mainly used in chemical vapour deposition tools and for "dry etching". A summary of the emissions from the Industrial Processes sector is given in Table 4.2 for the period 1990-2009.

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 1990-2009

	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
2.A.1 Cement Production	CO_2	Gg	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
2.A.2 Lime Production	CO_2	Gg	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	Gg	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	Gg	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 Glass Production	CO_2	Gg	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.A.7 Other Mineral Products	CO_2	Gg	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.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
2.B.2 Nitric Acid Production*	N_2O	Gg 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
Emissions of HFC	HFC	Gg CO_2 eq	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
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
Emissions of SF6	SF_6	Gg CO_2 eq	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 Industrial Processes			3178.55	2888.68	2816.16	2804.76	3080.85	3073.12	3214.94	3666.77	3507.14	3571.78	4195.97	4305.31	3726.95	3041.01	3143.42	3253.26	3263.69	3280.52	2989.49	2117.12

4.2 Emissions from Mineral Products (2.A)

The IPCC Level 3 emission source categories relevant under *2.A Mineral Products* in 2009 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 1485.32 Gg, in 2009 of which cement production accounted for 89 percent.

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 2009 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 use, combustion and process CO_2 estimates in accordance with Decision 2004/156/EC. Total process emissions for cement production in 2009 were 1,326.78 Gg CO_2. The plant-specific emission factors for process CO_2 emissions in 2009 ranged from 0.522 to 0.542 t CO_2/ t clinker with an average of 0.535 t CO_2/ t clinker, which is very similar to the 2008 values.

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 1990-2009. 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 44 percent since 2007, falling from a peak of 2374.06 Gg CO_2 in 2007, to 1327.78 Gg CO_2 in 2009. This is a reflection of the recent economic downturn. Additional detailed information is available in Table E.1 in Annex E.

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 2009 have been obtained from the ETS returns to the CCERU of the EPA as for other recent years covered by the scheme and these have been used to confirm the estimates for previous years of the time-series, as given in Table 4.2. The implied emission factor for aggregated lime production was 0.76 t CO_2/t lime in 2009, which is very similar to that for the other years for which ETS data are available. The implied emission factors for the 1990-2004 time-series indicated by the information supplied by the lime producers are in the range 0.75 to 0.88 t CO_2/t lime produced with an average of 0.81 t CO_2/t lime.

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 2005-2009 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 as indicated by the ETS data and the 1996 Revised IPCC Guidelines. This approach has allowed a full 1990-2009 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 utilised to report the emissions estimates in the national inventory.

In the case of bricks and ceramics, the ETS data for the four companies concerned provide estimates of emissions for the years 2005-2009 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 0.044 to 0.048 tonne CO_2/tonne carbonate input while the emission factor for ceramic tiles averages 0.067 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.3 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 percent in 1990, increasing to 30 percent 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 only remaining glass manufacturing plant closed in 2009. Additional detailed information is available in Table E.4 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 fertilizers. However, during 1999 and 2000 the major fertilizer manufacturers introduced severe rationalisation and restructuring measures, which resulted in the closure of the nitric acid and ammonia plants in 2002 and 2003, respectively. Fertilizer manufacture in Ireland no longer takes place and all fertilizers 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 fertilizers 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 are 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 fertilizer. 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 fertilizer spreader. Other fertilizer 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 and the uses of many of the substances concerned are 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 emissions and the methodologies to quantify them 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 rather 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 study 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. 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 work on the 2004 inventory and 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 of the fluids 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 1990-2009 are shown in Table 4.3. They clearly indicate that the combined emissions of HFC, PFC and SF_6 have generally increased year on year to 2006. This overall trend between 1990 and 2006 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 over the period 1990-2006. This trend is determined principally by their use in the manufacture of semiconductors. Data received directly from manufacturing companies in Ireland show annual fluctuations of SF_6 in line with changing manufacturing activity and global trends in the market. From 2006 onwards, emissions of PFC show significant decline as a result of reduce use of these gases in the semiconductor manufacturing sector. Emissions of HFC are dominated by air conditioning and refrigeration with the result that they have now become the largest contributors to the total F-gas emission. In 2009, air conditioning and refrigeration account for some 56 percent of the total F-gas emission.

4.4.2 HFC, PFC and SF_6 Time-Series 1990-2009

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 1990-2009. 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)

HFCs and HFC blends have been widely used as replacement refrigerants for CFC and HCFC refrigerants across virtually all refrigeration sub-sectors (i.e. domestic refrigeration, small commercial distribution systems, industrial systems, building air conditioning systems and refrigerated transport). In terms of stationary refrigeration data, 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 the share of refrigeration unit manufacturer's 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 into 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 into 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 utilises national vehicle fleet statistics from the Department of the Environment, Heritage and Local Government 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 in line with IPCC Good Practice Guidance.

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 utilises 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 percent of product is HFC-227ea and the remainder is HFC-23. Estimates of annual growth factors based on a value of 12.5 percent from 2000 are used to calculate the quantity of these HFCs in new systems based on average annual increase in growth provided by the industry. 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 (0.01) covers lifetime emissions, combining operational and accidental releases, and the third stage factor (0.01) 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 with 90 percent of the share and HFC-152a with 10 percent. 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 two main semiconductor manufacturers in Ireland, both of which provide data on the annual use and estimated emissions of HFCs, PFCs and SF_6 in their plants over the full time series 1990-2009.

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 has supplied an estimate of SF_6 emissions from their equipment 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.

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.

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 1995-2009 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.

4.7 Recalculations for *Industrial Processes*

There have only been three substantial recalculations in the industrial processes sector. They are all associated with HFC emissions, and give rise to very small revisions. The largest revision results in an increase of only 0.05 percent of the source emission. The impact on total HFC emissions is given in Table 4.4 below.

- HFC emissions from Aerosols (2F4) have been revised for 2003-2005. This is due to a revision to population statistics.
- The methodology for estimating emissions of SF_6 from Sporting Goods (2F9) also uses population data. However, a delay of 8 years (the lifetime of trainers) is included in this calculation. So no change is evident from this source.
- HFC emissions from Foams (2F2) have been revised up for 2007-2008. This is due to the use of more recent sales data for HFC134a in closed cell foams.

- HFC emission estimates from MDI's (2F4) in 2008 have been revised down. This is due to a revision in the source data relating to HFC134a.

All of these revisions are very small. Additional minor recalculations are discussed in Chapter 10.

4.8 Improvements in *Industrial Processes*

The inventory agency operate a continuous improvement approach to the inventory. To deliver this, the agency will continue to use verified CO_2 emissions estimates that are reported under the EU emissions trading scheme as the most reliable data for emission sources within category *2.A*. The agency also plans to continue the practice of outsourcing contracts on a periodic basis to re-examine and extend the inventory time-series for emissions of F-gases. This approach has been found to be an efficient way of compiling the estimates for sources and gases that the inventory experts in the EPA have not worked on in detail in the past.

Following a recommendation from the centralized review of Ireland's 2010 submission, the inventory agency will examine whether it is feasible to include data on HFC-23 in CRF table 2(II)Fs2 in its next annual submission if CRF Reporter will allow so. There is known issues with the approach to F-gases within CRF Reporter for Ireland.

Following a recommendation from the centralized review of Ireland's 2010 submission, the inventory agency will provide additional information on calcium oxide/magnesium oxide (CaO/MgO) content of clinker in its next annual submission.

Table 4.3. Emissions of HFC, PFC and SF_6 from Industrial Processes 1990-2009 (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
2.F.1 Refrigeration and Air-Conditionir	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	148.308
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	147.185	168.510	190.197	206.122	204.992
2.F.2 Foams	NO	NO	0.016	0.063	0.303	0.644	1.107	1.779	3.619	5.222	6.275	9.211	11.499	13.636	17.008	19.559	21.744	23.829	25.795	27.625
2.F.3 Fire-extinguishers	0.219	0.700	1.179	1.677	2.235	2.839	3.496	4.210	4.988	5.834	6.755	7.806	9.026	10.385	11.915	13.636	15.571	17.749	20.199	22.956
2.F.4 Aerosols	0.006	0.648	0.721	1.782	7.101	24.917	45.049	76.010	98.777	73.351	80.027	86.350	77.862	83.875	77.314	79.271	81.667	83.876	85.764	86.772
2.F.4 Metered Dose Inhalers	NO	NO	NO	NO	NO	NO	0.020	0.059	0.081	1.053	2.686	14.126	16.992	18.211	18.409	21.738	21.638	6.361	7.006	7.347
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
TOTAL HFC	**0.693**	**5.273**	**6.168**	**9.445**	**19.974**	**44.847**	**76.109**	**133.349**	**191.948**	**198.255**	**231.228**	**253.052**	**278.144**	**351.422**	**387.287**	**436.659**	**509.174**	**500.762**	**520.876**	**500.925**
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
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**
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	41.139	42.441
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
2.F.9 Other - window soundproofing	0.431	0.451	0.472	0.492	0.512	0.532	0.551	0.570	0.590	0.465	0.333	0.195	0.193	0.191	0.189	0.187	0.185	0.183	0.181	0.180
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
2.F.9 Other - sporting goods	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.793	3.695	3.632	3.635	5.403	6.640	5.364	5.407	10.852	7.741	7.813	7.902
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
TOTAL SF_6	**35.405**	**40.635**	**45.866**	**55.350**	**64.835**	**82.827**	**102.062**	**132.100**	**94.187**	**68.866**	**55.807**	**69.300**	**69.952**	**118.179**	**66.644**	**95.462**	**67.456**	**68.747**	**60.829**	**65.300**
TOTAL HFC, PFC and SF_6	**36.191**	**53.531**	**67.184**	**95.004**	**130.075**	**203.056**	**281.256**	**396.273**	**348.006**	**463.053**	**592.441**	**618.336**	**560.499**	**698.395**	**636.359**	**700.461**	**724.950**	**700.089**	**687.902**	**631.795**

Table 4.4. Percentage Change in Total Emissions from Industrial Processes due to Recalculations 1990-2008

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			Estimates in 2010 Submission (Gg CO_2eq)																		
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
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
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
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
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
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
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
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
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	351.44	387.31	436.72	509.17	500.49	520.83
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
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
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	3,041.03	3,143.45	3,253.32	3,263.69	3,280.25	2,989.44
			Recalculated Estimates in 2011 Submission (Gg CO_2eq)																		
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
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
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
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
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
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
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
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
2.F.	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
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
2.F.	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
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
			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
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
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
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
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
2.A.7	Glass Production	CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
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
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
2.F.	Consumption of Halocarbons and SF_6	HFCs	0.00	0.00	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	-0.01	0.00	0.05	0.01
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
2.F.	Consumption of Halocarbons and SF_6	SF_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

Chapter Five

Solvent and Other Product Use

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

This IPCC source sector is considered separately because of its importance in relation to the emissions of NMVOC (non-methane volatile organic compounds), one of the indirect greenhouse gases, which result from the use of solvents and various other volatile compounds. However, some minor direct uses of N_2O (such as anaesthesia) are covered in this source sector and the IPCC reporting format also explicitly provides for the inclusion of CO_2 emissions that result from the oxidation of the carbon in NMVOC emissions. This is consistent with the overall approach adopted for estimating CO_2 from the combustion of fuels using the sectoral approach (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. The Irish inventories include an estimate of CO_2 emissions in this way but emissions associated with the direct use of N_2O are not estimated.

The activity data used for computing estimates of CO_2 emissions in *Solvent and Other Product Use* are the mass emissions of NMVOC computed 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 compiled according to the CORINAIR methodology for reporting to UNECE under the Convention on Long Range Transboundary Air Pollution (CLRTAP) (UNECE, 1999). As part of the work on recalculations for the 2002 submission, Ireland produced a revised and consistent time-series of such NMVOC emissions estimates based on the results of detailed analysis and investigations for 1998 (Finn et al, 2001). CO_2 emission estimates are derived from the NMVOC estimates by assuming that 85 percent of the mass of NMVOC emission in the four CRF categories (3A-D) is converted to CO_2.

5.2 NMVOC and CO_2 Inventory Time Series

Emission control strategies are being implemented in Ireland to comply with a limit of 65 kt for total emissions of NMVOC in 2010 under the National Emissions Ceilings Directive (EP and CEU, 2001). The levels of solvent use and the emissions from solvents are changing 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). In these circumstances, the inventories of NMVOC emissions from solvent use over recent years were reassessed as part of the general improvements conducted for Irish emission inventories during 2005. The inventory agency commissioned a project to carry out in-depth analysis of the specified NMVOC source categories (CTC, 2005) in order to compile the best possible estimates of emissions in 2004 as a follow-up to the earlier commissioned work and to revise the inventories for the years 1998-2003 as necessary in the light of new information. The revised estimates for these target years indicated lower NMVOC emissions than had been previously reported and used as the basis for CO_2 in the sector *Solvent and Other Product Use.* In 2010, substantial further improvements were undertaken, focussing in particular on ensuring that the way in which activity data was extrapolated to recent years was appropriate and consistent.

A bottom-up approach was possible for activities subject to IPPC licensing in the four source categories. 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 not covered by the IPPC licensing system. These included the use of paints and the use of domestic solvents, the two principal source categories. Input, usage and emissions data for each individual activity was collated into IPPC and non-IPPC spreadsheets and emissions were estimated by applying EMEP/CORINAIR methods, default emission factors and general guidance as appropriate. Scaling up to national level was applied where necessary.

The estimates of CO_2 emissions from Solvent and Other Product Use for the period 1990-2009 are presented in Table 5.1. The largest contributor to overall emissions is the 3D Other Use of Solvents, and approximately two thirds of this can be attributed to domestic solvent use sub-category. It is also to be noted that emissions from this sub-category have increased in recent years, while those from the majority of other sub-categories are decreasing. The main drivers for the increasing emissions are considered to be the increased per-capita consumption of, cosmetics, toiletries, household products.

It should be noted that emission estimates have been made by drawing on emission factors from the UK as well as the literature. These have been combined with Irish statistics for number of vehicles, persons and households and a range of other activity data. In some sectors, there is a lack of data for recent years. The way in which available data is extrapolated then becomes very important.

The application of paint is a large source. However emissions 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- the Deco Paints Directive which acted to amend the Solvents Directive (EP and CEU, 2004b, CEC 1999) both having a substantial impact on the solvent content of available paint and associated products.

Legislation has also impacted on the industrial users of solvents, requiring solvent management plans, and improvements to working practices. There has also been a substantial down-turn in recent years, with a number of closures, particularly of a few of the large emitters, which have decreased emissions- although there has also been some new processes licensed. In addition there is a large degree of uncertainty associated with the non-IPPC element of the emissions estimates for these sources. However, the study (CTC, 2005) found that there are specific instances of IPPC licensed sites reducing NMVOC emissions through prevention at source or through abatement.

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.

A number of the methodologies were revised for this inventory cycle (see comments below in Section 5.3 Recalculations). Changes were extensive enough that it was considered appropriate to draft an explanatory document for internal use. This also allowed review and acceptance of the proposed changes.

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

Recalculations for Solvent and Product Use are large, primarily due to changes in the way country specific data for individual years has been extrapolated across the time series (Table 5.2), and the incorporation of reduced solvent content in products in more recent years. All of the recalculations sum to give an overall impact on the emissions from Solvent and Product use in 2008 of -13.5 percent.

The most significant reductions are in 3A Paint application. This arises from the incorporation of a reducing solvent content of different types of paint across the time series. This is driven by the need to comply with the Deco Paints Directives (EP and CEU, 2004b) and substantially reduces emissions in the latter part of the time series.

In addition, there have also been improvements to the way data has been extrapolated. Rather than determine trends, and hence the timeseries, from very few data points, relationships with surrogate data (such as GDP) have been investigated. Where a strong linear correlation is found with the limited country specific data, or data drawn from the UK emissions inventory, this has been used to populate emissions across the time series. This results in a timeseries which follows the national economic trends more closely, and is therefore considered to be more representative of the trend over time. The recent economic downturn in Ireland is better represented, and combines with the reduced solvent content of products in recent years to give substantial reductions in NMVOC emissions, and hence CO_2 emissions. Estimates for 2008 have been recalculated to give a 33.5 percent reduction in emissions from paint application (3A).

Emissions from Dry Cleaning, in sector 3B, have been recalculated. The methodology for estimating the solvent in waste has been amended to assume a constant fraction since 1998, when estimates were based on measurement data. This is likely to be a pessimistic calculation, but is an improvement on the original method, which assumed an unrealistic trend for latter years in the time series.

The recalculation of emissions from Chemical Products and Manufacturing (3C), is associated with a revision to the way the measured data is extrapolated to the time series. The recalculation is only relevant for years after 2004, and has resulted in an increase in emissions of nearly 11.6 percent in 2008.

There are a large number of sources in the 3D category, and several of these have been recalculated. The way in which measurement data has been used to establish a timeseries of emission estimates has been changed for domestic solvent use, and wood impregnation.

Table 5.1 Estimates of NMVOC and CO_2 Emissions from Solvent and Other Product Use 1990-2009

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	11,666	23,868	74.39
2004	8,271	1,142	2,532	11,771	23,717	73.92
2005	8,044	1,246	2,532	11,939	23,760	74.05
2006	7,938	1,364	2,532	12,275	24,109	75.14
2007	7,648	1,304	2,532	12,798	24,282	75.68
2008	7,013	1,270	2,532	13,043	23,859	74.36
2009	6,241	1,178	2,532	13,085	23,036	71.80

Table 5.2 Recalculations for Solvent and Other Product Use 1990-2008

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		Estimates in 2010 Submission (Gg)																		
3.A	Paint Application	6.535	6.646	6.863	7.064	7.337	7.593	7.919	8.195	8.612	8.285	8.084	8.389	8.782	8.855	9.028	9.383	9.882	10.218	10.552
3.B	Degreasing, dry cleaning, electronics	2.727	2.727	2.727	2.727	2.715	2.919	2.618	2.433	2.110	2.019	1.883	1.659	1.067	1.142	1.122	1.228	1.350	1.285	1.248
3.C	Chemical Products and Manufacturing & Pı	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	2.466	2.401	2.335	2.269
3.D	Other Use of Solvents	12.686	13.120	13.060	12.953	13.018	13.087	13.054	13.144	13.257	12.946	12.165	12.138	11.980	11.859	11.967	12.175	12.538	13.103	13.517
3	Total NMVOC emissions	25.486	26.031	26.188	26.282	26.607	27.137	27.128	27.309	27.517	26.620	25.335	25.222	24.696	24.557	24.649	25.251	26.171	26.941	27.585
3	Estimated CO_2 from NMVOC	79.431	81.129	81.618	81.912	82.925	84.578	84.549	85.113	85.761	82.966	78.961	78.607	76.971	76.537	76.822	78.700	81.566	83.965	85.973
		Recalculated 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
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
3.C	Chemical Products and Manufacturing & Pı	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
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
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
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
		Percentage Change in Total Emissions due to Recalculations																		
3.A	Paint Application	4.49	4.68	4.55	4.75	4.87	4.98	4.74	4.41	4.49	4.23	2.06	-0.66	-3.17	-5.77	-8.38	-14.27	-19.68	-25.16	-33.53
3.B	Degreasing, dry cleaning, electronics	-0.83	-0.83	-0.83	-0.83	-0.83	-0.77	-0.46	-0.33	0.00	0.17	0.36	0.60	1.28	1.37	1.80	1.44	1.08	1.50	1.83
3.C	Chemical Products and Manufacturing & Pı	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	5.48	8.45	11.62
3.D	Other Use of Solvents	-0.63	-0.61	-0.66	-0.67	-0.72	-0.72	-0.72	-0.83	-0.82	-0.84	-1.22	-1.46	-1.45	-1.63	-1.63	-1.94	-2.10	-2.32	-3.51
3	Total NMVOC emissions	0.75	0.80	0.78	0.86	0.90	0.96	0.99	0.90	1.01	0.92	0.10	-0.88	-1.77	-2.81	-3.78	-5.90	-7.88	-9.87	-13.51
3	Estimated CO_2 from NMVOC	0.75	0.80	0.78	0.86	0.90	0.96	0.99	0.90	1.01	0.92	0.10	-0.88	-1.77	-2.81	-3.78	-5.90	-7.88	-9.87	-13.51

Chapter Six

Agriculture

6.1 Overview of Agriculture Sector

Table 6.1 lists the IPCC Level 3 source categories in *Agriculture,* where CH_4 and N_2O are the key greenhouse gases. The agricultural activities of particular importance in Ireland are those under *4.A Enteric Fermentation, 4.B Manure Management* and *4.D Agricultural Soils* only, some of which are identified as being among the largest greenhouse gas emission sources in the country (Chapter One and Chapter Two). The inventory time-series for the years 1990-2009 contains emission estimates for all relevant sources and gases in these three important source categories. The availability of better up-to-date data and the completion of major national research in agriculture in 2004 and 2005 has 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 it 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 under Irish circumstances. The IPCC methods require considerable information detail on activity data, emission factors and other input parameters needed 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 robust improvement in estimates of emissions from manure management 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 elaborate new NH_3 inventory for agriculture in 2005 and regulations on the implementation of Good Agricultural Practices for the protection of Waters in SI 101 of 2009 (DEHLG, 2009) 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 ongoing work and assessment in relation to agricultural emissions. Some amendments have been made since the last submission to the methodology for estimating emissions from livestock. These revisions have improved the apportionment of animal manures into the different animal waste management systems (AWMS) and there have been some indirect effects due to developments in the national NH_3 inventory. Manure management emissions from pigs are now calculated using Tier 2 methdology.

Because of the importance of agriculture in the country, Ireland has very extensive and up-to-date statistical data on all aspects of the sector, compiled and published by the Central Statistics Office (CSO). This is the official source of the basic data for inventory purposes, except for synthetic fertilizer use and poultry population statistics, for which annual data are obtained from the Department of Agriculture, Fisheries and Food (DAFF). The CSO and

DAFF are key data providers whose annual statistical inputs to the inventory agency are covered by 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 (livestock populations and fertilizer use) is given in Annex F. It may be noted that in the case of cattle, the populations related to housing (Table F.1 (a)) are different to those for pasture (Table F.1 (b)) to take full account of the respective production systems as they affect emissions. The manner in which the populations are applied is explained in the documentation boxes of the CRF tables. The publication of separate census data for June and December annually and the application of these statistics in order to achieve the most representative activity data for the different emissions categories 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 2009, the emissions from Agriculture were 17,491.31 Gg CO_2 equivalent or 28.0 percent of national emissions. This proportion has decreased in relative terms from 35.1 percent in 1990 as the emissions from energy use increased significantly while emissions from Agriculture have decreased by 9.4 percent. Methane accounted for 62.0 percent and N_2O accounted for 38.0 percent of the emissions in the sector in 2009. 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 percent and 3.6 percent respectively, of total GHG emissions in 2003. It 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 percent of the national total. In addition the recommendation to use Tier 2 methods had also been made in several reports on the review 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. The results of this research (O'Mara, 2006) were applied for the first time in the 2006 submission.

In the 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 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 for each particular subsystem.

Having derived the time spent at pasture and the time spent in housing for cattle, the Farm Facilities Survey (Hyde et al., 2008) 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 which are out-wintered (i.e. at pasture all year round). The Farm Facilities Survey was conducted on a representative sample of farms, the results of which are available either at a National level, or the three designated Nitrates Directives regions.

The use of the O'Mara (2006) and Hyde (2008) datasets therefore provide the information required for the generation of country specific emission factors and a Tier 2 methodological approach. The following sub sections outline the approach in more detail for each of the source categories.

The Tier 2 approach has been used for 1990 and 2003-2009. Interpolation has been used to complete the time series.

Table 6.2 Animal Classifications for Cattle Population

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

6.2.2 Enteric Fermentation in Breeding Cattle

For both dairy cows and suckler cows, the country is divided into three regions: (1) south and east, (2) west and midlands, and (3) north-west, coinciding with the regions used for the implementation of regulations on Good Agricultural Practices for the protection of Waters in SI 101 of 2009 (DEHLG, 2009). This division facilitates in-depth analysis for 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). The CSO produces two censuses of animal numbers per year, one reflecting the number of animals in the national herd 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 percent 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, as dairy cow live-weights are not in general monitored on farms. It 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 percent activity allowance was added for the housed period and a 20 percent 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 percent of GE (Harry Clark, 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, 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). Important parameters such as housing dates (expert opinion), turnout dates (expert opinion) 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 and Food. 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 approximately 7 percent 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 category 1–2 years old). In-calf heifers only need 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.

6.2.5 Summary of Tier 2 Emission Factors for Cattle

The Tier 2 emission factors developed by the detailed analysis outlined above for the years 1990, 2007, 2008 and 2009 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 1990–2009 in respect of the 11 principal classifications are presented in Table F.2 (a) 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 2009 indicates an increase of 5.0 percent from 1990 in line with increased milk yield, although this has fallen from peak values in 2007.

The emission factors for beef cattle indicate little change between 1990 and 2009, except in the case of male cattle in the category of animals greater than two years old. This 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 and 2009

	Enteric Fermentation (kg/head/year)				Manure Management (kg/head/year)			
	1990	2007	2008	2009	1990	2007	2008	2009
Dairy cows	101.38	110.22	109.21	106.41	21.60	20.63	20.53	20.20
Suckler cows	74.03	73.87	75.92	73.84	14.25	14.08	14.49	14.03
Male cattle < 1 year	30.46	29.69	29.71	29.77	8.41	7.91	7.91	7.90
Male cattle 1 - 2 years	62.22	59.19	59.07	58.57	16.89	14.02	13.95	13.88
Male cattle > 2 years	55.08	38.58	36.98	38.84	5.16	2.25	2.02	2.28
Female cattle < 1 year	27.05	27.77	27.72	27.68	8.41	7.91	7.91	7.90
Female cattle 1 - 2 years	53.54	46.60	47.00	47.71	14.93	9.91	10.08	10.44
Female cattle > 2 years	21.65	22.42	22.55	22.63	0.33	0.34	0.34	0.35
Bulls for breeding	86.38	81.55	81.55	81.55	23.79	18.95	18.95	18.95
Dairy in-calf heifers	51.82	50.16	50.16	50.16	13.40	10.93	10.93	10.93
Beef in-calf heifers	55.42	53.68	53.68	53.68	15.61	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 utilize 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 (a) of Annex F. In 2009 the weighted average mass of the pig population is 59.3. The largest proportion of the pig population is the sub-category Fatteners > 20 kg which have an average mass of 58 kgs and account for 63.8 percent of the pig population in 2009. In the case of sheep the sub-category lambs is the only category for which an adjustment is made from the IPCC default emission factor of 8kg CH_4/hd/yr. This is undertaken on the basis that lambs reared for meat production have an average lifetime of 6 months. In 2009 lambs accounted for 44.8 percent of the total sheep population. 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 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 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. Table F4 of Annex F outlines the main results of the farm facilities survey pertinent to inventory calculations.

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 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 because agricultural experts advise that no difference would be expected between the methane potential of dairy cattle manures and non-dairy cattle manures in Ireland, 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, horses, mules and asses and poultry using the Tier 1 approach. 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. For pigs CH_4 emissions are estimated using the Tier 2 approach (as recommended in Table 4.1 of the IPCC Reference Manual). Volatile solids excretion rates are estimated using country specific research and international research on the nutrient requirements of the various sub-categories of swine (NRC, 1998; O'Shea et al., 2009; Lynch et al., 2008; Lynch et al., 2007a; Lynch et al., 2007b; Leek et al., 2007; O'Connell et al., 2005). Emission factors for each sub-category of swine are then calculated using default values for B_o and MCF and country specific information on manure management practices (Hyde et al. 2008). The application of the manure management emission factors for sheep, goats, swine, horses, mules and asses and poultry means that all CH_4 emissions from livestock are included in current estimates. The CH_4 emissions from manure management in 2009 amounted to 24.6 percent of those from enteric fermentation.

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. The nitrogen excretion rates of all livestock are endorsed by the Department of Agriculture and Food and by Teagasc for national use and guidance for farmers in relation to implementation of the Nitrates Directive Action Programme and SI 101 of 2009 (DEHLG, 2009). In the case of cattle, the excretion rates are consistent with the nitrogen content of cattle feeds and the quantities excreted by the animal, as analysed in conjunction with the determination of Tier 2 CH_4 emission factors for cattle. The published 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 are housed in Ireland and a significant contribution from the large sheep population. Animal manures excreted at pasture are unmanaged and the associated emissions are accounted for under agricultural soils (Section 6.5.1). In 2009 the bulk of animal manures in housing are managed in liquid storage systems (93.9 percent and 73.7 percent for dairy cattle and other cattle respectively, and 100 percent 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 percent, 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 2009 amounted to 1.18 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 1990-2009 are presented in Table F.3 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 fertilizer nitrogen applied to soils, adjusted for the amount that volatilizes as NH_3 and NO_X;
F_{AM} = amount of animal manure nitrogen applied directly to soils, adjusted for the amount that volatilizes 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 1990-2009 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. Consequently, nitrogen inputs due to the cultivation of organic soils can be taken as 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:

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

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

$F_S = SS_l * NSSF$;

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

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

and

N_{fert} = total amount of synthetic fertilizer nitrogen applied to soils (kg N);
$Frac_{GASF}$ = fraction of synthetic fertilizer nitrogen that volatilizes as NH_3 (0.018 in 2009);
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 (0.66 in 2009);
$Frac_{GASM1}$ = fraction of animal manure nitrogen that volatilizes as NH_3 during housing, manure storage and landspreading (0.501 in 2009);
N_2O-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 percent 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 fertilizer use (N_{fert}) are obtained from the Department of Agriculture and Food while the organic nitrogen inputs (N_{ex}) are known as outlined in section 6.4. Significant proportions of the nitrogen applied to soils in synthetic fertilizers and animal manures are normally volatilized as NH_3 with some additional conversion to 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 fertilizer and animal manure nitrogen lost in this way as 10 percent and 20 percent, respectively. The volatilization rates for Ireland are however determined from an elaborate NH_3 inventory for agriculture (McGettigan et al, 2010) and 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 2009 values of $Frac_{GASM1}$ and $Frac_{GASM2}$ are 0.501 and 0.037, respectively indicating an overall volatilisation rate of 0.194 for animal manure nitrogen.

The expression for 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 volatilization 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 Tier 2 inventory of NH_3. The fractions $Frac_{GASF}$ and $Frac_{GASM1}$ are estimated at 0.018 and 0.501, respectively in 2009 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 percent (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 percent of the organic nitrogen input to agricultural soils in 2009.

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 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 2009 for category *4.D.1 Direct Soil Emissions* amounted to 7.56 Gg, of which synthetic fertilizers accounted for 5.92 Gg, 1.42 Gg was due to land spreading of animal manures and crops (N-fixing and crop residue) produced 0.20 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 0.66 for $Frac_{GRAZ}$ in 2009, due to the relatively short period that cattle remain in housing and the contribution from large sheep populations, the majority of which are not housed. 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 2009 was 8.77 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 fertilizers 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

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

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

where:

$N_2O_{indirect\text{-}dep}$ = the indirect emissions of N_2O due to atmospheric nitrogen deposition;
$N_2O_{indirect\text{-}leach}$ = the indirect emissions of N_2O due to nitrogen leaching;
$Frac_{GASM2}$ = fraction of animal manure nitrogen that volatilizes as NH_3 during grazing (0.036 in 2008);
$Frac_{LEACH}$ = fraction of synthetic fertilizer nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2009);
EF_4 = N_2O emission factor for nitrogen inputs from atmospheric deposition;
EF_5 = N_2O emission factor for nitrogen leaching.

The expressions for $N_2O_{indirect\text{-}dep}$ and $N_2O_{indirect\text{-}leach}$ 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 $N_2O_{indirect\text{-}dep}$ from F_S, the nitrogen input from sludge spreading, but F_S increases $N_2O_{indirect\text{-}leach}$ through its inclusion in F_{AW}. The default value for $Frac_{LEACH}$, the fraction of nitrogen lost through leaching, in the IPCC Guidelines is 30 percent. Research studies conducted in Ireland suggest that approximately 10 percent of all applied nitrogen is lost through leaching (Del Prado et al, 2006; Neill, 1989; NEUT, 1999, Ryan et al. 2006; Watson et al. 1998). The research undertaken ranges from farm scale studies (Del Prado et al. 2006 and Ryan et al. 2006) to larger catchment based studies (Neill, 1989 and NEUT, 1999) A value of 0.1 is therefore considered to be a more representative estimate of $Frac_{LEACH}$ for Ireland than the default value of 0.3 (range 0.1-0.8) and it is used for 2009, as it was for previous years.

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 2009 amounted to 3.96 Gg N_2O, or approximately 50 percent 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. These uncertainties are the main determinant behind uncertainty in total national emissions outlined in Table 1.8.

The emission time series for agriculture 1990–2009 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 1990-2009.

Table 6.4 Activity Data and Emission Factor Uncertainty in Agriculture

<table>
<tr><th rowspan="2" colspan="2"></th><th colspan="2">Pre 2006</th><th colspan="2">Post 2006</th></tr>
<tr><th>Activity Data Uncertainty</th><th>Emission Factor Uncertainty</th><th>Activity Data Uncertainty</th><th>Emission Factor Uncertainty</th></tr>
<tr><td>4.A Dairy Cattle</td><td>CH_4</td><td>1</td><td>20</td><td>1</td><td>15</td></tr>
<tr><td>4.A Other Cattle</td><td>CH_4</td><td>1</td><td>30</td><td>1</td><td>15</td></tr>
<tr><td>4.A Other Livestock</td><td>CH_4</td><td>1</td><td>50</td><td>1</td><td>30</td></tr>
<tr><td>4.B Dairy Cattle</td><td>CH_4</td><td rowspan="3">32</td><td rowspan="3">50</td><td>1</td><td>15</td></tr>
<tr><td>4.B Other Cattle</td><td>CH_4</td><td>1</td><td>15</td></tr>
<tr><td>4.B Other Livestock</td><td>CH_4</td><td>1</td><td>30</td></tr>
<tr><td>4.B Liquid System</td><td>N_2O</td><td rowspan="2">32</td><td rowspan="2">100</td><td rowspan="2">11.2</td><td rowspan="2">100</td></tr>
<tr><td>4.B Solid Storage and Dry lot</td><td>N_2O</td></tr>
<tr><td>4.D Direct Soil emissions</td><td>N_2O</td><td rowspan="3">32</td><td rowspan="3">100</td><td rowspan="3">11.2</td><td rowspan="3">100</td></tr>
<tr><td>4.D Pasture Rand and Paddock</td><td>N_2O</td></tr>
<tr><td>4.D Indirect Emissions</td><td>N_2O</td></tr>
</table>

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 undertaken 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 and the outputs are directly compatible with the CRF Reporter. The entire compilation for the 2011 submission was reviewed externally by an independent consultant, qualified as a UNFCCC expert reviewer for Agriculture. This provides an important element of quality assurance for the 2011 submission, and a number of quality checks were added to ensure consistency across pollutants, and across the emissions time series. No further reviews of this type are planned until there is a major methodological change to the sector, the current

QA/QC procedures being considered sufficient for the status of inventory now achieved for *Agriculture*.

The collaboration between inventory experts and researchers involved in developing the improved inventory methodologies for both CH_4 and NH_3 adds significantly to the quality and reliability of the emissions estimates for agriculture. The ongoing assessment and endorsement of the outcomes by other experts in Teagasc and the DEHLG according to the IPCC good practice guidance is being maintained by the inventory agency and is an important part of the overall QA/QC procedures being undertaken on an annual basis. Similar to the 2010 submission a member of the inventory team undertook a re-examination of some of the underlying assumptions in relation to the AWMS splits, assessed emissions from some of the minor livestock types which had been omitted from NH_3 inventory to date and other data underlying the Tier 2 CH_4 estimates. The effect of these QA/QC procedures is described in detail in the following section (section 6.8).

6.8 Recalculations in Agriculture

6.8.1 Consistency of AWMS Methodology

A methodological change was made as an outcome of the centralized review of Ireland's 2010 submission. This methodological change was undertaken and national emission estimates resubmitted to the UNFCCC Secretariat on the 1st November 2010 as requested by the expert review team (ERT).

It was identified by the ERT that there were inconsistencies between the use of reference information to determine the AWMS splits for CH_4 and N_2O. An internal review conducted by the inventory agency confirmed this to be the case. As a result a consistent methodological approach was adopted to determine the AWMS splits for both CH_4 and N_2O emission estimates.

The methodological approach that is now consistently used in estimating emissions of CH_4, N_2O and NH_3 is to use AWMS data from O'Mara et. al. (2006), which apportions the year between grazing and housing, and to supplement this with data from Hyde et. al. (2008) to determine the fractions of solid and liquid AWMS split for housed cattle, and to identify the proportion of individual cattle subcategories which are outwintered (as has heretofore been the case).

Ensuring that this methodology was used consistently for CH_4 and N_2O gave rise to a change in the amount of nitrogen deposited to pasture range and paddock. It was therefore necessary to recalculate the direct and indirect emissions of N_2O from soils and NH_3 emissions from soils as this is also required for the N_2O emissions calculation, as well as being submitted under the Convention on Long-Range Transboundary Air Pollution in its own right.

The overall impact of this methodological change for N_2O in 2008 was an increase of less than 1 percent.

6.8.2 Other recalculations

An external review by an independent consultant, qualified as a UNFCCC expert reviewer for Agriculture of all agricultural emissions identified a number of missing sources of NH_3 emissions for which both CH_4 and N_2O were being estimated. As a result NH_3 emissions are now estimated for horses, mules and asses and goats thus necessitating the recalculation of both direct and indirect emissions of N_2O from soils. In addition the adoption of recently published fertilizer use statistics has allowed for revised apportionment of fertilizer types by crop in the NH_3 inventory for the period 2004-2008.

On foot of the centralized review of Ireland’s 2010 submission, the inventory agency undertook to review the modification of defaults emission factors for CH_4 emissions from swine. Firstly for enteric fermentation, the application of revised animal weights (consistent with the NH_3 inventory) and the assumption that the default emission factor is equivalent to an 85 kg animal (average pig weight for manure management emission factor derivation), has led to an increase in the implied emission factor for swine from 0.45 to 1.08 kg/hd/yr. For manure management, CH_4 emissions are now estimated using the Tier 2 approach as recommended in Table 4.1 of the IPCC Reference Manual using country specific information on feed intake and manure management (section 6.3.2).

The overall impact of these recalculations can be seen in Table 6.5.

6.9 Improvements in Agriculture

Agricultural sources of CH_4 and N_2O make a large contribution to total GHG emissions from Ireland (see Chapter 2). So quantifying the emissions as accurately as possible is given a high priority.

A large number of input variables determine the emissions in the case of both gases and the final results are very sensitive to changes in many of these variables. Assumptions relating to some calculation parameters have an important bearing on the results. While the IPCC methodologies for the agricultural emission sources that are relevant in Ireland are now very comprehensive, they remain generalised and necessarily simplified, considering the complex systems and processes that produce the CH_4 and N_2O emissions.

The key to developing better estimates 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 when applying these methodologies. 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. A research project is currently underway to advance development of soil carbon and nitrogen models and to consolidate the findings arising from recent Irish and international research in this area. Through a series of modelling workshops and novel application of GIS and meta-analysis tools, the objective is to provide robust country specific emission factors and modelling solutions to incorporate into inventory procedures.

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.

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
Estimates in 2010 Submission (Gg)																					
4.A	Enteric Fermentation	CH_4	452.08	456.25	459.10	461.03	458.82	458.72	469.18	479.43	486.97	475.10	452.52	447.31	443.96	440.04	440.20	437.46	435.35	421.00	419.24
4.B	Manure Management	CH_4	111.01	111.94	113.02	113.26	112.47	112.00	115.81	118.59	120.20	115.67	109.96	109.81	109.84	108.06	107.43	107.12	106.25	102.71	102.53
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
4.D.1	Direct Soil emissions	N_2O	9.11	8.96	8.75	9.10	9.67	10.18	9.96	9.28	10.36	10.60	9.82	9.00	8.92	9.44	9.00	8.69	8.33	7.88	7.64
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
4.D.3	Indirect emissions	N_2O	4.16	4.18	4.18	4.27	4.40	4.50	4.55	4.47	4.75	4.77	4.51	4.28	4.25	4.34	4.22	4.16	4.10	3.91	3.84
4	Total Methane	CH_4	563.09	568.19	572.13	574.29	571.29	570.71	584.99	598.03	607.17	590.77	562.48	557.12	553.79	548.10	547.63	544.58	541.59	523.71	521.78
4	Total Nitrous oxide	N_2O	23.78	23.82	23.83	24.23	24.92	25.52	25.60	25.05	26.70	26.76	25.23	23.99	23.74	24.39	23.82	23.39	22.85	21.84	21.44
4	Total (CO_2 eq)	CO_2 eq	19,196.64	19,315.17	19,401.97	19,571.04	19,721.08	19,896.89	20,219.57	20,322.57	21,026.77	20,701.49	19,633.03	19,137.06	18,989.03	19,071.44	18,883.07	18,687.60	18,458.14	17,769.55	17,605.08
Recalculated 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
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
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
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
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
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
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
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
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
Percentage Change in Total Emissions due to Recalculations																					
4.A	Enteric Fermentation	CH_4	0.18	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.24	0.23	0.24	0.24	0.25	0.24	0.24	0.24	0.24	0.23	0.23
4.B	Manure Management	CH_4	0.09	0.10	0.08	0.14	0.16	0.16	0.21	0.21	0.28	0.26	0.23	0.28	0.29	0.30	0.27	0.31	0.30	0.27	0.26
4.B	Manure Management	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.D.1	Direct Soil emissions	N_2O	-0.20	-0.20	-0.21	-0.21	-0.20	-0.19	-0.20	-0.22	-0.20	-0.20	-0.20	-0.22	-0.23	-0.21	-0.23	-0.26	-0.32	-0.25	-0.48
4.D.2	Pasture Range and Paddock	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.D.3	Indirect emissions	N_2O	3.37	3.35	3.33	3.31	3.14	2.90	3.04	3.12	3.10	3.03	3.04	2.82	2.81	2.72	2.75	2.73	2.87	2.76	3.18
4	Total Methane	CH_4	0.16	0.17	0.18	0.20	0.20	0.21	0.22	0.22	0.25	0.24	0.23	0.25	0.26	0.25	0.24	0.25	0.25	0.24	0.24
4	Total Nitrous oxide	N_2O	0.51	0.51	0.51	0.50	0.48	0.44	0.46	0.47	0.47	0.46	0.47	0.42	0.42	0.40	0.40	0.39	0.40	0.41	0.40
4	Total (CO_2 eq)	CO_2 eq	0.30	0.30	0.30	0.31	0.31	0.30	0.31	0.32	0.34	0.33	0.33	0.32	0.32	0.31	0.30	0.30	0.31	0.30	0.30

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 four 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. 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 nitrogen fertilization of forest land, 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-

2009 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. The reporting of estimates for all land-use categories in LULUCF represents a major improvement in terms of inventory completeness for Ireland. 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 1990-2009. The estimates for 5.A Forest Land (except for the soils pool) are prepared under the responsibility of COFORD and submitted to the inventory agency in accordance with the MOU between COFORD and the Office of Climate Licensing and Resource Use 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

DOM : dead organic matter
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 2009 inventory for LULUCF (the 2011 submission) follows the same general approach and methodologies as those used for the submissions from 2008 to 2010 submissions. 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 source period 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 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 1990-2009 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 2010 submission for the years 1990-2009 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.

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 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 1990-2009 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 CORINE land-cover data. 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. The annual totals for individual years in the matrices do not necessarily correspond with the areas that appear as activity data for each year under the different land categories in the various sectoral background data tables in the CRF tables because the latter account for the rolling 20-year transition period that began in 1970. In addition, the area relevant to the biomass pool is not the same as that for the soils pool for *5.A.2 Land Converted to Forest Land* due to the combination of the three national forest area classes (young, mature and clear-felled) used in Ireland’s approach to quantify carbon stock change in forest biomass.

It is not possible, to fully reconcile forest areas as reporting under LULUCF and KP Art. 3.3 and 3.4. This is due to important differences between the definitions of forest area when considering the forest biomass carbon pools and the soil pool. The LULUCF estimate of the area of land converted to forest is based on the gross areas bounded within the afforested areas. This is in contrast to the area of forest used to estimate above and below ground biomass, for KP reporting which is based on the canopy cover. The covered area due to forest canopy development is based on forward projection of forest growth from the FIPS 1995 base year and subsequent afforestation, felling, replantation and deforestation where relevant. A similar backward projection analysis is undertaken to estimate forest canopy from 1990 to 1995. The FIPS 1995 analysis identified approximately 190kha areas which were pre-canopy closure plots. These areas are termed Unclassified Forests. Total afforestation and replantation in the 7 years prior to 1995 was c140kha, clearly pointing to the conclusion that much of the Unclassified area is indeed early development forest. Within 7 to 10 years a given afforested (or replanted) plot will mature to develop a complete canopy, and thereafter LULUCF and KP reporting of this plot would coincide. However, within the national forest there will always be significant areas of young growth which do not have sufficient canopy to be classified. Change in the above ground, below ground and dead wood/litter pools are estimated based on those areas of forest which have sufficient canopy to satisfy the Irish definition of forest areas. Carbon change in soil pools are based on total forest area including early stage forests, as the land use will impact of soil during the conversion/preparation of plots for afforestation or replanting. That is to say, the different areas for forest biomass compared to forest soil are consistent with the definitions of forest areas, canopy and soil disturbance.

Table 7.4 records the net area in terms of the LULUCF Soil definition of forest area, being the higher conservative estimate of areal extent of forest. The CRF tables report forest areas in terms of biomass definition, this being the more important and dynamic carbon pool. The area of forest area under canopy has increased by 61.5 percent between 1990 (370,160 ha) and 2009 (597,952 ha). The total area of land within the forestry increased from 481,635 ha to 728,420 ha (+51.2%), this includes recent afforested and replantation areas which have not yet reached full canopy. However, the proportion of *Forest Land* to total land in the country is only 8.7 percent, which is low compared to many other Annex I Parties.

Grassland is the dominant land-use category in all years, accounting for 58.2 percent of total area in 1990, followed by *Wetland* accounting for 17.2 percent. The *Other Land* category is the next largest at 11.2 percent, followed by C*ropland* at 5.7 percent with *Forest Land* accounting for the remaining 5.2 percent 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 1990-2008 (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_2eq.)																			
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)	-1165.11	-1336.37	-1086.37	-1085.90	-817.26	-650.07	-598.31	-514.18	-795.82	-862.17	-408.71	-312.77	-680.45	-1506.00	-1084.20	-1234.54	-1204.12	-1840.03	-2739.54	-2988.58
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	-1038.63	-1296.59	-1111.36	-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**

[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 2009 (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 or 50% of conventional stocking and includes recently clearfelled areas. 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. Trees grown for fruit or flowers are excluded, as are woody species such as furze and rhododendron. The larger area is the total area within forest boundaries, and includes access roads and other clear areas. The lower figure (in brackets) is the area of land under forest canopy, and is forest land in the strict sense.	497,143 (370,160)	745,324 (597,952)	National Forest Inventory (NFI) FIPS (Forest Inventory and Planning System) 1995 COILLTE database Forest Service Premiums database CORINE Land Cover General Soil Map	Settlement	Grassland & Wetland
Cropland	Permanent crops and tillage areas (including setaside) recorded by the Central Statistics Office (CSO)	404,563	399,500	CSO, CORINE Land Cover LPIS (Land Parcels information System	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	3,787,800	CSO, CORINE Land Cover LPIS (Land Parcels information System) CORINE Land Cover General Soil Map	Cropland	Other Land
Wetlands	Natural unexploited wetlands	1,226,723	1,131,575	CORINE Land Cover General Soil Map	Peatlands	Forestry
Peatland	Wetland areas commercially exploited for public and private extraction of peat and areas used for domestic harvesting of peat	73,401	53,415	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	98,152	114,600	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	671,420	879,572	Natural grasslands not in use for agricultural purposes, water bodies, bare rock	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 1990-1997 (ha)

	Forest Land	Grassland	Cropland	Peatland	Wetland	Settlements	Other Land	Total
1990	**497,143**	**4,140,385**	**404,563**	**73,401**	**1,226,723**	**98,152**	**671,420**	**7,111,785**
Forest Land	497,133					10		497,143
Grassland	8,774	4,131,323				288		4,140,385
Cropland	356	2,488	401,694			26		404,563
Peatland	320	61		72,466	554			73,401
Wetland	9,687				1,217,036			1,226,723
Settlements						98,152		98,152
Other Land		16,382				19	655,019	671,420
1991	**516,269**	**4,150,253**	**401,694**	**72,466**	**1,217,590**	**98,495**	**655,019**	**7,111,785**
Forest Land	516,259					10		516,269
Grassland	7,255	4,119,655	1,217			293	21,832	4,150,253
Cropland	269		401,399			26		401,694
Peatland	320	61		71,958	127			72,466
Wetland	8,844				1,208,745			1,217,590
Settlements						98,495		98,495
Other Land						19	655,000	655,019
1992	**532,948**	**4,119,716**	**402,616**	**71,958**	**1,208,872**	**98,844**	**676,831**	**7,111,785**
Forest Land	532,938					10		532,948
Grassland	7,707	4,099,263	11,512			313	921	4,119,716
Cropland	314		402,273			28		402,616
Peatland	320	61		71,226	352			71,958
Wetland	7,647				1,201,226			1,208,872
Settlements						98,844		98,844
Other Land						20	676,811	676,831
1993	**548,925**	**4,099,324**	**413,785**	**71,226**	**1,201,577**	**99,216**	**677,732**	**7,111,785**
Forest Land	548,915					10		548,925
Grassland	9,266	4,085,880				388	3,789	4,099,324
Cropland	416	3,033	410,301			35		413,785
Peatland	320	61		70,682	163			71,226
Wetland	9,446				1,192,131			1,201,577
Settlements						99,216		99,216
Other Land						25	677,707	677,732
1994	**568,364**	**4,088,974**	**410,301**	**70,682**	**1,192,294**	**99,675**	**681,496**	**7,111,785**
Forest Land	568,364							568,364
Grassland	10,678	4,077,895				402		4,088,974
Cropland	525	463	409,277			36		410,301
Peatland	140	30		69,873	639			70,682
Wetland	12,034				1,180,260			1,192,294
Settlements						99,675		99,675
Other Land		9,459				26	672,011	681,496
1995	**591,740**	**4,087,847**	**409,277**	**69,873**	**1,180,899**	**100,138**	**672,011**	**7,111,785**
Forest Land	591,740							591,740
Grassland	9,443	4,032,277	7,816			508	37,803	4,087,847
Cropland	495		408,736			46		409,277
Peatland	140	30		68,626	1,077			69,873
Wetland	10,570				1,170,330			1,180,899
Settlements						100,138		100,138
Other Land						33	671,978	672,011
1996	**612,388**	**4,032,307**	**416,552**	**68,626**	**1,171,407**	**100,725**	**709,781**	**7,111,785**
Forest Land	612,388							612,388
Grassland	5,322	4,015,094				558	11,334	4,032,307
Cropland	326	2,076	414,100			50		416,552
Peatland	140	30		67,739	717			68,626
Wetland	5,313				1,166,093			1,171,407
Settlements						100,725		100,725
Other Land						36	709,744	709,781
1997	**623,489**	**4,017,200**	**414,100**	**67,739**	**1,166,810**	**101,369**	**721,078**	**7,111,785**

Table 7.4 (continued) Land Use Matrices 1997-2004 (ha)

	Forest Land	Grassland	Cropland	Peatland	Wetland	Settlements	Other Land	Total
1997	**623,489**	**4,017,200**	**414,100**	**67,739**	**1,166,810**	**101,369**	**721,078**	**7,111,785**
Forest Land	623,489							623,489
Grassland	6,129	4,001,050				600	9,420	4,017,200
Cropland	326	5,720	408,000			54		414,100
Peatland	140	30		66,845	724			67,739
Wetland	6,000				1,160,811			1,166,810
Settlements						101,369		101,369
Other Land						39	721,039	721,078
1998	**636,083**	**4,006,800**	**408,000**	**66,845**	**1,161,535**	**102,063**	**730,459**	**7,111,785**
Forest Land	636,083							636,083
Grassland	6,910	3,999,245				646		4,006,800
Cropland	423	6,619	400,900			58		408,000
Peatland	140	30		65,539	1,136			66,845
Wetland	4,862				1,156,673			1,161,535
Settlements						102,063		102,063
Other Land		11,506				42	718,911	730,459
1999	**648,418**	**4,017,400**	**400,900**	**65,539**	**1,157,809**	**102,809**	**718,911**	**7,111,785**
Forest Land	648,247					171		648,418
Grassland	8,088	4,008,776				535		4,017,400
Cropland	490	261	400,100			48		400,900
Peatland	327	75		63,509	1,628			65,539
Wetland	6,103				1,151,706			1,157,809
Settlements						102,809		102,809
Other Land		32,788				35	686,088	718,911
2000	**663,256**	**4,041,900**	**400,100**	**63,509**	**1,153,334**	**103,598**	**686,088**	**7,111,785**
Forest Land	663,085					171		663,256
Grassland	8,081	3,994,425	15,086			758	23,551	4,041,900
Cropland	517		399,514			68		400,100
Peatland	327	75		61,565	1,542			63,509
Wetland	5,853				1,147,480			1,153,334
Settlements						103,598		103,598
Other Land						49	686,039	686,088
2001	**677,863**	**3,994,500**	**414,600**	**61,565**	**1,149,023**	**104,645**	**709,590**	**7,111,785**
Forest Land	677,692					171		677,863
Grassland	8,223	3,948,525	8,886			664	28,202	3,994,500
Cropland	526		414,014			60		414,600
Peatland	327	75		59,617	1,546			61,565
Wetland	5,292				1,143,731			1,149,023
Settlements						104,645		104,645
Other Land						43	709,546	709,590
2002	**692,060**	**3,948,600**	**422,900**	**59,617**	**1,145,277**	**105,583**	**737,748**	**7,111,785**
Forest Land	691,889					171		692,060
Grassland	4,745	3,929,816	13,192			848		3,948,600
Cropland	315		422,508			76		422,900
Peatland	327	75		57,670	1,545			59,617
Wetland	3,024				1,142,253			1,145,277
Settlements						105,583		105,583
Other Land		4,010				55	733,683	737,748
2003	**700,300**	**3,933,900**	**435,700**	**57,670**	**1,143,798**	**106,734**	**733,683**	**7,111,785**
Forest Land	700,129					171		700,300
Grassland	5,430	3,868,464				901	59,104	3,933,900
Cropland	358	12,461	422,800			81		435,700
Peatland	327	75		55,726	1,542			57,670
Wetland	2,938				1,140,860			1,143,798
Settlements						106,734		106,734
Other Land						59	733,624	733,683
2004	**709,182**	**3,881,000**	**422,800**	**55,726**	**1,142,402**	**107,947**	**792,728**	**7,111,785**

Table 7.4 (continued) Land Use Matrices 2004-2009 (ha)

	Forest Land	Grassland	Cropland	Peatland	Wetland	Settlements	Other Land	Total
2004	**709,182**	**3,881,000**	**422,800**	**55,726**	**1,142,402**	**107,947**	**792,728**	**7,111,785**
Forest Land	709,011					171		709,182
Grassland	5,821	3,862,193				1,087	11,899	3,881,000
Cropland	384	38,519	383,800			98		422,800
Peatland	133	88		55,288	216			55,726
Wetland	3,072				1,139,329			1,142,402
Settlements						107,947		107,947
Other Land						71	792,657	792,728
2005	**718,421**	**3,900,800**	**383,800**	**55,288**	**1,139,546**	**109,374**	**804,556**	**7,111,785**
Forest Land	718,404					17		718,421
Grassland	4,728	3,874,820				1,281	19,971	3,900,800
Cropland	293	4,592	378,800			115		383,800
Peatland	133	88		54,872	195			55,288
Wetland	2,524				1,137,021			1,139,546
Settlements						109,374		109,374
Other Land						84	804,473	804,556
2006	**726,082**	**3,879,500**	**378,800**	**54,872**	**1,137,216**	**110,872**	**824,444**	**7,111,785**
Forest Land	726,077					5		726,082
Grassland	4,228	3,873,943				1,329		3,879,500
Cropland	262	1,119	377,300			120		378,800
Peatland	133	88		54,386	265			54,872
Wetland	2,219				1,134,997			1,137,216
Settlements						110,872		110,872
Other Land		21,350				87	803,007	824,444
2007	**732,918**	**3,896,500**	**377,300**	**54,386**	**1,135,262**	**112,413**	**803,007**	**7,111,785**
Forest Land	732,852					66		732,918
Grassland	3,613	3,780,912	39,822			1,052	71,101	3,896,500
Cropland	228		376,978			95		377,300
Peatland	133	88		53,889	275			54,386
Wetland	2,047				1,133,215			1,135,262
Settlements						112,413		112,413
Other Land						69	802,939	803,007
2008	**738,873**	**3,781,000**	**416,800**	**53,889**	**1,133,490**	**113,695**	**874,039**	**7,111,785**
Forest Land	738,854					18		738,873
Grassland	3,926	3,770,723				768	5,583	3,781,000
Cropland	242	16,989	399,500			69		416,800
Peatland	133	88		53,415	252			53,889
Wetland	2,168				1,131,322			1,133,490
Settlements						113,695		113,695
Other Land						50	873,989	874,039
2009	**745,324**	**3,787,800**	**399,500**	**53,415**	**1,131,575**	**114,600**	**879,572**	**7,111,785**

7.2.3 Soil Type and Soil Organic Carbon

Soil organic carbon (SOC) is the basic parameter in the IPCC estimation methods for determining carbon stock changes in soils, which is the dominant source of carbon emissions in land conversion categories in LULUCF. 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}.

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	
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:

ΔC = annual change in carbon stocks;
A = area of land converted from a former land use;
SOC_0 = soil organic carbon stock for current land use;
$SOC_{0\text{-}T}$ = 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 adjustment factors derived from the product of F_{LU}, F_{MG} and F_I taken from Table 3.3.4 of the IPCC good practice guidance on LULUCF for the land uses defined for Ireland (Table 7.3). 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. Adjustment Factors for SOC

Land Use	F_{LU}	F_{MG}	F_I	Adjustment factor, AF
Cropland	0.71	1.09	1.11	0.86
Improved grassland	1.0	1.0	1.14	1.14
Unimproved grassland	1.0	1.0	NA	1.0
Rough grazing	1.0	0.95	NA	0.95
Other 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.

7.3 Forest Land (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 2008 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 fully 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 by making the appropriate split between their respective contributing areas on the basis of the age of forests. The model as used to date accounts for total forest area in the following classes:

(i) Areas of young forest from 7 to 25 years of age;

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

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

The area representing category *5.A.2 Land Converted to Forest Land* may be readily determined from the area of young forests in class (i) above. The area for category *5.A.1 Land Remaining Forest Land* is then the total productive area less that for category 5.A.2. 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. 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. The following paragraphs summarise the carbon accounting methodology applied for carbon stock change in living biomass in the CARBWARE 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 1990-2009.

7.3.1.1 Forest Area and Species

A time series of forest strata by area and age was constructed for the years 1990-2007 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 (age up to 7 years) 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, recent plantings less than 7 years old, which are assumed to have no measurable biomass, and other productive un-forested areas.

Having established the basic area-species matrix for 1995, the corresponding data for the years 1996 to 2009 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 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 F.1 of Annex G have been slightly revised up to 2009 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 was applied to unclassified forest areas in column E of Table F1, which is assumed to have a zero net emission. Therefore, this does not influence the emission or removals estimates for forest land and does not warrant a recalculation for this land use category.

7.3.1.2 Volume

The FIPS survey results do not contain wood volume or increment data. Therefore, the volume of stemwood was determined from Irish yield models (Hamilton *et al*, 1971; Forest Service, 2000) and is based on periodic current annual increment. 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 ages assumed for young and mature conifers were 15 and 35 years, respectively. Young broadleaved crops were allocated a nominal standing volume of 10 m^3/ha.

The volume in mature broadleaved forests was determined from the total timber plus firewood 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 percent to allow for forest roads and rides. 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) and by dry density in the range 0.35-0.55, depending on species and age, to obtain whole-tree wood volume (m^3/ha).

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 through the company's timber sales reporting system. 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 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 Increment

The carbon uptake of each FIPS category is calculated by multiplying whole-tree volume by a carbon content of 0.5 and by area. In the original version of the CRF, increment values were used to determine annual increments in carbon stocks and from these the harvest was subtracted to find the net changes in carbon stocks. In the current approach, reduced actual standing volumes (standing volumes less thinnings) on *a net areas basis* are used to estimate standing volume. Annual increment in the latest year is then calculated by subtracting the carbon stock in the previous year from the estimated carbon stock in the latest year. This 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):

$$\Delta C_{L(AB)} = TOTAL_{(AB)} \text{ and } \Delta C_{L(BB)} = TOTAL_{(BB)} \quad \text{...(7.2)}$$

The carbon stocks in the AB and BB pools were calculated from the standing volume (V) of the forest stand, as specified on the limited felling licence application, a basic density (D) in the range 0.35 to 0.55 (depending on tree species), a biomass expansion factor (BEF) of 1.68t/t^{-1}, a carbon fraction (CF) of 0.5 and a root to shoot ratio R of 0.2, as follows:

$$TOTAL_{(AB)} = (V \times D \times BEF \times CF) \times (1 - R) \quad \text{...(7.3)}$$

$$TOTAL_{(BB)} = V \times D \times BEF \times CF \times R \quad \text{...(7.4)}$$

The volume of timber associated with harvest was derived from felling licence records (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 2006-2009 (biomass gains and losses) are applied to area data to derive estimated of looses 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 (Section 3.2.1.2 of the good practice guidance 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 percent 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 percent 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 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 percent broadleaf and 93 percent 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 percent and 69 percent, 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 Ch 11). Mean implied emission factors for the period 2006-2009 are applied to area data to derive estimated of looses in the years before 2006.

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 COFORD 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 percent of the total area.

Using GIS analysis, land areas were allocated to the conversion categories 5.A.2.1 through 5.A.2.5 and to soil classes using Table 7.5. The agricultural lands converted to forest land were determined from the LPIS (Land Parcel Information Systems) 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. It was assumed that planting practice was consistent with the practices in the early 1990's, and therefore forest areas were allocated to the various soil types in the same proportions as prevailed in the early 1990's.

The afforested areas were superimposed on the general soil map and 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 are classified as organic soils or (peats) if the peat depth is greater than 30 cm and the organic content is greater than 20%. 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 percent and 40 percent, respectively. The allocation to mineral, organo-mineral and organic soils is now determined separately for each year using LPIS data.

7.3.3.1.1 Mineral soils – Forest Land remaining Forest Land (5.A.1)

Under the Tier 1 approach it is assumed that the carbon stock in soil organic matter for category *5.A.1 Forest Land remaining Forest Land, FF,* on mineral soils remains constant, regardless of changes in forest management, forest type and disturbance. The notation key NO is therefore used for mineral soils under this land category in CRF Table 5.A.

A significant revision has been made in the assessment of carbon loss from afforested organic soils. As detailed below, emissions are now believe to continue throughout the first rotation period, as the order of 50 years following afforestation. In the submission, lands are re-designated as FF 20 years after land use change. Therefore, a significant proportion of FF on organic soils are an emission source. Previous submission had assumed no emission from this activity, and the emissions were reported as NO.

7.3.3.1.2 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; NIR, 2010) 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 ongoing 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.

7.3.3.1.3 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. While the emission 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 by 1990 and organic soils emissions from these forests are deemed to be zero and reported as NO (Byrne and Farrell, 2005).

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

$$\Delta C_{So} = \sum_i \left(A_i \times EF_{soil}\right) \quad \text{(7.5)}$$

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.

7.3.3.1.4 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, $\Delta C_{So} = \sum_j \left(A_j \times (EF_{soil} \times SD\right)$ .... (7.6)

where:

$$SD = \frac{depth(cm)}{30cm} \quad \text{(7.7)}$$

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 occur in the young forest land class under *5.A.1 Forest Land Remaining Forest Land* and *5.A.2 Land Converted to Forest Land*. The allocation of biomass burned in the two categories is based on the representative areas of land converted to forests and forests remaining forests. Wildfires normally occur in stands prior to canopy closure due to existence of non-forest vegetation in the under story. Fires are generally carried over by heather or furze vegetation in adjacent lands;
2) 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;
3) Emissions from the burning of forest biomass 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;
4) Emissions directly resulting from fire (i.e. combustion) are included for all years from 1990. Where area data were not available (1990 through 1992) a mean value of 200 ha per year for the period 1993-2008 was assumed;
5) 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;
6) The direct effect of wildfires on litter and soil carbon stocks is assumed to be negligible.

7.3.5 Emissions of N_2O from Fertilization

Ireland does not report 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 percent at the 95 percent 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. 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 10 to 15 Gg CO_2 equivalents for the years 1990 to 2009.

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 (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 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 peatlands forest 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 2008/9 is associated with an increase in the sale of units of forest land for erection of telecommunication masts, quarries and windfarm developments during this period.

New methodology:
Lack of a method to record historic land use change was a significant gap in the previous LULUCF inventory. There are now currently two available data sources available to transparently report historic deforestation:

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 Ch 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.

The final deforestation-land use change-soils matrices for 1995-2000 and 2000-2006 were obtained by interesting 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 interested with a national soils map using ARCGIS to derive a land use change and soil type matrix to the periods 1990 to 2000.

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. 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 are based on the NFI, PSP average of all 10 year old forest areas.

The final deforestation trends for the period 1990 to 2009 were derived using a combination of the approaches described above.

Table 7.7. 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			Settlement			Wetland			Other		
		Mineral	Organic	Organo-mineral	Mineral	Organic	Organo-mineral	Mineral	Organic	Organo-mineral	Mineral	Organic	Organo-mineral
1990-1994[a]													
Area (ha) per year	**20.6**	2.5	NO	5.7	10.2	NO	NO	NO	NO	NO	2.2	NO	NO
% for period	100	12.2		27.9	49.4						10.5		
1995-1999[b]													
Area (ha) per year	**333.3**	266.7	NO	NO	NO	NO	NO	NO	NO	NO	66.6	NO	NO
% for period	100	80									20		
2000-2005[c]													
Area (ha) per year	**857.1**	342.8	NO	57.4	171.4	NO	NO	56.6	114	NO	57.4	57.4	NO
% for period	100	40		6.7	20			6.6	13.3		6.7	6.7	
2006[d]													
Area (ha) per year	**375.8**	5.3	NO	19.7	17.1	NO	0.6		299.9	30.8	3.1		
% for period	100.0	1.4		5.2	4.5		0.2	0.0	79.8	8.2	0.8		0.0
2007[d]													
Area (ha) per year	**338.7**	0.6	14.5	NO	4.6	0.8	NO	0.0	297.2	NO	8.6	12.4	NO
% for period	100.0	0.2	4.3		1.4	0.2		0.0	87.7		2.5	3.7	
2008[d]													
Area (ha) per year	**294.6**	80.3	0.0	NO	66.5	NO	NO	NO	24.5	21.2	101.0	NO	1.1
% for period	100.0	27.2	0.0		22.6				8.3	7.2	34.3		0.4
2009[d]													
Area (ha) per year	**196.9**	5.1	NO	NO	15.4	1.5	1.5	NO	NO	NO	121.1	19.9	32.4
% for period	100.0	2.6			7.8	0.8	0.7				61.5	10.1	16.4

* 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 (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 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, 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.

The trend lands converted to croplands is driven by the accumulated area converted to cropland over the period since 1990. It has been assumed that in those years that the estimates of cropland from the Central Statistics Office show an increase in utilised land area, that it reflects a long term decisions on behalf of the farmers, and the lands remain as cropland for at least the default 20 year transition period. This means that from the period 1990-2009, the area of lands converted to cropland is monotonically increasing. In reality, this is probably an overestimate of lands converted to cropland, and hence over estimates the loss of carbon. Ireland intends to advance analysis across all land uses to address the uncertainty inherent in the current assumptions.

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. In order for the net change in cropland to correspond to that indicated by the CSO statistics, the cropland areas lost *5.E Settlements* must be offset by new lands converted from *5.C Grassland*. This is achieved by adding those areas of cropland in transition to either forest lands or settlements to the area of land in transition to cropland, and deducting an equal amount from the area under *5.B.1 Croplands Remaining Croplands*. The relevant emissions and removals are determined by net carbon stock changes in living biomass and soils for *5.B.2 Lands Converted to Cropland*.

7.4.2 Carbon Stock Change in Biomass

The stock change relates only to above-ground biomass and its estimation is based on the difference between initial and final carbon content of biomass for the lands converted. In the conversion of land to cropland, it is assumed under the Tier 1 approach that the dominant vegetation from the initial land use is removed entirely. The carbon stock change is then quantified as the net sum of carbon lost on conversion and the carbon added by the first year’s growth of crops. Grassland is the only relevant land-use type undergoing conversion to cropland in Ireland. The dry matter content of grassland is taken as 13.6 tonnes/ha and the carbon content of dry matter is 0.5 percent. The default value of 5 t C/ha from Table 3.3.8 of the IPCC good practice guidance for LULUCF is adopted for the carbon stock in crop biomass after one year. The carbon stock change in biomass on the area (A) converted to cropland is then calculated from Equation 3.3.8 of the IPCC good practice guidance as follows:

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

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

7.4.3 Carbon Stock Change in Soils

The spatial distribution of cropland areas over IPCC soil class is derived from GIS analysis of the LPIS 2004 dataset provided by the Department of Agriculture, superimposed on the General Soil Association Map of Ireland (Gardiner and Radford, 1980). The GIS analysis shows that a very high proportion (98 percent) 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.

Carbon stock changes in mineral soils are estimated using Equation 7.1. Farm management and input practices are assumed to have been constant over the inventory period for established croplands. Therefore the SOC will not have changed for mineral soils, with the exception of those lands going to set-aside for short periods within the transition period of 20 years. In line with expert option it is assumed that no cultivation occurs on organic soils, as discussed in 7.4.1.

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:

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

where ΔC is the annual change in carbon stocks given by Equation 7.1 and $R_{C:N}$ is the C:N mass ratio in soil organic matter for which a default value of 15 is given in the IPCC good practice guidance.

7.5 Grassland (5.C)

7.5.1 Grassland Areas

Grassland is the dominant land-use category in Ireland. Area estimates are based principally on CSO annual statistics for improved grassland (pastures and areas harvested for silage and hay) and unimproved grassland, which refers to rough grazing. 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 recognized that as the dominant land cover and land use class in the Irish landscape, grassland are deserving of particular attention with respect to evaluation of carbon stock changes. With the possible exception of carbon loss from drained organic soils under grasslands, it is believed the default methodology underestimates sinks. Recent findings from Irish and other relevant regions indicate that managed grassland on mineral soils are an on-going sink of carbon from the atmosphere. Ireland is investing significant research funding and resources into development of high resolution systems to estimate carbon stock change across all land use categories, with particular emphasis on grassland and wetlands (including peatland). We have initiated a focused studied to determine carbon loss from drained organic soils under grass. Also, a major project is underway to complete the national soil survey which will provide critical data required for higher tier assessment of carbon loss from soils. As robust higher tier methods are developed, they will be incorporated into reporting.

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 is an underestimate of the effect of grazing, but insufficient data exists to quantify the impact.

There is a strong dynamic of lands moving between grassland and cropland (with a knock effect on the area assigned to other land). This is because of the nature of the CSO statistics, which record only the areas of grassland and cropland in a particular year. Under Irish conditions, conversion of grassland to cropland leads to a net loss of carbon from the soil, and also a loss of living biomass when the Tier 1 default methods are applied.

The main source of CO_2 emissions within the grassland remaining grassland category is the release of CO_2 due to lime application. However the interannual variation is driven by changes in the area of drained organic soils under agricultural grassland, and the conversion of cropland to grassland.

7.5.2 Carbon Stock Changes in Grassland

The relevant carbon stock changes are for living biomass under *5.C.2 Land Converted to Grassland* and for soils under both *5.C.1 Grassland Remaining Grassland* and *5.C.2 Land Converted to Grassland.*

7.5.2.1 Carbon Stock Changes in Living Biomass

The Tier 1 methodology assumes that grassland remaining grassland has zero biomass carbon stock change under static management practices. This approach is adopted here and the notation NO is entered in CRF Table 5.C. The category *5.C.2.5 Other Land Converted to Grassland* is the most important conversion category in most years while some conversions from cropland and exhausted peatlands also occur. Carbon stock changes are estimated using the Tier 1 methodology in the same way as for land converted to cropland using Equation 7.2 above. The biomass value of cropland converted to grassland is taken to be 10 t/ha and the carbon stock increase due to growth in grasslands (ΔC growth) in the first year is 6 t C/ha from GPG Tables 3.4.2 and 3.4.3. In the case of peatlands there is no initial biomass at the time of conversion to grassland and therefore the carbon stock change is due only to the first year's growth at 6.0 t C/ha. The 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[1]. 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 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. The estimates are reported in CRF Table 5(IV) rather than in CRF Tables 5.B and 5.C, the carbon stock change tables for cropland and grassland, respectively.

7.6 Wetlands (5.D)

7.6.1 Wetland Areas

[1] 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.

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). This split is necessary to account for the conversion of wetlands to peatland, which is an internal change under the IPCC definition of wetlands. The activity data areas that appear under category *5.D.1 Wetlands Remaining Wetlands* in CRF Table 5.C therefore refer to managed peatlands in the Irish context and conversion to wetland is not applicable.

The commercial exploitation of wetlands as peatlands by Bord na Mona (the Irish Peat Board) according to the land-use definition in Table 7.3 proceeds is three separate stages, all of which may lead to changes in carbon stocks. Drainage is the first management activity, followed after several years by removal of the top layers of plant growth in the first season of peat extraction and then by the industrial extraction and harvesting of a layer of 10 to 15 cm of peat annually. The average working life of commercially developed Irish peatland is of the order of 30-50 years. Conversion to grasslands or forest land has been the historically favoured use of cutaway peatland. However, in recent years wetland 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.

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 2009 submission a refined estimate has been made using the value of residential peat use in the national energy balance and a bulk density estimate of 0.25 t/m^3 for peat m^{-3} (McGoff et al. 2007). This new approach ensures consistency between the quantities of peat combusted in *1.A.3.b Residential* and the area of private peat exploitation in LULUCF. More recent data is not available for 2009 activity, however, discussion with Bord na Mona concurred with the decision to project activity in the period 2006-2008 into 2009.

Table 7.8 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 the 2006 NIR, it was assumed that the restoration of biomass occurred in the year of conversion. However, discussions with experts from Bord na Mona suggest a more appropriate biomass transition period of 5 years.

The area from which vegetation is removed is taken to be the amount of peatland reserve that is drained to come under production annually and the restoration area is taken as the annual increase in cutaway wetland given by Table 7.7. The vegetation is typically heather-dominated bog or heathland cover for which a biomass carbon content of 3 t C/ha is adopted (Cruickshank et al, 2000).

Table 7.7 in section 7.3.7 above gives the area of forest land converted to wetlands for the years 1990-2009. 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).

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 such peatlands are nutrient-poor raised bogs or rain-fed blanket bogs for which the appropriate carbon emission factor is 0.2 t C/ha, given for boreal and temperate climatic regions in the IPCC good practice guidance. The activity land area in respect of the soils carbon pool is the value that appears in CRF Table 5.D. This area is significantly larger than that relevant to the estimation of carbon stock change in biomass above.

7.6.3 Emissions of Non-CO_2 Gases

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

7.7 Settlements (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 1995-2000) was used to estimate the residential building footprint from floor area. It was assumed that approximately 50 percent 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. 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. In this submission, there has been a downward revision of the potential biomass loss. Based on the carbon estimates in Section 7.3, the average biomass of forested lands in Ireland is of the order of 32 t C/ha, reduced from c42 t C/ha in previous submissions. No account has been made of the potential increased carbon stock in biomass in urban areas, e.g. in parks or roadside planting. This may be a significant carbon sink, especially under the policy of actively encouraging urban tree planting along new roads and in new housing developments, but no data is available.

Table 7.7 in section 7.3.7 above gives the area of forest land converted to settlements for the years 1990-2009. The immediate oxidation of biomass, litter and dead wood for years prior to 2006 were derived using the mean IEF for 2006 to 2009 (see section 7.3.3).

7.8 Other Land (5.F)

7.8.1 Areas of Other Land

The category *5.F Other Land* includes all lands not classified under the categories 5.A through 5.E. It represents the difference between the sum of categories 5.A through 5.E and the total land area of Ireland. A large part of *5.F Other Land* is not relevant in terms of its potential for emissions or removals but for Ireland this category includes areas of natural grassland which are an available reserve for rough grazing but which are not grazed in the inventory year. As indicated above in section 7.5.1, when the demand for areas of pasture in a particular year is less than in the previous year, surplus areas of improved or unimproved pasture are allowed to revert to rough grazing, which are then not recorded as "in use" as grassland by CSO statistics. For area accounting purposes, such lands are assumed to be in transition and are assigned to category *5.F.2.3 Grassland Converted to Other Land* in a manner that maximises the area in *5.F.1 Other Land Remaining Other Land*.

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 windfarms, 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 1990-2009. 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).

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. It may be concluded that the uncertainties in reported emissions and removals are large for the sector overall and their full evaluation in quantitative terms has not been possible for the current submission.

7.10 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.

- Revised estimates of forest biomass due to biomass loss from young forests as a result of biomass burning/forest fires in *5.A. Forest Land*;
- Revised estimate of carbon loss from Forest land remain Forest Land on organic soils during the first forest rotation period of 50 years.

- Revised estimate of carbon loss from “Land converted to Forest lands” on organic soils based on revised emission factor and revised transition period.
- Adjustment to total forest area shown in Table G.1 of Annex G to be consistent with areas reported under Article 3.3 of the Kyoto Protocol in chapter 11 (KP_LULUCF);
- Upgrade from tier 1 method to tier 3 method for estimating carbon stock change in the litter pool in forest land;
- Inclusion of N_2O emissions in drained forest soils;
- Minor revisions for biomass burning;
- Revised area estimates for deforestation 1990 to 2009 which are accounted for in carbon stock change estimates for forest land conversions to grasslands wetland, settlement and other lands.

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

7.11 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 1990-2009. The present submission also contains estimates for 2008 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 ongoing 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.

Work on developing a single forest cover and attribute data set has been progressing in the Forest Service. Most of the data set has been compiled, apart from a subset of grant and premium data that needs to have species attributes input manually. In its final version the full data set will include 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 practices on drained organic soils. The land use conversion to settlements, particularly as regards new construction, remains a coarse estimate.

Table 7.9 Percentage Change in Emissions and Removals from LULUCF due to Recalculations 1990-2009

a) 2010 Submission (Gg CO_2 eq)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
										Estimates in 2010 Submission (Gg CO_2eq.)										
5.A	**Forest Land**	**-328.12**	**-296.41**	**-96.56**	**-181.14**	**-119.20**	**-119.59**	**-111.66**	**-256.85**	**-435.15**	**-543.84**	**-429.74**	**-567.78**	**-763.50**	**-1,026.73**	**-700.63**	**-890.57**	**-958.79**	**-1,500.36**	**-2,150.54**
5.A.1	Forest Land remaining Forest Land (CO_2)	-999.06	-1,151.18	-876.51	-863.00	-574.29	-395.39	-338.08	-235.83	-523.13	-572.63	-96.06	4.77	-374.72	-1,210.56	-750.29	-898.98	-856.46	-1,490.32	-2,368.95
5.A.2	Land converted to Forest Land (CO_2)	659.24	842.91	768.05	669.05	441.88	261.42	211.43	-35.22	74.00	14.71	-348.74	-589.04	-403.97	166.09	32.81	-7.75	-118.68	-26.58	201.54
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
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
5.B	**Cropland**	**20.00**	**21.19**	**16.96**	**-23.58**	**-14.50**	**-31.92**	**53.17**	**58.21**	**10.74**	**-13.71**	**27.61**	**113.39**	**128.43**	**137.18**	**162.07**	**140.00**	**86.51**	**110.51**	**361.95**
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
5.B.2	Land converted to Cropland	NE,NO	NE,NO	7.01	32.24	69.96	27.85	73.33	73.33	44.89	44.89	44.89	132.98	152.36	158.53	174.41	126.18	126.18	126.18	359.47
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
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
5.C	**Grassland**	**493.47**	**556.83**	**431.52**	**344.93**	**174.67**	**379.01**	**414.97**	**496.96**	**310.43**	**398.80**	**468.81**	**452.81**	**457.96**	**553.37**	**334.93**	**197.11**	**299.50**	**333.44**	**290.28**
5.C.1	Grassland remaining Grassland	621.96	583.23	529.88	618.43	523.23	718.45	707.74	648.56	543.55	613.75	598.52	614.19	512.98	611.73	480.36	505.90	494.31	604.49	493.91
5.C.2	Land converted to Grassland	-128.49	-26.39	-98.37	-273.51	-348.56	-339.44	-292.77	-151.60	-233.12	-214.96	-129.71	-161.38	-55.02	-58.36	-145.43	-308.79	-194.81	-271.05	-203.64
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
5.D	**Wetlands**	**50.66**	**49.76**	**49.20**	**48.46**	**45.83**	**44.36**	**42.54**	**41.00**	**39.46**	**37.59**	**48.81**	**46.48**	**44.13**	**41.79**	**39.46**	**39.01**	**38.58**	**27.12**	**30.08**
5.D.1	Wetlands remaining Wetlands	47.07	46.21	45.68	44.97	42.37	40.94	39.18	37.69	36.19	34.39	45.66	43.36	41.06	38.77	36.47	36.07	35.67	24.31	27.34
5.D.2	Land converted to Wetlands	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.D	Drainage of soils	3.59	3.54	3.52	3.48	3.46	3.42	3.35	3.31	3.27	3.20	3.15	3.11	3.07	3.03	2.99	2.95	2.91	2.81	2.74
5.E	**Settlements**	**12.80**	**11.72**	**11.94**	**12.74**	**15.69**	**15.81**	**19.86**	**21.66**	**23.12**	**24.74**	**26.08**	**34.34**	**30.51**	**37.23**	**39.19**	**46.05**	**48.29**	**49.60**	**41.24**
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
5.E.2	Land converted to Settlements	12.80	11.72	11.94	12.74	15.69	15.81	19.86	21.66	23.12	24.74	26.08	34.34	30.51	37.23	39.19	46.05	48.29	49.60	41.24
5.F	**Other Land**	**-1.24**	**NO**	**-13.26**	**-0.57**	**-2.31**	**NO**	**-22.82**	**-6.75**	**-5.59**	**NO**	**NO**	**-14.01**	**-16.83**	**NO**	**-35.60**	**-6.95**	**-12.17**	**NO**	**-43.12**
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
5.F.2	Land converted to Other Land	-1.24	NO	-13.26	-0.57	-2.31	NO	-22.82	-6.75	-5.59	NO	NO	-14.01	-16.83	NO	-35.60	-6.95	-12.17	NO	-43.12
5.G	**G. Other**	**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)**	**232.27**	**327.69**	**384.08**	**181.45**	**80.42**	**266.78**	**372.74**	**331.74**	**-79.20**	**-118.67**	**118.39**	**36.99**	**-148.33**	**-291.91**	**-194.39**	**-508.41**	**-531.30**	**-1,013.01**	**-1,513.37**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**247.56**	**343.09**	**399.80**	**200.83**	**100.18**	**287.67**	**396.05**	**354.22**	**-56.99**	**-96.43**	**141.58**	**65.22**	**-119.29**	**-257.17**	**-160.58**	**-475.34**	**-498.07**	**-979.69**	**-1470.10**

b) 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
		Estimates in 2011 Submission (Gg CO_2eq.)																		
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**
5.A.1	Forest Land remaining Forest Land (CO_2)	-1165.11	-1336.37	-1086.37	-1085.90	-817.26	-650.07	-598.31	-514.18	-795.82	-862.17	-408.71	-312.77	-680.45	-1506.00	-1084.20	-1234.54	-1204.12	-1840.03	-2739.54
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	-1038.63	-1296.59	-1111.36	-525.83	-619.75	-622.36	-695.14	-584.18	-329.03
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
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
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**
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
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
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
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
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**
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
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
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
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**
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
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
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
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**
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
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
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**
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
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
5.G	**G. Other**	**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**
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**

c) Percentage Change

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
		Percentage Change in Total Emissions due to Recalculations																		
5.A	**Forest Land**	**246.76**	**307.01**	**1016.41**	**548.16**	**869.57**	**920.83**	**1028.04**	**444.87**	**252.53**	**188.34**	**233.29**	**180.54**	**132.69**	**96.16**	**140.80**	**106.69**	**96.38**	**60.47**	**41.90**
5.A.1	Forest Land remaining Forest Land (CO_2)	16.62	16.09	23.94	25.83	42.31	64.41	76.98	118.03	52.13	50.56	325.47	-6654.28	81.59	24.41	44.50	37.33	40.59	23.47	15.64
5.A.2	Land converted to Forest Land (CO_2)	-97.63	-85.99	-100.46	-115.09	-179.59	-323.81	-419.83	2453.82	-1116.42	-4994.09	197.82	120.12	175.11	-416.59	-1989.06	7930.69	485.74	2097.93	-263.26
5.A	Biomass burning (CH_4 and N_2O)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.A	Drainage of soils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.B	**Cropland**	**0.00**	**0.00**	**0.00**	**-159.99**	**290.33**	**0.00**	**0.00**	**-48.85**	**0.00**	**0.00**	**0.00**	**0.00**	**-17.70**	**11.58**	**-29.76**	**0.00**	**0.00**	**0.00**	**0.00**
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	0.00
5.B.2	Land converted to Cropland	NA	NA	0.00	116.99	-60.19	0.00	0.00	-38.78	0.00	0.00	0.00	0.00	-14.92	10.02	-27.66	0.00	0.00	0.00	0.00
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	0.00
5.B.2	Emissions from soil disturbance	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.C	**Grassland**	**0.19**	**0.16**	**0.20**	**0.24**	**0.46**	**7.28**	**6.47**	**5.28**	**8.18**	**6.15**	**7.96**	**8.06**	**7.79**	**6.25**	**12.32**	**20.94**	**0.64**	**-2.35**	**-0.18**
5.C.1	Grassland remaining Grassland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04
5.C.2	Land converted to Grassland	-0.74	-3.44	-0.89	-0.31	-0.23	-8.13	-9.18	-17.33	-10.92	-11.45	-28.84	-22.69	-65.07	-59.58	-28.50	-13.44	-1.09	2.81	0.15
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	0.00
5.D	**Wetlands**	**-0.87**	**-0.88**	**-0.89**	**-0.90**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**36.33**	**38.04**	**39.93**	**42.07**	**44.16**	**16.94**	**22.42**	**72.90**	**140.43**	**34.74**
5.D.1	Wetlands remaining Wetlands	-0.93	-0.95	-0.96	-0.98	0.00	0.00	0.00	0.00	0.00	39.68	2.00	2.11	2.23	2.36	-29.93	-24.73	-19.40	24.71	21.40
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
5.D	Drainage of soils	0.00	0.09	0.06	0.09	0.07	0.05	0.16	0.16	0.17	0.29	0.53	-1.20	-2.98	-4.81	-6.69	-8.85	-11.06	-11.68	-9.96
5.E	**Settlements**	**-28.72**	**-28.35**	**-28.77**	**-29.46**	**-30.91**	**-36.28**	**-35.85**	**-35.42**	**-34.87**	**-34.53**	**19.45**	**7.07**	**13.01**	**4.88**	**3.33**	**-1.68**	**-29.61**	**-31.57**	**-18.08**
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
5.E.2	Land converted to Settlements	-28.72	-28.35	-28.77	-29.46	-30.91	-36.28	-35.85	-35.42	-34.87	-34.53	19.45	7.07	13.01	4.88	3.33	-1.68	-29.61	-31.57	-18.08
5.F	**Other Land**	**-21.82**	**NA**	**-1.97**	**-45.27**	**-11.04**	**NA**	**-30.96**	**-104.55**	**-125.24**	**NA**	**NA**	**-84.61**	**-70.67**	**NA**	**-33.55**	**-173.19**	**-3.23**	**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
5.F.2	Land converted to Other Land	-21.82	NA	-1.97	-45.27	-11.04	NA	-30.96	-104.55	-125.24	NA	NA	-84.61	-70.67	NA	-33.55	-173.19	-3.23	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**
5	**TOTAL LULUCF CO_2 (net emissions/removals)**	**-349.84**	**-278.50**	**-256.24**	**-528.15**	**-1345.96**	**-401.93**	**-300.76**	**-345.29**	**1356.74**	**832.30**	**-785.29**	**-2583.44**	**651.03**	**309.88**	**500.70**	**174.78**	**170.84**	**87.87**	**58.61**
5	**TOTAL LULUCF GHGs (net emissions/removals)**	**-328.23**	**-266.00**	**-246.17**	**-477.17**	**-1080.53**	**-372.75**	**-283.06**	**-323.37**	**1885.39**	**1024.31**	**-656.68**	**-1465.43**	**809.56**	**351.79**	**606.25**	**187.00**	**182.30**	**90.89**	**60.36**

Chapter Eight

Waste

8.1 Overview of Waste Sector

The main activities normally giving rise to greenhouse gas emissions in the *Waste* sector are solid waste disposal in landfill sites, wastewater treatment and waste incineration (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 (Chapter One) 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 2011 submission shows total GHG emissions of 1,242.60 Gg CO_2 equivalent in the *Waste* sector in 2009, of which 87.1 percent came from 6.A Solid Waste disposal and the remainder was due to wastewater treatment. The latest estimates show that emissions in this sector have decreased by 4.5 percent from 1990 to 2009 due to a 7.8 percent 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. No incineration of municipal waste currently takes place and the incineration of clinical wastes was discontinued in the mid 1990's. Since then clinical wastes are treated using non-burn disinfection and dependent on the type of material it is either disposed of at landfills or exported for incineration. The practice of incineration in Ireland 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. The incineration of municipal waste will become an additional source of emissions for inclusion in annual inventories in the Ireland's 2012 submission as a newly built waste incinerator is expected to be commissioned in the second half of 2011. A second incinerator is also in the process of being built but it will be a number of years before it is operational. This source of emissions will be included when the incinerators are commissioned.

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 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 where reasonable predictions could be made for decreasing waste quantities into the future. The method 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 has stood up to scrutiny in the UNFCCC review process, the inventories team was aware that the simple approach used to estimate CH_4 generation did not adequately reflect the major changes in landfill operation and management after 1998 (introduction of licences for landfill operation) and better use could be made of the information currently available for landfills in general. More detailed analysis was needed to address the inadequate representation of the cumulative time-dependent production of CH_4 resulting from estimation on the basis of total waste disposal – effectively as a single hypothetical landfill. Therefore the OCLR 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. It is a simple first order decay spreadsheet model that keeps a running total of the amount of decomposable DOC available in the landfill as the basis for calculating the amount of DOC converted to CH_4 and CO_2 annually. In the present analysis the model is applied on a multi-phase basis, where data on waste composition from the 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. In the present model analyses undertaken for both individual sites and groups of landfills, annual MCF values show an increase 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 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 and captures the time dependency of methane generation in a more representative manner than the previous approach based on all waste taken together in one hypothetical landfill. This 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 percent of the municipal waste disposal in Ireland over the period to which the analysis relates, which means that assumptions regarding the numerous landfills taken in groups, which are largely closed sites, have a significant bearing on the estimates of CH_4 generation, particularly for the early years of the 1990-2009 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) 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 National Waste Report (McCoole et al. 2011) states that a total of 2,824,977 tonnes of municipal waste was managed in 2009. Of this total 1,498,469 tonnes was household waste, 1,299,807 tonnes was commercial waste (waste from commercial premises such as shops, offices, restaurants, schools and hospitals) and the remaining 26,701 tonnes was cleansing waste (street sweepings, municipal bins, parks and gardens waste). Approximately 61 percent (1,723,705 tonnes) was disposed of in landfills and the remaining 39 percent (1,101,272) was recycled.

The other waste streams that occur in Ireland are construction and demolition waste and hazardous waste. The bulk of construction and demolition waste is made up of soil and stones, with the remainder consisting of rubble, metals, timber, plastics and glass, which are inert materials. In 2009, 99 percent of construction and demolition waste (McCoole et al 2011) was recovered and used as cover/landscaping material or for other engineering purposes (e.g. haul roads in landfills). Hazardous wastes are described as those that are dangerous or potentially harmful to human health or the environment. Industry is the largest generator of hazardous waste in Ireland, giving rise to waste materials such as solvents, sludges, oils and chemicals. In 2009, approximately 150,395 tonnes of hazardous waste was exported for further treatment or destruction. A further 164,660 tonnes of hazardous waste was either recovered or disposed on site (i.e. at the installation where it was generated) or offsite in Ireland (commercial hazardous waste treatment facilities). Of the 164,660 tonnes approximately 37 percent was disposed of in landfill, underwent biological treatment or in case of solvents, incinerated. The remaining hazardous waste was recovered.

The NWD reports published since 1995 provide a good starting point for assigning municipal solid waste quantities to individual landfills, which is supplemented by the other sources indicated, which provide a representation of waste composition. However, assumptions on waste quantities and composition are still needed to establish the basic information historically, 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 and the quantities for other years are estimated by interpolation and from various published reports for the larger landfills in Ireland. 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 percent in 1995 to 21 percent in 2009, which reflects the increase in recycling of paper. In the analysis for historical years, the paper content was fixed at 40 percent for 1980 and previous years and decreases linearly from 40 percent in 1980 to 31 percent in 1995. The NWD is used to give the values for all years in the period 1995 to 2009. 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 are food waste, waste paper, wood, textiles and disposable nappies are identified in the available NWD breakdown for 1995, 1998 and 2001 through 2009. The IPCC default proportions of DOC content are used for all these constituents (Table H.2 of Annex H). Street cleansing composition data is available, and the DOC content is therefore calculated from its constituent components. In addition, a DOC content of 5 percent 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. 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

Following a detailed study conducted for the inventory agency by Fehily Timoney Consultants of methane flaring and utilisation for the years 1996-2008 (c.f. Ireland's NIR 2010), 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 there were known issues with the information presented in the previous study 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% response rate. Any issues with the validity of the data provided were clarified directly with landfill operators.

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 percent for open flares (UNFCCC, 2006) and 98 percent for closed flares (manufacturer specifications and combustion efficiencies from on site monitoring as part of license requirements under IPPC).The study found that there were eight methane utilisation plants at landfills in Ireland in 2009 with a total of 23 engines. 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) using an overall efficiency of 36.6 percent 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 1990-2009

	Methane Generation (Tonnes)	Methane Flaring (Tonnes)	Methane Utilisation (Tonnes)	Methane Recovery (Tonnes)	Percent Methane Recovery	Methane Emissions (Tonnes)	Methane Emissions (Gg CO_2eq)
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	20,072	60,468	51	57,429	1,206
2008	121,967	46,523	21,768	68,291	56	53,675	1,127
2009	123,426	52,131	19,771	71,902	58	51,523	1,082

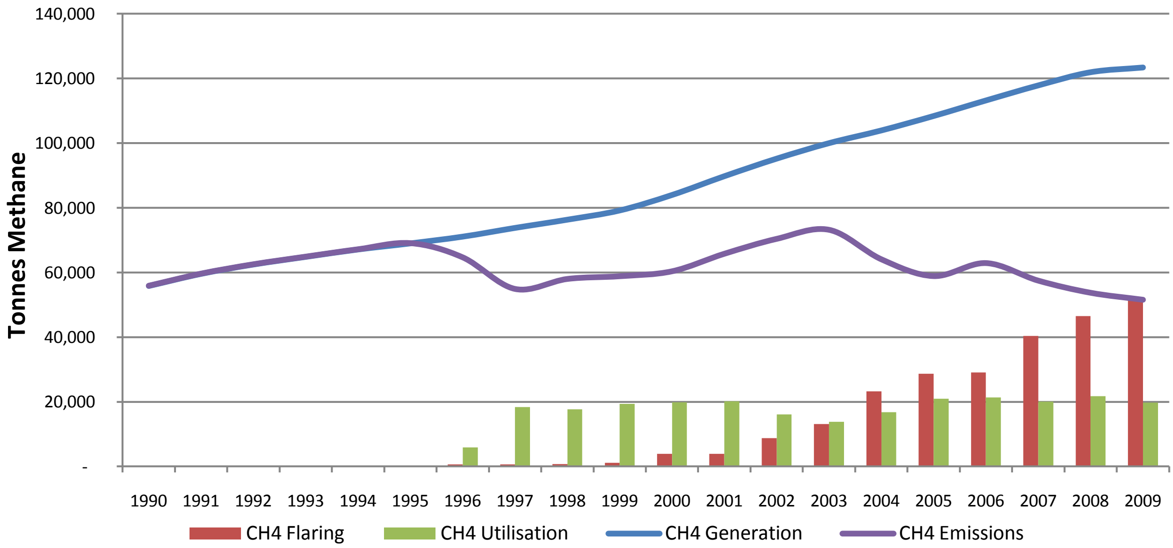


Figure 8.1. Methane Emissions from Solid Waste Disposal 1990-2009

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 previous estimates, and they show a steady increase in CH_4 production over the period 1990-2009, reflecting Ireland's strong dependence on solid waste disposal to landfills. The utilisation of CH_4 has remained generally constant since becoming established in 1997, with no additional sites being used for this purpose for a number of years. In contrast, the amount of flared methane increased sharply after 2003. This reflects the proliferation in the use of enclosed flares as a means of odour control at landfills generally throughout the country, which all operate under EPA licence and stringent environmental controls. Methane recovery through flaring and utilisation reached 58.3 percent in 2009. The recovery of CH_4 for energy purposes was the principal offset to production over the period 1996-2001 causing a sharp initial reduction, but emissions increased from 1997 to reach the 1995 level again in 2003. 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_2eq to 1081.98 Gg CO_2eq in 2009. The emissions in 2009 are approximately 7.8 percent 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)

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). It consists of the septic tank (over 1 metre deep) and the percolation area, which comprises of an effluent distribution system, which is where the real treatment of the effluent takes place. However septic tanks will not operate properly if pesticides, paints, thinners, disinfectants, chemicals, water softeners and the use of cold water detergents, etc discharge to it. Septic tanks are generally installed so that the top is at or near the soil surface. Under optimum conditions of operation bacterial action occurs deeper at the bottom of the tank, however prevailing soil temperatures at this depth in Ireland rarely exceed 15°C (the temperature above which significant methanogenesis is likely to occur) and where it does it is only for short periods of time and only in certain areas of the country. Thus in conjunction with the use of modern domestic chemicals and low prevailing temperatures at depth in septic tanks, 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).

The anaerobic stabilisation of sludge is a source of CH_4 in Ireland. The amounts of industrial wastewater sludge produced are available from biennial reports on urban wastewater treatment and approximately three percent 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 percent 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 equation 11 on page 6.21 of the Revised 1996 IPCC Guidelines 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 fertilizer. The CH_4 produced 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[2] 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 or used as organic fertilizer 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 percent of sludge produced (tonnes of dry solids) in 1990 and 54 percent in 2000. Since then, the value has fallen substantially, to 5 percent in 2009. 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 percent of both industrial and domestic sludge in 1990 to 83 and 70 percent for industrial and domestic sludge respectively in 2009.

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 and is then disposed of directly onto land, into the soil through percolation areas or discharged to a water body. Nitrous oxide can be produced during these processes through nitrification and denitrification. This source of emissions was first included as part of the recalculation exercise undertaken for the 2002 submission, although N_2O emission estimates now use the IPCC methodology with 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

[2] 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

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 1990-2009

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	365	4.044	0.16	0.01	0.424
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	365	4.422	0.16	0.01	0.463
2009	114.2	365	4.459	0.16	0.01	0.467

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

8.4 Emissions from Incineration of Waste (6.C)

Incineration of clinical waste is no longer carried out in Ireland. Recently, health care waste and other non-renewable wastes were used in co-firing of cement kilns in 2009. Detailed information on the biomass and non-biomass fractions of all wastes co-fired in cement kilns is known, and this is taken into account under 1.A.2.f.

For reporting under the Convention on Long Range Transboundary Air Pollution (CLRTAP) Ireland estimate that 4,000 tonnes per annum of clinical wastes (hazardous/non-hazardous) were incinerated for the years 1990-1999. No information on the proportion of this waste which is biogenic or non biogenic is available to the inventory agency. As such it is not possible to include estimates of CO2 from this source.

Additional information on clinical waste incineration is discussed in Section 7.3.1 of Ireland's Informative Inventory Report 2011.

8.5 Uncertainties and Time-Series Consistency

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

While the work undertaken for the 2011 submission improves the robustness of emissions estimates, it is recognised that the overall uncertainty associated with estimating CH_4 emissions from source category 6.A are likely to remain very high, even under detailed analysis of national data as described above. This is primarily due to the lengthy 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 percent are assumed in relation to the quantity of MSW, its composition and DOC contents, giving a combined uncertainty of 34.6 percent for activity data using equation 6.4. This is also the emission factor uncertainty when 20 percent is taken as the uncertainty for the fraction of DOC dissimilated, MCF and decay rate constant. This gives an uncertainty of 48.9 percent for CH_4 generation again using equation 6.4, which is combined with uncertainties of 30 percent and 10 percent for CH_4 flaring and utilisation, respectively using equation 6.3 to give an uncertainty of 32.0 percent 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 percent and 30 percent are assigned to the activity data and emission factor used, respectively.

8.6 Quality Assurance and Quality Control

As part of ongoing 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 through 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 EPA inventory team in the Climate Change and Environmental Research Unit. All survey returns with respect to landfill gas flaring and utilisation undertaken as part of this submission were reviewed by a member of the inventory team and where issues arose they were clarified with the operator of the landfill. The inventory team also maintains close collaboration with specialists and license inspectors in the waste sector who are in a position to give advice or guidance on the use of the NWD or on methane recovery at landfill sites.

8.7 Recalculations for Waste

For this submission, improvements have only been made to the methodology for 6.A.1 and 6.A.2, Managed and Unmanaged Waste Disposal to Land.

The revisions to the methodology for 6.A.1 are associated with decreasing the extent of landfill gas flaring. This results in an overall increase in the CH_4 emission. This revision has been possible because a full survey of landfill gas flaring was undertaken for estimates of 2008 and 2009 (previously the 2008 returns were not complete). The survey provided an improved understanding of the activities, and in particular it was noted that some flaring was not being operated on a continuous basis following consultation with individual landfill operators. The whole time series of emissions was revised accordingly.

The changes to the estimates from unmanaged waste disposal sites are due to revisions in the quantities of waste allocated to these sites from 1996 onwards. These increases were small, being less than a 0.5 percent increase in the overall mass of waste assigned to unmanaged sites.

Table 8.4 sets out the quantitative changes in the emissions estimates for the waste sector for the years 1990-2008, which are dominated by those for 6.A Solid Waste Disposal. The impact generally increases across the time series, reaching a peak in 2008, with a 25 percent increase.

The overall impact of these revisions is to increase the emission estimate for the Waste Sector by 17.5 percent in 2008.

8.8 Improvements in Waste

Ireland's refined approach to the estimation of CH_4 emissions from solid waste disposal and the delivery of recalculated estimates for the waste sector is an important improvement for the GHG inventory that has been pending for a number of years. The inventory agency believes that the use of the model provided by the 2006 IPCC Guidelines is justified as a robust estimation methodology where its flexibility in accommodating changes to input parameters to suit national circumstances is fully exploited. In the present analysis, 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, based on one hypothetical landfill site. The adoption of this methodology simplifies the task of the inventories team with regard to inventory preparation and its response to the UNFCCC review process. It provides a convenient basis on which to incorporate further modifications in respect of particular data items or model parameters and gives an efficient and improved mechanism for undertaking emissions projections in relation to landfills, which is an issue of increasing importance.

The inventory agency aims to, on an annual basis, seek detailed analyses of landfill gas flaring and utilisation statistics from landfill operators by surveying landfill sites and also aims to maintain close links with reporting of this information to the agency through other mechanisms such as annual environmental reports and EPRTR.

Table 8.4 Recalculated Estimates for Waste 1990-2008

			1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
			Estimates in 2010 Submission (Gg CO_2 eq.)																		
6.A.1	Managed Waste Disposal on Lan	CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	808.78	865.27	993.96	1,104.96	1,180.91	959.14	848.10	979.59	844.08	760.14
6.A.2	Unmanaged Waste Disposal Site:	CH_4	1,173.05	1,251.74	1,312.47	1,362.09	1,409.97	1,449.66	1,333.58	1,083.48	1,140.76	333.11	314.93	297.03	279.81	260.47	239.77	221.12	204.38	189.32	175.69
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
6.B.2.b	Domestic & Commercial Wastew	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
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
6	Total	CO_2 eq.	1,301.78	1,382.10	1,447.56	1,494.55	1,539.80	1,575.59	1,460.79	1,219.61	1,279.49	1,285.27	1,329.08	1,439.67	1,535.48	1,593.02	1,353.80	1,217.95	1,336.56	1,189.50	1,094.93
			Recalculated Estimates in 2011 Submission (Gg CO_2 eq.)																		
6.A.1	Managed Waste Disposal on Lan	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
6.A.2	Unmanaged Waste Disposal Site:	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
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
6.B.2.b	Domestic & Commercial Wastew	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
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
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
			Percentage Change in Total Emissions due to Recalculations																		
6.A.1	Managed Waste Disposal on Lan	CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	11.43	9.97	9.00	8.37	8.02	15.17	19.60	13.87	20.43	25.15
6.A.2	Unmanaged Waste Disposal Site:	CH_4	0.00	0.00	0.00	0.00	0.00	0.00	1.79	6.34	6.70	0.13	0.13	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10
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
6.B.2.b	Domestic & Commercial Wastew	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
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	0.00	0.00	0.00	0.00	0.00
6	Total	CO_2 eq.	0.00	0.00	0.00	0.00	0.00	0.00	1.63	5.63	5.97	7.23	6.52	6.24	6.04	5.97	10.77	13.67	10.18	14.51	17.48

Chapter Nine

Other Sources

The sector *Other* in the IPCC source sector classification (Table A.2, Annex A) that is the basis for the CRF reporting tables provides for the inclusion of greenhouse gas emission sources that may be particular to individual Parties. There are no such sources to report in Ireland.

Chapter Ten

Recalculations and Improvements

10.1 Introduction

Ongoing 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 2011 submission and they present the corresponding quantitative changes in emissions and removals within the individual sectors. The recalculations in all cases are due to methodological refinement rather than major methodological change, as defined by the IPCC good practice guidance. Table 10.1 records the major changes and where they are described in the 2011 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 2011 submission CRF tables. The original and revised numerical values of the emissions estimates for the years 1990-2008, 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 impact of all recalculations on national total emissions in 2008 was an increase of 0.48 percent. The principal changes that that give rise to recalculated estimates for the years 1990-2008 included in the 2011 submission are as follows:

1.A.2 Manufacturing Industries and Construction

The following recalculations are due to minor revisions to the national energy balance.

- Revised allocation of energy data (sub-categories 1.A.2b, 1.A.2c, 1.A.2d) for liquid fuels for the years 2005 to 2008;
- Revised allocation of energy data (sub-category 1.A.2e) for liquid fuels for the years 2005 to 2008;

- Revised allocation of energy data (sub-category 1.A.2f) for liquid fuels for all years from 1990 to 2008;
- Revised allocation of energy data (sub-category 1.A.2c) for solid fuels for the years 2007 to 2008;
- Revised allocation of energy data (sub-category 1.A.2d) for solid fuels for the years 2002 to 2004;
- Revised allocation of energy data (sub-categories 1.A.2e and 1.a.2f) for solid fuels for the years 2002 to 2008;
- Revised allocation of energy data (sub-categories 1.A.2c, 1.A.2d and 1.A.2e) for gaseous fuels for the year 2008;
- Revised allocation of energy data (sub-category 1.A.2f) for gaseous fuels for the years 1997 to 1999 and 2008;
- Revised CO_2 emission factor for natural gas (sub-categories 1.A.2e and 1.A.2f) for all years from 1997 to 1999;
- Revised CO_2 emission factor for petroleum coke (sub-categories 1.A.2e and 1.A.2f) for all years from 1990 to 2004.

1.A.3 Transport

- Revised allocation of energy data (sub-category 1.A.3b) for diesel fuel for the years 2007 and 2008;
- Revised emission factors for CH_4 and N_2O for sub-category 1.A.3b (Gasoline and Diesel) introduced by the application of COPERT 4 version 8.0.

1.A.4 Other Sectors

- Revised CO_2 emission factor for natural gas (sub-category 1.A.4a) for all years from 1996 to 1999;
- Revised CO_2 emission factor for petroleum coke (sub-category 1.A.4b) for all years from 1990 to 2004;
- Revised CO_2 emission factor for natural gas (sub-category 1.A.4b) for all years from 1996 to 1999.

1.B.2 Fugitive emissions from fuels

- New estimates for fugitive CH_4 emissions from oil refining/storage (1.B.2.a iv) for all years from 1990-2008.

2.B Chemical Industry

- Minor revision to the country specific natural gas CO_2 emission factor (sub-category 2.B.1) for all years from 2000 to 2002;
- 2.F.1 Potential emissions of PFCs. Notation key revised from NE to NO for all years. No actual or potential emissions of PFCs occur in this category
- 2.F.1 Ref and Air Conditioning-potential emissions 2005-2008. Revised data in actual emissions in 2.F.1 Refrigeration and Air Conditioning
- 2.F.2 Foam blow HFC134a 2007-2008. Revised industry data in 2.F.2 Foams
- 2.F.4.1 MDIs HFC 134a 2008. Revised industry data in 2.F.4 MDIs

- 2.F.4.2 Other HFC 134a 2003-2005. Revised data for 2.F.4 Aerosols
- 2.F.P2.1 In bulk: HFC 125 and HFC 143a 2008. Revised industry data for 2008, previous data was provisional
- 2.F.P2.2 In products: HFC 134a 2003-2005 and 2007-2008. Revised data for 2.F.2 Foams, 2.F.4 Aerosols and 2.F.4 MDIs
- 2.F.P2.2 In products: HFC 152a 2003-2005. Revised data for 2.F.4 Aerosols
- 2.F.P2.2 In products: HFC 227ea 2008. Revised industry data for 2.F.4 MDIs
- 2.F.P3.2 In products: HFC 125 2008. Revised industry data in 2.F.1 Refrigeration and Air Conditioning
- 2.F.P3.2 In products: HFC 134a 2001-2008. Revised industry data in 2.F.1 Refrigeration and Air Conditioning
- 2.F.P3.2 In products: HFC 143a 2008. Revised industry data in 2.F.1 Refrigeration and Air Conditioning

3. Solvent and Other Product Use

- Revisions to estimates in the Solvent and there Product Use category primarily arise from revisions to the solvent content of products across the time series, or the way in which measurement data for specific years has been used to generate a time series of emissions. Both of these can have a substantial impact on the resulting trends across 1990-2009. Emissions in category 3A Paint Application have been revised to take account of the reducing solvent content of different types of paint across the time series. This gives rise to a substantial reduction in emissions in the later years of the time series, emission estimates for 2008 being revised down by over 33 percent.
- Emissions from dry cleaning, in category 3B Degreasing, Dry Cleaning and Electronics have been revised- the calculation used for estimating the solvent content of waste being amended to give a more representative trend with time.
- There are a number of sources in categories 3C Chemical Products and Manufacturing, and 3D Other Use of Solvents where the way in which data has been extrapolated to generate a timeseries has been amended. This results in an increase in emissions of nearly 12 percent in 2008 sector 3C, and a decrease of over 3 percent for sector 3D.

4.A. Enteric Fermentation – Swine

- Revised swine weights in line with NH_3 inventory and revised applicability of default IPCC emission factors

4.B. Manure Management – Swine (CH_4)

- Derivation of Tier 2 emission factors for CH_4 emissions from manure management.

4.D.1.1 Synthetic Fertilisers

- Revised Tier 2 ammonia model which now includes Goats, Horses and Mules & Asses. Revised estimate of ammonia volatilised for the year 2005 to 2008.

4.D.1.2 Animal Manure Applied to Soil

- Revised Tier 2 ammonia model which now includes Goats, Horses and Mules & Asses. Revised estimate of ammonia volatilised for the year 1990 to 2008.

4.D.3.1 Atmospheric Deposition

- Revised Tier 2 ammonia model which now includes Goats, Horses and Mules & Asses. Revised estimate of ammonia volatilised for the year 1990 to 2008.

5. LULUCF Sector

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 1990-2008.

- Revised estimates of forest biomass due to biomass loss from young forests as a result of biomass burning/forest fires in *5.A. Forest Land*;
- Revised estimate of carbon loss from Forest land remain Forest Land on organic soils during the first forest rotation period of 50 years.
- Revised estimate of carbon loss from “Land converted to Forest lands” on organic soils based on revised emission factor and revised transition period.
- Adjustment to total forest area shown in Table G.1 of Annex G to be consistent with areas reported under Article 3.3 of the Kyoto Protocol in chapter 11 (KP_LULUCF);
- Upgrade from tier 1 method to tier 3 method for estimating carbon stock change in the litter pool in forest land;
- Inclusion of N_2O emissions in drained forest soils;
- Minor revisions for biomass burning;
- Revised area estimates for deforestation 1990 to 2008 which are accounted for in carbon stock change estimates for forest land conversions to grasslands wetland, settlement and other lands.

6.A Solid Waste Disposal on Land

- CH_4 emissions from sub-category 6.A.1 have been revised due a revision in the quantities of waste allocated to solid waste disposal systems and the amount of CH_4 recovered for years 1999-2008;
- CH_4 emissions from sub-category 6.A.2.1 have been revised due to the amount of CH_4 recovered for the years 1996 to 1998;
- CH_4 emissions from sub-category 6.A.2.2 have been revised due a revision in the quantities of waste allocated to solid waste disposal systems for years 1996 to 2008.

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 1990-2008 according to greenhouse gas and the IPCC sectors, respectively. The overall effect on total emissions excluding LULUCF is an increase of 0.03 percent in 1990 to 0.48 percent in 2008 (Table 10.2(c)). The change is greatest for the latter years of the time-series due to higher impact of the revisions for category 6.A Solid Waste in these years. The effects of other revisions are much smaller and they are similar in all years. 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 and 2009 centralized 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. Annex I summarises the issues raised in the UNFCCC 2010 review and Ireland's response to those issues through the present submission. It may be stated therefore that the inventory material being submitted in 2011 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 2010 (FCCC/ARR/2010/IRL) was not available to the inventory agency in sufficient time to implement all of its recommendations. The inventory agency has outlined in Annex I of this report how it addressed some of the recommendations in this submission. All remaining recommendations will be addressed in Ireland's 2012 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 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.

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. The revisions relating to categories 2.A.3 and 2.A.7 mentioned above result from efforts by EU Member States to harmonise reporting in these categories for their 2010 submissions.

Table 10.1 Changes in Methodological Descriptions compared to 2010 NIR

METHODS	RECALCULATIONS	REFERENCE
IPCC categories where the 2011NIR includes changes in methodological descriptions compared to the 2010 NIR	**Sub-categories where changes are reflected in recalculations of estimates for previous years**	**Reference to sub-category, gas, pages in the NIR, Annex**
1.A.3. Energy (Transport)	1.A.3.b Road Transport	Revised CH_4 and N_2O emissions due to a change in Road Transport model COPERT 4. Version 8.0 used in this Submission 2011 and Version 6.1 used in Submission 2010. See section 3.2.1.3 of NIR (page 54).
1.B.2 Fugitive Emissions from Fuels (Oil and Natural Gas)	1.B.2.a. Oil (iv Refining/Storage)	Fugitive CH_4 emissions from 1.B.2.a iv included for the first time in this Submission 2011. See section 3.2.2 of NIR (page 58).
3. Solvents and Other Product Use	3.A- 3.D	Revised approach in estimating emissions of NMVOC and CO_2 from sub-categories 3.A to 3.D. See section 5.2 and 5.3 of NIR (page 82-84).
4.A Agriculture (Enteric Fermentation)	4.A	Revision of pig weights and applicability of default emission factors. See section 6.2.6 of NIR 2011.
4.B Agriculture (Manure Management)	4.B	Revision to the AWMS Methodology in Submission 2011 due to a UNFCCC expert review team finding. See section 6.8.1 of NIR 2011 (page 100). Application of Tier 2 methodology for CH_4 emissions from manure management for swine. See section 6.3.2 of NIR 2011
4.D Agriculture (Agricultural Soils)	4.D.1.1, 4.D.1.2 and 4.D.3.1	Revised Tier 2 Ammonia model now includes additional animal species; goats, horses mules and asses for the first time in submission 2011. See section 6.8.1 and 6.8.2 of NIR 2011 (page 100-101).
5. LULUCF (Forest Soils)	5.A.1, 5.A.2	Due to the revised emission factors and period of carbon loss from organic soils under afforestation, it was necessary to estimate afforestation areas from 1940 onwards. See Sections 7.3.7 of NIR.
5. LULUCF (Forestland, Grassland and Cropland)	5.A.1, 5.A.2, 5.B.2.1 and 5.C.2.1	Revised methodology for the estimation of Deforestation based on CORINE Land Cover change and data from Forest Service. This has the knock on implication for areas of land allocated to the other land uses with respect to demand for settlement land. See Section 7.3.3 of NIR.

Table 10.2 Recalculations by Gas 1990-2008

(a) Emissions by Gas 1990 –2008 reported in 2010 Submission (Gg CO_2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO_2 (inc net CO_2 from LULUCF)	32,609.46	33,511.74	33,467.67	33,396.28	34,522.01	35,486.98	37,285.02	38,689.66	40,390.92	42,037.48	44,769.27	47,094.98	45,500.21	44,605.75	45,568.19	47,011.21	46,578.91	46,292.19	45,878.16
CO_2 (exc net CO_2 from LULUCF)	32,377.19	33,184.05	33,083.59	33,214.83	34,441.59	35,220.20	36,912.28	38,357.92	40,470.12	42,156.16	44,650.87	47,057.98	45,648.54	44,897.65	45,762.58	47,519.62	47,110.21	47,305.20	47,391.52
CH_4 emissions (inc CH_4 from LULUCF)	13,582.53	13,757.49	13,844.37	13,926.48	13,870.56	13,872.81	14,055.14	14,047.91	14,297.90	13,900.24	13,337.86	13,335.35	13,327.75	13,811.96	12,993.78	12,786.97	12,822.89	12,304.13	12,166.61
CH_4 emissions (exc CH_4 from LULUCF)	13,581.41	13,756.77	13,843.91	13,925.55	13,869.50	13,871.38	14,053.56	14,047.05	14,297.44	13,899.87	13,336.93	13,333.50	13,327.33	13,809.36	12,992.26	12,786.42	12,822.34	12,303.51	12,165.85
N_2O emissions (inc N_2O from LULUCF)	8,804.08	8,600.42	8,610.02	8,748.11	8,983.96	9,186.92	9,219.57	9,075.98	9,621.43	9,651.98	9,202.55	8,614.25	8,255.43	8,176.42	7,980.22	7,872.85	7,708.22	7,397.60	7,266.16
N_2O emissions (exc N_2O from LULUCF)	8,789.91	8,585.74	8,594.77	8,729.65	8,965.26	9,167.47	9,197.83	9,054.36	9,599.68	9,630.10	9,180.30	8,587.87	8,226.81	8,144.28	7,947.93	7,840.33	7,675.55	7,364.91	7,223.67
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	351.44	387.31	436.72	509.17	500.49	520.83
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
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
Total including LULUCF	**55,032.26**	**55,923.18**	**55,989.24**	**56,165.87**	**57,506.60**	**58,749.77**	**60,840.98**	**62,209.82**	**64,658.25**	**66,052.75**	**67,902.12**	**69,662.91**	**67,643.89**	**67,292.55**	**67,178.57**	**68,371.55**	**67,834.96**	**66,693.74**	**65,998.79**
Total excluding LULUCF	**54,784.70**	**55,580.09**	**55,589.44**	**55,965.04**	**57,406.42**	**58,462.10**	**60,444.92**	**61,855.60**	**64,715.24**	**66,149.18**	**67,760.54**	**69,597.69**	**67,763.18**	**67,549.72**	**67,339.15**	**68,846.89**	**68,333.04**	**67,673.43**	**67,468.89**

(b) Recalculated Emissions by Gas 1990 –2008 reported in 2011 Submission (Gg CO_2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
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
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
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
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
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
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
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
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
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
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**
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**

(c) Percentage Change in Emissions by Gas 1990-2008

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO_2 (inc net CO_2 from LULUCF)	-2.48	-2.71	-2.93	-2.86	-3.12	-3.01	-3.00	-2.95	-2.65	-2.34	-2.07	-2.02	-2.12	-1.62	-1.74	-1.49	-1.53	-1.54	-1.62
CO_2 (exc net CO_2 from LULUCF)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.41	0.40	0.40	0.41	0.37	0.31
CH_4 emissions (inc CH_4 from LULUCF)	0.06	0.06	0.06	0.09	0.09	0.09	0.27	0.61	0.67	0.80	0.79	0.83	0.86	0.85	1.29	1.49	1.25	1.59	1.76
CH_4 emissions (exc CH_4 from LULUCF)	0.06	0.06	0.06	0.09	0.09	0.09	0.27	0.61	0.67	0.80	0.79	0.83	0.86	0.85	1.29	1.49	1.25	1.59	1.76
N_2O emissions (inc N_2O from LULUCF)	0.27	0.27	0.25	0.22	0.18	0.13	0.11	0.07	0.03	0.01	-0.04	-0.12	-0.13	-0.10	-0.08	-0.07	-0.05	-0.14	-0.15
N_2O emissions (exc N_2O from LULUCF)	0.27	0.27	0.25	0.22	0.18	0.13	0.11	0.07	0.03	0.01	-0.04	-0.12	-0.12	-0.10	-0.07	-0.07	-0.04	-0.14	-0.15
HFCs	0.00	0.00	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	-0.01	0.00	0.05	0.01
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
SF_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total including LULUCF	**-1.41**	**-1.57**	**-1.70**	**-1.64**	**-1.83**	**-1.78**	**-1.76**	**-1.69**	**-1.50**	**-1.32**	**-1.22**	**-1.22**	**-1.27**	**-0.91**	**-0.94**	**-0.75**	**-0.82**	**-0.79**	**-0.82**
Total excluding LULUCF	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.05**	**0.09**	**0.15**	**0.16**	**0.18**	**0.15**	**0.15**	**0.16**	**0.43**	**0.51**	**0.54**	**0.51**	**0.53**	**0.52**

Table 10.3 Recalculations by IPCC Sector 1990-2008

(a) Emissions by IPCC Sector 1990 –2008 reported in 2010 Submission (Gg CO_2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1. Energy	31,028.31	31,913.00	31,842.14	32,012.77	32,981.77	33,831.92	35,465.07	36,561.54	38,816.08	40,507.68	42,523.67	44,637.96	43,435.36	43,767.69	43,882.01	45,609.32	45,193.07	45,350.17	45,693.47
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	4,195.80	4,304.40	3,726.33	3,041.03	3,143.45	3,253.32	3,263.69	3,280.25	2,989.44
3. Solv ent and Other Product Use	79.43	81.13	81.62	81.91	82.92	84.58	84.55	85.11	85.76	82.97	78.96	78.61	76.97	76.54	76.82	78.70	81.57	83.97	85.97
4. Agriculture	19,196.64	19,315.17	19,401.97	19,571.04	19,721.08	19,896.89	20,219.57	20,322.57	21,026.77	20,701.49	19,633.03	19,137.06	18,989.03	19,071.44	18,883.07	18,687.60	18,458.14	17,769.55	17,605.08
5. LULUCF	247.56	343.09	399.80	200.83	100.18	287.67	396.05	354.22	-56.99	-96.43	141.58	65.22	-119.29	-257.17	-160.58	-475.34	-498.07	-979.69	-1,470.10
6. Waste	1,301.78	1,382.10	1,447.56	1,494.55	1,539.80	1,575.59	1,460.79	1,219.61	1,279.49	1,285.27	1,329.08	1,439.67	1,535.48	1,593.02	1,353.80	1,217.95	1,336.56	1,189.50	1,094.93
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total exc LULUCF	**54,784.70**	**55,580.09**	**55,589.44**	**55,965.04**	**57,406.42**	**58,462.10**	**60,444.92**	**61,855.60**	**64,715.24**	**66,149.18**	**67,760.54**	**69,597.69**	**67,763.18**	**67,549.72**	**67,339.15**	**68,846.89**	**68,333.04**	**67,673.43**	**67,468.89**

(b) Recalculated Emissions by IPCC Sector 1990 –2008 reported in 2011 Submission (Gg CO_2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
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
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
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
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
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
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
7. Other	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**

(c) Percentage Change in Emissions by Sector 1990-2008

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1. Energy	-0.07	-0.07	-0.08	-0.08	-0.09	-0.09	-0.10	-0.11	-0.12	-0.11	-0.11	-0.11	-0.10	0.32	0.33	0.34	0.36	0.32	0.25
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.01	0.00
3. Solvent and Other Product Use	0.75	0.80	0.78	0.86	0.90	0.96	0.99	0.90	1.01	0.92	0.10	-0.88	-1.77	-2.81	-3.78	-5.90	-7.88	-9.87	-13.51
4. Agriculture	0.30	0.30	0.30	0.31	0.31	0.30	0.31	0.32	0.34	0.33	0.33	0.32	0.32	0.31	0.30	0.30	0.31	0.30	0.30
5. LULUCF	-328.23	-266.00	-246.17	-477.17	-1,080.53	-372.75	-283.06	-323.37	1,885.39	1,024.31	-656.68	-1,465.43	809.56	351.79	606.25	187.00	182.30	90.89	60.36
6. Waste	0.00	0.00	0.00	0.00	0.00	0.00	1.63	5.63	5.97	7.23	6.52	6.24	6.04	5.97	10.77	13.67	10.18	14.51	17.48
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total exc LULUCF	0.06	0.06	0.06	0.06	0.06	0.05	0.09	0.15	0.16	0.18	0.15	0.15	0.16	0.43	0.51	0.54	0.51	0.53	0.52

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 2009 on 271.38 ha of lands subject to afforestation since 1990 is estimated at 2,833.76 Gg while there were net emissions of 33.69 Gg CO_2 on a deforested area of 8.12 ha. The overall forest sink for Article 3.3 forest increased from 2,428.4 Gg CO_2eq in 2008 to 2,800.07 Gg CO_2eq in 2009, 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 2,678.67 and 2,826.20 Gg CO_2 in 2008 and 2009, 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 (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. 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 is sufficient 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 ongoing 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 is due for completion in 2011/12.

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	NO	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

Table 11.2 Land Transition Matrix (CRF Table NIR 2)

From previous inventory year / To current 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	264.733	0.197						264.930
	Deforestation		7.921						7.921
Article 3.4 activities	Forest Management (if elected)		NA	NA					NA
	Cropland Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Grazing Land Management[4] (if elected)	NA	NA		NA	NA	NA		NA
	Revegetation[4] (if elected)	NA			NA	NA	NA		NA
Other[5]		6.647	0.000	NA	NA	NA	NA	6,832.288	6,838.935
Total area at the end of the current inventory year		271.380	8.118	NA	NA	NA	NA	6,832.288	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	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	Total(6)		
	(Gg CO_2 equivalent)					
A. Article 3.3 activities						
A.1. Afforestation and Reforestation						-5,564.194
A.1.1. Units of land not harvested since the beginning of the commitment period(2)		-2,704.302	-2,859.891	-5,564.194		-5,564.194
A.1.2. Units of land harvested since the beginning of the commitment period(2)						0.000
Ireland		250.237	26.128	276.365		0.000
All Harvested AR land (101-114)		IE,NO	IE,NO	IE,NO		IE,NO
A.2. Deforestation		25.663	33.689	59.353		59.353
B. Article 3.4 activities						
B.1. Forest Management (if elected)		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	0.000	0.000
B.3. Grazing Land Management (if elected)	0.000	NA	NA	NA	0.000	0.000
B.4. Revegetation (if elected)	0.000	NA	NA	NA	0.000	0.000

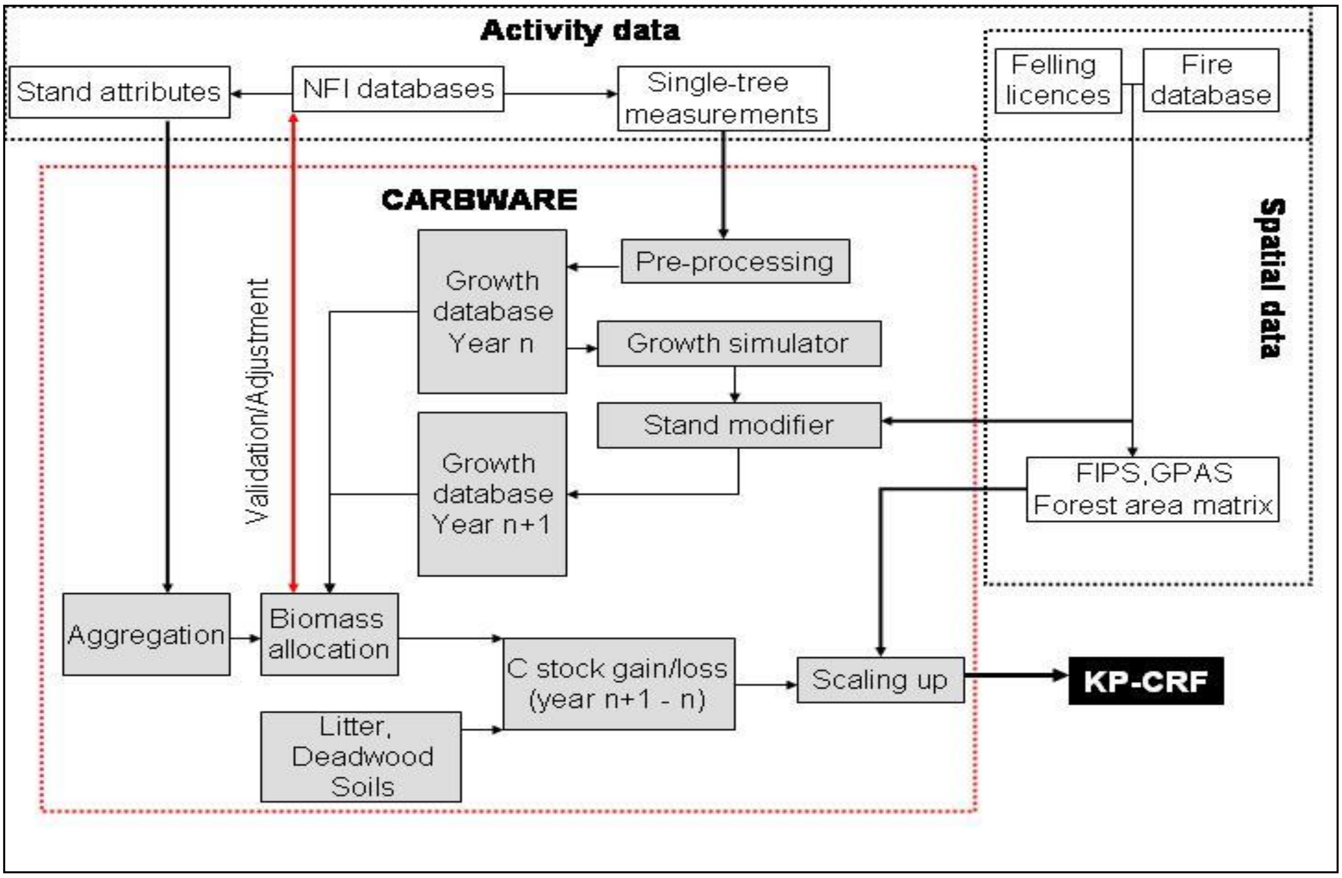


Figure 11.1: Schematic Overview of Reporting System and CARBWARE Functionality

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 percent 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 percent 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 small open areas on forest land; forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest;
- The forest area excludes tree stands in agricultural production systems, for example in fruit plantations and Christmas tree plantations;
- The term forest also includes trees in urban parks and gardens, provided these areas satisfy the forest definition.

Reforestation activities do not occur in Ireland and the relevant activities under Article 3.3 are limited to afforestation and deforestation. All afforested areas are the result of planting and establishment of forest areas of 5 ha or greater under guidelines of the Forest Service Grant and Premiums Scheme (Forest Service, 2003). All of these forest areas are consistent with the forest definition. The scheme was introduced under European Commission Council Regulation 2080/92 to support afforestation of agricultural land as part of accompanying measures to reform the Common Agricultural Policy. The afforestation grant and premiums dataset captures all areas afforested following successful grant application. Afforestation areas recorded by the Forest Service are verified using a strict control and referrals process, following a post-establishment site visit by a forestry inspector (Forest Service, 2003). All deforestation areas are derived from legally-binding licence applications under the Forestry Act. These provisions fulfil the requirement to demonstrate that afforestation 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. 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 2008 area time-series. In addition, a consistent time series has been recalculated for deforested areas, based on new activity data obtained for the years 2006, 2007 and 2008 (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 F) 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) 2009

Year	KP areas			Convention areas			Total area
	FM	AR	D	F-L	F-F	UNCL	
1990	481.33	15.82	0.02	175.43	194.73	127.00	497.16
1991	479.86	34.96	0.04	184.46	189.26	141.14	514.87
1992	476.90	51.66	0.06	191.21	185.02	152.38	528.62
1993	479.32	67.66	0.08	197.39	183.55	166.12	547.06
1994	480.60	87.12	0.10	207.57	179.03	181.22	567.82
1995	473.70	110.83	0.44	222.08	172.75	190.13	584.97
1996	462.44	131.81	0.77	234.46	172.06	188.49	595.02
1997	460.22	143.25	1.10	237.54	181.67	185.36	604.57
1998	461.88	156.17	1.44	242.19	192.68	184.62	619.49
1999	464.98	168.84	1.77	247.00	200.90	187.70	635.59
2000	459.51	184.54	2.63	256.51	203.09	187.08	646.67
2001	452.54	200.00	3.48	265.60	209.14	181.29	656.02
2002	446.51	215.06	4.34	274.14	220.51	171.26	665.91
2003	453.62	224.15	5.20	277.21	235.62	170.14	682.97
2004	450.40	233.89	6.06	281.28	241.46	167.60	690.34
2005	447.43	243.99	6.91	286.14	248.27	163.93	698.33
2006	439.93	251.89	7.29	287.21	258.29	153.60	699.10
2007	436.89	258.90	7.63	286.03	276.45	140.93	703.42
2008	439.02	264.88	7.92	286.14	294.95	130.73	711.82
2009	439.17	271.38	8.12	272.10	325.86	120.71	718.67

*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 not reported under convention reporting (see Chapter 7, CRF Tables). For comparison to Convention reporting, KP (3.4) **FM = F-F + UNCL+ F-L – AR- D***

11.1.5 Changes made since the last submission

Numerous changes have been implemented to the KP LULUCF 2008 and 2009 inventory following comments from the 2010 ERT and internal QC/QA checks, these include:

1) Inclusion of emissions from lime application to deforested lands converted to grassland (see section 11.3.1.6). This was previously reported as NO (table 5(KP-II)4, but now reported as a source of 0.07 Gg in 2008 (a relative decrease of 0.003% of the net removal in 2008). The emissions from lime application to deforested land for 2009 was 0.09 Gg (CRF table 5(KP-II)4).

2) The areas subjected to deforestation prior to 2006 have been re-assessed using these new methodologies (section 7.3.7). This resulted in an increase in the deforestation area (1990 to 2008) from 1.38 kha, in the 2010 re-submission (v2.1 November 2010), to 7.92 kha in this submission for 2011. Inclusion of these areas increases the deforestation emission from 11.11 Gg CO_2 to 25.66 Gg CO_2 for the period 1990-2008.

3) The 2011 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 2011 submission.

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. Afforestation and deforestation areas are reported within the entire territory of Ireland, with no further sub division within internal national boundaries. Afforestation areas are tracked on a spatially explicit basis (IPCC Approach 3) while deforestation areas are identifiable but not spatially explicit (IPCC Approach 2). Both approaches can detect a land use change at a resolution consistent with the forest definition area of 0.1 ha. Forest areas under Article 3.3 shown in CRF Table NIR 2 are sub categorised into forest categories in order to transparently report and compare implied carbon stock change factors for different forest and soil types (Tables 5(KP-I)A.1.1 and 5(KP-I)A.1.2).

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)

Spatially explicit GIS polygons, representing all afforestation areas, were derived from the available FIPS98 spatial layer (NIR Chapter 7), which represents all forested land in 1998 (621.31 kha in Table 11.5 and Table F.1 Annex F) 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 percent 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)

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). 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 11.5 represented 36 percent of the total forest area, so it was assumed that 36 percent 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.

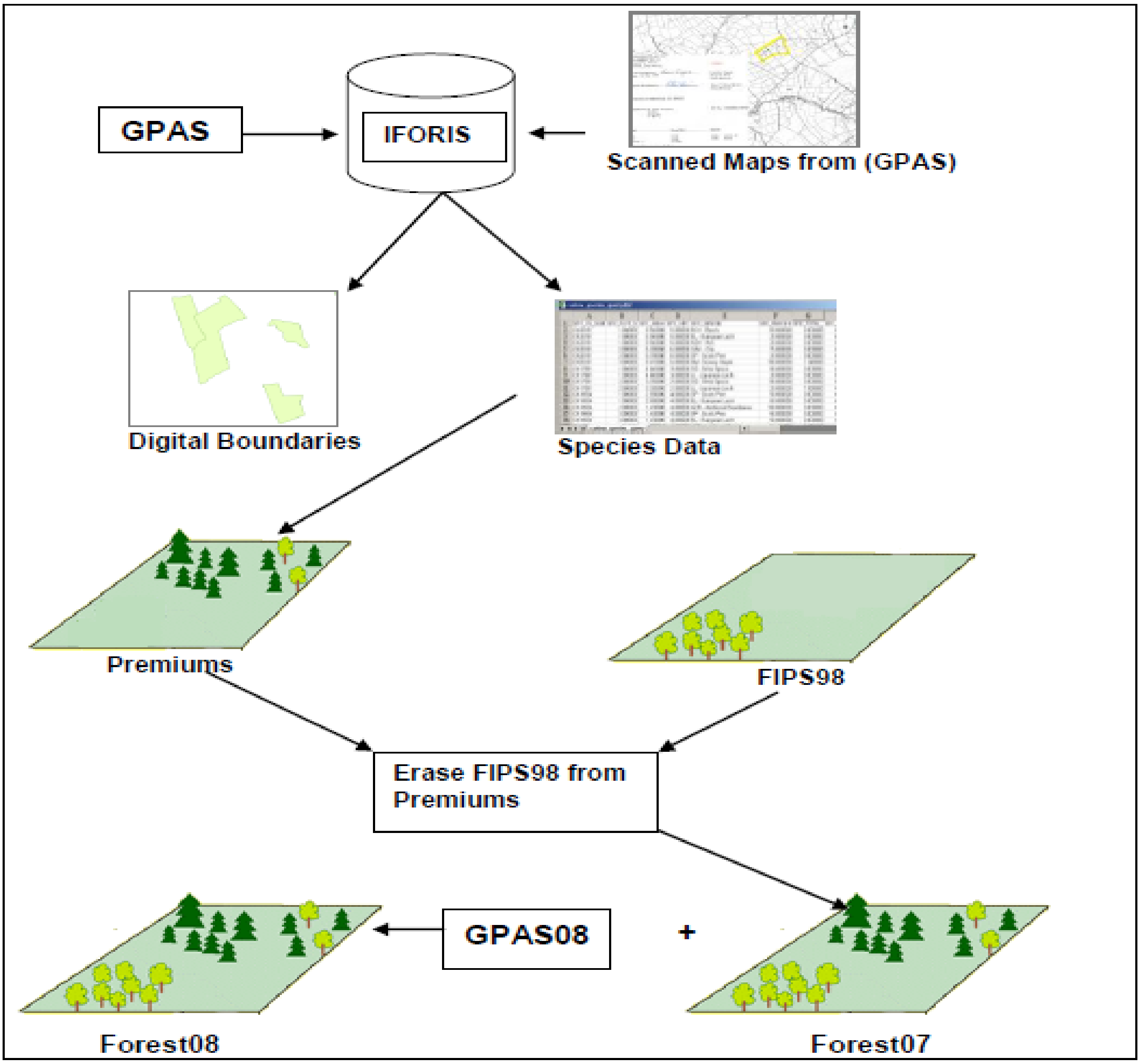


Figure 11.2 Schematic overview of data and procedures used to create spatially explicit data

11.2.3 Activity Data for Afforestation Areas

11.2.3.1 Use of National Forest Inventory data

Activity data 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 percent at the 95 percent 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.

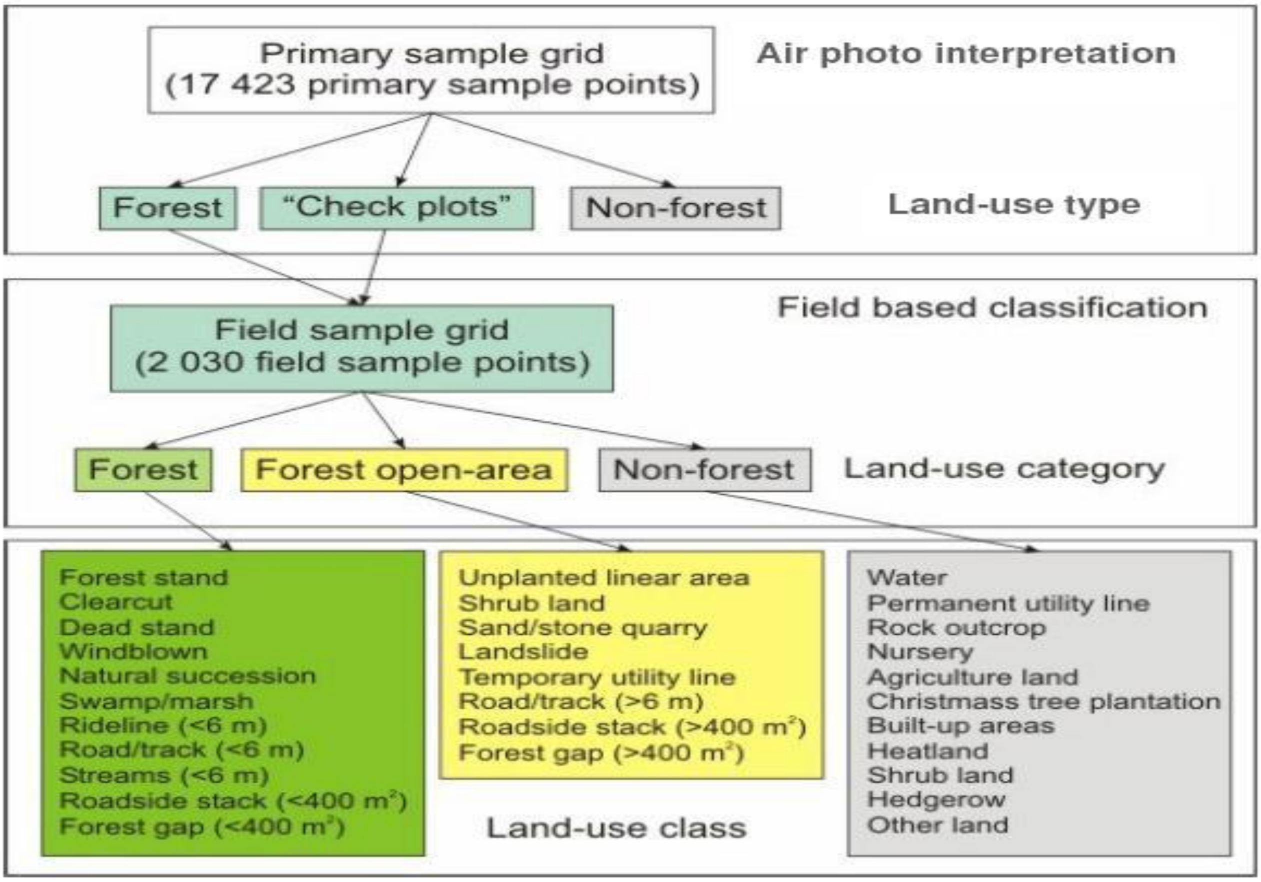
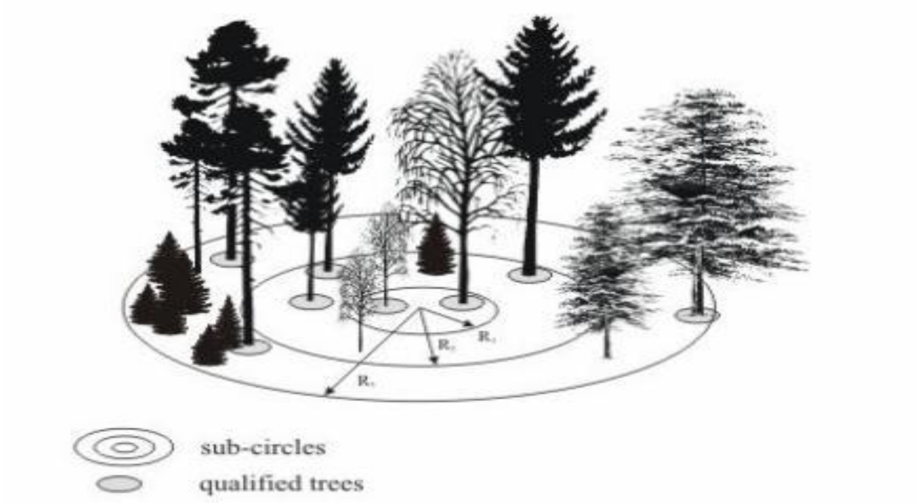


Figure 11.3 Overview of the NFI classification system (taken from NFI, 2007a)

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

Forest stand attributes were also collected to classify forest age, rotation stage and management status so that inventories plots could be disaggregated into appropriate KP forest categories (see KP CRF 5 (KPI) A1.11/2). 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. 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 percent 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.

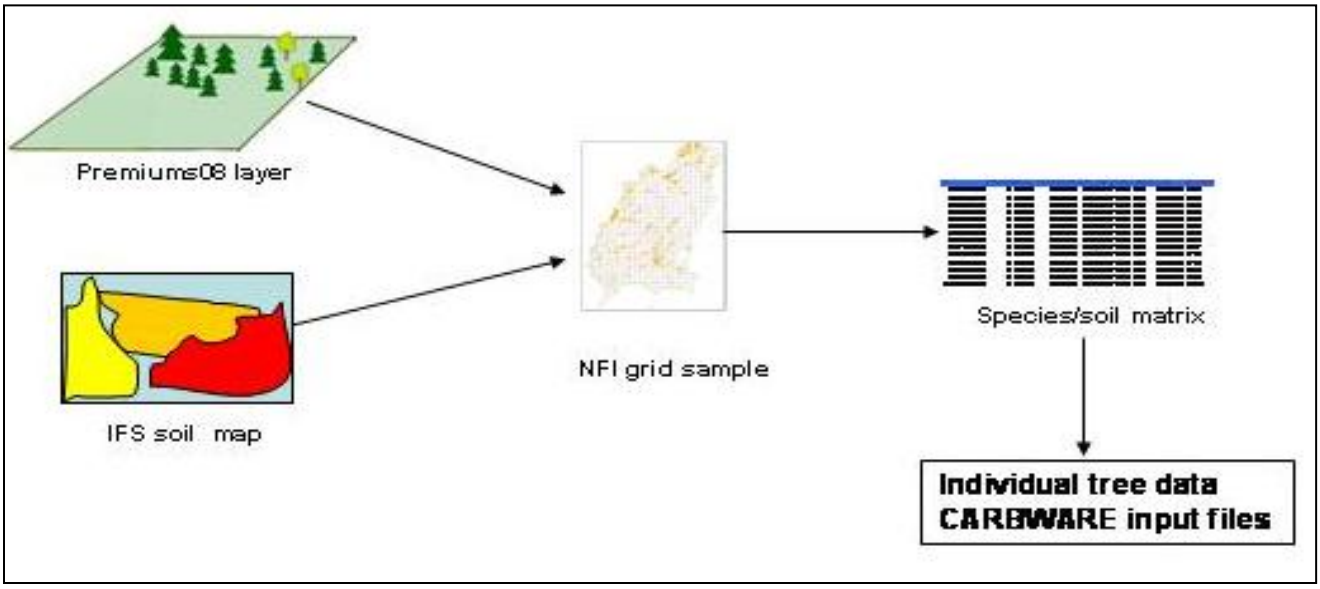


Figure 11.5 Procedure to derive activity data for Afforestation Areas after 2006

11.2.3.3 Harvest Activity Data

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 was 372,864 m^3 in 2007 and 351,480 m^3 in 2008. No harvesting occurred on afforestation land prior to 2007. Harvesting from the Coillte lands represented 91 percent and 80 percent of the total timber harvest from article 3.3 forests (afforestation areas only) in 2007 and 2008, respectively.

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 compared against independently derived **FAO/Eurostat** data and **Coillte invoice** information and adjusted if required. 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.

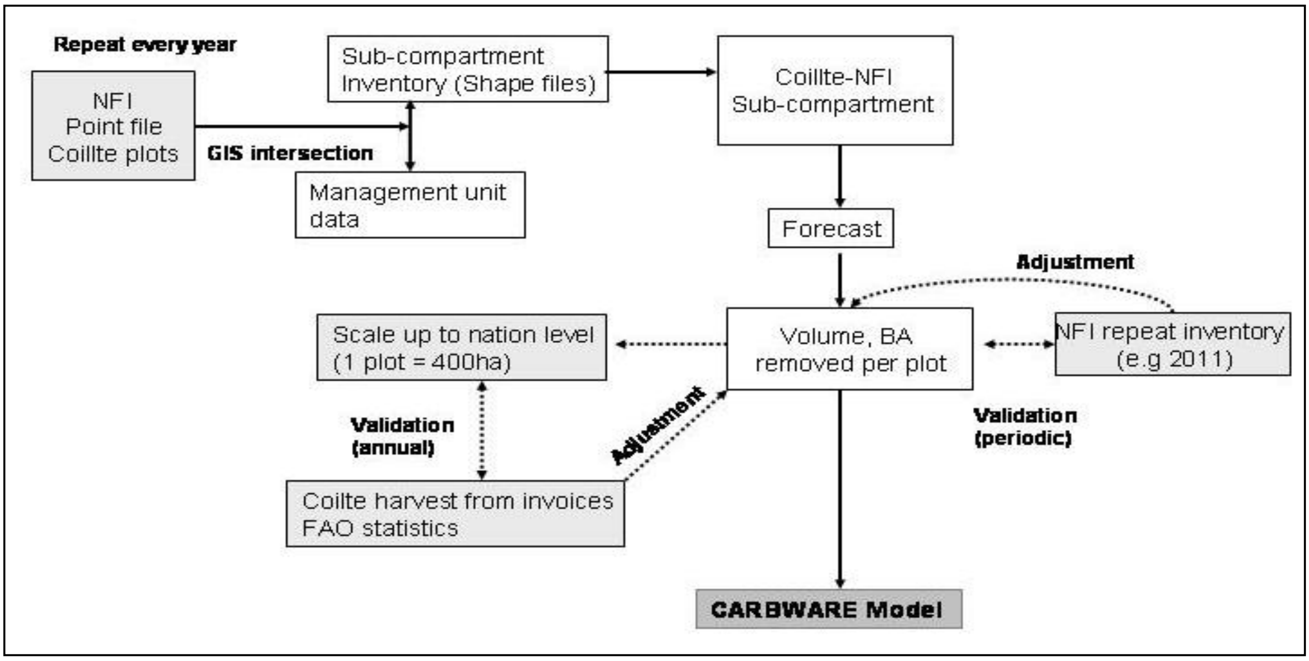


Figure 11.6 Methodology used to derive harvest information for State Forests

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.

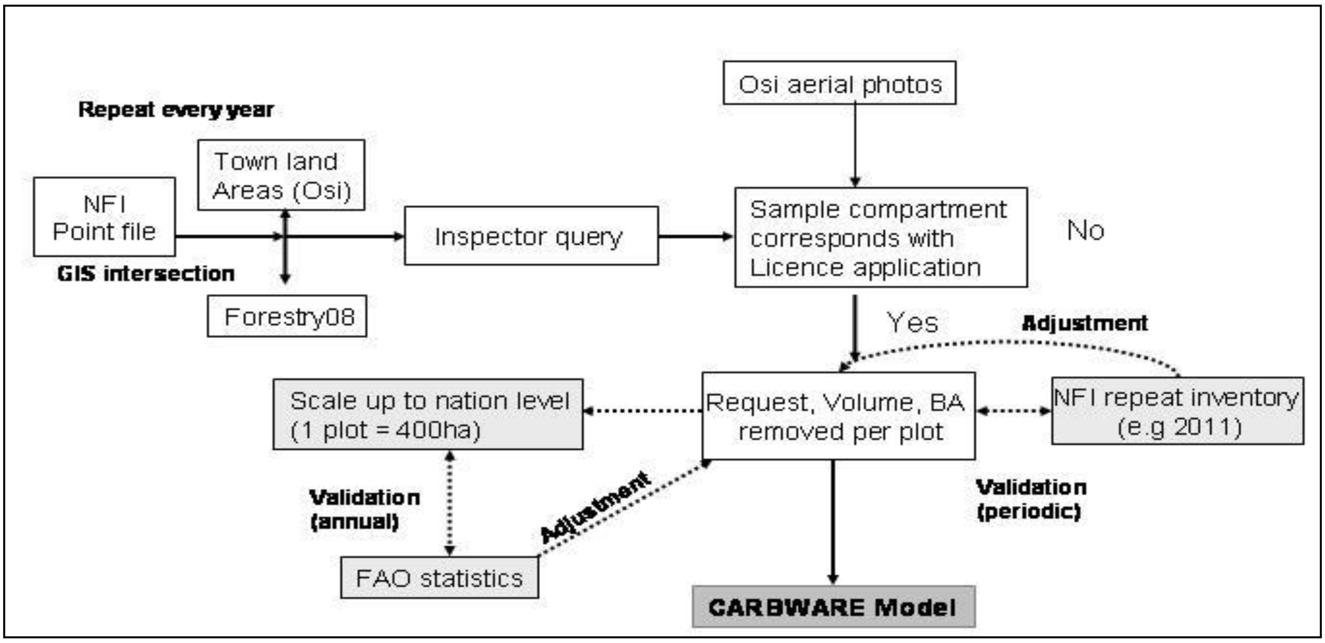


Figure 11.7 Procedure used to derive harvest activity data for private forested areas

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 11.6). 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 11.6). 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.

All of these deforested areas are reported for the years 1990-2009 (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 1st 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).

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. 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):

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

Biomass estimates include biomass for trees only, non-tree vegetation is assumed to be in steady state following canopy closure. 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

$$\Delta C = \Delta C_G + \Delta C_L \text{ ......(11.2)}$$

The biomass carbon gains (ΔC_G) for both above-ground biomass (AB) and below-ground biomass (BB) are calculated for each forest category i, listed in Table 11.6 using

$$\Delta C_G = \sum_i \left(A_i \times GTOTAL_i \times CF \right) \text{ ......(11.3)}$$

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 percent 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:

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

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 all trees were calculated using biomass algorithms for different species cohorts based on national research information, 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, See Figure 11.1). The increases in DBH and H of individual trees between NFI years were simulated in the single tree growth models (Table 11.5). 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).

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}):

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

L_{timber} is calculated based on the above-ground biomass removed from harvest, simulated in the stand modification module (Annex J 2A). The **allocation** algorithms for timber based on AB, H or DBH were derived from national research information (Annex J 1A 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:

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

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 turn over rates (F_t) (Tobin et al., 2006):

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

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. 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 A). The above-ground biomass loss from mortality ($L_{mort(AB)}$) was calculated using DBH and H as dependent variables in biomass algorithms (Annex J). 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.

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}):

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

L_{HRroot} is the root biomass transferred to the deadwood pool following harvest. 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 A). The below-ground biomass loss from mortality ($L_{mort(BB)}$) was calculated using above-ground and total biomass algorithms (Annex J). The BB biomass losses associated with fires (L_{fire}) was determined in the same way as described above for AB losses due to fires and reported in Table 5(KP-II)5). The below-ground biomass gains in burned forest are assumed to be zero.

Carbon stock changes associated with deforestation reported in CRF Table 5(KP-I)A.2 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):

$\Delta C_{L(AB)} = TOTAL_{(AB)}$ and $\Delta C_{L(BB)} = TOTAL_{(BB)}$ ……………………...…………..(11.9)

The carbon stocks in the AB and 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, 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, as follows

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

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

11.3.1.2 Litter Carbon Stock Change

Net litter stock change (ΔC_{Li}) was calculated based on litter inputs (gains) due to litterfall (L_{LF}), as given by equation 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}):

$\Delta C_{Li} = (L_{LF} + L_{HR} + M_{Li}) - L_{decomp}$ ……………………………………………..(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 ($_{mort(tim)}$):

$M_{Li} = L_{mort(AB)} - L_{mort(tim)}$ …………………………………………...…………(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):

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

$L_{old} = \sum [\{(L_{LF}, L_{HR}, M_{Li})_{n-1,n-2,n-x}), L_{ini}\}]^{-D_{LI}}$ ………………………………..... (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 11.6, 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.

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

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

A small amount (approximately 4 percent) 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 (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):

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

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

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

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):

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

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

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

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 that 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.

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

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,

$$\Delta C_{So} = \sum_j \left(A_j \times EF_{soil} \times SD\right) \quad \text{.........(11.24)}$$

and

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

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 percent of the total forest area in 2008. Therefore, the emissions from forest fires reported in CRF Table 5(KP-II)5 are derived from the total emissions reported for the category *5.A.1 Forest Land Remaining Forest Land* in CRF Table 5(V) in the Convention inventory multiplied by a factor of 0.36. The emissions 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.

11.3.1.6 Lime application

Emissions from lime application to deforested land converted to grasslands is 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 and 3,903 ha in 2008 and 2009 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 and 0.186 Mg/ha in 2009.
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

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 distribution of spatial diameter, informs the calculation of a sampling weight or *expansion factor* (EF) 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 that 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:

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

where R_i 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, 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 2).

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

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 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:

$$GTOTAL_{(AB)} = \frac{\sum \left[ABij \times EFij \right] \times 20}{1000} \qquad \text{(11.28)}$$

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.

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 J 1-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 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 (Annex J).

11.3.2.2 Justification for Omitting a Carbon Pool

Changes in mineral soil C pools over time (ΔC_{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). 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.

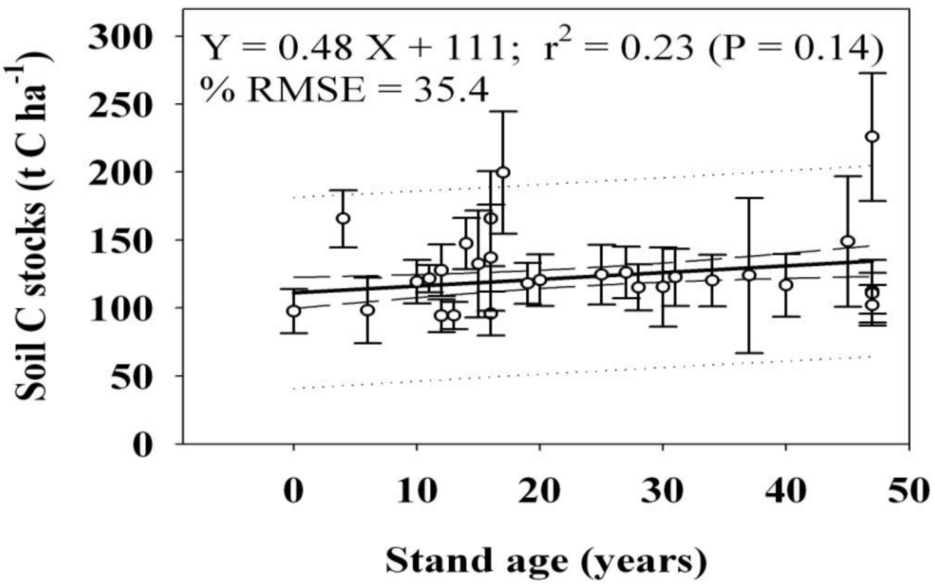


Figure 11.8 Variation in mineral soil carbon stocks and estimation of ΔC_{so} using the nationally derived data (n = 30). The solid line represents the linear change on C stock over time. The dashed and dotted lines represent the 95% confidence and prediction intervals

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) do not occur, or are very rare in Ireland. These land use transitions were not detected in the stratified sample grid and deforestation statistics (Section 7.3.7, Chapter 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 11.7 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 11.8 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. Although there were marginal differences between the mean soil C stocks across different land uses within the soil categories, these were not significantly different.

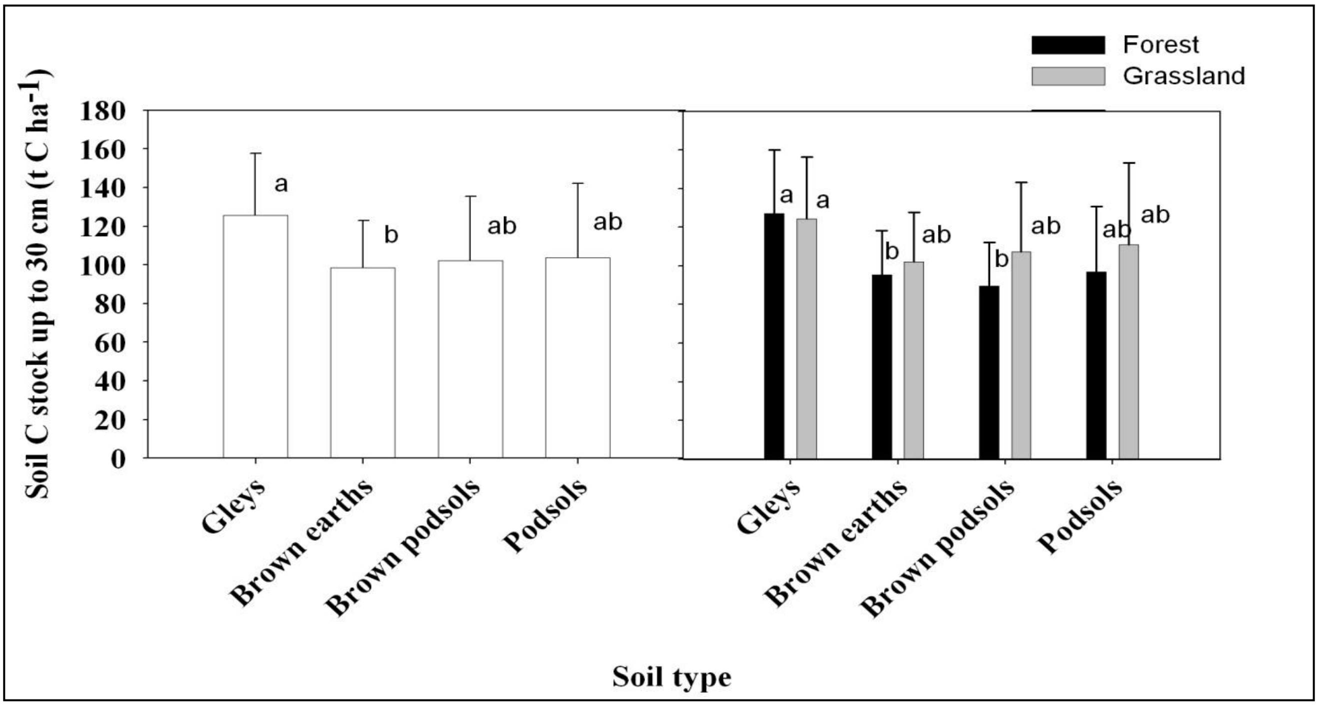


Figure 11.9 Mean soil C reference values for forest and grasslands at steady state across different mineral soil types. Histogram bars with different letters are significantly different at P < 0.05

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 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 ongoing and new methods will be developed if new trends emerge.

11.3.2.3 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.

11.3.2.4 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 11.9). 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 percent probability of being dead (Annex J 2_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 11.10. The combined uncertainties of the products of the respective parameters associated with each component pool are calculated using equation 11.29 (equation 6.4 of the IPCC good practice guidance):

$$U_{total} = \sqrt{U_1^2 + U_2^2 + U_3^2 + U_n^2} \quad \ldots\ldots(11.29)$$

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 11.9. The calculated percentage uncertainties for pools are given in Table 11.10 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 11.9 as the sum of the uncertainties for carbon pools using equation 11.30 (equation 6.3 of the IPCC good practice guidance):

$$U_{total} = \frac{\sqrt{(U_1 \times x_1)^2 + (U_2 \times x_2)^2 + (U_n \times x_n)^2}}{|x_1 + x_2 + x_n|} \quad \ldots\ldots(11.30)$$

where U_{total} is the combined uncertainty, U_1, U_2 and U_n are the uncertainties of pool estimates (Table 11.10) 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 11.11b for the net CO_2 removals for afforestation reported in CRF Table 5(KP-I)A.1.1 in 2009 is 1.975 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 1.166 Mg C/ha for the litter pool, x_3 is the carbon stock change of 0.057 Mg C/ha for deadwood and x_4 is the carbon stock change of -0.445 Mg C/ha for soils. This gives and uncertainty of 23.24 percent for CRF 5(KP-1) A1.1 in 2009 (Table 11.11b). The overall uncertainty is calculated using the net emission/removal value (in Gg CO_2) and uncertainties categories A1.1, A1.2 A2. and KPII5 (Tables 11.11a and 11.11b). The overall uncertainty for all ARD activities was 26.54 percent in 2008 and 23.24 percent in 2009.

Table 11.9 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	21.0	Black, 2008; Black et al., 2009b
D1	Area data (Afforestation)	GPAS (11.2.2)	0.60	Derived from Black et al, 2009a[c]
D2	Area data (Deforestation)	Deforestation (section 7.3.3)	50.1	Coefficient of variation from stratified sample analysis
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
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 11.10 Uncertainty estimates of major C pools

Code	Component	Reference equation in section 11.3.1	% uncertainty* equation 11.29	Individual parameter codes from Table 11.7
TB	Biomass	Eq 11.3 AB and BB		
TBA		Afforestation	24.21	A, B, C, D1
TBD		Deforestation	58.45	B, D2, G
Li	Litter	Eq 11.12 Li		
LiA		Afforestation	3.28	B, D1, E
LiD		Deforestation	58.40	B, D2, H
DW	Deadwood	Eq 11.7		
DWA		Afforestation	22.03	B, D1, F
DWD		Deforestation	58.40	B, D2, I
So	Soils	Eq 11.23	90.0	D1, D2, J
FI	Fire		58.36	K, L

Table 11.11a Combined uncertainties of reported values in the KP CRF tables for 2008

CRF Table	% uncertainty	Equation 11.30 and variable (See Table 11.10 and CRF totals)
5(KP-I)A.1.1	23.30	$\frac{\sqrt{(24.21\times 1.903)^2+(3.28\times 1.141)^2+(22.03\times 0.033)^2+(90.00\times -0.447)^2}}{\lvert 1.903+1.141+0.033-0.447\rvert}$
5(KP-I)A.1.2	51.76	$\frac{\sqrt{(24.21\times -45.787)^2+(3.28\times 17.074)^2+(22.03\times 7.509)^2+(90.00\times -0.492)^2}}{\lvert -45.787+17.074+7.509-0.492\rvert}$

5(KP-I)A.2	51.68	$\frac{\sqrt{(58.45\times -0.784)^2+(58.40\times -0.076)^2+(58.40\times -0.007)^2}+(90.00\times -0.025)^2}{\lvert -0.784-0.076-0.007-0.025\rvert}$
5(KP-II)5*	58.36	$\frac{\sqrt{(58.36\times 0.001613)^2}}{\lvert 0.001613\rvert}$
NIR-3 (total)	26.54	$\frac{\sqrt{(23.44\times -2709.329)^2+(52.13\times 250.237)^2+(52.10\times 25.391)^2}+(58.36\times 5.027)^2}{\lvert -2709.329+250.237+25.391+5.027\rvert}$

*The mean emission per unit tonnes of dry matter (0.001613 Gg CO_2 eq/t dm) for fires is derived from the CO_2 emissions (5.027 Gg CO_2 eq) divided by the proportional tonnes of dry matter of Article 3.3 forests subjected to fire (3,117.027 tonnes dm)

Table 11.11b Combined uncertainties of reported values in the KP CRF tables for 2009

CRF Table	% uncertainty	Equation 11.30 and variable (See Table 11.10 and CRF totals)
5(KP-I)A.1.1	22.70	$\frac{\sqrt{(24.21\times 1.975)^2+(3.28\times 1.166)^2+(22.03\times 0.057)^2}+(90.00\times -0.445)^2}{\lvert 1.975+1.166+0.057-0.445\rvert}$
5(KP-I)A.1.2	110.98	$\frac{\sqrt{(24.21\times -7.354)^2+(3.28\times 4.544)^2+(22.03\times 1.643)^2}+(90.00\times -0.531)^2}{\lvert -7.354+4.544+1.643-0.531\rvert}$
5(KP-I)A.2	51.40	$\frac{\sqrt{(58.45\times -0.995)^2+(58.40\times -0.098)^2+(58.40\times -0.021)^2}+(90.00\times -0.024)^2}{\lvert -0.995-0.098-0.021-0.024\rvert}$
5(KP-II)5*	58.36	$\frac{\sqrt{(58.36\times 0.001613)^2}}{\lvert 0.001613\rvert}$
NIR-3 (total)	23.24	$\frac{\sqrt{(22.34\times -2862.777)^2+(67.87\times 26.128)^2+(51.95\times -33.369)^2}+(58.36\times 2.885)^2}{\lvert -2862.777+26.128+33.369+2.885\rvert}$

* The mean emission per unit tonnes of dry matter (0.001613 Gg CO_2 eq/t dm) for fires is derived from the CO_2 emissions (2.885 Gg CO_2 eq) divided by the proportional tonnes of dry matter of Article 3.3 forests subjected to fire (1,789.114 tonnes dm)

11.4 Other Information for Article 3.3 Activities

All afforested areas are a result of planting and establishing forest areas under guidelines of the Forest Service Grant and Premiums Scheme (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.

In the case where deforestation does occur, but it is not detected using the felling license information or there is legal violation of the forestry act, retrospective NFI information can distinguishing 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 replanted within one NFI cycle (i.e. 5 years), the area is classified deforestation***. These areas will be reported for the year deforestation is detected.

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).

Chapter Twelve

Information on Accounting of Kyoto Units

12.1 Background Information

Ireland's Standard Electronic Format report for 2010 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_2011_1_16-36-6 6-1-2011. 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 311,036,143 AAUs in Ireland's National Emission Trading Registry at the end of the year 2010, of which 253,149,685 units were in the Party holding account; 21,225,739 units in the entity holding accounts; 490 units in the other cancellation accounts and 36,660,229 units in the retirement account.

There was 7,326,647 CERs in the registry at the end of 2010: 6,387,753 CERs were held in the entity holding accounts; 2059 in the other cancellation accounts and 936,835 CERs were held in the retirement account.

There was 722,440 ERUs in the registry at the end of 2010; these were all held in the entity holding accounts.

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 319,085,230 tonnes CO_2 eq.

Ireland's assigned amount is 314,184,272 tonnes CO_2eq.

Table 12.1 Information on the SEF tables

Annual Submission Item	Reported in 2011
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	Ireland's Standard Electronic Format report for 2010 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_2011_1_16-36-6 6-1-2011.xls The contents of the SEF report (R1) can also be found in Appendix 1 – *SIAR Supplementary Information*.

12.3 Discrepancies and notifications

There were no discrepant transactions, no CDM notifications, no non-replacements and no invalid units in 2010 (Table 12.2).

Table 12.2 Discrepancies and notifications

Annual Submission Item	Reported in 2011
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions, pursuant of 15/CMP.1 annex I.E paragraph 12, occurred in the 2010 reporting period. 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. In addition, refer to Separate Electronic Attachment "SIAR Reports 2011-IE v 1.0.xls" Worksheet R2.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications were received by the National Registry during the 2010 reporting period, pursuant of 15/CMP.1 annex I.E paragraphs 13 & 14. The contents of the Report R3 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment "SIAR Reports 2011-IE v 1.0.xls" Worksheet R3.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred during the 2010 reporting period, pursuant of 15/CMP.1 annex I.E paragraph 15. The contents of the Report R4 can be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment "SIAR Reports 2011-IE v 1.0.xls" Worksheet R4.

Annual Submission Item	Reported in 2011
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2010, pursuant of 15/CMP.1 annex I.E paragraph 16. The contents of the Report R5 can also be found in Appendix 1 – *SIAR Supplementary Information* of this document. Refer to Separate Electronic Attachment “SIAR Reports 2011-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, 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 Publicly accessible information	There was no change regarding publicly accessible information during 2010. The following information is publicly accessible via the homepage of Ireland's National Emissions Trading Registry – www.etr.ie In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below. **Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)** In light of the amendments introduced by Article 78 of the Commission Regulation No 920/2010 and for security reasons, it is considered that the representative name and contact information (required by paragraph 45) and the legal entity contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report. **JI projects in Ireland (Paragraph 46)** 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. **Holding and transaction information of units (Paragraph 47)** Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by Commission Regulation. Article 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 Publicly accessible information	Paragraph 47c Ireland does not host JI projects in line with the National Climate Change Strategy. Paragraph 47e Ireland does not perform LULUCF activities and therefore does not issue RMUs Paragraph 47g No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date. Paragraph 47j No ERUs, CERs, AAUs and RMUs have been retired to date Paragraph 47k There is no previous commitment period to carry ERUs, CERs, and AAUs over from.

12.5 Calculation of the Commitment Period Reserve

The commitment period reserve (CPR) is the lower of the two values given by 90 percent of the assigned amount and five times the estimate of total emissions in the most recently reviewed inventory. The inventory for 2008 submitted on the 1st of November 2010 is the most recently reviewed inventory for Ireland (FCCC/ARR/2010/IRL). The total emissions in 2008 amounted to 67,468,893 tonnes CO_2 equivalent and five times this estimate is 337,344,465 tonnes CO_2 equivalent. This value is greater than 90 percent 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 the commitment period in regard to activities under Article 3.3 of the Kyoto Protocol. As such, accounting for the years 2008 and 2009 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 significant changes in the institutions involved in the national system during the 2010 reporting cycle.

Sustainable Energy Ireland (SEI) was renamed Sustainable Energy Authority of Ireland (SEAI) in 2010.
The Climate Change Unit (CCU) within the EPA's Office of Climate Licensing and Resource Use (OCLR) was renamed as the Climate Change and Environmental Research Unit (CCERU) in 2010.

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 relation to the registry during 2010 included changes to contacts, software upgrades to improve functionality and application and some improvements to 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 in 2011
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	Addition of contact details: **Ms. Sinead WHITE** Environmental Protection Agency PO Box 3000, Johnstown Castle Estate, Co Wexford. Email: s.white@epa.ie / etradmin@epa.ie Telephone: +353 (0)53 91 60600 Fax: +353 (0)53 91 60699 Removal of contact details: **Ms. Jacinta PONZI** Environmental Protection Agency PO Box 3000, Johnstown Castle Estate, Co Wexford. Email: j.ponzi@epa.ie / etradmin@epa.ie Telephone: +353 (0)53 91 60600 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) Change of cooperation arrangement	No change of the cooperation arrangement occurred during the 2010 reporting period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database or the capacity of National Registry	Two Greta software upgrades occurred during 2010. Greta Version 4.3 was installed on 3rd March 2010 and Version 5.1 was installed on 2nd December 2010.

Software Changes

A general description of functional changes in Greta Version 4.3 and Version 5.1 are as follows:

Version 4.3

This version included the following changes:

- The ability to perform NAP management functions, as per the automatic new entrants and closures process set out in the EU Registry Regulations. The account application process was also altered slightly in order to meet the NAP management requirements.
- The addition of SQL Server Reporting Services 2005 for report generation and management.
- Addition of Installation Permit into Force date

Version 5.1

This version included the following changes

- Improvements to reconciliation processing. In order to improve performance and reliability, the processing of reconciliation messages was changed from a synchronous to an asynchronous process. This ensures that IE's Registry responds to ITL messages within an appropriate time period, thus eliminating time-out errors. A windows service is used to process the reconciliation messages; this improves reliability and makes the process more robust by enabling processing failures to be retried. In addition, the reconciliation function was streamlined and is more efficient than in previous versions. This enhances the robustness of the system, necessary as the number and size of transactions increases.
- User interface changes to streamline the compliance process, so reducing user errors and improving data integrity.

Security improvements including:

- The removal of phishing by url redirection
- The removal of the auto-complete function

- Mark cookies as HttpOnly

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 4.3
- Release Notes Version 5.1

SQL Server 2005 was mandated for Version 4.3 and this has bought improvements in relation to Registry performance, reliability and scalability. Improved capacity was delivered through the reconciliation re-development in Version 5.1. This has meant that reconciliation is now more efficient, able to process large reconciliation messages and able to process reconciliations on more fragmented databases than previously.

Please consult the attached release notes (Appendix 1 – *SIAR Supplementary Information*) for details on the changes compared to GRETA Version 4.2 used in 2009.

The following test reports are also attached in Appendix 1 – *SIAR Supplementary Information*:
- Test Report Version 4.3
- Test Report Version 5.1

Database and Application Backup
There were no change to the database and application backup in 2010.

Disaster Recovery Plan
There was no change to the Disaster Recovery Plan in 2010.

Test Plan and Test Report
There was no change to the Test Plan and Test Report in 2010.

15/CMP.1 annex II.E paragraph 32.(d) Change of conformance to technical standards	No change in the registry's conformance to technical standards occurred for the 2010 reporting period. The new external transfer message flow (ITL RSNCM-13) will be implemented in Greta Version 5.2 which is planned for release Q1 2011.
15/CMP.1 annex II.E paragraph 32.(e) Change of procedures	No changes were made to the procedures to prevent and/or resolve discrepancies during the 2010 reporting period.

15/CMP.1 annex II.E paragraph 32.(f) Change of Security	During 2010, the UN Registry Security Working Group, mandated by the CAB, proposed a procedure to ensure adequate authentication mechanisms are in place following a number of security incidents. As a consequence, Ireland adopted an approach whereby, from September 2010, it became mandatory for all accounts to have an additional authorised representative to authorise transactions. Up to 2010, this had been a voluntary option. During 2010, Ireland implemented all recommendations from a security audit that was carried out by independent auditors, Deloitte, in September 2009. The security audit covered six areas namely (i) Network penetration test (ii) Application penetration test (iii) System vulnerability test (iv) Physical site security review (v) IT technical procedures review and (vi) Administrative procedures review. In relation to the software, a number of security improvements were made in Greta Version 5.1, these include: • Removal of phishing by url redirection • Turn off auto-complete • Mark cookies as HttpOnly to prevent access to the cookies by Javascript. In addition to software changes, a security guide was provided with Greta Verions 5.1 to include recommendations regarding, for example, configuration settings. Further security enhancements are planned for Greta Version 5.2, to be released in Q1 2011, including: • Session locking • Dual approval for transactions initiated by the Registry Administrator • Recording successful logon attempts and displaying the last logged on date on the user interface. • Displaying a generic error message upon a logon failure, regardless of the reason for the failure.

15/CMP.1 annex II.E paragraph 32.(g) Change of list of publicly available information	There were no changes to publicly available information in 2010. The following information is publicly accessible and as such is available via the homepage of the IE registry – www.etr.ie In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below. **Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)** In light of Commission Regulation No 920/2010 and for security reasons, the representative name and contact information (required by paragraph 45) and the legal entity contact information (required by paragraph 48) is held as confidential. Accordingly, this information is not included in the Account Information Report. **JI projects in Ireland (Paragraph 46)** 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. **Holding and transaction information of units (Paragraph 47)** Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation. 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.*" Paragraph 47c Ireland does not host JI projects in line with the National Climate Change Strategy. Paragraph 47e Ireland does not perform LULUCF activities and therefore does not issue RMUs Paragraph 47g

	No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date. Paragraph 47j No ERUs, CERs, AAUs and RMUs have been retired to date Paragraph 47k There is no previous commitment period to carry ERUs, CERs, and AAUs over from.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the 2010 reporting period.
15/CMP.1 annex II.E paragraph 32.(i) Change of data integrity measure	Software Changes Ongoing improvements have been made in Greta Version 4.3 and Version 5.1 with respect to data validation and data relationships. In Greta Version 4.3 the majority of these improvements were in relation to NAP management to ensure that data remains synchronised with the CITL at all times. The Greta Test report for Version 4.3 and Version 5.1 is included in the complete SIAR submission, Appendix 1 – *SIAR Supplementary Information* of this document. No change of data integrity measures occurred during 2010 in relation to Application Logging, Disaster Recovery, Test Plan and Test Report.
15/CMP.1 annex II.E paragraph 32.(j) Change of test results	Test Plan and Test Report The following test plans and test results for Greta version 4.3 and 5.1 have been included in the complete SIAR submission, Appendix 1 – *SIAR Supplementary Information*: - GRETA test plan and report for Version 4.3 and Version 5.1 - (C)ITL test plan for Version 4.3 and Version 5.1

	- Certification emails from the European Commission

14.4 Response to Review Recommendations on the National Registry

Publicly Available Information (Paragraph 120 FCCC/ARR/2010/IRL)

Holding and transaction information pursuant to paragraph 47 subparagraphs a, d, f and l is only provided on a holding type level, due to more detailed information being declared confidential by EU regulation. This follows from Article 10 of EU Regulation 2216/2004/EC, that states 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." Unit Holding and Transaction Information on the account level will be made available on 15 January of year (X+5) as allowed by paragraphs 7 & 12 of annex XVI of this Regulation.

See reporting item 15/CMP.1 annex II.E paragraph 32.(g) outlined in section 14.3 above.

Chapter 15

Minimization 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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Glossary

Annex 1 Parties	Countries listed in Annex I to the United Nations Framework Convention on Climate Change
Base year	The year or period under the Kyoto Protocol on which quantified emission limitation or reduction commitments in the commitment period are based.
BOD	Biochemical Oxygen Demand
CARBWARE	A forest model to calculate carbon stock change and growth increment for Irish forests
CCERU	Climate Change and Environmental Research Unit (OCLR, EPA)
CERT	Committee for Energy Research and Technology
CFCs	Chlorofluorocarbons
CH_4	Methane
CHP	Combined Heat and Power.
CMMS	Cattle Movement and Monitoring System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2 equivalent	The equivalent mass as CO_2 of other greenhouse gases converted on the basis of their global warming potential (GWP)
COFORD	National Council for Forest Research and Development
Commitment Period	The years 2008 to 2012 inclusive for which quantified emission limitation or reduction commitments are established under the Kyoto Protocol
COP	Conference of the Parties
CORINAIR	Co-ordinated Information on the environment in the European Community-AIR. CORINAIR was one of several collaborative exercises initiated under the CORINE programme to harmonise the collection and dissemination of information on the environment in the EU.
CRF	Common Reporting Format
CSLF	Carbon Sequestration Leadership Forum
DAFF	Department of Agriculture Fisheries and Food
DCENR	Department of Communications, Energy and Natural Resources
DEHLG	Department of Environment Heritage and Local Government
DNDC	DeNitrification-DeComposition, is a computer simulation model of carbon and nitrogen biogeochemistry in agri-ecosystems
EMEP	European Monitoring and Evaluation Programme, a co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe
Emission	(of a greenhouse gas). The release of greenhouse gases into the atmosphere.
Enteric Fermentation	The digestive process in ruminant animals (e.g cattle and sheep) where bacteria convert the feed to a usable form of energy for the animal, producing CH_4 as a by product
EUROSTAT	Statistical Agency of the European Union
FAO	Food and Agriculture Organisation of the United Nations
FFS	Farm Facilities Survey
FIPS	Forest Inventory and Planning System
Fluorinated Gases	HFCs, PFCs and SF_6
Fossil Fuel	Peat, coal, oil and natural gas and associated derivatives
FTA	Fraction of BOD in sludge that degrades anaerobically
FP7	Seventh Framework Programme
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product

GEEREF	Global Energy Efficiency and Renewable Energy Fund
Gg	Gigagram (10^9 g) = kilo tonne = 1,000 tonnes
Greenhouse Gas	A gas in the atmosphere that allows solar radiation through to the earth's surface, but traps some of the heat radiated back from the earth's surface
GWP	The cumulative warming over a specified time period, e.g. 100 years, resulting from a unit mass of a greenhouse gas emitted at the beginning of that time period, expressed relative to an absolute GWP of 1 for CO_2
HCFCs	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbons
HGV	Heavy Goods Vehicle
IEA	International Energy Agency
IEF	Implied Emission Factor
IPC	Integrated Pollution Control
IPCC	Intergovernmental Panel on Climate Change
IUCC	Information Unit on Climate Change
kt	kilo tonne (1,000 tonnes)
Kyoto Protocol	The Protocol to the UNFCCC adopted by Decision 1/CP.3 under which industrialised countries agreed to reduce their combined greenhouse gas emissions in 1990 by at least 5 percent by the period 2008-2012
Montreal Protocol	Protocol on substances that deplete the ozone layer
Mt	million tonnes or mega tonnes
N_2O	Nitrous Oxide
NIR	National Inventory Report
NMVOC	Non Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
NRA	National Roads Authority
OCLR	Office of Climate Licensing and Resource Use (EPA)
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
PFCs	Perfluorocarbons
REEEP	Renewable Energy and Energy Efficiency Partnership
RETD	Renewable Energy Technology Deployment
SBSTA	Subsidiary Body for Scientific and Technological Advice
SEAI	Sustainable Energy Authority of Ireland
SEFI	Sustainable Energy Finance Initiative
SF_6	Sulphur Hexafluoride
Sink	The reservoir or pool in which sequestered carbon is stored; the process of sequestration
SO_2	Sulphur Dioxide
Teagasc	Irish Agriculture and Food Development Authority
TPER	Total Primary Energy Requirement
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compounds

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 2009

Table B.1 Expanded Energy Balance Sheet 2009

2009 Units = ktoe	NACE	Coal	Bituminous Coal	Anthracite + Manufactured Ovoids	Coke	Lignite	Peat	Milled Peat	Sod Peat	Briquettes	Oil	Crude	Refinery Gas	Gasoline	Kerosene	Jet Kerosene
Indigenous Production		0.00	0.00				584.03	415.01	169.02		0.00					
Imports		1,331.40	1,268.64	47.45		15.31	0.00				5,664.98	2,849.30		1,134.61	538.19	1,142.89
Exports		5.15	0.00	5.15		0.00	4.66			4.66	0.00			0.00	0.00	0.00
Mar. Bunkers		0.00					0.00				0.00					
Stock Change		-112.59	-92.20	-17.13		-3.27	276.73	278.95	0.43	-2.65	-3.68	9.42		-13.85	-11.64	12.39
Primary Energy Supply (incl non-energy)		1,213.66	1,176.44	25.17	0.00	12.04	856.11	693.96	169.45	-7.30	5,661.31	2,858.72	0.00	1,120.76	526.55	1,155.28
Primary Energy Requirement (excl. non-energy)		1,213.66	1,176.44	25.17	0.00	12.04	856.11	693.96	169.45	-7.30	5,661.31	2,858.72	0.00	1,120.76	526.55	1,155.28
Transformation Input		851.96	851.96	0.00	0.00	0.00	693.56	693.56	0.00	0.00	2,864.23	2,858.72	5.52	0.00	0.00	0.00
Public Thermal Power Plants		851.96	851.96				563.87	563.87	0.00		0.00					
Combined Heat and Power Plants		0.00	0.00				9.31	9.31			5.52		5.52			
Pumped Storage Consumption																
Briquetting Plants		0.00					120.38	120.38			0.00					
Oil Refineries & other energy sector		0.00					0.00				2,858.72	2,858.72				
Transformation Output		0.00	0.00	0.00	0.00	0.00	107.82	0.00	0.00	107.82	819.79	0.00	86.12	522.49	211.19	0.00
Public Thermal Power Plants		0.00					0.00				0.00					
Combined Heat and Power Plants - Electricity		0.00					0.00				0.00					
Combined Heat and Power Plants - Heat																
Pumped Storage Generation																
Briquetting Plants							107.82			107.82	0.00					
Oil Refineries							0.00				819.79		86.12	522.49	211.19	0.00
Exchanges and transfers		0.00	-10.73	10.73	0.00	0.00	0.00	0.00	0.00	0.00	-1.73	0.00	0.00	-0.18	260.96	-262.51
Electricity																
Heat																
Other		0.00	-10.73	10.73							-1.73			-0.18	260.96	-262.51
Own Use and Distribution Losses		0.00					28.41	28.41			80.60		80.60			
Available Final Energy Consumption		361.70	313.75	35.90	0.00	12.04	241.97	-28.01	169.45	100.52	3,534.53	0.00	0.00	1,643.07	998.69	892.77
Non-Energy Consumption		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Final non-Energy Consumption (Feedstocks)		0.00					0.00				0.00					
Total Final Energy Consumption		368.47	295.06	61.78	0.00	11.64	272.30	0.00	168.59	103.71	3,587.97	0.00	0.00	1,740.66	1,080.40	766.90
Industry*		111.82	111.82	0.00			0.60	0.00	0.00	0.60	146.30	0.00	0.00	0.00	146.30	0.00
Non-Energy Mining	13-14	0.00	0.00				0.00				7.44				7.44	
Food & beverages	15	18.00	18.00				0.00				83.91				83.91	
Textiles and textile products	17 - 18	0.00	0.00				0.00				1.27				1.27	
Wood and wood products	20	0.00	0.00				0.00				3.87				3.87	
Pulp, paper, publishing and printing	21 - 22	0.00	0.00				0.00				0.46				0.46	
Chemicals & man-made fibres	24	3.39	3.39				0.00				22.66				22.66	
Rubber and plastic products	25	0.00	0.00				0.00				0.67				0.67	
Other non-metallic mineral products	26	87.61	87.61				0.00				18.28				18.28	
Basic metals and fabricated metal products	27 - 28	0.00	0.00				0.00				0.00				0.00	
Machinery and equipment n.e.c.	29	0.02	0.02				0.00				1.80				1.80	
Electrical and optical equipment	30 - 33	0.00	0.00				0.00				2.91				2.91	
Transport equipment manufacture	34 - 35	2.80	2.80				0.00				0.00				0.00	
Other manufacturing	36 - 37, 16, 19, 23	0.00	0.00				0.60			0.60	3.03				3.03	
Transport		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,507.56	0.00	0.00	1,740.66	0.00	766.90
Road Freight		0.00					0.00				0.00					
Road Private Car		0.00					0.00				1,467.48			1,467.48		
Public Passenger Services		0.00					0.00				53.68			53.68		
Rail		0.00					0.00				0.00					
Domestic Aviation		0.00					0.00				33.67			1.40		32.27
International Aviation		0.00					0.00				734.63					734.63
Fuel Tourism		0.00					0.00				164.04			164.04		
Unspecified		0.00					0.00				54.06			54.06		
Residential		256.65	183.23	61.78		11.64	271.70		168.59	103.11	934.10			0.00	934.10	
Commercial/Public Services		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Commercial Services		0.00	0.00	0.00		0.00	0.00				0.00				0.00	
Public Services		0.00					0.00		0.00	0.00	0.00					
Agricultural		0.00	0.00				0.00				0.00			0.00	0.00	
Statistical Difference		-6.78	18.69	-25.87	0.00	0.40	-30.33	-28.01	0.87	-3.19	-53.44	0.00	0.00	-97.59	-81.71	125.87

Table B.1 (continued) Expanded Energy Balance Sheet 2009

Fueloil	LPG	Gasoil / Diesel /DERV	Petroleum Coke	Naphta	Bitumen	White Spirit	Lubricants	Natural Gas	Renewables	Hydro	Wind	Biomass & Renewable Waste	Landfill Gas	Biogas	Liquid Biofuel	Solar	Geothermal	Non-Renewable Waste	Electricity	Heat	TOTAL
								319.09	605.96	77.55	254.15	182.91	23.54	12.20	29.11	4.42	22.09	12.91			1,521.99
427.09	92.13	2,446.12	143.19	0.00	224.86	1.56	40.75	3,988.85	58.94			9.33			49.60				80.77		14,459.89
896.84	10.51	22.75	0.57	24.38	0.00	0.00	4.13	0.00	0.16			0.16			0.00				15.09		980.12
32.05		65.65							0.00												97.70
51.52	1.58	-28.18	3.06	-0.56	0.00	0.00	0.00	1.08	0.58			1.70			-1.11						189.55
-450.28	83.20	2,329.54	145.68	-24.94	224.86	1.56	36.62	4,309.02	665.32	77.55	254.15	193.78	23.54	12.20	77.59	4.42	22.09	12.91	65.68	0.00	15,093.62
-450.28	83.20	2,329.54	145.68	-24.94	0.00	0.00	0.00	4,309.02	665.32	77.55	254.15	193.78	23.54	12.20	77.59	4.42	22.09	12.91	65.68	0.00	14,867.21
201.65	0.24	7.86	0.00	0.00	0.00	0.00	0.00	2,758.79	42.62	0.00	0.00	13.92	23.54	5.16	0.00	0.00	0.00	0.00	58.47	0.00	7,479.39
201.65		7.86						2,514.59	33.64			10.10	23.54								4,173.57
0.00	0.24	0.00						244.20	8.98			3.82		5.16							268.25
																			49.67		49.67
									0.00												120.38
									0.00										8.80		2,867.52
911.20	38.68	1,069.86	0.00	24.94	0.00	0.00	0.00	0.00	15.70	0.00	0.00	5.59	8.63	1.48	0.00	0.00	0.00	0.00	2,084.43	0.00	5,072.43
									12.73			4.09	8.63						1,896.46		1,909.18
									2.97			1.49		1.48					157.42		160.39
									0.00												0.00
																			30.55		30.55
									0.00												107.82
911.20	38.68	1,069.86		24.94					0.00												2,864.48
5.63	0.00	-6.06	-18.99	0.00	0.00	0.00	0.00	0.00	-347.40	-77.55	-254.15	-5.59	-8.63	-1.48	0.00	0.00	0.00	0.00	347.40	0.00	-15.10
									-347.40	-77.55	-254.15	-5.59	-8.63	-1.48					347.40		0.00
																					0.00
5.63		-6.06	-18.99						0.00												-15.10
22.90	3.00	1.45						65.14	0.00										281.18		482.69
241.99	118.64	3,384.04	126.69	0.00	224.86	1.56	36.62	1,485.09	291.00	0.00	0.00	179.86	0.00	7.04	77.59	4.42	22.09	12.91	2,157.86	0.00	12,188.88
0.00	0.00	0.00	0.00		224.86	1.56	36.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	226.41
					224.86	1.56	36.62	0.00	0.00												226.41
265.66	114.18	3,482.68	126.81	1.05	0.00	0.00	0.00	1,577.88	289.45	0.00	0.00	178.73	0.00	7.04	77.34	4.42	22.04	12.91	2,147.35	0.00	12,246.70
255.81	50.09	149.53	100.38	1.05	0.00	0.00	0.00	530.53	140.23	0.00	0.00	136.11		4.12	0.00	0.00	0.00	12.91	715.61	0.00	2,214.87
6.25	0.48	53.57	6.50					11.30	0.00										57.58		143.13
70.42	5.76	30.16	0.15					117.44	38.99			34.87		4.12					141.93		506.76
1.07	0.39	1.46	0.00					0.23	0.00										7.25		11.67
3.25	0.03	2.23	0.00					2.36	84.69			84.69							33.18		129.61
0.38	0.02	1.23	0.00					2.30	0.00										16.26		20.65
19.02	1.39	8.44	0.00					68.13	1.01			1.01							117.53		241.56
0.56	4.66	2.64	0.00					5.58	0.00										36.46		50.58
15.34	1.87	35.61	93.73					36.29	15.54			15.54						12.91	80.73		397.91
133.02	3.57	2.60	0.00					167.67	0.00										42.23		349.09
1.51	1.54	1.96	0.00					6.97	0.00										17.52		31.33
2.45	28.20	6.91	0.00					106.63	0.00										103.50		250.60
0.00	1.28	0.05	0.00					3.79	0.00										6.02		13.93
2.54	0.91	2.67	0.00	1.05				1.84	0.00										55.41		68.05
0.00	0.74	2,485.14	0.00	0.00	0.00	0.00	0.00	0.00	77.34	0.00	0.00	0.00	0.00	0.00	77.34	0.00	0.00	0.00	3.85	0.00	5,074.64
		809.55							0.00												809.55
	0.74	650.39							77.34						77.34						2,195.95
		172.27							0.00												225.95
		40.01							0.00										3.85		43.86
									0.00												33.67
									0.00												734.63
		427.90							0.00												591.94
0.00		385.03							0.00												439.08
0.00	55.25	192.82	26.43					624.71	52.33			28.09				4.30	19.94		685.37		3,099.34
9.85	8.10	443.68	0.00	0.00	0.00	0.00	0.00	422.64	19.18	0.00	0.00	14.16	0.00	2.92	0.00	0.12	2.10	0.00	682.86	0.00	1,586.31
0.96	6.03	293.11						185.23	16.26			14.16					2.10		489.57		991.16
8.89	2.07	150.57						237.46	2.92					2.92					193.32		595.23
	0.00	211.51						0.00	0.37			0.37							59.65		271.53
-23.67	4.46	-98.65	-0.12	-1.05	0.00	0.00	0.00	-92.79	1.55	0.00	0.00	1.13	0.00	0.00	0.26	0.00	0.05	0.00	10.51	0.00	-284.24

Annex C

Calculation Sheets for Energy 2009

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 2009 (continued on following 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**
	1A1a Public Electricity								
1	Coal	851.96	35669.86	85379	0.7	0.5	3045.45	24.97	17.83
2	Peat	563.87	23608.24	115219	3.0	7.0	2720.12	70.82	165.26
3	Fuel Oil and Gas Oil	209.51	8771.63	77570	0.8	0.3	680.41	7.02	2.63
4	Natural Gas	2514.59	105280.90	57183	1.9	2.4	6020.33	200.03	252.67
5	Biomass (LFG & Wood)	33.64	1408.39	68471	4.0	4.2	96.43	5.64	5.92
	Public Electricity Total	**4173.57**	**174739.01**				**12466.32**	**308.48**	**444.32**
	1A1b Refinery Fuel								
6	Refinery Gas	86.12	3605.52	56242	1.0	0.1	202.78	3.61	0.36
7	Fuel Oil	22.90	958.95	76919	3.0	0.6	73.76	2.88	0.58
8	LPG	3.00	125.60	253167	1.0	0.1	31.80	0.13	0.01
9	Gasoil/Diesel/DERV	1.45	60.89	107813	3.0	0.6	6.56	0.18	0.04
	Refinery Total	**113.47**	**4750.95**				**314.91**	**6.79**	**0.99**
	1A1c Manufacture of Briquettes								
10	Peat	**37.72**	**1579.22**	91751	2.0	1.5	**144.89**	**3.16**	**2.37**
	1A2a-1A2f Industry Fuel								
11	Bituminous Coals	111.82	4681.88	94600	10.0	1.5	442.91	46.82	7.02
12	Briquettes	0.60	25.00	98860	2.0	1.5	2.47	0.05	0.04
13	Kerosene	146.30	6125.48	71400	3.0	0.6	437.36	18.38	3.68
14	Fuel Oil	255.81	10710.31	76000	3.0	0.6	813.98	32.13	6.43
15	LPG	50.09	2097.17	63700	1.0	0.1	133.59	2.10	0.21
16	Gasoil/Diesel/DERV	149.53	6260.63	73300	3.0	0.6	458.90	18.78	3.76
17	Pet Coke	100.38	4202.91	93554	3.0	0.6	393.20	12.61	2.52
18	Naphta	1.05	44.00	73330	3.0	0.6	3.23	0.13	0.03
19	Natural Gas	758.27	31747.17	57022	1.0	0.1	1810.27	31.75	3.17
20	Biomass (solid)	136.11	5698.51	110000	30.0	4.0	626.84	170.96	22.79
21	Biomass (gas)	4.12	172.63	54600	1.0	0.1	9.43	0.17	0.02
22	Non Renewable wastes	12.91	540.43	54210	3.0	0.6	29.30	1.62	0.32
	Industry Total	**1714.09**	**71765.70**				**4525.20710**	**335.49**	**49.99**
	1A3a Aviation								
23	Civil Aviation Kerosene	34.12	1428.55	71363	1.1	2.5	101.95	1.59	3.50
	1A3b Road Transport Fuel								
24	Gasoline	1739.26	72819.41	69960	11.9	1.99	5094.45	867.52	142.94
25	Gasoil/Diesel/DERV	2445.13	102372.84	73300	0.9	1.92	7503.93	92.12	192.68
26	LPG	1.21	50.77	63700	6.52	1.81	3.23	0.33	0.09
27	Liquid Biofuels	77.34	3239.72	70535	4.15	1.91	228.51	13.43	6.17
	Road Transport Total	**4262.95**	**178482.75**				**12601.61**	**973.41**	**341.89**

Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2009 (continued from previous 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**
	1A3c-1A3e Other Transport Fuel								
28	Railway Diesel	40.01	1675.17	73300	4.2	28.6	122.79	6.95	47.91
29	Navigation Fuel Oil	0.00	0.00	76000	7.0	2.0	0.00	0.00	0.00
30	Navigation Gasoil	0.00	0.00	73300	7.0	2.0	0.00	0.00	0.00
31	Gas Distribution Use (Natural Gas)	63.06	2640.40	57022	5.0	2.0	150.56	13.20	5.28
	Other Transport Total	**103.08**	**4315.57**				**273.35**	**20.15**	**53.19**
	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	8.10	339.25	63700	5.0	0.1	21.61	1.70	0.03
38	Gasoil / Diesel/ DERV	443.68	18575.95	73300	10.0	0.6	1361.62	185.76	11.15
39	Natural Gas	439.11	18384.50	57022	5.0	0.1	1048.31	91.92	1.84
40	Biomass	14.16	592.71	110000	300.0	4.0	65.20	177.81	2.37
41	Biogas	2.92	122.27	54600	5.0	0.1	6.68	0.61	0.01
	Commercial/Institutional Total	**917.81**	**38427.03**				**2462.88**	**461.93**	**15.65**
	1A4b Residential Fuel								
42	Bituminous Coal	183.23	7671.65	94600	300.0	1.5	725.74	2301.49	11.51
43	Anthracite + Manufactured Ovoids	61.78	2586.46	98260	300.0	1.5	254.15	775.94	3.88
44	Lignite	11.64	487.24	101200	300.0	1.5	49.31	146.17	0.73
45	Sod Peat	168.59	7058.34	104000	300.0	1.4	734.07	2117.50	9.88
46	Briquettes	103.11	4317.14	98860	300.0	1.4	426.79	1295.14	6.04
47	Kerosene	934.10	39108.85	71400	10.0	0.6	2792.37	391.09	23.47
48	LPG	55.25	2313.05	63700	5.0	0.1	147.34	11.57	0.23
49	Gasoil / Diesel/ DERV	192.82	8072.92	73300	10.0	0.6	591.74	80.73	4.84
50	Petroleum Coke	26.43	1106.42	93554	10.0	0.6	103.51	11.06	0.66
51	Natural Gas	624.71	26155.22	57022	5.0	0.1	1491.41	130.78	2.62
52	Biomass	28.09	1176.20	110000	300.0	4.0	129.38	352.86	4.70
	Residential Total	**2389.74**	**100053.49**				**7316.43**	**7614.33**	**68.57**
	1A4c Agriculture Fuel								
53	Gasoil	211.51	8855.50	73300	4.7	25.8	649.11	41.93	228.47
54	Biomass	0.37	15.64	110000	300.0	4.0	1.72	4.69	0.06
	Agriculture Total	**211.88**	**8871.13**				**649.11**	**46.62**	**228.53**
	Total Energy	**13958.06**	**584397.77**				**40856.64**	**9767.26**	**1208.93**

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	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
		(TJ)	(t/TJ)	(kg/TJ)	(kg/TJ)		(Gg)	
A	**1.A.1. Energy Industries**	**181,069.1850**				**12,926.1160**	**0.3184**	**0.4477**
B	Solid Fuels	60,857.3151	97.1201	1.6260	3.0475	5,910.4694	0.0990	0.1855
C	Liquid Fuels	13,522.5854	73.6041	1.0211	0.2674	995.3177	0.0138	0.0036
D	Gaseous Fuels	105,280.8993	57.1835	1.9000	2.4000	6,020.3288	0.2000	0.2527
E	Biomass	1,408.3852	68.4709	4.0029	4.2011	96.4334	0.0056	0.0059
F	**1.A.2 Manufacturing Industries and Construction**	**72,306.1270**				**4,525.2071**	**0.3355**	**0.0500**
G	Solid Fuels	4,706.8860	94.6226	9.9575	1.5000	445.3779	0.0469	0.0071
H	Liquid Fuels	29,440.5100	76.0945	2.8575	0.5644	2,240.2613	0.0841	0.0166
I	Gaseous Fuels	31,747.1688	57.0215	1.0000	0.1000	1,810.2713	0.0317	0.0032
J	Biomass	5,871.1337	108.3711	29.1473	3.8853	636.2612	0.1711	0.0228
K	Other Fuels	540.4286	54.2099	3.0000	0.6000	29.2966	0.0016	0.0003
L	**1.A.3 Transport**	**184,226.8664**				**12,976.9039**	**0.9952**	**0.3986**
M	Solid Fuels	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
N	Liquid Fuels	178,346.7453	71.9180	5.4305	2.1706	12,826.3445	0.9685	0.3871
O	Gaseous Fuels	2,640.3968	57.0215	5.0000	2.0000	150.5594	0.0132	0.0053
P	Biomass	3,239.7243	70.5347	4.1459	1.9060	228.5131	0.0134	0.0062
Q	**1.A.4 Other Sectors**	**147,351.6536**				**10,428.4163**	**8.1229**	**0.3128**
R	Solid Fuels	22,120.8296	99.0041	300.0000	1.4486	2,190.0521	6.6362	0.0320
S	Liquid Fuels	78,784.3011	72.3322	9.2399	3.4157	5,698.6426	0.7280	0.2691
T	Gaseous Fuels	44,539.7143	57.0215	5.0000	0.1000	2,539.7215	0.2227	0.0045
U	Biomass	1,906.8086	106.4476	281.0840	3.7499	202.9753	0.5360	0.0072
V	**1.A.5 Other *(Not specified elsewhere)*** [6]	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
W	**1.A. Fuel Combustion**	**584,953.8320**				**40,856.6432**	**9.7720**	**1.2090**
	Memo Items							
X	Aviation Bunkers	30,738.6920	71.3652	1.0513	2.3521	2,193.6741	0.0323	0.0723
Y	Marine Bunkers	4,090.3082	74.1858	NE,NO	NE,NO	303.4426	NE,NO	NE,NO
Z	CO_2 from Biomass	12,426.0517	93.6889			1,164.1830	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
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 2009 [CRF 2009 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	2,786.325	NO		-9.213	2,795.539	42.814	NCV	119,688.750	20.000	2,393.775	NA	2,393.775	1.000	8,777.175
		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		1,065.362	NO	NO	13.003	1,052.359	44.589	NCV	46,924.076	19.080	895.311	NA	895.311	1.000	3,282.808
		Jet Kerosene	kt		1,085.056	NO	697.029	-11.760	399.788	44.100	NCV	17,630.472	19.473	343.318	NA	343.318	1.000	1,258.833
		Other Kerosene	kt		509.839	NO	NO	11.025	498.814	44.196	NCV	22,045.551	19.473	429.286	NA	429.286	1.000	1,574.050
		Shale Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Gas / Diesel Oil	kt		2,364.770	21.998	63.462	27.240	2,252.069	43.308	NCV	97,533.295	19.991	1,949.778	NA	1,949.778	1.000	7,149.187
		Residual Fuel Oil	kt		433.634	910.592	32.541	-52.314	-457.185	41.236	NCV	-18,852.400	20.727	-390.757	NA	-390.757	1.000	-1,432.777
		Liquefied Petroleum Gas (LPG)	kt		81.801	9.331		-1.402	73.872	47.156	NCV	3,483.501	17.373	60.518	NA	60.518	1.000	221.899
		Ethane			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Naphtha	kt		NO	23.200		0.534	-23.734	44.003	NCV	-1,044.393	20.000	-20.888	NO	-20.888	1.000	-76.589
		Bitumen	kt		249.729	NO		NO	249.729	37.698	NCV	9,414.259	22.000	207.114	207.114	0.000	1.000	0.000
		Lubricants	kt		40.342	4.085	NO	NO	36.257	42.287	NCV	1,533.189	20.000	30.664	15.332	15.332	1.000	56.217
		Petroleum Coke	kt		186.861	0.742		-3.991	190.110	32.088	NCV	6,100.250	25.515	155.646	NO	155.646	1.000	570.700
		Refinery Feedstocks			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												65.256		1.305	NO	1.305		4.785
Other non-specified			kt	NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	0.000	NO
White Spirit			kt	NO	1.483	NO	NO	NO	1.483	44.003	NCV	65.256	20.000	1.305	NO	1.305	1.000	4.785
Liquid Fossil Totals												304,521.806		6,055.070	222.446	5,832.624		21,386.289
Solid Fossil	Primary Fuels	Anthracite (2)	kt	NO	58.800	NO		7.241	51.559	27.842	NCV	1,435.516	26.798	38.469	NO	38.469	1.000	141.054
		Coking Coal	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Other Bituminous Coal	kt	NO	2,002.357	17.106	NO	138.663	1,846.588	27.842	NCV	51,413.080	25.800	1,326.457	NA	1,326.457	1.000	4,863.677
		Sub-bituminous Coal		NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Lignite	kt	NO	32.346	NO		6.903	25.443	19.816	NCV	504.184	27.600	13.915	NO	13.915	1.000	51.023
		Oil Shale		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Peat	kt	2,231.258	NO	NO		-1,499.724	3,730.982	7.787	NCV	29,054.649	29.863	867.659	NA	867.659	1.000	3,181.416
	Secondary Fuels	BKB(3) and Patent Fuel	kt		NO	10.508		5.979	-16.487	18.548	NCV	-305.793	26.962	-8.245	NA	-8.245	1.000	-30.231
		Coke Oven/Gas Coke			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Other Solid Fossil												6,713.195		191.008	NO	191.008		700.361
Manufactured Ovoids			kt	NO	10.928	6.744	NO	16.107	-11.923	32.000	NCV	-381.532	26.798	-10.224	NO	-10.224	1.000	-37.489
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Sod Peat			kt	540.000	NO	NO	NO	-1.388	541.388	13.105	NCV	7,094.727	28.364	201.232	NO	201.232	1.000	737.851
Solid Fossil Totals												88,814.831		2,429.264	NA,NO	2,429.264		8,907.302
Gaseous Fossil		Natural Gas (Dry)	TJ	13,359.674	167,005.291	NO		-45.022	180,409.987	1.000	NCV	180,409.987	15.551	2,805.613	NO	2,805.613	1.000	10,287.249
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												180,409.987		2,805.613	NO	2,805.613		10,287.249
Total												573,746.624		11,289.947	222.446	11,067.502		40,580.840
Biomass total												11,214.817		276.014	NO	276.014		1,012.052
		Solid Biomass	TJ	5,548.760	390.839	6.660		-71.096	6,004.035	1.000	NCV	6,004.035	30.000	180.121	NO	180.121	1.000	660.444
		Liquid Biomass	TJ	1,216.174	2,505.578	NO		7.677	3,714.075	1.000	NCV	3,714.075	19.793	73.514	NO	73.514	1.000	269.553
		Gas Biomass	TJ	1,496.707	NO	NO		NO	1,496.707	1.000	NCV	1,496.707	14.952	22.379	NO	22.379	1.000	82.055

Table C.5 Comparison of Results from Sectoral Approach and Reference Approach for 2009 (CRF 2009 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)	304.522	293.509	21,386.289	300.094	21,760.566	-2.194	-1.720
Solid Fuels (excluding international bunkers) [(5)]	88.815	88.815	8,907.302	87.685	8,545.900	1.288	4.229
Gaseous Fuels	180.410	180.410	10,287.249	184.208	10,520.881	-2.062	-2.221
Other [(5)]	0.541	0.541	29.302	0.540	29.297	0.019	0.019
Total [(5)]	***574.287***	***563.274***	***40,610.142***	***572.528***	***40,856.643***	***-1.616***	***-0.603***

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	
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	29201.32	25573.39	15238.51	14014.68	8442.75	**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	2867.04	3130.66	1325.36	434.86	328.88	**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**	**32068.36**	**28704.05**	**16563.87**	**14449.54**	**8771.63**	**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	
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	
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	2219.30	1943.58	1158.13	1065.12	641.65	
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	210.15	229.48	97.15	31.88	24.11	
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**	**2429.45**	**2173.05**	**1255.28**	**1096.99**	**665.76**	
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**	**75.76**	**75.71**	**75.78**	**75.92**	**75.90**	**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	**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%**	**5.20%**	**2.20%**	**2.25%**	**4.06%**	**2.15%**	
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**	**79.92**	**77.41**	**77.53**	**79.13**	**77.57**	**IEF CRFReporter**
	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	79.92	77.41	77.53	79.13	77.57	

Table C.6 (b) Implied emission factors (IEFs) for CO_2 – Liquid Fuels in Sector 1.A.1.a

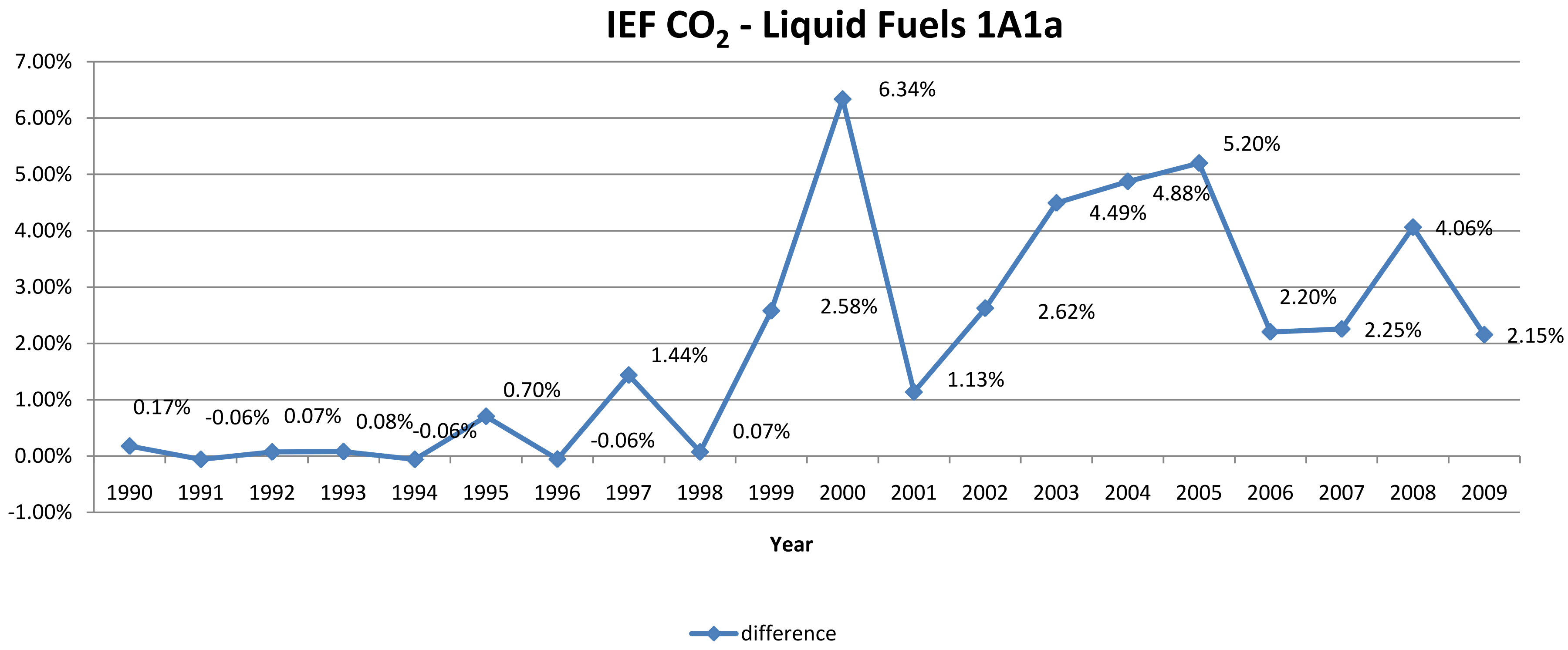

Table C.7 (a) Implied emission factors (IEFs) for CO_2 – Solid Fuels in Sector 1.A.1.a

Energy (TJ)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
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	57925.06	59050.32	52968.76	47054.58	43813.75	35669.86	**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	12109.48	21092.90	18279.76	18036.97	23380.70	23608.24	**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	**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**	**70034.54**	**80143.22**	**71248.51**	**65091.55**	**67194.44**	**59278.10**	**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	
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	
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	
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	5479.71	5586.16	5010.84	4451.36	4144.78	3374.37	
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	1392.59	2425.68	2102.17	2074.25	2688.78	2714.95	
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	
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**	**6872.30**	**8011.84**	**7113.02**	**6525.61**	**6833.56**	**6089.32**	
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**	**98.13**	**99.97**	**99.83**	**100.25**	**101.70**	**102.72**	**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	**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%**	**2.91%**	**-1.29%**	**-2.11%**	**2.66%**	**-3.05%**	**-5.62%**	
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**	**101.07**	**98.69**	**97.77**	**102.99**	**98.68**	**97.26**	**IEF CRFReporter**

Table C.7 (b) Implied emission factors (IEFs) for CO_2 – Solid Fuels in Sector 1.A.1.a

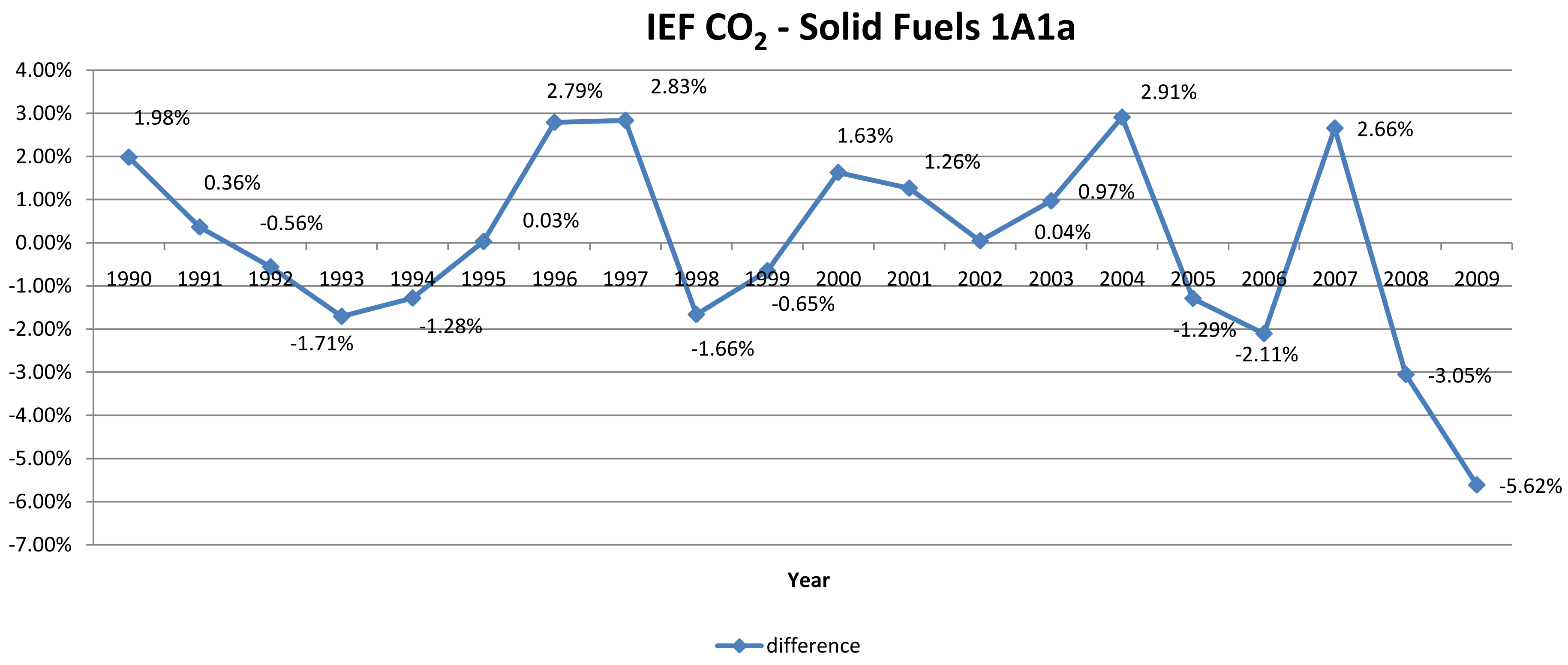

Table C.8 Implied emission factors (IEFs) for CO_2 – Liquid Fuels in Sector 1.A.2.f

Energy (TJ)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
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	1562.52	1644.67	**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	1337.78	1380.35	**Energy balance data**
LPG	1924.86	1569.13	1512.07	1540.60	1597.66	1540.60	1483.54	1597.66	1569.13	1569.13	1683.24	1537.94	1755.19	2049.33	2302.36	2092.88	2100.35	2299.93	2712.72	1647.78	**Energy balance data**
Gasoil	3119.23	4336.97	4421.46	4336.97	5012.86	5716.92	4477.78	4674.92	4731.24	5041.02	5181.84	5461.59	5362.92	5288.70	4858.54	5767.26	5522.14	5352.04	5327.52	4484.17	**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	9150.23	4196.54	**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	**Energy balance data**
total	**10816.03**	**10041.91**	**9940.69**	**9813.33**	**11944.47**	**12643.68**	**10060.29**	**12390.72**	**12111.20**	**12922.25**	**15360.60**	**15463.81**	**15826.47**	**17426.08**	**18559.48**	**22081.65**	**20001.81**	**21549.14**	**20134.78**	**13397.51**	**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	
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	
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	
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	
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	
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	
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	111.56	117.43	
Fuel Oil	274.46	152.56	183.59	187.46	239.64	223.12	208.88	228.97	226.43	241.68	257.70	202.84	171.42	148.34	138.18	179.90	128.42	116.65	101.67	104.91	
LPG	122.61	99.95	96.32	98.14	101.77	98.14	94.50	101.77	99.95	99.95	107.22	97.97	111.81	130.54	146.66	133.32	133.79	146.51	172.80	104.96	
Gasoil	228.64	317.90	324.09	317.90	367.44	419.05	328.22	342.67	346.80	369.51	379.83	400.33	393.10	387.66	356.13	422.74	404.77	392.30	390.51	328.69	
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	850.35	392.60	
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	
total	**823.95**	**766.84**	**750.26**	**738.06**	**908.53**	**964.16**	**750.80**	**956.36**	**929.17**	**993.03**	**1211.86**	**1232.44**	**1269.58**	**1416.63**	**1527.23**	**1807.55**	**1627.52**	**1776.52**	**1630.12**	**1051.82**	
IEF calculated	**76.18**	**76.36**	**75.47**	**75.21**	**76.06**	**76.26**	**74.63**	**77.18**	**76.72**	**76.85**	**78.89**	**79.70**	**80.22**	**81.29**	**82.29**	**81.86**	**81.37**	**82.44**	**80.96**	**78.51**	**IEF National Approach**
CO_2 emissions	823.95	766.84	750.26	738.06	908.53	964.16	750.80	956.36	929.17	993.03	1211.86	1232.44	1269.58	1416.63	1527.23	1807.55	1627.52	1776.52	1630.12	1051.82	**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%**	
IEF reported	**76.18**	**76.36**	**75.47**	**75.21**	**76.06**	**76.26**	**74.63**	**77.18**	**76.72**	**76.85**	**78.89**	**79.70**	**80.22**	**81.29**	**82.29**	**81.86**	**81.37**	**82.44**	**80.96**	**78.51**	**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**	
Kerosene	1.34%	0.90%	0.86%	0.98%	1.38%	1.68%	2.86%	2.53%	3.08%	3.67%	2.94%	3.07%	2.89%	2.83%	2.44%	10.53%	8.47%	6.45%	7.76%	12.28%	
Fuel Oil	33.39%	19.99%	24.30%	25.14%	26.40%	23.22%	27.32%	24.32%	24.60%	24.61%	22.07%	17.26%	14.25%	11.20%	9.80%	10.72%	8.45%	7.12%	6.64%	10.30%	
LPG	17.80%	15.63%	15.21%	15.70%	13.38%	12.18%	14.75%	12.89%	12.96%	12.14%	10.96%	9.95%	11.09%	11.76%	12.41%	9.48%	10.50%	10.67%	13.47%	12.30%	
Gasoil	28.84%	43.19%	44.48%	44.19%	41.97%	45.22%	44.51%	37.73%	39.07%	39.01%	33.73%	35.32%	33.89%	30.35%	26.18%	26.12%	27.61%	24.84%	26.46%	33.47%	
Petroleum Coke	**18.23%**	**19.86%**	**14.71%**	**13.55%**	**16.51%**	**17.35%**	**10.13%**	**22.17%**	**19.94%**	**20.23%**	**30.00%**	**34.13%**	**37.61%**	**43.60%**	**48.94%**	**42.95%**	**44.75%**	**50.71%**	**45.44%**	**31.32%**	
Naphta	0.41%	0.44%	0.44%	0.45%	0.37%	0.35%	0.44%	0.36%	0.36%	0.34%	0.29%	0.28%	0.28%	0.25%	0.24%	0.20%	0.22%	0.20%	0.22%	0.33%	
	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

Road Transport (IPCC Sector 1.A.3.b)

Table D.1 Vehicle Numbers, by Class 1990-2009

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pass. Cars	Gasoline <1,4 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/00-01	31830		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/02	235783		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/03	35249		4285	2063	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/04	220458		192288	157760	115198	87750	60785	44162	30208	21293	14731	7424
Pass. Cars	Gasoline <1,4 l	Open Loop	4683		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	PC Euro 1	0		291726	277565	271198	252511	234058	201949	175166	139275	113592	133343
Pass. Cars	Gasoline <1,4 l	PC Euro 2	0		305296	387716	380373	375274	368217	354676	340548	320459	312717	308269
Pass. Cars	Gasoline <1,4 l	PC Euro 3	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	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
Pass. Cars	Gasoline <1,4 l	PC Euro 6	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	4901		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	77578		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	11370		1809	883	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	80153		81171	67563	51553	39906	28597	21643	15689	11320	8970	4757
Pass. Cars	Gasoline 1,4 - 2,0 l	Open Loop	7024		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 1	0		123147	118872	121366	114834	110113	98971	90979	74046	69163	85441
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 2	0		128876	166046	170224	170663	173229	173820	176876	170373	190406	197526
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 3	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	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
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 6	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/00-01	1787		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/02	6841		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/03	1057		122	85	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/04	4069		5493	6505	4895	4302	3304	2667	2114	1642	770	418
Pass. Cars	Gasoline >2,0 l	PC Euro 1	0		8333	11445	11525	12378	12723	12195	12259	10743	5940	7504
Pass. Cars	Gasoline >2,0 l	PC Euro 2	0		8722	15987	16164	18396	20016	21417	23834	24719	16354	17347
Pass. Cars	Gasoline >2,0 l	PC Euro 3	0		0	0	3465	7726	12835	14072	16162	17627	11164	12090

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pass. Cars	Gasoline >2,0 l	PC Euro 4	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
Pass. Cars	Gasoline >2,0 l	PC Euro 6	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel <2,0 l	Conventional	71928		39587	31809	23614	18276	13201	10384	8432	6832	3105	1043
Pass. Cars	Diesel <2,0 l	PC Euro 1	0		58749	55242	55591	52592	50833	47487	48898	44687	23104	26595
Pass. Cars	Diesel <2,0 l	PC Euro 2	0		61483	77165	77970	78161	79970	83399	95064	102819	58346	70583
Pass. Cars	Diesel <2,0 l	PC Euro 3	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	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
Pass. Cars	Diesel <2,0 l	PC Euro 6	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Diesel >2,0 l	Conventional	3785		5398	4753	3844	3225	2515	1978	1210	922	771	3257
Pass. Cars	Diesel >2,0 l	PC Euro 1	0		8011	8255	9050	9281	9683	9045	7015	6030	5738	6550
Pass. Cars	Diesel >2,0 l	PC Euro 2	0		8385	11530	12693	13793	15233	15886	13638	13875	14490	17384
Pass. Cars	Diesel >2,0 l	PC Euro 3	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	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
Pass. Cars	Diesel >2,0 l	PC Euro 6	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	LPG	Conventional	2830		220	220	150	153	153	0	0	0	0	0
Pass. Cars	LPG	PC Euro 1	0		280	280	169	153	153	70	75	75	70	70
Pass. Cars	LPG	PC Euro 2	0		216	216	169	153	153	85	80	80	85	85
Pass. Cars	LPG	PC Euro 3	0		0	0	0	0	0	90	90	90	85	85
Pass. Cars	LPG	PC Euro 4	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
Pass. Cars	LPG	PC Euro 6	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
Pass. Cars	Hybrid Gasoline 1,4-2,0 l	PC Euro 4	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
LDV	Gasoline <3,5t	Conventional	33306		1821	1271	850	588	394	224	122	69	48	37
LDV	Gasoline <3,5t	LD Euro 1	0		3097	917	727	585	453	299	185	116	84	67
LDV	Gasoline <3,5t	LD Euro 2	0		0	2123	1668	1374	1125	802	554	384	308	263
LDV	Gasoline <3,5t	LD Euro 3	0		0	0	408	692	874	637	468	354	312	295
LDV	Gasoline <3,5t	LD Euro 4	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
LDV	Gasoline <3,5t	LD Euro 6	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
LDV	Diesel <3,5 t	Conventional	89223		62672	53848	53361	38845	31914	24683	19306	14838	11634	9485
LDV	Diesel <3,5 t	LD Euro 1	0		106574	38870	45653	38652	36684	33059	29333	24912	20424	17205
LDV	Diesel <3,5 t	LD Euro 2	0		0	89942	104772	90837	91112	88497	87861	82717	74707	67526
LDV	Diesel <3,5 t	LD Euro 3	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	31300	67027	104716	129528	140423
LDV	Diesel <3,5 t	LD Euro 5	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
HD Trucks	Gasoline >3,5 t	Conventional	294		167	140	119	102	87	71	54	44	42	38
HD Trucks	Rigid <=7,5 t	Conventional	9628		2608	2024	1503	1130	841	580	412	301	216	115
HD Trucks	Rigid <=7,5 t	HD Euro I	0		3467	3222	2955	2671	2353	1913	1579	1274	984	817
HD Trucks	Rigid <=7,5 t	HD Euro III	0		4034	5080	4717	4455	4243	3821	3597	3277	2795	2357
HD Trucks	Rigid <=7,5 t	HD Euro III	0		0	0	1154	2247	3293	3034	3039	3021	2834	2641
HD Trucks	Rigid <=7,5 t	HD Euro IV	0		0	0	0	0	0	1351	2744	4148	4845	4902
HD Trucks	Rigid <=7,5 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid <=7,5 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 7,5 - 12 t	Conventional	9219		3946	3048	2258	1687	1234	870	608	424	280	133
HD Trucks	Rigid 7,5 - 12 t	HD Euro I	0		5247	4852	4423	3968	3465	2884	2333	1796	1278	942
HD Trucks	Rigid 7,5 - 12 t	HD Euro III	0		6103	7651	7067	6471	6249	5753	5314	4619	3632	2719
HD Trucks	Rigid 7,5 - 12 t	HD Euro III	0		0	0	1716	3266	4873	4560	4490	4258	3683	3047
HD Trucks	Rigid 7,5 - 12 t	HD Euro IV	0		0	0	0	0	0	2046	4054	5847	6298	5654
HD Trucks	Rigid 7,5 - 12 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 7,5 - 12 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 12 - 14 t	Conventional	1555		1405	1178	920	726	564	453	348	205	132	60
HD Trucks	Rigid 12 - 14 t	HD Euro I	0		1868	1876	1803	1708	1585	1501	1337	867	603	429
HD Trucks	Rigid 12 - 14 t	HD Euro III	0		2174	2958	2880	2851	2859	2994	3044	2230	1713	1237
HD Trucks	Rigid 12 - 14 t	HD Euro III	0		0	0	700	1439	2229	2374	2572	2056	1737	1386
HD Trucks	Rigid 12 - 14 t	HD Euro IV	0		0	0	0	0	0	1065	2323	2824	2970	2573
HD Trucks	Rigid 12 - 14 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 12 - 14 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 14 - 20 t	Conventional	132		143	126	100	90	74	64	52	94	70	34
HD Trucks	Rigid 14 - 20 t	HD Euro I	0		190	201	196	214	208	211	200	397	320	244
HD Trucks	Rigid 14 - 20 t	HD Euro III	0		220	316	313	356	374	422	456	1020	910	705
HD Trucks	Rigid 14 - 20 t	HD Euro III	0		0	0	77	180	291	335	385	940	923	790
HD Trucks	Rigid 14 - 20 t	HD Euro IV	0		0	0	0	0	0	149	346	1291	1578	1466

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HD Trucks	Rigid 14 - 20 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 14 - 20 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 20 - 26 t	Conventional	0		0	0	5	5	4	4	3	3	2	1
HD Trucks	Rigid 20 - 26 t	HD Euro I	0		0	0	11	12	12	14	13	11	11	9
HD Trucks	Rigid 20 - 26 t	HD Euro III	0		0	0	17	20	21	29	29	29	30	26
HD Trucks	Rigid 20 - 26 t	HD Euro III	0		0	0	4	10	16	23	25	27	31	29
HD Trucks	Rigid 20 - 26 t	HD Euro IV	0		0	0	0	0	0	10	22	37	53	53
HD Trucks	Rigid 20 - 26 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 20 - 26 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 26 - 28 t	Conventional	0		0	0	1	0	0	1	0	0	0	0
HD Trucks	Rigid 26 - 28 t	HD Euro I	0		0	0	1	2	1	2	1	2	2	1
HD Trucks	Rigid 26 - 28 t	HD Euro III	0		0	0	2	2	2	2	3	4	4	3
HD Trucks	Rigid 26 - 28 t	HD Euro III	0		0	0	1	1	2	2	2	4	4	3
HD Trucks	Rigid 26 - 28 t	HD Euro IV	0		0	0	0	0	0	0	2	5	8	6
HD Trucks	Rigid 26 - 28 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 26 - 28 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 28 - 32 t	Conventional	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 28 - 32 t	HD Euro I	0		0	0	1	1	1	1	0	1	1	1
HD Trucks	Rigid 28 - 32 t	HD Euro III	0		0	0	1	1	1	1	1	2	4	3
HD Trucks	Rigid 28 - 32 t	HD Euro III	0		0	0	0	0	1	0	1	2	4	3
HD Trucks	Rigid 28 - 32 t	HD Euro IV	0		0	0	0	0	0	0	0	0	6	6
HD Trucks	Rigid 28 - 32 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 28 - 32 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid >32 t	Conventional	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid >32 t	HD Euro I	0		0	0	1	1	1	2	0	0	0	0
HD Trucks	Rigid >32 t	HD Euro III	0		0	0	2	2	2	2	0	2	1	1
HD Trucks	Rigid >32 t	HD Euro III	0		0	0	1	2	2	2	2	2	1	1
HD Trucks	Rigid >32 t	HD Euro IV	0		0	0	0	0	0	0	2	2	2	2
HD Trucks	Rigid >32 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid >32 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	Conventional	0		0	0	0	0	1	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	HD Euro I	0		0	0	1	1	1	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	HD Euro III	0		0	0	0	0	0	1	0	0	0	0
HD Trucks	Articulated 40 - 50 t	HD Euro III	0		0	0	0	0	0	0	0	1	0	0

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HD Trucks	Articulated 40 - 50 t	HD Euro IV	0		0	0	0	0	0	0	1	1	1	1
HD Trucks	Articulated 40 - 50 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	Conventional	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	HD Euro I	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	HD Euro III	0		0	0	0	0	0	0	0	0	0	1
HD Trucks	Articulated 50 - 60 t	HD Euro III	0		0	0	0	0	0	1	0	0	0	1
HD Trucks	Articulated 50 - 60 t	HD Euro IV	0		0	0	0	0	0	0	0	0	1	1
HD Trucks	Articulated 50 - 60 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
Buses	Urban Buses 15-18 t	Conventional	3011		1034	812	611	468	348	247	173	126	98	55
Buses	Urban Buses 15-18 t	HD Euro I	0		1373	1294	1202	1106	974	814	663	533	445	388
Buses	Urban Buses 15-18 t	HD Euro III	0		1593	2044	1918	1845	1756	1625	1511	1371	1264	1121
Buses	Urban Buses 15-18 t	HD Euro III	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	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
Buses	Urban Buses 15-18 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
Buses	Coaches <=18 t	Conventional	753		1050	813	605	467	348	247	173	126	98	55
Buses	Coaches <=18 t	HD Euro I	0		1395	1296	1189	1103	974	814	663	533	445	388
Buses	Coaches <=18 t	HD Euro III	0		1620	2047	1898	1841	1756	1625	1511	1371	1264	1121
Buses	Coaches <=18 t	HD Euro III	0		0	0	463	930	1364	1290	1277	1264	1282	1256
Buses	Coaches <=18 t	HD Euro IV	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
Buses	Coaches <=18 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
Mopeds	<50 cm³	Conventional	4548		8716	9301	8530	8444	7395	4451	3443	2527	1987	1684
Mopeds	<50 cm³	Mop - Euro I	0		0	0	0	0	0	1500	1475	1684	1988	1684
Mopeds	<50 cm³	Mop - Euro II	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
M.cycles	2-stroke >50 cm³	Conventional	2274		0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke <250 cm³	Conventional	0		10036	10292	9638	9535	8817	6605	5885	5561	4937	4397
M.cycles	4-stroke <250 cm³	Mot - Euro I	0		0	0	0	0	0	1500	1962	2383	3291	3598
M.cycles	4-stroke <250 cm³	Mot - Euro II	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
M.cycles	4-stroke 250 - 750 cm³	Conventional	15922		10736	11988	13481	15404	16778	14220	14959	15765	14691	13954

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
M.cycles	4-stroke 250 - 750 cm^3	Mot - Euro I	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
M.cycles	4-stroke 250 - 750 cm^3	Mot - Euro III	0		0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke >750 cm^3	Conventional	0		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	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
M.cycles	4-stroke >750 cm^3	Mot - Euro III	0		0	0	0	0	0	0	0	0	0	0

Table D.2 Vehicle Kilometres, by Class 1990-2009

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pass. Cars	Gasoline <1,4 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/00-01	17666		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/02	17666		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/03	17666		20627	21609	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	ECE 15/04	17666		21496	21609	19594	19684	17710	17620	17528	17964	18156	17326
Pass. Cars	Gasoline <1,4 l	Open Loop	17666		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline <1,4 l	PC Euro 1	0		21616	21609	20553	20154	20058	20066	19515	19162	19376	18474
Pass. Cars	Gasoline <1,4 l	PC Euro 2	0		21616	21859	20553	21152	20657	20066	19515	19162	19376	18474
Pass. Cars	Gasoline <1,4 l	PC Euro 3	0		0	0	20553	21152	20657	20565	19515	19162	19376	18474
Pass. Cars	Gasoline <1,4 l	PC Euro 4	0		0	0	0	0	0	20565	21012	19960	20176	19263
Pass. Cars	Gasoline <1,4 l	PC Euro 5	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
Pass. Cars	Gasoline 1,4 - 2,0 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	19613		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	19613		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	19613		23095	21609	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	19712		22595	21609	23040	20703	19658	18618	20463	20110	20326	19393
Pass. Cars	Gasoline 1,4 - 2,0 l	Open Loop	20112		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 1	0		24563	23558	24498	21152	21157	21563	20463	20110	20326	19393
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 2	0		24563	23558	24498	21652	21157	21563	20463	20359	20576	19622
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 3	0		0	0	24498	21652	21157	22062	20463	20459	20676	19722
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 4	0		0	0	0	0	0	22562	21511	20459	20776	19832
Pass. Cars	Gasoline 1,4 - 2,0 l	PC Euro 5	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
Pass. Cars	Gasoline >2,0 l	PRE ECE	0		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/00-01	22108		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/02	22108		0	0	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/03	22108		23594	23558	0	0	0	0	0	0	0	0
Pass. Cars	Gasoline >2,0 l	ECE 15/04	22108		24563	23558	22451	21652	19658	18618	20513	20110	20326	19393
Pass. Cars	Gasoline >2,0 l	PC Euro 1	0		24563	23558	24498	21652	21656	21563	20513	20110	20326	19393
Pass. Cars	Gasoline >2,0 l	PC Euro 2	0		24563	23558	24498	21652	21656	21563	20513	20459	20676	19722
Pass. Cars	Gasoline >2,0 l	PC Euro 3	0		0	0	24498	21652	21656	22562	20513	20459	20676	19722
Pass. Cars	Gasoline >2,0 l	PC Euro 4	0		0	0	0	0	0	22562	21511	21457	21646	20671
Pass. Cars	Gasoline >2,0 l	PC Euro 5	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

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pass. Cars	Diesel <2,0 l	Conventional	29875		34747	34036	29940	30247	29937	29845	28831	28829	27018	25488
Pass. Cars	Diesel <2,0 l	PC Euro 1	0		34747	34036	31949	30951	31946	29845	28831	28829	27018	25488
Pass. Cars	Diesel <2,0 l	PC Euro 2	0		34747	34036	31949	31956	32951	30347	28831	28829	27018	25488
Pass. Cars	Diesel <2,0 l	PC Euro 3	0		0	0	31949	32910	32951	31852	28831	28829	27018	25488
Pass. Cars	Diesel <2,0 l	PC Euro 4	0		0	0	0	0	0	31852	28831	28829	27018	25488
Pass. Cars	Diesel <2,0 l	PC Euro 5	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
Pass. Cars	Diesel >2,0 l	Conventional	29875		34747	35041	31949	30951	29937	29845	28831	28829	27018	25488
Pass. Cars	Diesel >2,0 l	PC Euro 1	0		34747	35041	31949	31956	31946	29845	28831	28829	27018	25488
Pass. Cars	Diesel >2,0 l	PC Euro 2	0		34747	35041	31949	32910	32951	29845	28831	28829	27018	25488
Pass. Cars	Diesel >2,0 l	PC Euro 3	0		0	0	31949	32910	32951	31852	28831	28829	27018	25488
Pass. Cars	Diesel >2,0 l	PC Euro 4	0		0	0	0	0	0	32855	28831	28829	27018	25488
Pass. Cars	Diesel >2,0 l	PC Euro 5	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
Pass. Cars	LPG	Conventional	39554		48200	34048	44482	39971	36624	0	0	0	0	0
Pass. Cars	LPG	PC Euro 1	0		48200	34048	44982	41875	36624	50688	49924	49188	56244	33161
Pass. Cars	LPG	PC Euro 2	0		48200	34048	44982	41875	36624	50688	49924	49188	56244	33161
Pass. Cars	LPG	PC Euro 3	0		0	0	0	0	0	50688	49924	49188	56244	33161
Pass. Cars	LPG	PC Euro 4	0		0	0	0	0	0	50688	49924	49188	56244	33161
Pass. Cars	LPG	PC Euro 5	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
Pass. Cars	Hybrid Gasoline <1,4 l	PC Euro 4	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
Pass. Cars	Hybrid Gasoline >2,0 l	PC Euro 4	0		0	0	0	0	0	0	0	0	0	0
LDV	Gasoline <3,5t	Conventional	24553		44211	45167	46040	43304	44251	44125	42174	41168	41592	39525
LDV	Gasoline <3,5t	LD Euro 1	0		56158	45167	45091	43304	44251	44125	42174	41168	41592	39525
LDV	Gasoline <3,5t	LD Euro 2	0		0	45417	45091	43304	44251	44125	42174	41168	41592	39525
LDV	Gasoline <3,5t	LD Euro 3	0		0	0	45091	43304	44251	44125	42174	41168	41592	39525
LDV	Gasoline <3,5t	LD Euro 4	0		0	0	0	0	0	44125	42174	41168	41592	39525
LDV	Gasoline <3,5t	LD Euro 5	0		0	0	0	0	0	0	0	0	41592	39525
LDV	Gasoline <3,5t	LD Euro 6	0		0	0	0	0	0	0	0	0	0	0
LDV	Diesel <3,5 t	Conventional	30885		63083	62071	54947	56877	58970	59189	57761	57698	55049	51706
LDV	Diesel <3,5 t	LD Euro 1	0		63083	62825	54947	59390	58970	59189	58915	57698	55049	51706
LDV	Diesel <3,5 t	LD Euro 2	0		0	62825	55459	59390	59472	60694	58915	57698	55049	51706
LDV	Diesel <3,5 t	LD Euro 3	0		0	0	55459	59390	59472	60694	58915	57698	55049	51706
LDV	Diesel <3,5 t	LD Euro 4	0		0	0	0	0	0	60694	58915	57898	55049	51706
LDV	Diesel <3,5 t	LD Euro 5	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

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HD Trucks	Gasoline >3,5 t	Conventional	25551		37663	37695	37526	37684	37673	37419	39109	39066	39113	37081
HD Trucks	Rigid <=7,5 t	Conventional	53493		59588	60111	51943	54918	58468	37821	59747	59100	59763	56017
HD Trucks	Rigid <=7,5 t	HD Euro I	0		59588	60111	51943	56928	58468	58687	59747	59100	59763	56017
HD Trucks	Rigid <=7,5 t	HD Euro III	0		59588	60111	51943	56928	58468	72130	59747	59100	59763	56017
HD Trucks	Rigid <=7,5 t	HD Euro III	0		0	0	51943	56928	58468	72130	59747	59100	59763	56017
HD Trucks	Rigid <=7,5 t	HD Euro IV	0		0	0	0	0	0	72130	59747	59100	59763	56017
HD Trucks	Rigid <=7,5 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid <=7,5 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 7,5 - 12 t	Conventional	52988		74522	76094	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 7,5 - 12 t	HD Euro I	0		74522	76094	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 7,5 - 12 t	HD Euro III	0		74522	76094	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 7,5 - 12 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 7,5 - 12 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 7,5 - 12 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 7,5 - 12 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 12 - 14 t	Conventional	52988		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 12 - 14 t	HD Euro I	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 12 - 14 t	HD Euro III	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 12 - 14 t	HD Euro III	0		0	0	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 12 - 14 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 12 - 14 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 12 - 14 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 14 - 20 t	Conventional	52988		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 14 - 20 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 14 - 20 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 14 - 20 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 14 - 20 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 14 - 20 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 14 - 20 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 20 - 26 t	Conventional	52988		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 20 - 26 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 20 - 26 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 20 - 26 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 20 - 26 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 20 - 26 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 20 - 26 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 26 - 28 t	Conventional	52635		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 26 - 28 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HD Trucks	Rigid 26 - 28 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 26 - 28 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 26 - 28 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 26 - 28 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 26 - 28 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 28 - 32 t	Conventional	52635		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 28 - 32 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid 28 - 32 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 28 - 32 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid 28 - 32 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid 28 - 32 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid 28 - 32 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid >32 t	Conventional	52635		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid >32 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Rigid >32 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid >32 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Rigid >32 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Rigid >32 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Rigid >32 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	Conventional	52635		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Articulated 40 - 50 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Articulated 40 - 50 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Articulated 40 - 50 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Articulated 40 - 50 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Articulated 40 - 50 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 40 - 50 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	Conventional	52635		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Articulated 50 - 60 t	HD Euro I	0		71556	74083	69927	71850	71980	72130	71700	70970	71757	67370
HD Trucks	Articulated 50 - 60 t	HD Euro III	0		71556	74083	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Articulated 50 - 60 t	HD Euro III	0		0	0	69927	71850	71929	72130	71700	70970	71757	67370
HD Trucks	Articulated 50 - 60 t	HD Euro IV	0		0	0	0	0	0	72130	71700	70970	71757	67370
HD Trucks	Articulated 50 - 60 t	HD Euro V	0		0	0	0	0	0	0	0	0	0	0
HD Trucks	Articulated 50 - 60 t	HD Euro VI	0		0	0	0	0	0	0	0	0	0	0
Buses	Urban Buses 15 - 18 t	Conventional	50112		58632	60071	59930	64917	69920	71127	71199	70369	71156	66420
Buses	Urban Buses 15 - 18 t	HD Euro I	0		58632	60071	59930	64917	69920	71127	71199	70369	71156	66420
Buses	Urban Buses 15 - 18 t	HD Euro III	0		58632	60071	59930	64917	69920	71127	71199	70369	71156	66420
Buses	Urban Buses 15 - 18 t	HD Euro III	0		0	0	59930	64917	69920	71127	71199	70369	71156	66420
Buses	Urban Buses 15 - 18 t	HD Euro IV	0		0	0	0	0	0	71127	71199	70369	71156	66420

Sector	Subsector	Technology	1990		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Buses	Urban Buses 15 - 18 t	HD Euro V	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
Buses	Coaches <=18 t	Conventional	48093		76433	75088	59930	73860	73939	73635	73706	72824	73643	68721
Buses	Coaches <=18 t	HD Euro I	0		76433	75088	59930	73860	73939	73635	73706	72824	73643	68721
Buses	Coaches <=18 t	HD Euro III	0		76433	75088	59930	73860	73939	73635	73706	72824	73643	68721
Buses	Coaches <=18 t	HD Euro III	0		0	0	59930	73860	73939	73635	73706	72824	73643	68721
Buses	Coaches <=18 t	HD Euro IV	0		0	0	0	0	0	73635	73706	72824	73643	68721
Buses	Coaches <=18 t	HD Euro V	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
Mopeds	<50 cm³	Conventional	14972		14984	14993	14981	14981	12486	12479	12478	12475	12498	11873
Mopeds	<50 cm³	Mop - Euro I	0		0	0	0	0	0	12479	12478	12475	12498	11873
Mopeds	<50 cm³	Mop - Euro II	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
M.cycles	2-stroke >50 cm³	Conventional	14972		0	0	0	0	0	0	0	0	0	0
M.cycles	4-stroke <250 cm³	Conventional	0		20477	20490	20473	20473	20477	20465	20463	19661	19696	18719
M.cycles	4-stroke <250 cm³	Mot - Euro I	0		0	0	0	0	0	20465	20463	19661	19696	18719
M.cycles	4-stroke <250 cm³	Mot - Euro II	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
M.cycles	4-stroke 250 - 750 cm³	Conventional	14972		20477	20490	20473	20473	20477	20465	20463	19661	19696	18719
M.cycles	4-stroke 250 - 750 cm³	Mot - Euro I	0		0	0	0	0	0	20465	20463	19661	19696	18719
M.cycles	4-stroke 250 - 750 cm³	Mot - Euro II	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
M.cycles	4-stroke >750 cm³	Conventional	0		20477	20490	20473	20473	20477	20465	20463	19661	19696	18719
M.cycles	4-stroke >750 cm³	Mot - Euro I	0		0	0	0	0	0	20465	20463	19661	19696	18719
M.cycles	4-stroke >750 cm³	Mot - Euro II	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

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 1990-2009

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
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
Cement Plant 2	685	613	608	584	660	680	667	770	776	799	908	915	902	905	977	957	900	934	902	501
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
Cement Plant 4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	381	411	547	608	609	557	441
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**
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
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
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
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
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**
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
Cement Plant 2	379	339	336	323	365	376	369	426	429	442	502	506	499	487	506	510	481	500	491	272
Cement Plant 3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	435	547	550	604	654	658	651	652	555	441
Cement Plant 4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	200	282	295	321	322	298	235
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**

Table E.2 Limestone and Dolomite Use 1990-2009

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
												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
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
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	0.00
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
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
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**
												Emission Factor t CO_2/t Limestone Use								
Power plant 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4362	0.4361	0.4362	0.4413	0.4361	0.4362	0.4361	0.4361	0.4299
Power plant 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4400	0.4400	0.4400
Brick Manufacturer	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4400	0.4394	0.4402	0.4400	0.4400	NA
Tile manufacturer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4419	0.4287	0.4352	NA
Sugar processing	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4400	0.4382	NA	NA	NA
IEF t CO_2/t Limestone Use	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4400**	**0.4363**	**0.4364**	**0.4365**	**0.4413**	**0.4367**	**0.4366**	**0.4365**	**0.4370**	**0.4337**
												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
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
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	0.00
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
Sugar processing	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	535.00	78.00	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**

Table E.3 Glass production 1990-2009

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
Carbonate use (kilotonnes)																				
Glass plant 1	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.4117	0.3629	0.4379	0.4379	0.3285	NO	NO	NO	NO
Glass plant 2	1.7204	1.6949	1.3639	1.6549	1.8367	1.5494	1.2657	1.6367	1.4076	1.4985	1.2730	0.5369	0.4401	0.4401	0.5806	0.4718	0.7010	0.6002	0.4215	0.0632
Glass bottle	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	60.0000	30.0000	NO	NO	NO	NO	NO	NO	NO
Glass w ool	1.7456	1.7456	1.4845	1.7456	1.7456	1.7456	1.7456	1.7456	1.5413	1.8704	2.0570	1.8091	1.1607	0.7341	0.7087	0.6280	0.7080	0.6987	0.4607	NO
Total	**63.8776**	**63.8521**	**63.2601**	**63.8121**	**63.9940**	**63.7066**	**63.4229**	**63.7939**	**63.3605**	**63.7806**	**63.7416**	**62.7577**	**31.9637**	**1.6121**	**1.7272**	**1.4283**	**1.4090**	**1.2989**	**0.8822**	**0.0632**
Emission Factor t CO_2/t Carbonate Use																				
Glass plant 1	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	NA	NA	NA	NA
Glass plant 2	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2749	0.2750	0.2748	0.2749	0.2750	0.2750
Glass bottle	0.1995	0.1951	0.1908	0.1864	0.1820	0.1776	0.1733	0.1689	0.1645	0.1601	0.1558	0.1514	0.1470	NA	NA	NA	NA	NA	NA	NA
Glass w ool	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4405	0.4382	0.4307	0.4248	0.4235	0.4153	0.4153	0.4150	0.4150	NA
IEF t CO_2/t Carbonate Use	**0.2086**	**0.2045**	**0.1990**	**0.1962**	**0.1923**	**0.1878**	**0.1833**	**0.1797**	**0.1744**	**0.1718**	**0.1681**	**0.1615**	**0.1605**	**0.3432**	**0.3359**	**0.3367**	**0.3454**	**0.3503**	**0.3481**	**0.2750**
Emissions CO_2 (kilotonnes)																				
Glass plant 1	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.1132	0.0998	0.1204	0.1204	0.0903	NO	NO	NO	NO
Glass plant 2	0.4730	0.4660	0.3750	0.4550	0.5050	0.4260	0.3480	0.4500	0.3870	0.4120	0.3500	0.1476	0.1210	0.1210	0.1596	0.1297	0.1927	0.1650	0.1159	0.0174
Glass bottle	11.9700	11.7075	11.4450	11.1825	10.9200	10.6575	10.3950	10.1325	9.8700	9.6075	9.3450	9.0825	4.4100	NO	NO	NO	NO	NO	NO	NO
Glass w ool	0.7690	0.7690	0.6540	0.7690	0.7690	0.7690	0.7690	0.7690	0.6790	0.8240	0.9062	0.7927	0.5000	0.3118	0.3001	0.2608	0.2940	0.2900	0.1912	NO
Total	**13.3252**	**13.0557**	**12.5872**	**12.5197**	**12.3072**	**11.9657**	**11.6252**	**11.4647**	**11.0492**	**10.9567**	**10.7144**	**10.1360**	**5.1307**	**0.5532**	**0.5801**	**0.4809**	**0.4867**	**0.4550**	**0.3071**	**0.0174**

Table E.4 Bricks and tiles 1990-2009

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
Raw material use (clays, shale, bricks and flues) (kilotonnes)																				
Fireclay plant 1	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	30.7500	32.6380	35.5910	37.1690	41.2060	34.3194	33.8070	16.5243	2.7331
Brick Manufacturer 1	40.0000	40.0000	40.0000	40.0000	40.0000	40.0000	40.0000	40.0000	40.0000	40.0000	43.1440	44.5420	45.8980	46.1240	47.5810	46.0600	47.7120	45.0648	26.2230	13.6166
Brick Manufacturer 2	39.6408	35.6772	33.6943	27.7488	33.6943	47.5692	43.6045	63.4249	60.4517	66.3982	65.8970	63.1575	49.2316	51.3515	48.4610	52.2220	48.2980	38.3890	20.8750	0.0000
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	18.8258	21.2185	19.7113	19.1620	NO
Total	**110.3908**	**106.4272**	**104.4443**	**98.4988**	**104.4443**	**118.3192**	**114.3545**	**134.1749**	**131.2017**	**137.1482**	**139.7910**	**138.4495**	**127.7676**	**133.0665**	**133.2110**	**158.3138**	**151.5478**	**136.9721**	**82.7843**	**16.3496**
Emission Factor t CO_2/t Raw Material Use																				
Fireclay plant 1	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0453	0.0359	0.0461	0.0449	0.0482	0.0457	0.0482	0.0482	0.0485	0.0554
Brick Manufacturer 1	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0440	0.0340	0.0279
Brick Manufacturer 2	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0485	0.0484	0.0485	0.0484	0.0485	NA
Tile manufacturer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0515	0.0615	0.0689	0.0674	NA
IEF t CO_2/t Raw Material Use	**0.0460**	**0.0459**	**0.0458**	**0.0457**	**0.0458**	**0.0461**	**0.0461**	**0.0464**	**0.0464**	**0.0465**	**0.0464**	**0.0442**	**0.0463**	**0.0460**	**0.0468**	**0.0468**	**0.0488**	**0.0499**	**0.0483**	**0.0325**
Emissions CO_2 (kilotonnes)																				
Fireclay plant 1	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.3935	1.1040	1.5060	1.5980	1.7900	1.8830	1.6548	1.6298	0.8009	0.1515
Brick Manufacturer 1	1.7597	1.7597	1.7597	1.7597	1.7597	1.7597	1.7597	1.7597	1.7597	1.7597	1.8980	1.9595	2.0192	2.0291	2.0932	2.0263	2.0990	1.9828	0.8916	0.3799
Brick Manufacturer 2	1.9215	1.7294	1.6333	1.3451	1.6333	2.3058	2.1136	3.0744	2.9303	3.2185	3.1942	3.0614	2.3864	2.4891	2.3490	2.5290	2.3420	1.8597	1.0130	NO
Tile manufacturer	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.9689	1.3040	1.3587	1.2912	NO
Total	**5.0747**	**4.8826**	**4.7865**	**4.4983**	**4.7865**	**5.4591**	**5.2669**	**6.2276**	**6.0835**	**6.3717**	**6.4858**	**6.1250**	**5.9116**	**6.1163**	**6.2323**	**7.4072**	**7.3997**	**6.8311**	**3.9967**	**0.5314**

Annex F

Animal Populations

Methane Emission Factors for Enteric Fermentation and Manure Management

Input Parameters used for the Calculation of Nitrous Oxide Emissions from Agricultural Soils

Table F.1 (a) Animal Populations 1990-2009

Housing and Storage (1000 head)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Cattle	5969.10	6100.40	6147.30	6236.40	6263.90	6343.80	6450.70	6661.00	6881.60	6951.80	6557.70	6330.10	6408.10	6332.90	6223.50	6211.50	6191.80	6001.70	5902.20	5934.80
Dairy Cows	1341.60	1322.20	1288.00	1246.20	1248.30	1233.00	1220.80	1215.60	1201.40	1198.80	1173.80	1152.80	1148.00	1128.70	1135.70	1121.80	1101.10	1087.10	1087.50	1104.80
All Other Cattle	4627.50	4778.20	4859.30	4990.20	5015.60	5110.80	5229.90	5445.40	5680.20	5753.00	5383.90	5177.30	5260.10	5204.20	5087.80	5089.70	5090.70	4914.60	4814.70	4830.00
Other Cows	659.20	729.40	784.00	916.70	936.60	968.70	1004.60	1083.40	1163.80	1196.20	1166.80	1155.20	1159.70	1150.80	1144.20	1150.80	1150.00	1128.80	1117.40	1115.10
Dairy Heifers	172.30	185.30	182.10	198.70	193.70	209.40	235.40	243.80	244.00	223.80	210.40	202.90	206.20	215.80	225.60	238.00	236.30	220.50	212.90	218.10
Other Heifers	100.00	91.30	91.70	117.30	121.40	107.20	129.20	139.00	154.00	128.80	125.20	140.40	147.50	141.60	140.90	143.60	146.30	144.40	147.50	131.30
Cattle <1 yrs	1436.20	1477.00	1491.00	1472.30	1564.90	1556.50	1631.40	1735.00	1828.60	1789.60	1648.90	1689.90	1879.40	1805.70	1751.10	1746.00	1693.30	1635.80	1633.40	1651.60
Cattle 1-2 yrs	1311.70	1347.60	1399.30	1379.00	1361.40	1403.90	1380.20	1424.60	1481.90	1548.90	1446.40	1269.30	1329.00	1363.80	1319.90	1253.40	1261.70	1194.20	1153.30	1176.50
Cattle >2yrs	922.60	920.10	881.50	873.80	803.10	829.10	810.50	778.00	763.10	818.90	738.70	669.80	485.30	471.20	449.50	499.20	543.50	532.80	491.60	479.50
Bulls	25.50	27.50	29.70	32.40	34.50	36.00	38.60	41.60	44.80	46.80	47.50	49.80	53.00	55.30	56.60	58.70	59.60	58.10	58.60	57.90
Total Sheep	8020.98	8483.65	8735.75	8977.22	8559.06	8363.83	8329.04	8050.87	8572.21	8547.20	7957.34	7454.79	6682.41	6480.70	6703.33	6431.32	6187.15	5655.57	5105.41	4726.98
Ewes Lowland	2396.60	2542.54	2621.99	2576.45	2511.11	2426.99	2369.07	2389.75	3056.41	2936.15	2814.25	2704.31	2637.25	2552.34	2463.79	2626.72	2414.32	2206.84	2056.56	1928.16
Ewes Upland	1960.85	2080.26	2145.26	2108.00	2054.54	1985.72	1938.33	1955.25	1309.89	1258.35	1206.11	1158.99	1130.25	1093.86	1055.91	656.68	603.58	551.71	514.14	482.04
Rams	116.85	122.55	126.45	125.05	122.05	120.00	113.15	115.50	115.70	113.25	110.65	106.55	104.65	102.35	100.00	96.25	92.70	85.75	78.70	72.25
Other Sheep>1	298.38	174.80	161.35	179.22	194.86	205.33	192.19	215.37	245.21	218.35	204.74	182.20	184.46	205.74	199.44	155.13	152.76	136.80	140.35	128.35
Lambs	3248.30	3563.50	3680.70	3988.50	3676.50	3625.80	3716.30	3375.00	3845.00	4021.10	3621.60	3302.74	2625.80	2526.41	2884.19	2896.54	2923.79	2674.47	2315.66	2116.18
Pigs	1212.10	1315.85	1394.60	1495.90	1506.95	1539.40	1632.65	1698.80	1800.95	1763.90	1718.65	1751.75	1784.40	1721.10	1696.15	1671.50	1625.40	1574.85	1529.65	1534.90
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	21.90	21.75	22.35
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	16.50	16.60	18.65
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	94.55	90.70	90.45
Other Sows for Breeding	21.00	22.45	23.45	24.20	22.60	24.00	25.65	27.55	29.20	26.65	23.85	27.85	26.45	24.75	22.80	25.90	24.30	22.60	20.05	21.60
Boars	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	1.75	1.50	1.40
Pigs 20 Kg +	749.20	802.65	836.50	904.95	917.65	951.90	1015.80	1063.90	1144.35	1094.15	1037.90	1036.20	1061.95	1043.20	1027.80	1010.30	1033.95	969.60	972.35	978.90
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	447.95	406.70	401.55
Poultry	11412.83	12338.21	12913.07	12712.41	13674.55	14078.45	15015.62	15189.04	15326.96	15130.48	15320.50	15663.15	15182.57	15787.87	16610.57	16094.68	15303.58	14826.15	14348.72	13871.28
Layer	1868.25	1800.00	2231.00	1831.50	1730.00	1370.50	1701.00	1580.00	1558.50	1537.00	1572.00	1676.00	1613.00	1906.60	1906.27	1950.00	1970.00	1900.00	1830.00	1760.00
Broiler	8035.13	8904.90	9066.82	9522.47	10392.54	11092.18	11729.88	12096.34	12286.79	12200.11	12426.10	12628.89	12321.96	12672.21	13242.90	12817.70	12236.93	12029.20	11821.47	11613.74
Turkey	1509.45	1633.30	1615.26	1358.44	1552.01	1615.77	1584.74	1512.70	1481.67	1393.37	1322.41	1358.26	1247.60	1209.06	1461.40	1326.98	1096.65	896.95	697.25	497.54
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	95.70	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
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
Fertiliser (1000's kg/N)	379311	370121	358302	377985	404811	428826	416918	380350	431999	442916	407598	368667	363513	388080	362525	352165	342137	321553	308960	306806

Table F.1 (b) Animal Populations 1990-2009

Pasture (1000 head)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Cattle	6816.10	6912.10	6951.40	6981.70	6996.30	7034.00	7313.50	7532.80	7639.90	7387.00	7037.40	7049.70	6992.20	6999.60	7015.70	6982.60	6915.80	6704.10	6719.90	6716.20
Dairy Cows	1359.70	1330.80	1277.90	1263.50	1260.60	1256.20	1266.40	1251.70	1233.80	1200.60	1177.50	1182.50	1164.10	1155.60	1156.10	1113.70	1109.20	1087.00	1113.90	1126.90
All Other Cattle	5456.40	5581.30	5673.50	5718.20	5735.70	5777.80	6047.10	6281.10	6406.10	6186.40	5859.90	5867.20	5828.10	5844.00	5859.60	5868.90	5806.60	5617.10	5606.00	5589.30
Other Cows	731.30	817.30	889.10	979.70	1011.00	1039.10	1112.70	1201.90	1247.90	1217.30	1187.00	1196.80	1154.20	1187.30	1207.10	1227.80	1215.40	1180.90	1179.90	1155.40
Dairy Heifers	158.60	129.70	174.50	187.90	203.90	224.10	231.40	243.90	228.80	213.60	206.50	198.30	230.70	215.80	229.60	230.20	228.70	217.80	225.40	227.90
Other Heifers	68.60	50.10	94.50	111.50	101.50	117.20	128.80	143.50	126.70	116.50	125.10	132.80	143.20	137.00	139.60	148.10	157.00	152.80	147.90	138.50
Cattle <1 yrs	1716.10	1764.70	1694.50	1737.50	1736.20	1746.10	1852.10	1938.20	1965.00	1820.70	1751.90	1824.40	1799.30	1761.20	1771.40	1689.50	1631.20	1593.50	1615.90	1586.80
Cattle 1-2 yrs	1663.10	1692.00	1637.60	1587.00	1585.70	1586.10	1639.40	1717.00	1782.60	1706.00	1517.10	1515.00	1593.20	1577.10	1534.80	1575.60	1553.80	1475.80	1466.30	1463.10
Cattle >2yrs	1092.60	1098.80	1151.80	1077.90	1057.70	1022.90	1036.20	985.70	1002.10	1057.70	1016.20	941.10	844.70	901.50	910.60	929.40	951.20	928.30	902.10	950.70
Bulls	26.10	28.70	31.50	36.70	39.70	42.30	46.50	50.90	53.00	54.60	56.10	58.80	62.80	64.10	66.50	68.30	69.30	68.00	68.50	66.90
Total Sheep	8020.98	8483.65	8735.75	8977.22	8559.06	8363.83	8329.04	8050.87	8572.21	8547.20	7957.34	7454.79	6682.41	6480.70	6703.33	6431.32	6187.15	5655.57	5105.41	4726.98
Lowland Ewes	2396.60	2542.54	2621.99	2576.45	2511.11	2426.99	2369.07	2389.75	3056.41	2936.15	2814.25	2704.31	2637.25	2552.34	2463.79	2626.72	2414.32	2206.84	2056.56	1928.16
Upland Ewes	1960.85	2080.26	2145.26	2108.00	2054.54	1985.72	1938.33	1955.25	1309.89	1258.35	1206.11	1158.99	1130.25	1093.86	1055.91	656.68	603.58	551.71	514.14	482.04
Rams	116.85	122.55	126.45	125.05	122.05	120.00	113.15	115.50	115.70	113.25	110.65	106.55	104.65	102.35	100.00	96.25	92.70	85.75	78.70	72.25
Other Sheep>1	298.38	174.80	161.35	179.22	194.86	205.33	192.19	215.37	245.21	218.35	204.74	182.20	184.46	205.74	199.44	155.13	152.76	136.80	140.35	128.35
Lambs	3248.30	3563.50	3680.70	3988.50	3676.50	3625.80	3716.30	3375.00	3845.00	4021.10	3621.60	3302.74	2625.80	2526.41	2884.19	2896.54	2923.79	2674.47	2315.66	2116.18
Pigs	1212.10	1315.85	1394.60	1495.90	1506.95	1539.40	1632.65	1698.80	1800.95	1763.90	1718.65	1751.75	1784.40	1721.10	1696.15	1671.50	1625.40	1574.85	1529.65	1534.90
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	21.90	21.75	22.35
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	16.50	16.60	18.65
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	94.55	90.70	90.45
Other Sows for Breeding	21.00	22.45	23.45	24.20	22.60	24.00	25.65	27.55	29.20	26.65	23.85	27.85	26.45	24.75	22.80	25.90	24.30	22.60	20.05	21.60
Boars	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	1.75	1.50	1.40
Pigs 20 Kg +	749.20	802.65	836.50	904.95	917.65	951.90	1015.80	1063.90	1144.35	1094.15	1037.90	1036.20	1061.95	1043.20	1027.80	1010.30	1033.95	969.60	972.35	978.90
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	447.95	406.70	401.55
Poultry	11412.83	12338.21	12913.07	12712.41	13674.55	14078.45	15015.62	15189.04	15326.96	15130.48	15320.50	15663.15	15182.57	15787.87	16610.57	16094.68	15303.58	14826.15	14348.72	13871.28
Layer	1868.25	1800.00	2231.00	1831.50	1730.00	1370.50	1701.00	1580.00	1558.50	1537.00	1572.00	1676.00	1613.00	1906.60	1906.27	1950.00	1970.00	1900.00	1830.00	1760.00
Broiler	8035.13	8904.90	9066.82	9522.47	10392.54	11092.18	11729.88	12096.34	12286.79	12200.11	12426.10	12628.89	12321.96	12672.21	13242.90	12817.70	12236.93	12029.20	11821.47	11613.74
Turkey	1509.45	1633.30	1615.26	1358.44	1552.01	1615.77	1584.74	1512.70	1481.67	1393.37	1322.41	1358.26	1247.60	1209.06	1461.40	1326.98	1096.65	896.95	697.25	497.54
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	95.70	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
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
Fertiliser	379311	370121	358302	377985	404811	428826	416918	380350	431999	442916	407598	368667	363513	388080	362525	352165	342137	321553	308960	306806

Table F.2 (a) CH_4 Emission Factors for Enteric Fermentation (kg/head/year)

	Animal Liveweight (kg)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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	109.68	110.22	109.21	106.46
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	75.92	73.84
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
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
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
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
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
> 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
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	27.72	27.68
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
> 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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Poultry	**2.18**	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.2 (b) 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
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	20.61	20.63	20.53	20.21
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	14.49	14.03
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
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
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
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
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
> 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
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
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
> 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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

* Note: This value is low because this category of animal only live part of their third year.

Table F.3 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
$Frac_{GASF}$	0.01477	0.01472	0.01613	0.01605	0.01551	0.01473	0.01990	0.02077	0.01835	0.01795	0.02131	0.01985	0.01657	0.01468	0.01538	0.01575	0.01696	0.01458	0.01789	0.01773
$Frac_{GRAZ}$	0.68382	0.68116	0.68180	0.67699	0.67455	0.67180	0.67279	0.66900	0.66644	0.66205	0.66297	0.66622	0.65694	0.66040	0.66285	0.66292	0.66368	0.66256	0.66451	0.66189
$Frac_{GASM1}$	0.49441	0.49497	0.49497	0.49535	0.49623	0.49632	0.49716	0.49719	0.49638	0.49702	0.49679	0.49780	0.49941	0.49960	0.50005	0.49981	0.50082	0.50123	0.50171	0.50087
$Frac_{GASM2}$	0.04359	0.04301	0.04198	0.04195	0.04178	0.04019	0.04121	0.04059	0.04106	0.04092	0.04125	0.03862	0.03855	0.03835	0.03837	0.03714	0.03693	0.03694	0.03705	0.03697
$Frac_{GASM}$	0.18613	0.18711	0.18612	0.18840	0.18968	0.18990	0.19041	0.19172	0.19294	0.19506	0.19478	0.19188	0.19665	0.19499	0.19402	0.19309	0.19295	0.19361	0.19294	0.19382
$Frac_{LEACH}$	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
F_{SN} (tonnes/year)	373,709	364,674	352,521	371,918	398,533	422,508	408,622	372,451	424,071	434,967	398,911	361,348	357,490	382,382	356,949	346,620	336,334	316,865	303,432	301,367
F_{AM} (tonnes/year)	69,083	70,842	72,034	73,134	73,641	74,349	75,645	78,197	81,084	81,005	77,239	74,794	76,315	75,555	74,571	74,217	73,173	70,758	69,652	70,398
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	1103.564	1228.756	1687.586	1839.495	1913.307	1952.212	1990.756	2028.262
F_{BN}	0.0100	0.0087	0.0087	0.0174	0.0167	0.0127	0.0144	0.0130	0.0217	0.0123	0.0052	0.0060	0.0050	0.0092	0.0096	0.0127	0.0134	0.0086	0.0070	0.0125
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	11,522	10,186
F_{AW} (tonnes/year)	69,188	70,948	72,141	73,241	73,749	74,446	75,737	78,452	81,449	81,574	77,980	75,727	77,419	76,784	76,259	76,056	75,086	72,710	71,643	72,426

Table F.4 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
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
Suckler Cows	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	141	142	141
Dairy Heifer	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
Under1yr	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	222	222	223
Oneto2yrs	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	156	157
Over2yrs	23	23	23	23	23	23	23	23	23	23	23	23	23	23	25	29	28	31	27	30
Bulls	156	156	156	156	156	156	156	156	156	156	156	156	156	156	154	156	156	155	156	157
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
Suckler Cows	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	224	223	224
Dairy Heifer	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
Under1yr	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	144	143	143	142
Oneto2yrs	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	209	208
Over2yrs	342	342	342	342	342	342	342	342	342	342	342	342	342	342	340	336	337	334	338	335
Bulls	209	209	209	209	209	209	209	209	209	209	209	209	209	209	211	209	209	210	209	208
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	0.30
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
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
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
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	0.41
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
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	0.05
Bulls	0.42	0.42	0.42	0.41	0.41	0.41	0.40	0.40	0.40	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Over2yrs	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.93	0.92	0.92	0.92	0.92	0.92
Bulls	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49

Table F.5 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	47.07	52.93	0.00	100	0.00	0.08	0.92
Upland Ewes	85	44.34	55.66	0.00	100	NA	0.10	0.90
Rams	85	22.34	77.66	0.00	100	NA	0.05	0.95
Lambs	58	16.88	83.12	0.00	100	NA	0.03	0.97
Other sheep	61	47.07	52.93	0.00	100	NA	0.08	0.92
Pigs								
Gilts in pig	365	100	0.00	100	0.00	1.00	0.00	0.00
Gilts not yet served	365	100	0.00	100	0.00	1.00	0.00	0.00
Sows in pig	365	100	0.00	100	0.00	1.00	0.00	0.00
Other sows for breeding	365	100	0.00	100	0.00	1.00	0.00	0.00
Boars	365	100	0.00	100	0.00	1.00	0.00	0.00
Pigs < 20 kg	365	100	0.00	100	0.00	1.00	0.00	0.00
Pigs > 20 kg	365	100	0.00	100	0.00	1.00	0.00	0.00
Poultry								
Layers	365	88.00	12.00	84.20	15.80	0.74	0.14	0.12
Broilers	365	100.00	0.00	0.00	100.00	0.00	1.00	0.00
Turkeys	365	100.00	0.00	0.00	100.00	0.00	1.00	0.00
Horses	143	100.00	0.00	0.00	100.00	0.00	0.39	0.61
Mules and Asses	143	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

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	Cleared & Unclass	Forest Cover	Total Forest	Harvest Volume	Harvest Carbon Stock	Affor Carbon Stock	Carbon Stock Young Forests	Carbon Stock Mature Forests	Carbon Stock Total Forests	Total Carbon Stock Change	5.A.1 Carbon Stock Change	5.A.2 Carbon Stock Change	5.A.2.1 Carbon Stock Change	5.A.2.2 Carbon Stock Change	5.A.2.3 Carbon Stock Change	5.A.2.4 Carbon Stock Change	5.A.2.5 Carbon Stock Change
	ha	ha	ha	ha	ha	ha	1000 m3	Gg C	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	127,004	370,160	497,164	1,676	508.83	273.03	1937.10	13948.13	15885.24	215.83	271.16	-55.32	-5.53	-16.60	-31.54	0.00	-1.66
1991	19,147	4,203	4,063	141,142	373,728	514,869	1,769	537.07	330.52	1853.07	14259.25	16112.32	227.09	311.12	-84.03	-8.40	-25.21	-47.90	0.00	-2.52
1992	16,699	4,063	4,621	152,383	376,237	528,621	2,083	632.42	288.26	1801.60	14496.41	16298.01	185.68	237.16	-51.48	-5.15	-15.44	-29.34	0.00	-1.54
1993	15,998	4,621	4,816	166,123	380,940	547,064	2,100	637.60	276.16	1776.21	14730.77	16506.97	208.97	234.36	-25.39	-2.54	-7.62	-14.47	0.00	-0.76
1994	19,459	4,816	5,447	181,224	386,598	567,822	2,287	694.30	335.90	1818.10	14888.70	16706.80	199.83	157.93	41.89	4.19	12.57	23.88	0.00	1.26
1995	23,710	5,447	6,203	190,134	394,834	584,968	2,382	723.28	409.28	1920.39	14999.52	16919.91	213.11	110.82	102.29	10.23	30.69	58.31	0.00	3.07
1996	20,981	6,711	7,090	188,494	406,522	595,016	2,465	748.35	362.17	2044.97	15093.96	17138.94	219.02	94.44	124.58	12.46	37.37	71.01	0.00	3.74
1997	11,434	7,655	7,185	185,363	419,209	604,572	2,322	705.11	197.37	2231.18	15160.72	17391.90	252.96	66.75	186.20	18.62	55.86	106.14	0.00	5.59
1998	12,928	7,494	7,924	184,615	434,877	619,492	2,638	800.90	223.16	2376.68	15300.15	17676.83	284.93	139.43	145.50	14.55	43.65	82.94	0.00	4.37
1999	12,668	8,137	7,747	187,695	447,899	635,594	2,777	843.12	218.67	2517.16	15455.01	17972.17	295.34	154.86	140.48	14.05	42.14	80.07	0.00	4.21
2000	15,695	9,421	8,677	187,079	459,593	646,672	3,008	913.36	270.93	2746.21	15487.80	18234.01	261.85	32.80	229.05	22.90	68.71	130.56	0.00	6.87
2001	15,465	9,139	9,132	181,291	474,733	656,024	2,836	861.01	266.96	3045.46	15494.90	18540.36	306.35	7.09	299.25	29.93	89.78	170.57	0.00	8.98
2002	15,054	9,771	10,286	171,261	494,645	665,906	2,911	883.69	259.86	3295.19	15594.12	18889.31	348.95	99.22	249.73	24.97	74.92	142.35	0.00	7.49
2003	9,097	10,516	9,289	170,139	512,827	682,966	3,000	910.80	157.03	3388.56	15922.14	19310.70	421.39	328.02	93.37	9.34	28.01	53.22	0.00	2.80
2004	9,739	10,699	9,828	167,604	522,738	690,342	2,846	864.19	168.11	3513.93	16130.64	19644.57	333.87	208.50	125.37	12.54	37.61	71.46	0.00	3.76
2005	10,096	8,382	9,781	163,929	534,404	698,333	2,942	893.19	174.28	3642.12	16373.43	20015.55	370.98	242.79	128.19	12.82	38.46	73.07	0.00	3.85
2006	8,037	7,144	9,811	153,603	545,499	699,103	2,968	901.02	138.73	3792.77	16602.88	20395.64	380.09	229.45	150.65	15.06	45.19	85.87	0.00	4.52
2007	7,175	7,194	8,832	140,932	562,486	703,418	2,981	904.98	123.85	3915.60	16999.49	20915.09	519.45	396.61	122.84	12.28	36.85	70.02	0.00	3.69
2008	6,249	6,206	6,279	130,469	581,350	711,818	2,226	675.81	107.87	3973.38	17634.38	21607.76	692.67	634.90	57.78	5.78	17.33	32.93	0.00	1.73
2009	6,648	4,902	8,431	120,722	597,952	718,674	2,583	784.19	114.75	3869.31	18326.33	22195.64	587.88	691.95	-104.07	-10.41	-31.22	-59.32	0.00	-3.12

K The value 3,869.31 Gg is the afforestation carbon stock for the years 1990 to 2003 inclusive, similarly 3,973.38 is the afforestation carbon stock for the years 1989 to 2002 inclusive, etc
N Carbon stock change after harvest (corresponding in 2009 to difference between carbon stocks of 22,195.64 Gg in 2009 and 21,607.76 Gg in 2008)
P Carbon stock change for young forests (corresponding in 2009 to difference between carbon stocks of 3,869.31 Gg in 2009 and 3,973.38 Gg in 2008)
Q, R, S, T, U The total carbon stock change for 5.A.2 (column P) is split as Cropland (Q) – 0.30; Grassland (R) – 0.10; Wetland (S) – 0.57; Settlements (T) – 0.00; Other Land (U) – 0.03

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

The minimum age for young trees is7 in all examples:

Accretion rate 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%.

Annex H

Summary of Parameter Input Values to Estimate Methane Generation using 2006 IPCC Guidelines Model

Solid Waste Disposal Composition 1990-2009

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 2008	MSW Total (t)	MSW 2008 (t)	[a]DOC Fraction	DOC_f	[b]Decay Rate k	[c]MCF
1	From 1969	13	1956-2008	Open	6,678,152	290,678	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	1972-2008	Open	6,262,785	307,128	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	1975-2007	Closed	7,487,139	-	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	1997-2008	Open	4,384,831	301,829	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	1971-2008	Open	3,424,942	79,977	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	1965-2008	Open	2,602,051	55,324	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	1999-2008	Open	1,925,320	208,751	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	1995-2008	Open	3,028,440	691,232	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	1995-2008	Open			0.05	0.60	0.20	0.8,1.0
14	Street Cleanings	1	1990-2008	Open	1,230,567	69,546	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 and the second is for subsequent years

Table H.2 Time Series of Solid Waste Disposal and Composition 1990-2009

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

Annex I

Ireland’s Response to the Recommendations in the Draft 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	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.	

			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.		
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. (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.

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 IPPCC 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. (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	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency will work with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	

			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.		
Energy	Reference and sectoral approaches: International bunker fuels	51	The ERT considers that the Party has not yet improved the explanation of the method used to distinguish between emissions from domestic and international navigation bunkers, which was recommended in the previous review report. The ERT again recommends that Party explain in detail how emissions from domestic and international segments are disaggregated between the two sources in its next annual submission (see para. 55 below).	Information is provided in NIR 2011. Fuels are split by domestic and international in the National Energy Balance.	Chapter 3, sections 3.2.1.3 and 3.5.
Energy	Reference and sectoral approaches: Feedstocks and non-energy use of fuels	52	Ireland indicated that work was ongoing to analyse whether emissions from the non-energy use of fuels, such as lubricants and bitumen, could be estimated. During the centralized review, the ERT found that a small amount of white spirit included in the energy balance was not included in the inventory estimates. In response to questions raised by the ERT, Ireland explained that it would include the consumption of white spirit in the CRF tables in future submissions. Further, Ireland stated that emission estimates from the non-energy use of fuels would be reassessed and revised if necessary. The ERT recommends that Ireland report on the results of this work in its next annual submission.	White spirit is now included in the CRF Submission for 2011.	
Energy	Key categories: Stationary combustion: all fuels – CO_2	53	Ireland uses CO_2 emissions reported under the EU ETS for the reporting of the energy industries category. However, the ERT noted that the fuel consumption data provided in the CRF tables are taken from the national energy balance. Because the fuel consumption data used to derive CO_2 emissions do not correspond to the energy balance, this results in implied emission factors (IEFs) that are not comparable to those of other reporting Parties. During the centralized review, Ireland confirmed that this was the case and also explained that the estimation of CH_4 and N_2O emissions was based on the energy balance data presented in the CRF tables. This means that the data basis for estimating and reporting CO_2 and non-CO_2 emissions is not consistent. However, the ERT noted that fuel consumption is not consistently lower or higher in the EU ETS data compared to the energy balance for individual categories, but varies between fuels and categories, and that, overall, the fuel consumption data in the EU ETS are slightly higher than in the energy balance. Therefore, the ERT believes that emissions of CH_4 and N_2O are not underestimated, while CO_2 emissions are accurately estimated. The ERT strongly recommends that Ireland uses consistent data for all GHG for the next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	
Energy	Non-key categories: Civil aviation: liquid fuels – CO_2, CH_4 and N_2O	55	Ireland has reported all fuel consumption and associated emissions for civil aviation under jet fuel. The ERT noted that the energy balance contains information on the use of both aviation gasoline and jet fuel. During the centralized review, Ireland informed the ERT that the fuel consumption used for civil aviation is calculated by the EPA, and that this is the source of the split in the energy balance. The ERT recommends that Ireland, in its next annual submission, report the consumption of aviation gasoline and the associated emissions separately to increase transparency.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has plans to improve reporting of domestic aviation in	Chapter 3, section 3.2.1.3 and 3.8.

				Submission 2012.	
Energy	Non-key categories: Road transportation: all fuels – CH4 and N2O	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 – CO2, CH4 and N2O	57	The ERT noted that the energy balance contains data on marine bunkers, but no information on the use of fuels in national navigation. However, Ireland has reported a consumption of 57.95 TJ of gas/diesel oil in 2008 under navigation, although no explanations are provided in the NIR on how this figure was derived from the energy balance. The ERT recommends that the Party provides clear explanations on how activity data for navigation is established, in the NIR for the next annual submission.	Additional information is provided in NIR 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	Chapter 3, sections 3.2.1.3 and 3.5.
Energy	Non-key categories: Navigation: liquid fuels – CO2, CH4 and N2O	58	The ERT also found that the trend of total liquid fuel consumption displays a drop of 52.1 per cent between 2001 (1,662.08 TJ) and 2002 (795.33 TJ) and by 93.4 per cent between 2005 (792.24 TJ) and 2006 (52.65 TJ). The consumption of residual oil in 2005 is 742.24 TJ, and is reported as “NO” for the following years (2006–-2008). During the centralized review, Ireland explained to the ERT that the consumption of residual oil had been incorrectly allocated for the period 1990–-2005. The ERT recommends that Ireland improve the reporting of data for national navigation and provide explanations in the NIR for the fluctuations in the time series in the next annual submission.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency has already arranged meetings with Energy Balance provider to address these issues in 2011, for reporting in Submission 2012.	
IP and Solvent and other product use	Sector overview	61	The Party has reported a number of categories as “"NE"”, such as: CO2 emissions from asphalt roofing, road paving with asphalt, and food and drink; and N2O emissions from the use of N2O 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 SF6 emissions from sporting goods (consumption of halocarbons and SF6) are reported as “"NE"”. Actual emissions are reported for 2008, while the Party stated in the NIR that the use of SF6 in sporting goods was discontinued in 2007. Ireland also reported potential emissions of HFCs from other (2.G) as “"NA"” and "“NE"”,	Notation keys have been corrected in the CRF Submission for 2011.	

			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.		
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. (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. 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	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011.	

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

			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"").		
Agriculture	Key categories: Enteric Fermentation	79	Ireland has used a tier 1 approach to estimate emissions for other livestock categories (e.g. swine and sheep), departing from the IPCC default EFs for these species and adjusting it for subcategory classes on the basis of the animals' weight. As a result, the aggregated IEFs for sheep (5.90 kg/head/year) and swine (0.45 kg/head/year) are lower than the IPCC default EFs (8.00 kg/head/year and 1.50 kg/head/year, for sheep and swine, respectively). During the centralized review, the Party provided supplementary information on animal weights for each subcategory. It is unclear to the ERT how Ireland's modification of the default EFs by subcategory constitutes an improvement from the use of the IPCC default EFs. The ERT strongly recommends that Ireland provide information to support the use of these adjusted default EFs but strongly encourages the development and implementation of a tier 2 approach for sheep, which is a key category, for the next annual submission.	Ireland has revised estimates for Swine for IPCC categories 4.A.8 and 4.B.8 in this submission. Additional information is provided in NIR 2011.	Chapter 6, sections 6.2.6 and 6.9 and Annex F, Table F.2(a).
Agriculture	Key categories: Manure management – CH4 and N2O (80, 81,82)	80, 81, 82	(80) During the centralized review, the ERT identified potential problems with the CH4 IEF for dairy cattle: (a) the value reported in CRF table 4.B(a) is 20.7 kg CH4/head/year, but the ERT estimated it to be equal to 27 kg CH4/head/year using the values provided by Ireland for the following parameters: CH4 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 CH4 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 N2O emissions from manure management (liquid (40.6 per cent), solid storage (2.7 per cent) and pasture range and paddock (56.7 per cent)). (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 CH4 and N2O 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. (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: CH4 and N2O emissions from manure management; N2O	Additional QA\QC was undertaken for Submission 2011.	Chapter 6, section 6.7.

			emissions from pasture range and paddock; and N2O 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.		
Agriculture	Key categories: Direct soil emissions – N2O	84	AD and emissions from sewage sludge spreading applied to soils are currently aggregated together with the N input to soils as animal manure. This reporting procedure impairs comparability with the reports of other reporting Parties and creates difficulties for the ERT when comparing this information with the information concerning the other categories related to animal activity. The ERT encourages the Party to report this category separately to improve the transparency of its reporting.	The timing of Ireland's draft ARR 2010 did not allow sufficient time for this recommendation to be implemented in submission 2011. The inventory agency will consider separate reporting of sewage sludge in Submission 2012.	
Agriculture	Key categories: Indirect soil emissions – 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 (FracLEACH) 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. 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	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.

			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.		
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.
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	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.

			Protocol activities.		
LULUCF	Sector overview	92	The ERT also noted inconsistencies between estimates reported under the Convention and corresponding activities under the Kyoto Protocol, and also between the NIR and the CRF tables. For example, CRF table 5.D shows that forest land converted to wetlands is reported as “"NE"” in 2006, 2007 and 2008, due to a lack of AD. However, CRF table 5(KP-I)A.2, reporting information on LULUCF activities under the Kyoto Protocol, indicates that 366 ha of forest land were converted to wetlands in 2006-–2007 and 4 ha of forest land were converted to wetlands in 2008; further, table 7.7 of the NIR indicates that 217.82 ha and 153.40 ha of forest land were converted to wetlands in 2006 and 2007, respectively. Likewise, Ireland has reported non-CO2 emissions from wildfires on afforested land in CRF table 5(KP-II)5, but it has used the notation key “"NE"” to report emissions from wildfires in areas of land converted to forest land in CRF table 5(V) under the Convention. The ERT recommends that Ireland correct these inconsistencies in its next annual submission by enhancing QC procedures.	Notation Keys have been amended in CRF Submission 2011.	
LULUCF	Key categories: Forest land remaining forest land – CO2	93	This category accounts for significant net carbon sinks. The ERT noted that Ireland relies on higher-tier methods for the living biomass and DOM pools, but carbon stock changes in soils are not estimated and are assumed to be zero as Ireland uses the tier 1 method. In light of the importance of the forest land remaining forest land category in the Irish GHG inventory, the ERT encourages Ireland to further pursue its methodological improvements in this pool.	Country specific research suggests mineral soils under forestry are typically a sink for carbon, however there is insufficient data to accurately represent the national forest area. Therefore a conservative estimate of carbon loss it to assume that it not occurring.	
LULUCF	Key categories: Land converted to forest land – CO2	94	In accordance with the explanations on inter-annual variability provided by Ireland during the centralized review, the ERT understands that Ireland estimates carbon stock changes in the category land converted to forest land in a given year by subtracting the total carbon stocks from the previous year to the total carbon stocks in the current year, regardless of whether these stock changes occur on the same land units. The ERT considers that this practice confuses two processes: the movement of land between the forest land remaining forest land and land converted to forest land categories (showing as a carbon loss in forest land converted to other land and a carbon gain in forest land remaining forest land), and the carbon gains and losses on land units that have remained in the land converted to forest land category during the entire year. The ERT recommends that Ireland re-examine the method used to calculate carbon stock changes for each year, and also recommends that the Party base its estimates on consistently defined land areas (e.g. land converted to forest land on 1 January each year). The ERT considers that this will reduce spurious variations that do not reflect actual carbon gains or losses in managed forests and will improve comparability between the LULUCF sector and KP-LULUCF activities.	There is no case for areas or emission/reductions from forest land converted to forest land in convention reporting to be the same as KP LULUCF since they reflect different time series. To our knowledge this is not required according to GPG. However, we understand that differences between convention and KP reporting need to be explained better. See Chapters 7 and 11 of NIR 2011.	Chapter 7 and 11.

LULUCF	Key categories: Land converted to forest land – CO_2	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 – CO_2	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 CO_2 in 1992 to 359.57 Gg CO_2 eq in 2008. The Party has not provided explanations in the NIR for this trend. The ERT recommends that Ireland provide such explanations in its next annual submission.	Additional information on Cropland is provided in NIR 2011.	Chapter 7 Section 7.4.1
LULUCF	Non key categories: Grassland remaining grassland – CO_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 to 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 – CH5	104	Ireland has recalculated the CH4 recovery estimates from solid waste disposal on land based on a detailed study prepared by Fehily Timony Consultants. This study quantified the CH4 recovered through landfill gas flaring for all years since the practice was introduced and validated the CH4 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 – CH4	106	Ireland has reported CH4 emissions from domestic septic tanks as "NO"". In response to a question raised by the ERT during the centralized review, the Party explained that this decision was based on expert judgement: in Ireland, the temperature of the surrounding soil is constantly below 15 °C throughout the year, except for short periods and only in certain areas of country. These climatic conditions therefore prevent the process of methanogenesis. During the centralized review, the Party provided the ERT with sufficient information and documentation to support this claim. The ERT encourages Ireland to include the information provided to the ERT during the review in its next annual submission.	Additional information is provided in NIR 2011.	Chapter 8, section 8.3.1.
Waste	Non-key categories: Waste incineration – 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. (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	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.

			that Ireland clarify in the NIR of its next annual submission how it monitors afforested land prior to 2006. (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.		
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
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	Additional information is provided in NIR 2011.	Chapter 11, sections

			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.		
Art 7.1 KP	Information on Kyoto Protocol units: National Registry	120	The SIAR identified the following problem: the national registry did not fulfil the requirements regarding the public availability of information in accordance with section II.E of the annex to decisions 13/CMP.1. In particular, the SIAR recommends that the Party include the information required by paragraph 47(a), (d), (f), and (l) of the annex to decision 13/CMP.1. The ERT reiterates this recommendation that should be implemented in Ireland's next annual submission.	Additional information is provided in NIR 2011.	Chapter 14, sections 14.3 and 14.4.
Conclusions and recommendations		141	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: (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); (b) Improve the transparency of the reporting on the national system by including more detailed information on the archiving system; (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; (d) Improve the uncertainty analysis with the consideration of a higher level of disaggregation for the LULUCF sector; (e) Improve completeness of the inventory, in particular by estimating the remaining emissions reported as "NE" (see paragraph 13 above); (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; (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; (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.

Appendix 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 there of, 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.

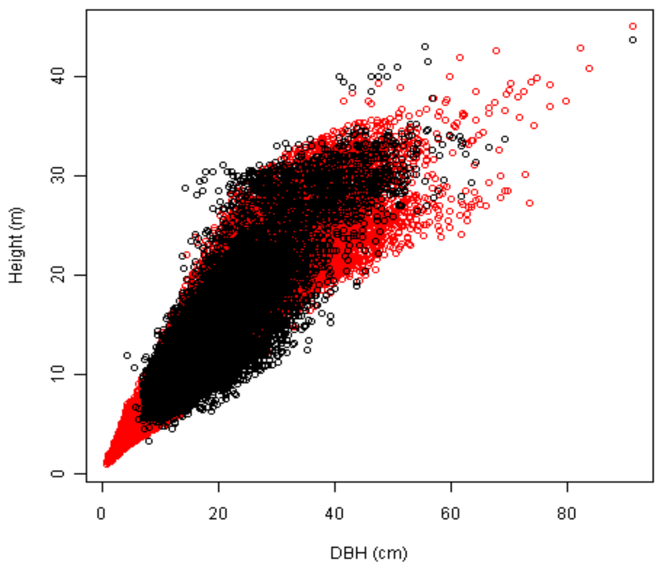

Figure J.1-A.1. Model 2 Height estimates (red) and actual heights (black).
The estimates presented here depict a "cloud" because they are conditioned on covariates that vary between trees (BAL) and plots (Density, Basal Area) and over time (BAL, Density, BA).

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	$H=(a_1+a_2BAL+a_3BA)(1-\exp(b.DBH^{(c_1-c_2BAL)}))$	33.69	-0.274	0.1603	0.024	0.8846	0.0064
Pine	$H=(a_1+a_2BAL+a_3BA)(1-\exp(-b.BAL))$	16.905	0.083	0.0803	0.042		
Larch	$H=(a_1+a_2BAL+a_3BA)(1-\exp(-b.BAL))$	32.59	0.1052	0.1229	0.023		
Conifers	$H=(a_1+a_2BAL+a_3BA)(1-\exp(-b.DBH^{c_1}))$	23.226	0.1381	0.0703	0.027	1.1021	
FGB	$H=(a_1+a_2BAL+a_3BA)(1-\exp(-b.DBH))$	14.661	0.1167	0.0187	0.076		
SGB	$H=(a_1+a_2BAL)(1-\exp(-b.DBH^{c}))$	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)

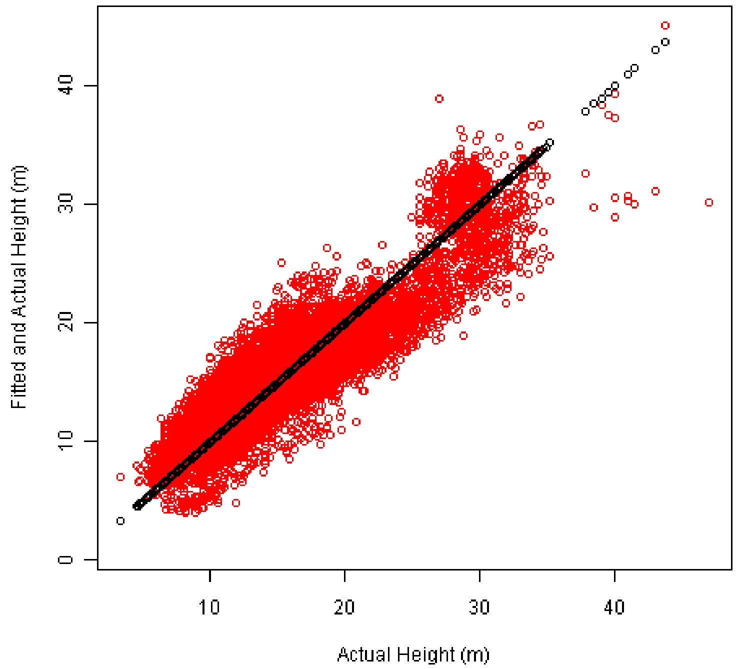

Figure J.1-A.2. Fitted and actual height plotted (all cohorts model 2) against actual height.

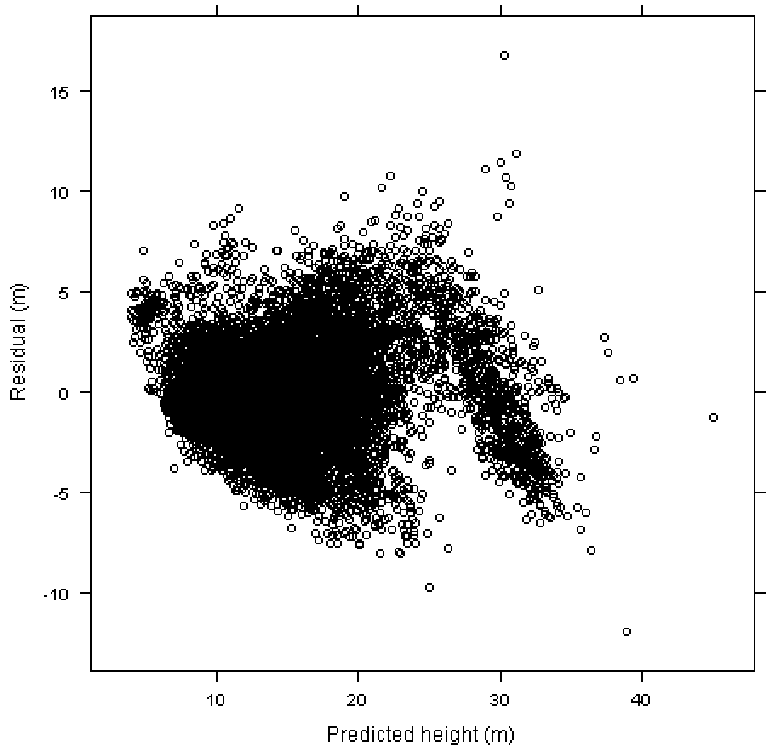

Figure J.1-A.3. Raw residuals from the fitted model plotted against the fitted height value.

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.

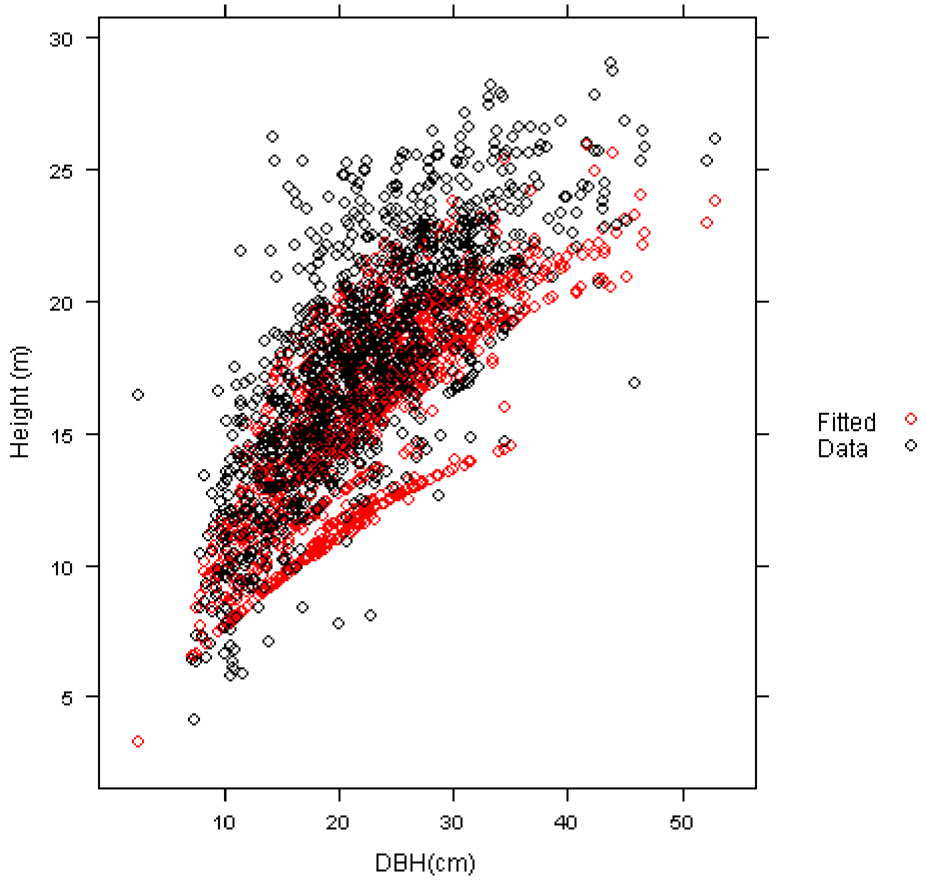

Figure J.1-A.4. Estimated and observed validation heights versus DBH.

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.

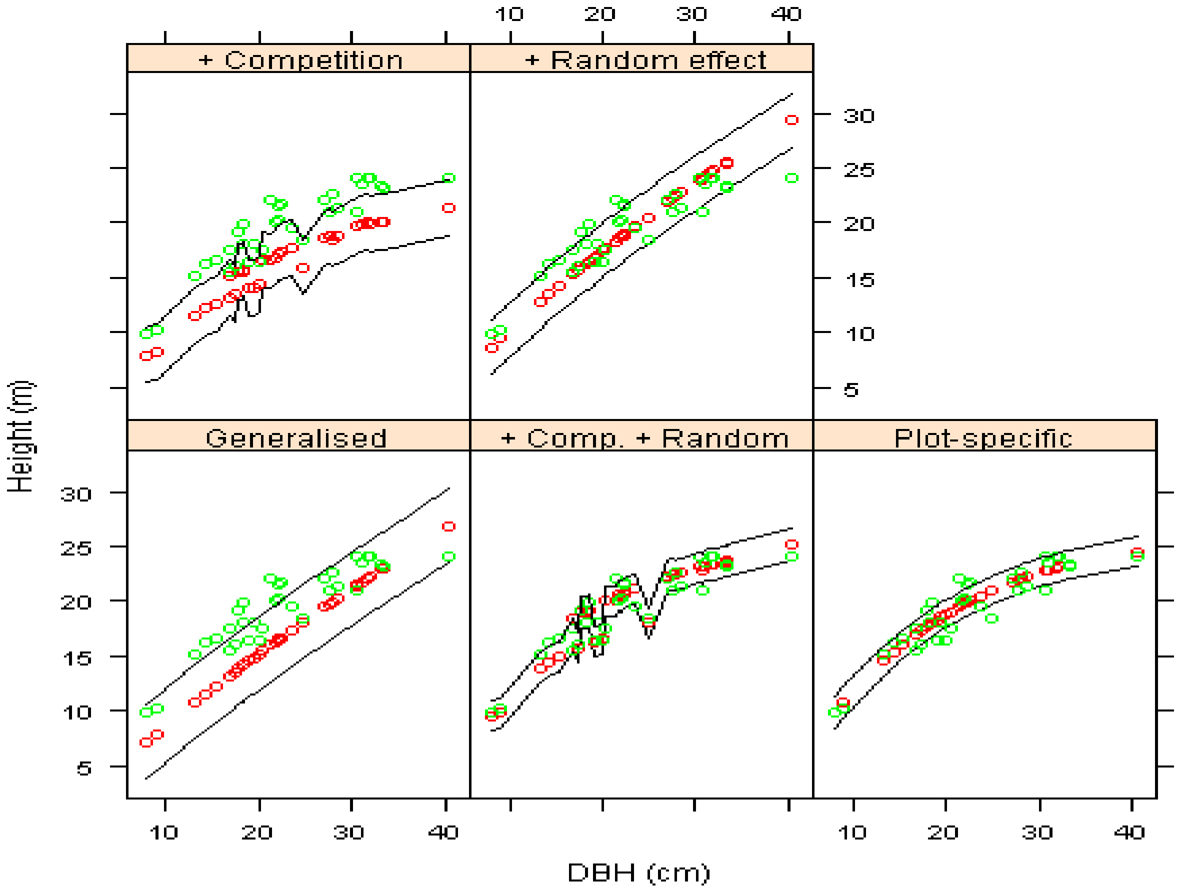

Figure J.1-A.5. Model predictions for a single plot with various models, all based on the Yang/Weibull funtion (cf. Table J.1-A.1).

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).

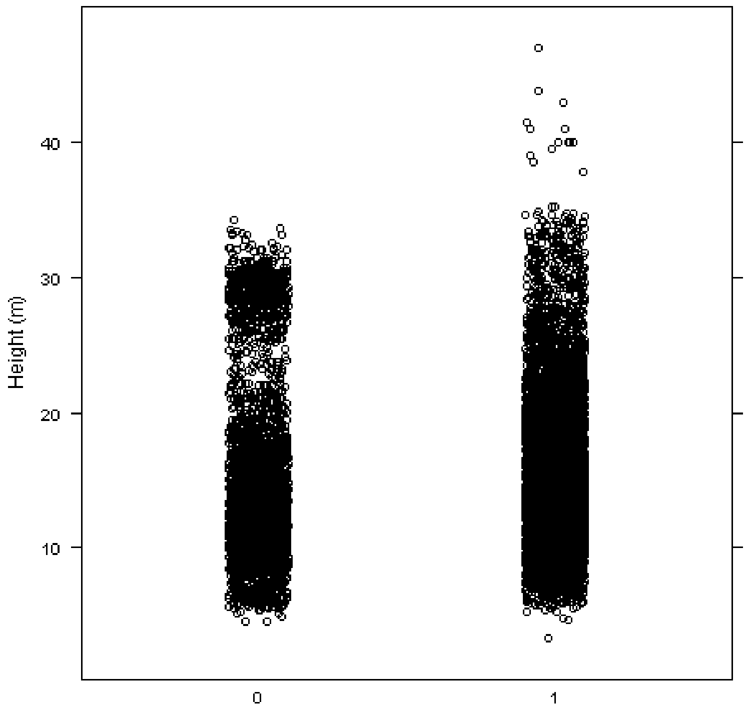

Figure J.1-A.6. Strip-plot of Heights in the calibration dataset.
1 = Thinned, 0 = Unthinned.

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).

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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. Theses 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

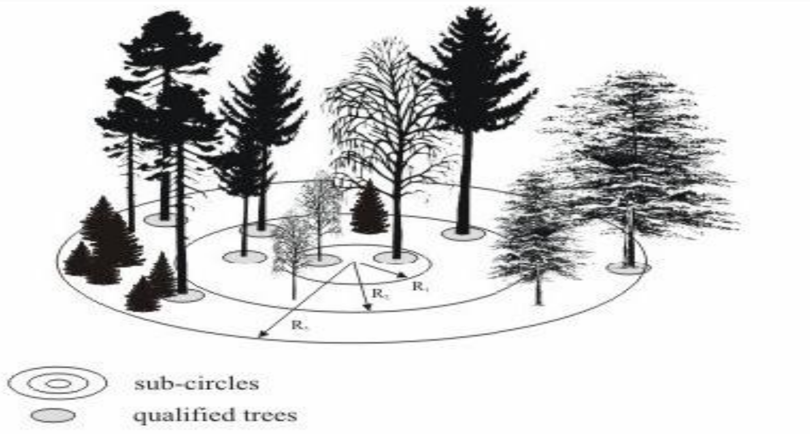
.

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 : $cw = \exp(\mathbf{0.1366})*((DBH)^{0.6183})$

(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.

$$Dinc = exp(a_0 + a_1 lnDBH + a_2 DBH\wedge^2 + a_3 .lnCR + a_4 .lnCCF + a_5 .BAL) + e$$

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 criteria 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 : $(1/n)[\Sigma(pred_{(-1)}\text{-}obs)^2 \text{-} \Sigma(pred\text{-}obs)^2]$. Where pred(-1) is the leave one out prediction error

Note that *empirical excess error* is only viable when doing external validation.

Temesgen and von Gadow (2004), for example, use *root mean squared error* (RMSE) and Bias to evaluate their models.

Bias : (Σ(pred-obs)/n)
RMSE : $\sqrt{(\Sigma(pred\text{-}obs)^2/n\text{-}p)}$. 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.

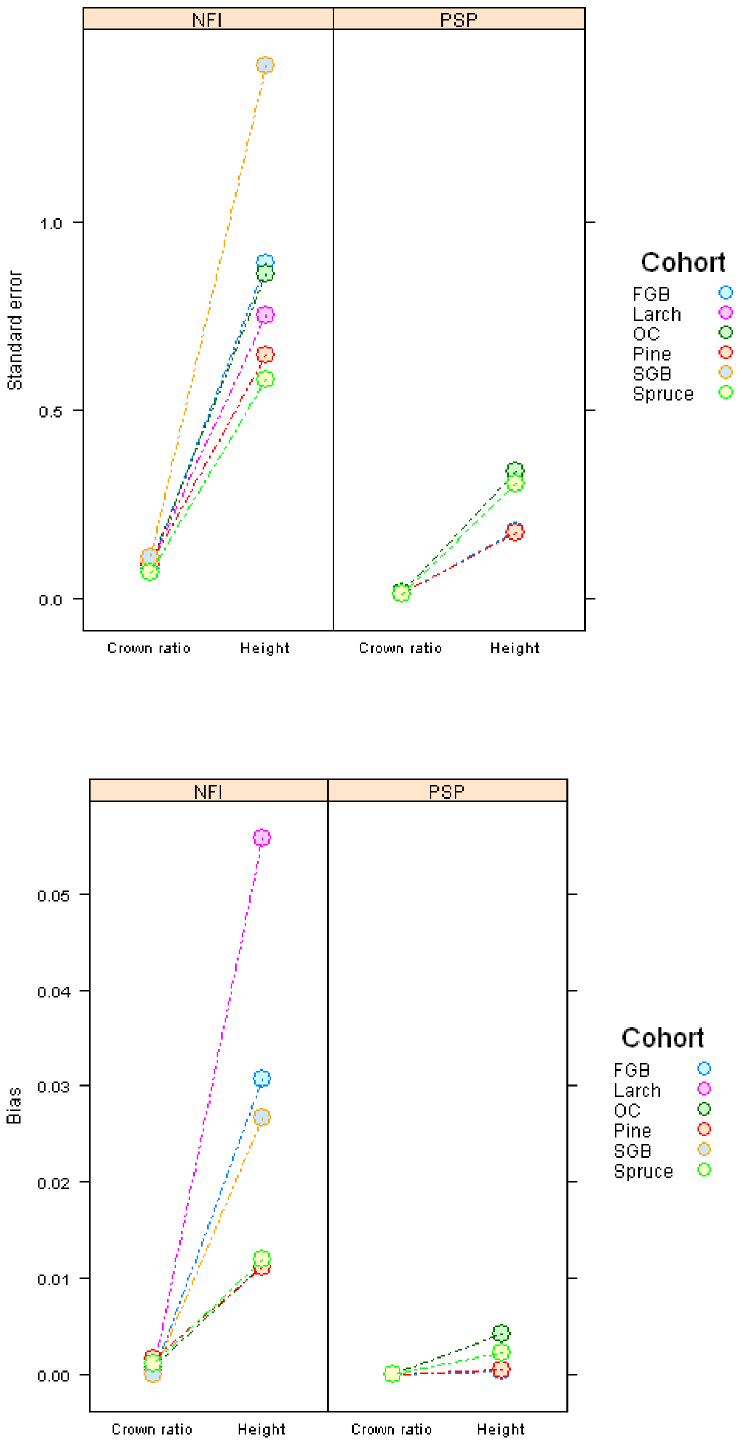


Figure J.1-B.2. Within-sample Precision (upper panel) and Bias (lower panel) for imputation.

Values are plotted for each dataset, for cohorts, and for models of Height and Crown ratio.

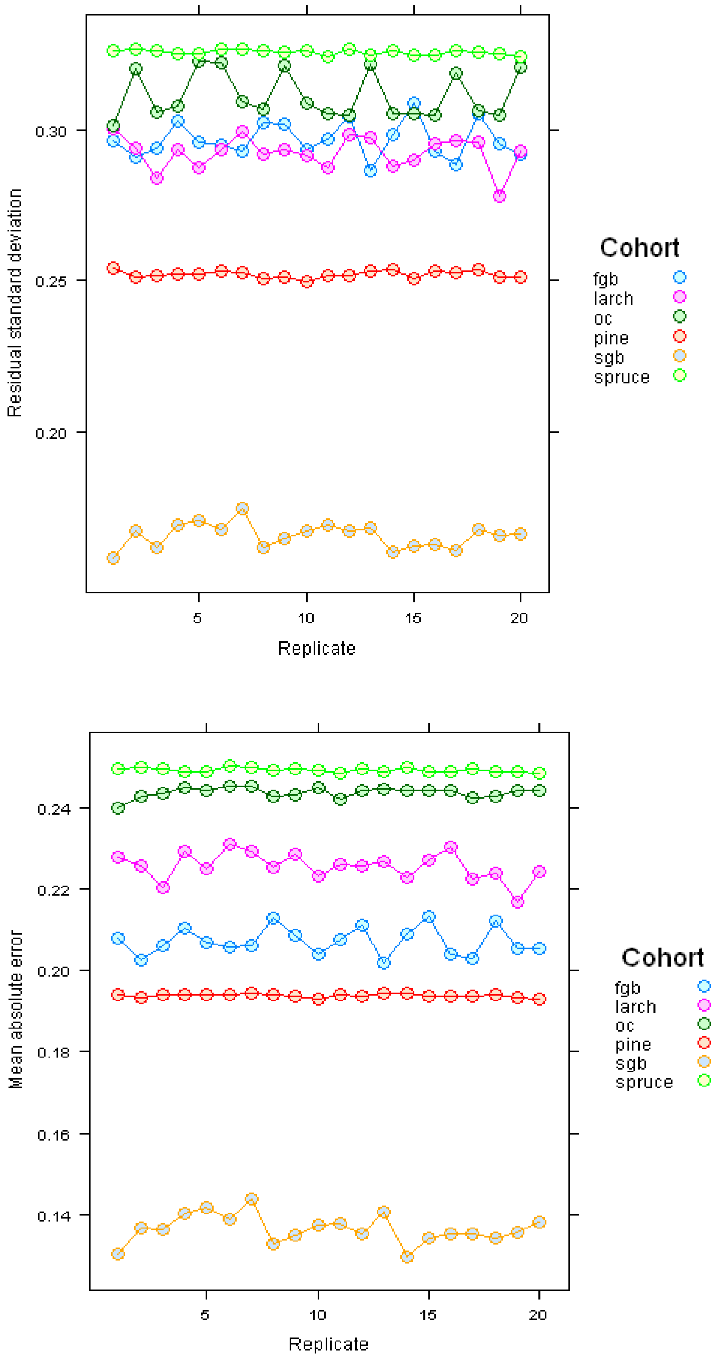


Figure J.1-B.3. Leave k-out crossvalidation results, precision (top) and mean absolute error (bottom) for the Dinc model.
The probability of inclusion in the validation dataset is 0.33. 20 cross-validation replicates are displayed.

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

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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 appendix E3). 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	YC*eq*				Precision	RMSE	Bias
		a_1	a_2	a_3			
>1.2	>24	1.02	5.59	2.04	1.8	4.69	0.32
1-1.2	24	1.05	7.05	2.32	1.42	4.23	-0.23
0.8-1	22	0.76	5.98	1.63	1.33	3.21	0.11
0.6-0.8	20	0.66	5.51	1.33	0.66	2.55	0.56
0.5-0.6	18	0.57	5.26	1.12	0.89	1.69	0.45
0.4-0.5	16	0.53	5.35	1.47	1.11	3.66	0.32
0.3-0.4	14	0.48	5.32	0.54	0.74	3.54	0.62
0.2-0.3	12	0.44	6.59	2.20	1.53	4.53	0.24
0.1-0.2	10	0.35	6.93	2.27	0.69	1.77	-0.43
<0.1	<10	0.28	8.02	0.35	1.9	4.23	-0.7

Appendix 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., approx 93%, although it is not clear from the text) as the threshold. On this basis, their model correctly classifieded 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, that 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 someway, 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].

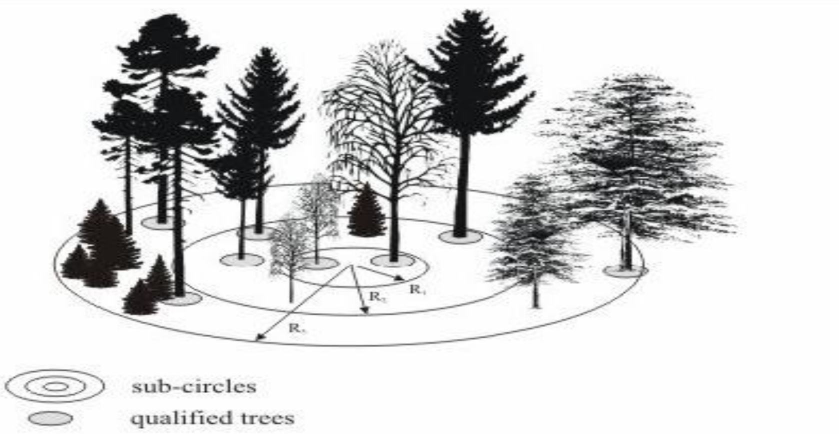
Although there are several categories of disease or mortality causes in the PSP database {including, Windblown, Uprooted, Diseased, Broken and Dead}, we modelled only the binary response Dead/Alive for the initial model. In this way, after derived variables { basal area, plot density, etc. {were calculated, 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:

$$\frac{R_3^2}{R_i^2} \quad \text{.....(1)}$$

where Ri denotes the radius of the concentric circle associated with the ith diameter class.

In practice, the expansion factor, or weight, is used to estimate plot-level features, e.g. basal area. In such calculations, we estimate the number of trees of the ith diameter class that were not included in the sample by $\frac{R_3^2}{R_i^2}$ * ni, where ni is the number of trees of the ith class



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

Figure 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).

$$n_{ij} \times EF_{ij} = \hat{N}_{ij} \quad \text{.....(2)}$$

where n_{ij} _ EF_{ij} is the product of the expansion factor for the *j* th tree in the *I* th class, and $\check{N}_{ij}$ is the corresponding estimate. In the terminology of the NFI, the RHS of Equation 2 is the representative tree number. With minor and obvious changes to the equation, we can calculate other tree-level estimates, including representative basal area, and individual-tree estimates can be aggregated for the entire plot to give plot-level estimates, including representative density.

The question to address in the current paper is whether we can arrive at a sensible definition of representative mortality. At issue is how to derive a binary individual-tree-level mortality rule based on information in the NFI dataset, given the fact that there is missing information due to the sampling scheme. With this in mind, Figure 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.

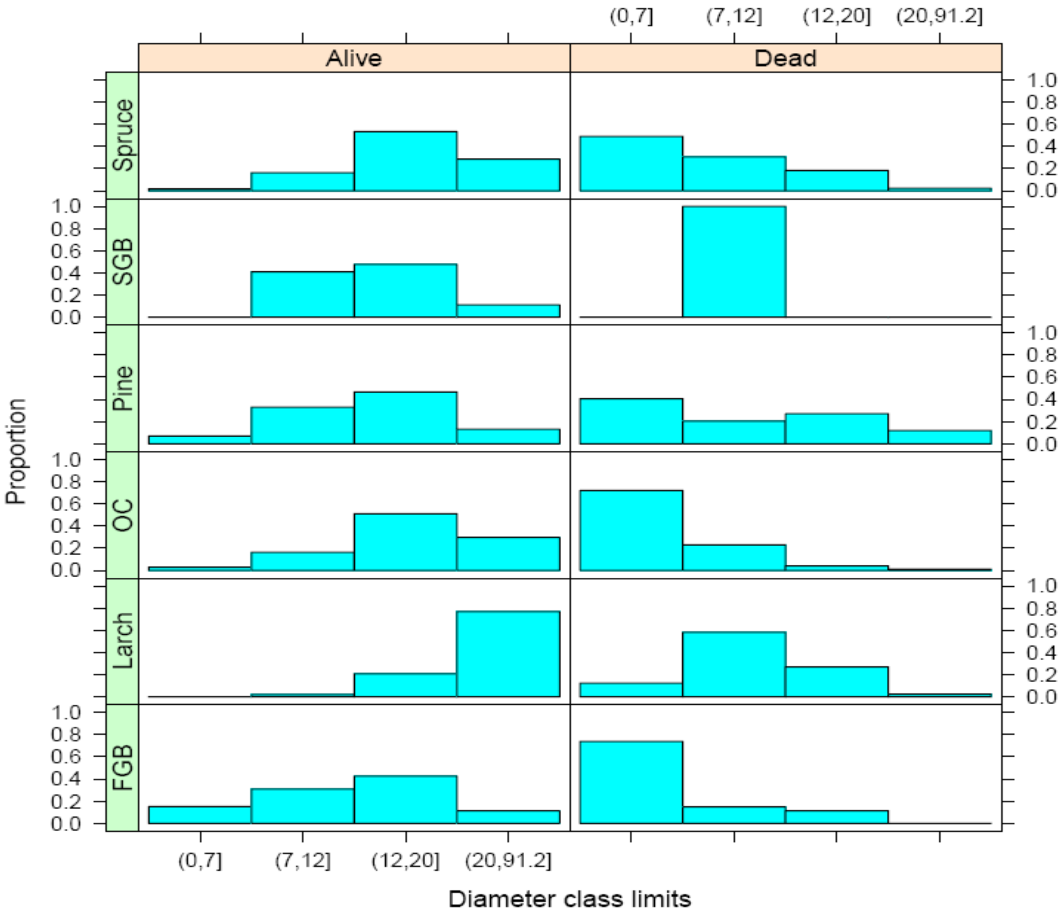


Figure J.2-A.2 The empirical distribution in the PSP dataset of diameter classes of dead/alive trees classified by cohorts.

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.

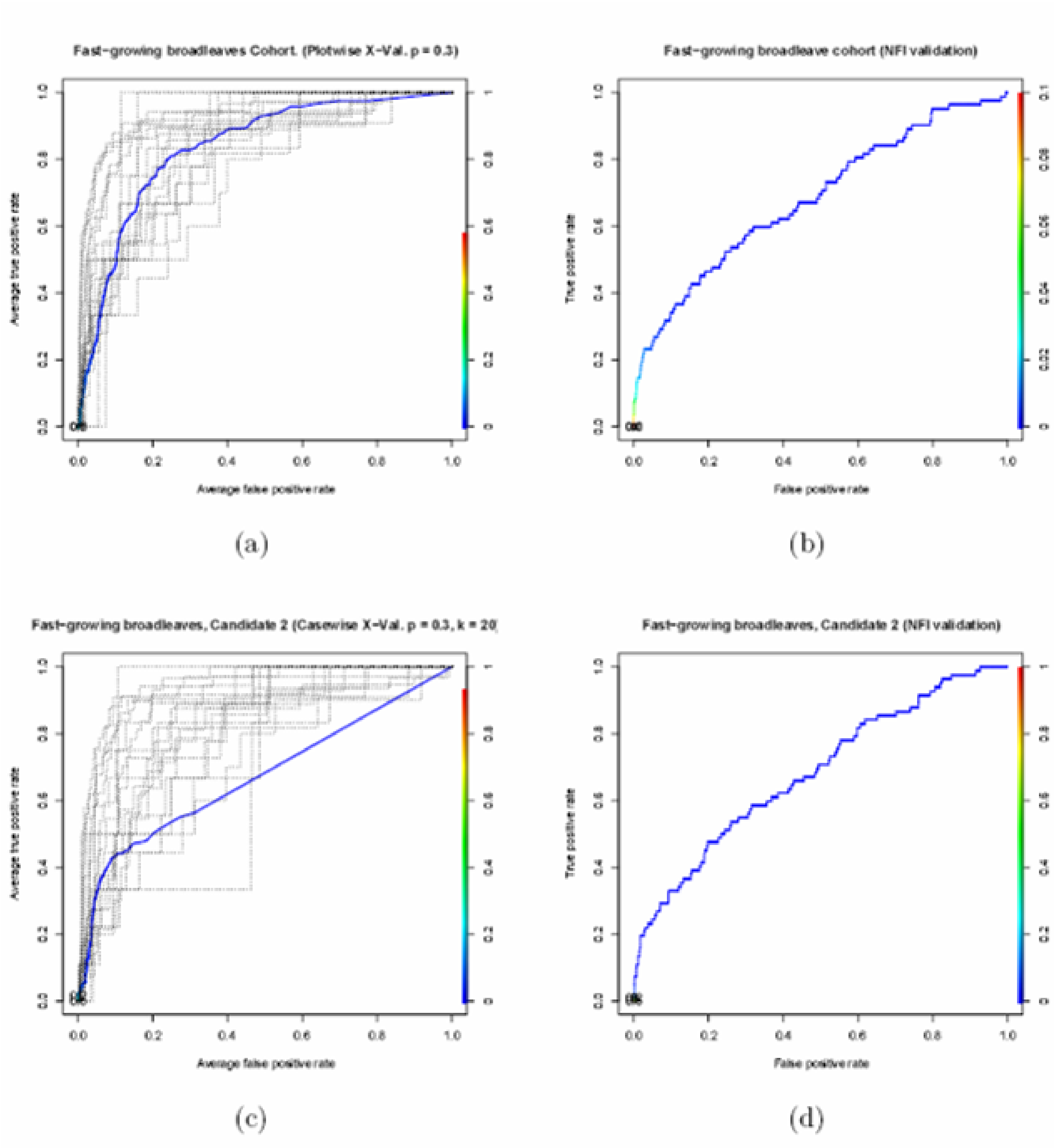


Figure J.2-A.3. The Receiver operating characteristic curve for Candidate model 1 (panels (a),(b)) and model 2 (panel (c),(d)) in the Fast-growing broadleaves cohort.

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 I.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.

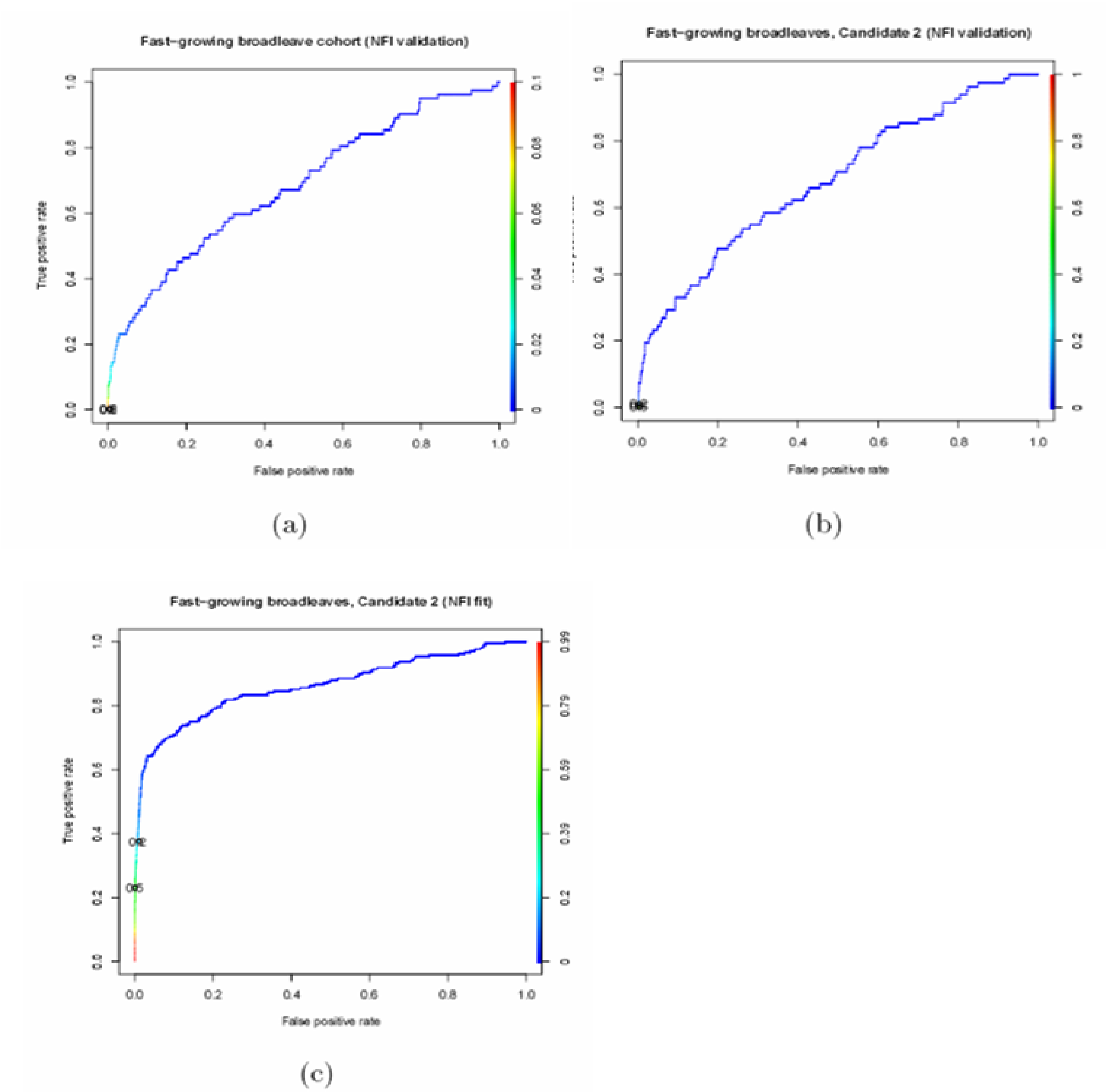


Figure J.2-A.4. The Receiver operating characteristic curve for Fast-growing broadleaves cohort Candidate models 1 and 2 fitted on PSP, and for the NFI-fitted model.

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].

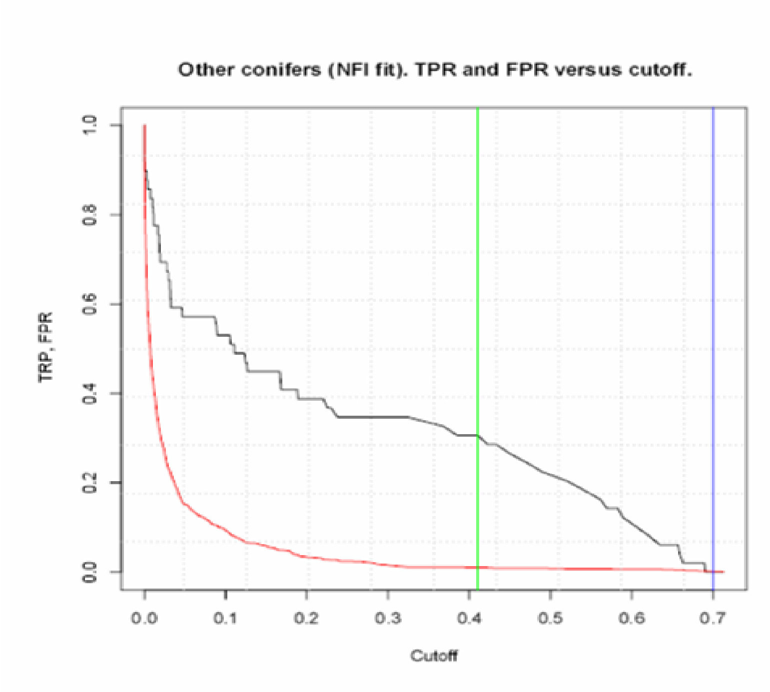


Figure J.2-A.5 TPR (Black) and FPR (Red) versus cut-off for Fast-growing broadleaves.
The vertical green line shows the cut-of where FPR < 0.01, the blue vertical line shows the cut-off where FPR< 0.001.

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.

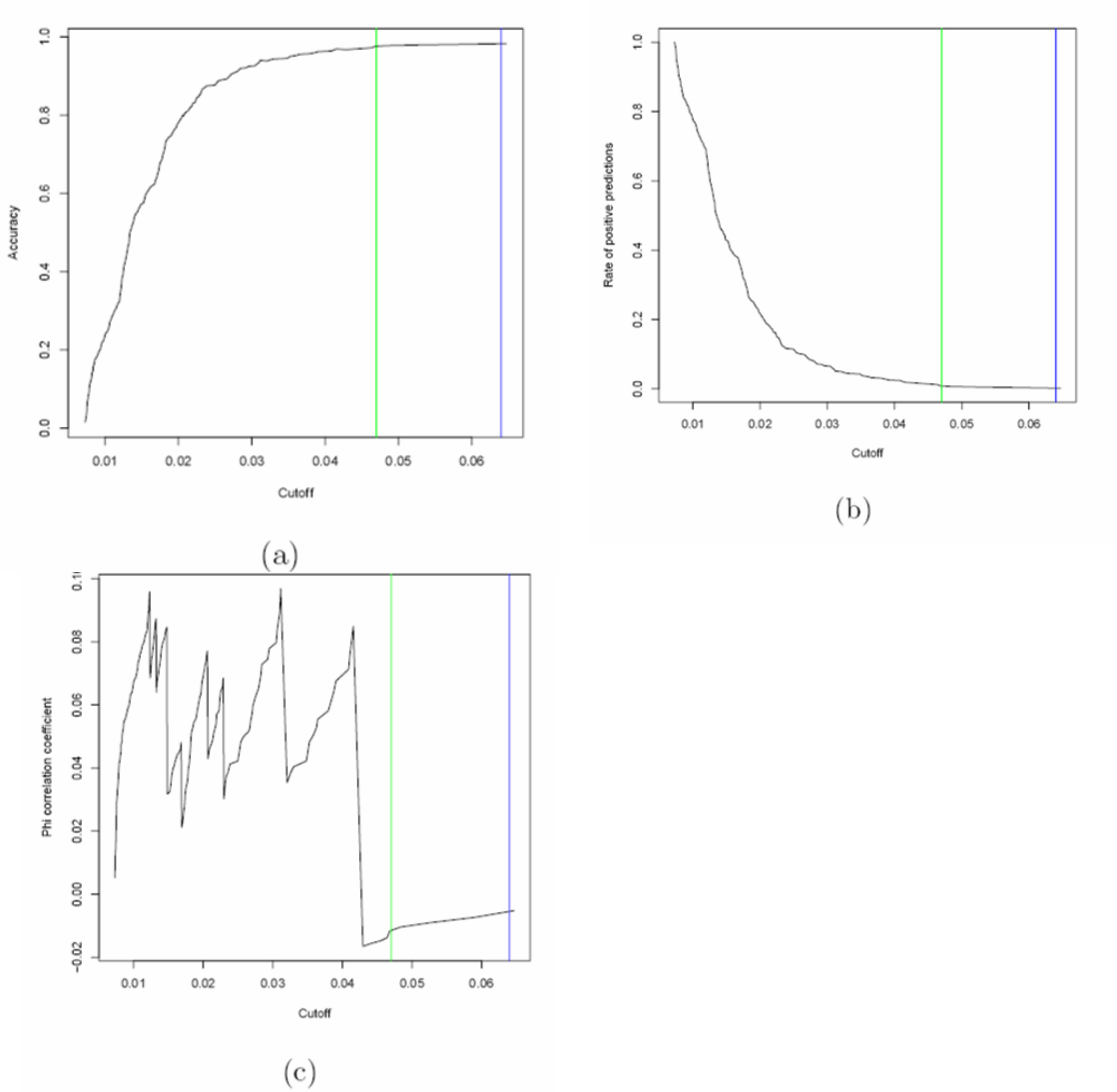


Figure J.2-A.6 Illustrating some other performance measures of the NFI-calibrated model for the Larch cohort across the cut-off range and in particular the 0.01 (green vertical) and 0.001(blue vertical) cut-off points.

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 (Appendix E2 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) 2010

UNFCCC SEF application
Version 1.2

Workflow

Functions

Export XML

Settings

Party:	Ireland
ISO:	IE
Submission year:	2011
Reported year:	2010
Commitment period:	1
Completeness check:	YES
Consistency check:	YES
File locked:	YES
Lock timestamp:	06/01/2011 16:36
Submission version number:	1
Submission type:	Official

Party	Ireland
Submission year	2011
Reported year	2010
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	2.74E+08	NO	NO	NO	NO	NO
Entity holding accounts	21195872	NO	NO	6480622	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	245	NO	NO	NO	NO	NO
Retirement account	19668515	NO	NO	713192	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	3.15E+08	NO	NO	7193814	NO	NO

Party	Ireland
Submission year	2011
Reported year	2010
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	2059	NO	NO
Sub-total		NO	NO				245	NO	NO	2059	NO	NO

Transaction type	Retirement					
	Unit type					
	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
Retirement	16991714	NO	NO	223643	NO	NO

Party	Ireland
Submission year	2011
Reported year	2010
Commitment period	1

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												
CDM	NO	NO	NO	1750000	NO	NO	NO	NO	NO	NO	NO	NO
AT	23000	NO	NO	NO	NO	NO	NO	NO	NO	85706	NO	NO
CZ	216000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
DK	28000	NO	NO	220666	NO	NO	373000	NO	NO	1	NO	NO
FI	NO	NO	NO	NO	NO	NO	635000	NO	NO	NO	NO	NO
FR	470740	NO	NO	441423	NO	NO	1105300	NO	NO	NO	NO	NO
DE	345400	NO	NO	10000	NO	NO	671000	NO	NO	301500	NO	NO
IT	NO	NO	NO	NO	NO	NO	19800	NO	NO	NO	NO	NO
JP	NO	NO	NO	NO	NO	NO	NO	NO	NO	4666529	NO	NO
NL	312800	7440	NO	296133	NO	NO	248018	NO	NO	NO	NO	NO
NZ	NO	NO	NO	88	NO	NO	NO	NO	NO	NO	NO	NO
PL	1630435	NO	NO	NO	NO	NO	80000	NO	NO	NO	NO	NO
PT	140000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
SK	193500	NO	NO	1	NO	NO	NO	NO	NO	1	NO	NO
ES	646500	NO	NO	NO	NO	NO	421000	NO	NO	882184	NO	NO
SE	73500	NO	NO	23706	NO	NO	NO	NO	NO	4718	NO	NO
CH	NO	NO	NO	1289749	NO	NO	NO	NO	NO	239463	NO	NO
GB	1359449	715000	NO	5210182	NO	NO	5785925	NO	NO	2929013	NO	NO
Sub-total	5439324	722440	NO	9241948	NO	NO	9339043	NO	NO	9109115	NO	NO

Additional information

Independently verified ERUs								NO				

Table 2 (c). Total annual transactions

Total (Sum of tables 2a and 2b)	5439324	722440	NO	9241948	NO	NO	9339288	NO	NO	9111174	NO	NO

Party Ireland
Submission year 2011
Reported year 2010
Commitment period 1

Table 3. Expiry, cancellation and replacement

Transaction or event type	Expiry, cancellation and requirement to replace — Unit type: tCERs	Expiry, cancellation and requirement to replace — Unit type: lCERs	Replacement — Unit type: 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	2011
Reported year	2010
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	2.53E+08	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	3.11E+08	722440	NO	7326647	NO	NO

Party	Ireland
Submission year	2011
Reported year	2010
Commitment period	1

Table 5 (a). Summary information on additions and subtractions

	Additions						Subtractions					
	Unit type						Unit type					
Starting values	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
Issuance pursuant to Article 3.7 and 3.8	3.14E+08											
Non-compliance cancellation							NO	NO	NO	NO		
Carry-over	NO	NO		NO								
Sub-total	3.14E+08	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)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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	10706116	722440	NO	22305982	NO	NO	13854735	NO	NO	14981394	NO	NO
Total	3.25E+08	722440	NO	22305982	NO	NO	13854735	NO	NO	14981394	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)	NO	NO	NO	NO	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	36660229	NO	NO	936835	NO	NO

Party	Ireland
Submission year	2011
Reported year	2010
Commitment period	1

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

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

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)