IRELAND

NATIONAL INVENTORY REPORT 2008

GREENHOUSE GAS EMISSIONS 1990 – 2006
REPORTED TO THE UNITED NATIONS
FRAMEWORK CONVENTION
ON CLIMATE CHANGE

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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 2008 and refers to the inventory time-series for the years 1990-2006. It is an update of the 2007 report and is compiled according to the structure adopted by Decision 18/CP.9. As such, it includes sections describing 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 source categories as defined by the Intergovernmental Panel on Climate Change (IPCC). A number of Annexes are part of the report, which includes calculation sheets and other appropriate reference material to support the description of methods and to provide adequate transparency, 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 submission of results to meet UNFCCC and EU reporting requirements. In addition to complying with the UNFCCC reporting guidelines, the 2008 NIR is intended to inform Irish Government departments and institutions involved in the national system, as well as other 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 sources and the up-to-date trend data provides useful support for the implementation of the Government's strategy to limit the increase in emissions in some key sectors. An informative 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.

ES.2 Emissions Profile and Key Categories

In 2006, total emissions of greenhouse gases (excluding the *LULUCF* sector) in Ireland were 69,762.35 Gigagrams (Gg) CO_2 equivalent. The *Energy* sector accounted for 66.1 percent of total emissions, *Agriculture* contributed 26.4 percent while a further 4.7 percent emanated from *Industrial Processes* and 2.6 percent was due to *Waste*. Emissions of CO_2 accounted for 66.8 percent of the national total in 2006, with CH_4 and N_2O contributing 18.8 percent and 12.7 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for 1.0 percent of total emissions in 2006.

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 26 key categories in 2006 (excluding the *LULUCF* sector). There were 14 key categories of CO_2, accounting for 66.6 percent of total emissions. There were seven key categories of CH_4, four key categories of N_2O and 1 key category of HFC in level assessment, which accounted for 18.4 percent, 10.0 percent and 0.7 percent, respectively, of total emissions. 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 26 key categories identified by level assessment in 2006 and for 63.3 percent of total emissions. The top ten key categories contributed almost 70 percent of total emissions in 2006 with emissions of CO_2 from the combustion of petrol and diesel by road traffic being the single largest source, accounting for 18.8 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 6.1 percent in the 2006 inventory and a trend uncertainty of 3.6 percent for the period 1990 to 2006. These values represent some reductions on those in previous submissions. The overall outcome is determined largely by the high uncertainty in the estimate of N_2O emissions from agricultural soils, which is a major source in Ireland and for which the IPCC methodology remains very simplified. Just over two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have an uncertainty of 1.2 percent. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2006 is negligible (0.2 percent) because they account for only 1 percent of total emissions.

ES.3 Overview of Emissions Estimates and Trends

A consistent time-series of greenhouse gas inventories is available for the years 1990 through 2006. The results are compiled 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. The annual inventories are substantially complete with respect to both the coverage of the six greenhouse gases for which information is required and the coverage of IPCC source categories. Some recalculations have again been undertaken for the purposes of the 2008 submission and the latest inventories for the years 1990-2006 reflect these revisions.

The latest time-series of estimates show that total GHG emissions in Ireland increased from 55,525.56 Gg CO_2 equivalent in 1990 to 70,734.70 Gg CO_2 equivalent in 2001. Following this long period of sustained increase, the emissions decreased to 68,646.20 Gg CO_2 equivalent in 2003, a reduction of approximately three percent on their highest level in 2001. The emissions increased again in 2004 and 2005 with the totals of 68,700.97 Gg CO_2 equivalent and 70,345.06 Gg CO_2 equivalent being 23.7 and 26.7 percent higher respectively than that for 1990..

Greenhouse gas emissions associated with road traffic increased by 5.9 percent in 2006, making this source category the main contributor to the sustained high level of emissions for Ireland. There was a decrease of 4.9 percent in emissions from electricity generation in 2006 while the emissions from agriculture, which account for a large proportion of Ireland's emissions, decreased by 1.3 percent. Emissions of the fluorinated gases increased by 3.4 percent in 2006 but they represent only one percent of the total.

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 1990-2006 are included in the submission. The emissions of most of these gases have decreased substantially in this period under various forms of control legislation emanating from the European Commission and the Convention on Long Range Transboundary Air Pollution. The reductions achieved in Ireland are of the order of 67 percent in the case of SO_2 and are 56 and 44 percent for CO and NMVOC, respectively. However, in the case of NO_X, the emissions reductions have been more difficult to achieve, due mainly to the large increase in road traffic, with the result that emissions in 2005 were only 3 percent below their 1990 level, following a decrease of approximately 13 percent on their highest levels around 2001.

Chapter One

Introduction

1.1 Background and Context

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 Ireland's NIR for 2008 and refers to the inventory time-series for the years 1990-2006 which has been achieved through improved and more formalised institutional arrangements. It is an update of the 2007 report and is compiled according to the structure adopted by Decision 18/CP.9. As such, it addresses the full range of reporting requirements related to annual inventories set down in the UNFCCC reporting guidelines. 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. 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 transparency may be fully tested.

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. 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 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.

1.2 Scope of Greenhouse Gas Inventories

1.2.1 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.

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 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 excludes the estimates for the Land Use Land-Use Change and Forestry (LULUCF) category in Table A.2 of Annex A, this total being consistent with that for the categories included in Annex A of the Kyoto Protocol.

1.3 Institutional and Procedural Arrangements

1.3.1 Inventory Agency

Under Section 52 of the Environmental Protection Agency Act of 1992 (DOE, 1992), the 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. The activities related to the compilation and reporting of greenhouse gas emissions constitute one specific ongoing project in the Agency's work programme. The inventories team is engaged in two other parallel projects dealing with emissions of other compounds.

The Department of the Environment Heritage and Local Government (DEHLG) has 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.

1.3.2 National System

In 2005, UK consultants NETCEN carried out a scoping study to identify the essential elements and structure of a national inventory system for Ireland to meet the needs of Decision 280/2004/EC and to comply with obligations under Articles 5 and 7 of the Kyoto Protocol. The report (Thistlethwaite et al, 2005) describes how institutional arrangements among the EPA, DEHLG and other stakeholders may be reorganised, extended and legally consolidated across all participating institutions to strengthen inventory capacity within the EPA and ensure that more formal and comprehensive mechanisms of data collection and processing are established for long term implementation. The report sets out the extent of institutional participation, resource requirements and the form of legal arrangements necessary to perform the functions prescribed in the guidelines for national systems and enable Ireland to meet the objectives specified in those guidelines. The consultants' proposals for system development were benchmarked on systems in operation in other EU Member States and they prescribed how the arrangements in place could be enhanced within the existing statutory framework. The scoping study developed a QA/QC system as an integral part of the national system and the report made recommendations on internal inventory review and proposed a database system to facilitate more efficient data management and reporting.

The establishment of Ireland's national inventory system was completed by Government Decision in early 2007, building on the framework that has been applied for many years. It 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 the key data providers leading to the adoption of Memoranda of Understanding (MOU) between them 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 sources. All formal mechanisms together with the QA/QC procedures are fully operational in this present 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. 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.

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 Unit in OCLR. Any issues arising from the Board's examination of the estimates are communicated to the inventory experts for resolution before final adoption of the inventory. The results are released at national level in advance of their official submission to the European Commission in accordance with Decision 280/2004/EC and subsequently to the UNFCCC secretariat. For the 2007/2008 reporting cycle, the inventory agency was able to comply with a request from Government to produce preliminary greenhouse gas emissions estimates for 2006 by the end of November 2007.

1.3.3 Emissions Trading Unit

The Emissions Trading Unit (ETU) was established under the EPA Office of Licence and Guidance (OLG) in late 2003 to implement Directive 2003/87/EC (EP and CEU, 2003) in Ireland. The ETU currently forms part of OCLR and is another key component of the national system. Information compiled for participants in the ETS under Directive 2003/87/EC is an important new source of activity-specific and company-specific data on emissions of greenhouse gases. Emissions trading covers approximately 110 installations in Ireland with combined CO_2 emissions of 21,690 Gg in 2006, equal to 31 percent of total greenhouse gas emissions. Guidance provided under the associated Decision on methodologies for estimating and reporting greenhouse gas emissions (CEC, 2004) to support the Directive, together with monitoring and verification mechanisms administered by the ETU, consolidates and improves the information in relation to a substantial proportion of emissions for the purposes of reporting under the Convention. The returns under the scheme for 2006 are fully utilised in the national inventory for 2006.

Various preparatory calculations, conversions and reallocations are generally required for both the emissions estimates reported directly to the inventory agency and the activity data acquired from the different sources before they become part of the annual inventory in each reporting cycle. This is undertaken at the lowest possible level of aggregation compatible with the adopted calculation methodologies and the CRF structure. Suitable emission factors are applied to the activity data to estimate emissions in a top-down manner and the results are combined with those already available from bottom-up approaches from some data suppliers for appropriate aggregation according to the IPCC reporting format. All inventory data, including background information and supporting calculation spreadsheets, are stored at the EPA Regional Inspectorate Offices in Monaghan.

1.4 Overview of Methodologies

An emissions inventory database normally contains information on measured emission quantities, activity statistics (populations, fuel consumption, vehicle/kilometres of travel, industrial production, forest area), 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 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 estimate of emissions. In the case of some source/gas combinations, 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) and IPCC Good Practice Guidance (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.

Table 1.1 and Table 1.2 present an overview of the methodologies and emission factors used by Ireland to estimate emissions now reported for the years 1990-2006. The current situation regarding data availability and national circumstances dictates the use of a combination of Tier 1, Tier 2 and Tier 3 methods across the IPCC source categories. These methods range from relatively simple calculations for CO_2 emissions from combustion sources and some industrial processes, where quite basic inputs are required, to much more in-depth analysis in other source categories. Examples of the latter include the estimation of N_2O from agricultural soils and CH_4 from landfills, for which several interdependent steps must be followed and many contributing factors must be taken into account. On a sector/gas basis, there is approximately equal application of country-specific and default emission factors. Source categories or gases for which the estimates are based largely on country-specific methods and emission factors account for approximately 80 percent of total emissions.

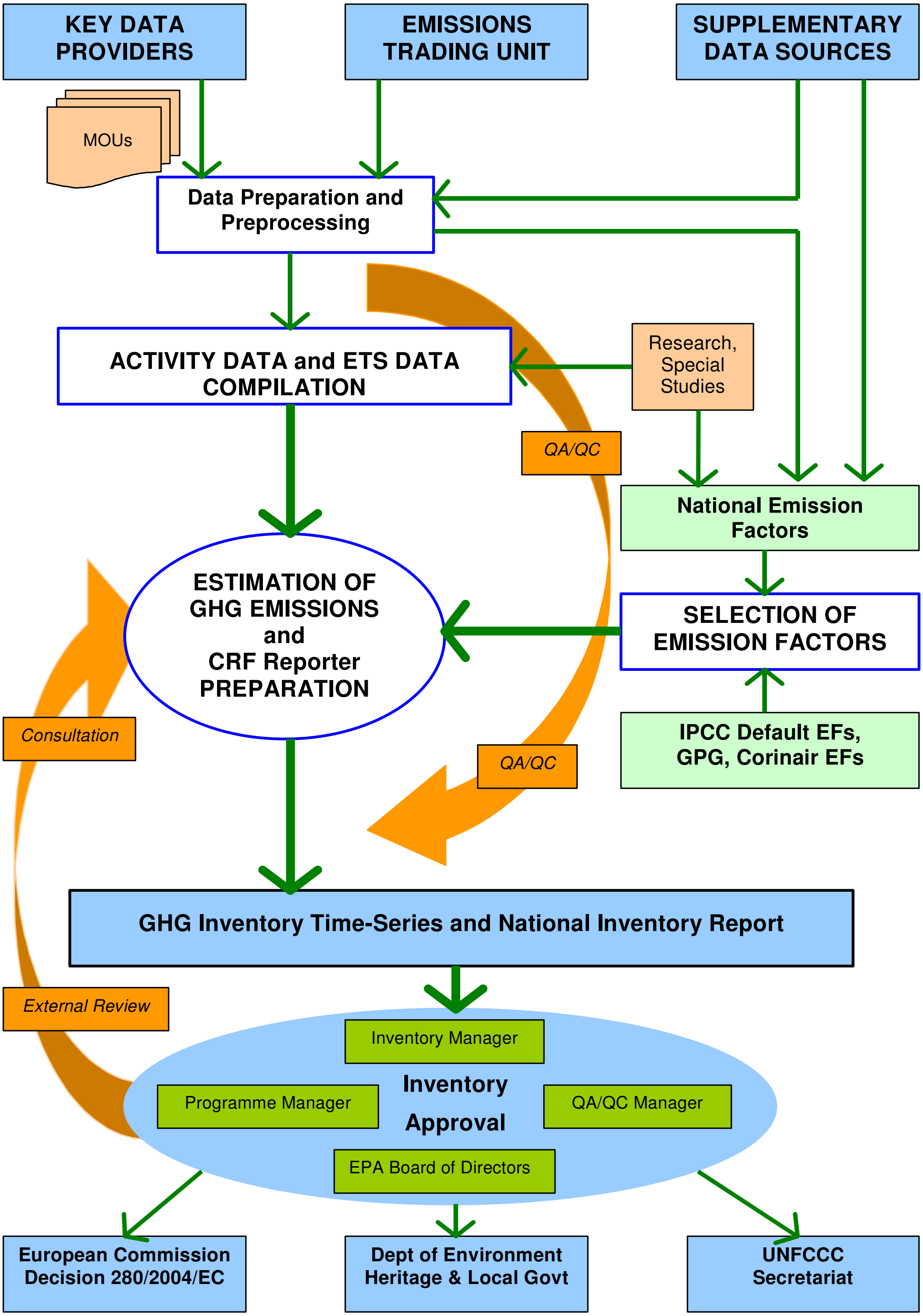

Figure 1.1. National Inventory System Overview

Table 1.1. 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	Tier 1& 3	Tier 1& 3	Tier 1& 3	NA	NA	NA
2. Manufacturing Industries and Construction	Tier 1	Tier 1	Tier 1	NA	NA	NA
3. Transport	Tier 1& 2	Tier 1& 3	Tier 1& 3	NA	NA	NA
4. Other Sectors	Tier 1	Tier 1	Tier 1	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	CS	CS	NA	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	Tier 1&2	NA	NA	NA	NA	NA
B. Chemical Industry	Tier 1	NA	Tier 1	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	Tier 1,2& 3	Tier 2	Tier 1& 2
G. Other	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CS, C	NA	NA	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	Tier 1& 2	NA	NA	NA	NA
B. Manure Management	NA	Tier 1& 2	Tier 1	NA	NA	NA
C. Rice Cultivation	NA	NA	NA	NA	NA	NA
D. Agricultural Soils	NA	NA	Tier 1a &1b	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	Tier 1& 3	Tier 1	Tier 1	NA	NA	NA
B. Cropland	Tier 1	NA	Tier 1	NA	NA	NA
C. Grassland	Tier 1	NA	NA	NA	NA	NA
D. Wetlands	Tier 1	NA	Tier 1	NA	NA	NA
E. Settlements	Tier 1	NA	NA	NA	NA	NA
F. Other Land	Tier 1	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NA	Tier 2	NA	NA	NA	NA
B. Wastewater Handling	NA	Tier 1	Tier 1	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
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

Tier 1 : IPCC Tier 1 or equivalent
Tier 2 : IPCC Tier 2 or equivalent
Tier 3 : IPCC Tier 3 or equivalent

CS : Country specific
C : CORINAIR
D : IPCC Default

Table 1.2. 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	PS, CS	C & D	C & D	NA	NA	NA
2. Manufacturing Industries and Construction	C	C & D	C & D	NA	NA	NA
3. Transport	CS	M, C	M, C	NA	NA	NA
4. Other Sectors	CS	C, D	C, 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	CS	CS	NA	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	CS, PS	NA	NA	NA	NA	NA
B. Chemical Industry	CS	NA	CS	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	C	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	D	NA	D	NA	NA	NA
E. Settlements	D	NA	NA	NA	NA	NA
F. Other Land	D	NA	NA	NA	NA	NA
G. Other	NA	NA	NA	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NA	CS	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
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
C : CORINAIR
D : Default
M : Model

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 approach is again used for 2006 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 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, were also major sources, even if the estimates were more uncertain than those of 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 2006 are shown in Table 1.3 and Table 1.4, respectively. It can be seen that there are six highly significant key categories of emissions in Ireland. They are the CO_2 combustion sources *in 1.A.1 Energy Industries, 1.A.4 Other Sectors, 1.A.2 Manufacturing Industries and Construction* and *1.A.3 Transport,* 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 84 percent and 87 percent of total emissions in 1990 and 2006, respectively. In the case of 2006 emissions, only three 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 9.1 percent in 1990 to 19.3 percent in 2006 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.

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 results of the analysis for Tier 1 level assessment in relation to emissions in both 1990 and 2006 are presented in Table 1.5 and Table 1.6 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 2006 are shown in Table 1.7. The results of the assessment for 2006 excluding LULUCF categories may be summarised as follows

(i) level assessment identifies 26 key categories;

(ii) there are 14 key categories of CO_2 in level assessment, accounting for 66.6 percent of total emissions;

(iii) there are seven key categories of CH_4 and four key categories of N_2O in level assessment, which account for 18.4 percent and 10.0 percent, respectively, of total emissions;

(iv) trend assessment identifies 23 key categories, 22 are the same as for level assessment;

(v) there are 13 key categories of CO_2 in trend assessment, accounting for 74.9 percent of the total trend;

(vi) there are five key categories of CH_4 and three key categories of N_2O in trend assessment, which account for 11.3 percent and 7.0 percent, respectively, of the total trend;

(vii) *Energy* accounts for 13 key categories, *Agriculture* for ten while *Industrial Processes* contributes two and *Waste* contributes one.

The list of key categories given by level assessment in 1990 is very similar to that for 2006 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 2006. The top ten key categories contributed 69.3 and 69.5 percent, of total emissions in 1990 and 2006, respectively. The emission of CO_2 from the combustion of petrol and diesel by road traffic was the single largest source category of greenhouse gas emissions in Ireland in 2006, accounting for 18.8 percent of the total.

Table 1.3. 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	CO_2	11,158.615	20.10	20.10
1.A.4	Other Sectors	CO_2	10,065.187	18.13	38.22
4.A	Enteric Fermentation	CH_4	9,493.748	17.10	55.32
4.D	Agricultural Soils	N_2O	7,009.306	12.62	67.95
1.A.3	Transport	CO_2	5,039.392	9.08	77.02
1.A.2	Manufacturing Industries and Construction	CO_2	3,969.482	7.15	84.17
4.B	Manure Management	CH_4	2,328.464	4.19	88.36
6.A	Solid Waste Disposal on Land	CH_4	1,332.27	2.40	90.76
2.B.2	Nitric Acid Production	N_2O	1,035.40	1.86	92.63
2.B.1	Ammonia Production	CO_2	989.17	1.78	94.41
2.A.1	Cement Production	CO_2	884.00	1.59	96.00

Table 1.4. Key Categories at IPCC Level 2 in 2006

	IPCC Level 2 Source Category	GHG	Emissions in 2006 Gg CO_2 eq	2006 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO_2	14,906.98	21.37	21.37
1.A.3	Transport	CO_2	13,483.34	19.33	40.70
1.A.4	Other Sectors	CO_2	10,562.65	15.14	55.84
4.A	Enteric Fermentation	CH_4	9,151.16	13.12	68.95
4.D	Agricultural Soils	N_2O	6,663.71	9.55	78.51
1.A.2	Manufacturing Industries and Construction	CO_2	5,687.78	8.15	86.66
2.A.1	Cement Production	CO_2	2,347.85	3.37	90.02
4.B	Manure Management	N_2O	2,234.14	3.20	93.23
6.A	Solid Waste Disposal on Land	N_2O	1,669.41	2.39	95.62

1.5.3 Application of Results

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 source determination for Ireland, based on Tier 1 level assessment. The results excluding LULUCF indicate that half of the key categories in 2006 each accounted for less than 3 percent of the total emissions and that only four 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 source categories.

The results of the Tier 1 key category analysis in Table 1.6 clearly show that the impact of CO_2 emissions from energy consumption on total emissions in Ireland continues to increase. These emissions account for 13 of the key categories listed in Table 1.6 and for 63 percent of total emissions in 2006. 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 and the use of verified estimates for CO_2 emissions from cement production means that the contributions from three additional key categories (ranked 3, 10 and 11 in Table 1.6) making up a further 15.3 percent of the total are also known with probably the highest certainty now achievable. The N_2O emissions from *4.D Agricultural Soils*, the CH_4 and N_2O emissions from *4.B Manure Management* and the CH_4 emissions from *6.A Solid Waste Disposal on Land* account for most of the remaining important key categories in Table 1.6. 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

In early 2005, the inventory agency in Ireland commissioned a project with UK consultants 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 review and expert review of inventory data and outlines the annual requirements for continuous improvement for the inventory.

The inventory agency used the 2006 reporting cycle to begin implementation of the basic elements of the new approach to QA/QC and its application was substantially completed in delivering the 2007 submission. 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 this the 2008 submission.

Ireland’s calculation spreadsheets in all sectors have been restructured and reorganised to facilitate the QA/QC process and to facilitate more efficient analysis and to ensure ease of transfer of the outputs to the CRF Reporter Tool. This facilitates rapid year-on-year extension of the time-series 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. These exercises have been repeated for the current reporting cycle. The review for Agriculture was performed by a technical inspector in the Department of Agriculture 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 and advice from the Department on various aspects of input data and calculation parameters. The ETS returns to the Agency’s Office of Climate, Licensing and Resource Use (OCLR) provided for the complete coverage of CO_2 estimates for categories 1.A.1, 2.A.1, 2.A.2, 2.A.3, 2.A.4 and 2.A.7 in 2006. When the allocation to these categories from the ETS raw data was completed, the output was returned to the ETS administrator in OCLR for final checking against the source data.

Inventory development continues to benefit from the internal review procedures that are ongoing with regard to the EU and its 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 2006 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 2006 is presented in Table 1.8, using emissions on a GWP basis and a level of aggregation that limits the likely dependency and correlation between source categories.

The input values of uncertainty for activity data have been assigned largely on the basis of general information and opinions elicited from the principal data suppliers, such as statistical offices, energy agencies, Government departments and individuals. In the case of country-specific emission factors for combustion sources, which relate largely to CO_2, expert judgement has been used to assign the uncertainties for the source categories given in Table 1.8 with reasonable confidence, given the well-established properties of the fuels concerned. Uncertainties in the emission factors for other gases released from combustion sources and for other source categories in general are based on information provided in the IPCC Good Practice Guidance and the CORINAIR/EMEP Emission Inventory Guidebook.

The 2003 in-country review report for Ireland concluded that the input values of uncertainty chosen for activity data or emission factors for some sources in the 2001 inventory may not have been entirely appropriate. The uncertainty analysis for subsequent years therefore incorporates changes that have been made following further investigation to determine the most conceptually meaningful values that can be used at the level of source disaggregation being used for the analysis. Sustainable Energy Ireland (SEI), the body responsible for compiling the national energy balance, completed a process to expand and improve Irish energy balances in 2006, which provides further insight into uncertainty in the statistical data compiled from annual fuel-use questionnaires. The inventory experts continue to collaborate with SEI in this process to ascertain the views of the energy-use compilers on uncertainty associated with energy quantities disaggregated by sector and by fuel type. New sources of data, such as the ETS returns, are also being investigated in an attempt to substantiate the quantitative estimates of uncertainty in activity data obtained in this way.

The latest in-country review undertaken in 2007 acknowledged that uncertainties had been reduced when compared to previous years through the introduction of higher-tier methods in some key categories and the re-evaluation of uncertainty values for some other categories. However relatively high uncertainties still remain within the national oil balance (an important source of data for the national energy balance). The inventory team are in discussions with both SEI and Government departments with the aim of reducing this uncertainty and its impact on overall inventory uncertainty in future submissions.

In some of the most important emissions sources in *Agriculture* (such as enteric fermentation and agricultural soils) and *Waste* (solid waste disposal, for example) 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 both activity data and emission factor 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, for each activity for input to the Tier 1 uncertainty assessment. The footnotes to Table 1.8 show how some of these revised uncertainty inputs were obtained. The application of the Tier 2 method for CH_4 emissions from enteric fermentation in cattle and the use of improved country-specific information related to manure management (Chapter Six) justifies the adoption of reduced input uncertainties for some of the emission sources in *Agriculture*. Some reduction is also appropriate in the case of CO_2 emissions from cement production, where verified data are now available through implementation of the EU emissions trading scheme (Chapter Three).

The Tier 1 uncertainty analysis for 2006 gives an overall uncertainty of 6.1 percent in total emissions and a trend uncertainty of 3.6 percent for the period 1990 to 2006. The application of improved Tier 2 methods for emissions from enteric fermentation and manure management for cattle has reduced the level of uncertainty to some extent. The overall outcome continues to be determined largely by the uncertainty in the estimate of N_2O emissions from agricultural soils, where an emission factor uncertainty of 100 percent is assumed in order to complete the analysis. Just over two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have a level uncertainty of just over 1.2 percent. When CH_4 is included, bringing the proportion of total emissions up to 86.9 percent, the total uncertainty is 2.4 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 2006 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.

1.8 Completeness and Time-Series Consistency

Table 1.9 gives an overview of the level of completeness of the 2006 GHG inventories with respect to the six greenhouse gases covered by the UNFCCC guidelines and the IPCC Level 2 source-category split in operation since 2005. 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 1991-2005 to bring them fully into line for those of 1990 and 2006, which were the main focus of the work in 2007. The opportunity has also been taken in this current cycle to improve further the estimates of emissions and removals for all years for LULUCF reported in accordance with the requirements of Decision 13/CP.9. It may be concluded that the principles of completeness and consistency are therefore being observed in so far as can be expected.

Table 1.5 Disaggregated Key Categories 1990

1990 Rank	IPCC Sub-Category	Emission Source/Activity	Gas	1990 Emission exc LULUCF Gg CO_2 eq	1990 Emission from LULUCF Gg CO_2 eq	1990 Emission inc LULUCF Gg CO_2 eq	1990 Level Assessment exc LULUCF %	Cumulative Level exc LULUCF %	1990 Level Assessment inc LULUCF %	Cumulative Level inc LULUCF %
1	1.A.1.	Energy Industries - Solid Fuels	CO_2	8009.44		8009.44	14.42	14.42	13.79	13.79
2	1.A.4.b	Residential- Solid Fuels	CO_2	5606.94		5606.94	10.10	24.52	9.65	23.44
3	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH_4	5546.63		5546.63	9.99	34.51	9.55	32.99
4	1.A.3.b.	Road Transportation - Liquid Fuels	CO_2	4700.93		4700.93	8.47	42.98	8.09	41.08
5	4.A.1.	Enteric Fermentation - Dairy Cattle	CH_4	2875.51		2875.51	5.18	48.16	4.95	46.03
6	4.D.1.	Agricultural Soils - Direct Soil Emissions	N_2O	2862.46		2862.46	5.16	53.31	4.93	50.96
7	4.D.2.	Agricultural Soils - Pasture, Range and Paddock	N_2O	2802.31		2802.31	5.05	58.36	4.82	55.78
8	1.A.2.	Manufacturing Industries & Construction - Liquid Fuels	CO_2	2225.39		2225.39	4.01	62.37	3.83	59.61
9	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO_2	1976.61		1976.61	3.56	65.93	3.40	63.01
10	1.A.1.	Energy Industries - Gaseous Fuels	CO_2	1880.66		1880.66	3.39	69.31	3.24	66.25
11	4.D.3.	Agricultural Soils - Indirect Emissions	N_2O	1344.53		1344.53	2.42	71.74	2.31	68.57
12	6.A.	Waste - Solid Waste Disposal on land	CH_4	1332.27		1332.27	2.40	74.13	2.29	70.86
13	1.A.1.	Energy Industries - Liquid Fuels	CO_2	1268.51		1268.51	2.28	76.42	2.18	73.04
14	4.B.1.	Manure Management - Non-Dairy cattle	CH_4	1255.57		1255.57	2.26	78.68	2.16	75.20
15	1.A.4.b.	Residential - Liquid Fuels	CO_2	1189.67		1189.67	2.14	80.82	2.05	77.25
16	5.A.1.	LULUCF - Forest land Remaining Forest Land	CO_2		-1059.21	1059.21	0.00	80.82	1.82	79.08
17	2.B.2.	Nitric Acid Production	N_2O	1035.40		1035.40	1.86	82.69	1.78	80.86
18	4.A.3.	Enteric Fermentation - Sheep	CH_4	1032.48		1032.48	1.86	84.55	1.78	82.64
19	2.B.1.	Ammonia Production	CO_2	989.17		989.17	1.78	86.33	1.70	84.34
20	2.A.1.	Cement Production	CO_2	884.00		884.00	1.59	87.92	1.52	85.86
21	1.A.2.	Manufacturing Industries & Construction - Gaseous Fuels	CO_2	872.86		872.86	1.57	89.49	1.50	87.36
22	1.A.2.	Manufacturing Industries & Construction - Solid Fuels	CO_2	871.24		871.24	1.57	91.06	1.50	88.86
23	1.A.4.c.	Agriculture/Forestry/Fisheries - Liquid Fuels	CO_2	660.30		660.30	1.19	92.25	1.14	90.00
24	5.A.2.	LULUCF - Land Converted to Forest Land	CO_2		659.22	659.22	0.00	92.25	1.13	91.13
25	5.C.1.	LULUCF - Grassland Remaining Grassland	CO_2		620.33	620.33	0.00	92.25	1.07	92.20
26	4.B.1.	Manure Management - Dairy Cattle	CH_4	611.80		611.80	1.10	93.35	1.05	93.25
27	4.B.13.	Manure Management - Solid Storage	N_2O	341.48		341.48	0.61	93.97	0.59	93.84
28	4.B.8.	Manure Management - Swine	CH_4	327.77		327.77	0.59	94.56	0.56	94.41
29	1.A.1.	Energy Industries - Solid Fuels	N_2O	319.02		319.02	0.57	95.13	0.55	94.96
30	1.A.4.b.	Residential - Gaseous Fuels	CO_2	269.73		269.73	0.49	95.62	0.46	95.42

Table 1.6 Disaggregated Key Categories 2006

2006 Rank	IPCC Sub-Category	Emission Source/Activity	Gas	2006 Emission exc LULUCF Gg CO_2 eq	2006 Emission inc LULUCF Gg CO_2 eq	2006 Emission inc LULUCF Gg CO_2 eq	2006 Level Assessment exc LULUCF %	Cumulative Level exc LULUCF %	2006 Level Assessment inc LULUCF %	Cumulative Level inc LULUCF %
1	1.A.3.b.	Road Transport - Liquid Fuels	CO_2	13092.68		13092.68	18.77	18.77	18.26	18.26
2	1.A.1.	Energy Industries - Solid Fuels	CO_2	7085.89		7085.89	10.16	28.92	9.88	28.14
3	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH_4	5792.37		5792.37	8.30	37.23	8.08	36.22
4	1.A.1.	Energy Industries - Gaseous Fuels	CO_2	5222.55		5222.55	7.49	44.71	7.28	43.51
5	1.A.4.b.	Residential - Liquid Fuels	CO_2	3442.68		3442.68	4.93	49.65	4.80	48.31
6	1.A.2.	Manufacturing Industries and Construction - Liquid Fuels	CO_2	3298.56		3298.56	4.73	54.38	4.60	52.91
7	4.D.2.	Agricultural Soils - Pasture, Range & Paddock	N_2O	2782.97		2782.97	3.99	58.37	3.88	56.79
8	1.A.1.	Energy Industries - Liquid Fuels	CO_2	2598.54		2598.54	3.72	62.09	3.62	60.41
9	4.D.1.	Agricultural Soils - Direct Soil Emissions	N_2O	2591.34		2591.34	3.71	65.81	3.61	64.03
10	4.A.1.	Enteric Fermentation - Dairy Cattle	CH_4	2545.88		2545.88	3.65	69.46	3.55	67.58
11	2.A.1.	Cement Production	CO_2	2347.85		2347.85	3.37	72.82	3.27	70.85
12	1.A.4.b.	Residential - Solid Fuels	CO_2	2092.07		2092.07	3.00	75.82	2.92	73.77
13	1.A.2.	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	1862.81		1862.81	2.67	78.49	2.60	76.37
14	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO_2	1793.58		1793.58	2.57	81.06	2.50	78.87
15	6.A.	Solid Waste Disposal on land	CH_4	1669.41		1669.41	2.39	83.45	2.33	81.20
16	1.A.4.b.	Residential - Gaseous Fuels	CO_2	1504.00		1504.00	2.16	85.61	2.10	83.30
17	4.D.3.	Agricultural Soils - Indirect Emissions	N_2O	1289.40		1289.40	1.85	87.46	1.80	85.09
18	4.B.1.	Manure Management - Non-Dairy Cattle	CH_4	1185.55		1185.55	1.70	89.16	1.65	86.75
19	5.A.1.	LULUCF - Forest land Remaining Forest Land	CO_2		-838.99	838.99		89.16	1.17	87.92
20	1.A.4.c.	Agriculture/Forestry/Fisheries - Liquid Fuels	CO_2	825.46		825.46	1.18	90.34	1.15	89.07
21	1.A.4.a.	Commercial/Institutional - Gaseous Fuels	CO_2	799.65		799.65	1.15	91.49	1.12	90.18
22	4.A.3.	Enteric Fermentation - Sheep	CH_4	762.43		762.43	1.09	92.58	1.06	91.25
23	1.A.2.	Manufacturing Industries and Construction - Solid Fuels	CO_2	526.41		526.41	0.75	93.33	0.73	91.98
24	2.F.	Consumption of Halocarbons & SF6	HFC	506.45		506.45	0.73	94.06	0.71	92.69
25	5.C.1.	LULUCF - Grassland remaining Grassland	CO_2		494.00	494.00		94.06	0.69	93.38
26	4.B.1.	Manure Management - Dairy Cattle	CH_4	477.78		477.78	0.68	94.74	0.67	94.04
27	4.B.8.	Manure Management - Swine	CH_4	431.35		431.35	0.62	95.36	0.60	94.64
28	4.B.13.	Manure Management - Solid Storage	N_2O	343.04		343.04	0.49	95.86	0.48	95.12

Table 1.7 Key Category Trend Assessment 2006 (excluding LULUCF)

Rank	Category	Emission Source	Gas	Emissions in 1990 Gg CO_2 eq	Emissions in 2006 Gg CO_2 eq	Level Assessment %	Trend Assessment	Contribution to Trend %	Cumulative Contribution to Trend %
1	1.A.3.b.	Road Transport - Liquid Fuels	CO_2	4700.93	13092.68	18.77	7.65	19.66	19.66
2	1.A.4.b	Residential - Solid Fuels	CO_2	5606.94	2092.07	3.00	5.74	14.74	34.40
3	1.A.1.	Energy Industries - Solid Fuels	CO_2	8009.44	7085.89	10.16	3.69	9.48	43.89
4	1.A.1.	Energy Industries - Gaseous Fuels	CO_2	1880.66	5222.55	7.49	3.05	7.82	51.71
5	1.A.4.b	Residential - Liquid Fuels	CO_2	1189.67	3442.68	4.93	2.08	5.34	57.05
6	4.A.1.	Enteric Fermentation - Non-Dairy Cattle	CH_4	5546.63	5792.37	8.30	1.58	4.07	61.12
7	4.A.1.	Enteric Fermentation - Dairy Cattle	CH_4	2875.51	2545.88	3.65	1.32	3.40	64.52
8	2.A.1.	Cement Production	CO_2	884.00	2347.85	3.37	1.31	3.38	67.89
9	1.A.4.b	Residential - Gaseous Fuels	CO_2	269.73	1504.00	2.16	1.27	3.25	71.15
10	4.D.1.	Agricultural Soils - Direct Soil Emissions	N_2O	2862.46	2591.34	3.71	1.25	3.22	74.37
11	1.A.1.	Energy Industries - Liquid Fuels	CO_2	1268.51	2598.54	3.72	1.04	2.67	77.04
12	4.D.2.	Agricultural Soils - Pasture, Range & Paddock	N_2O	2802.31	2782.97	3.99	0.96	2.46	79.49
13	1.A.4.a.	Commercial/Institutional - Liquid Fuels	CO_2	1976.61	1793.58	2.57	0.86	2.21	81.71
14	1.A.2.	Manufacturing Industries and Construction - Gaseous Fuels	CO_2	872.86	1862.81	2.67	0.80	2.05	83.75
15	1.A.2.	Manufacturing Industries and Construction - Solid Fuels	CO_2	871.24	526.41	0.75	0.67	1.72	85.48
16	4.A.3.	Enteric Fermentation - Sheep	CH_4	1032.48	762.43	1.09	0.64	1.65	87.13
17	1.A.4.a.	Commercial/Institutional - Gaseous Fuels	CO_2	223.65	799.65	1.15	0.56	1.43	88.56
18	2.F.	Consumption of Halocarbons & SF6	HFC	0.69	506.45	0.73	0.56	1.43	89.99
19	4.D.3.	Agricultural Soils - Indirect Emissions	N_2O	1344.53	1289.40	1.85	0.51	1.31	91.30
20	4.B.1.	Manure Management - Non-Dairy Cattle	CH_4	1255.57	1185.55	1.70	0.50	1.28	92.57
21	1.A.2.	Manufacturing Industries and Construction - Liquid Fuels	CO_2	2225.39	3298.56	4.73	0.44	1.12	93.69
22	4.B.1.	Manure Management - Dairy Cattle	CH_4	611.80	477.78	0.68	0.35	0.90	94.60
23	2.F.	Consumption of Halocarbons & SF6	PFC	0.09	148.32	0.21	0.16	0.42	95.02

Table 1.8 Tier 1 Uncertainty Estimates 2006 (continued on following page)

IPCC Source Category		Gas	Emissions in 1990	Emissions in 2006	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2006	Combined Emissions Uncertainty Squared	Type A Sensitivity	Type B Sensitivity	Uncertainty in Trend in Total Emissions due to AD	Uncertainty in Trend in Total Emissions due to EF	Combined Uncertainty in Trend in Total Emissions	Combined Trend Uncertainty Squared
			Gg CO_2	*Gg CO_2*	*%*	*%*	*%*	*%*		*%*	*%*	*%*	*%*	*%*	
1A1	Energy-Liquid	CO_2	1268.51	2598.54	1	2.5	2.69	0.10	0.01	0.02	0.05	0.07	0.05	0.08	0.01
1A1	Energy-Solid	CO_2	8009.44	7085.89	1	5	5.10	0.52	0.27	-0.05	0.13	0.18	-0.27	0.32	0.10
1A1	Energy-Gas	CO_2	1880.66	5222.55	1	2.5	2.69	0.20	0.04	0.05	0.09	0.13	0.13	0.19	0.03
1A2	Industry-Liquid	CO_2	2010.97	2326.40	10	2.5	10.31	0.34	0.12	0.00	0.04	0.59	-0.01	0.59	0.35
1A2	Industry-Coal	CO_2	871.24	526.41	2	5	5.39	0.04	0.00	-0.01	0.01	0.03	-0.05	0.06	0.00
1A2	Industry-Pet Coke	CO_2	214.42	972.16	5	10	11.18	0.16	0.02	0.01	0.02	0.12	0.13	0.18	0.03
1A2	Industry-Gas	CO_2	872.86	1862.81	2.5	2.5	3.54	0.09	0.01	0.01	0.03	0.12	0.03	0.12	0.02
1A3	Transport-Oil	CO_2	4977.35	13332.02	1	2.5	2.69	0.51	0.26	0.13	0.24	0.34	0.32	0.47	0.22
1A3	Transport-Gas	CO_2	62.04	151.33	1	2.5	2.69	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1A4	Comm-Liquid	CO_2	1976.61	1793.58	10	5	11.18	0.29	0.08	-0.01	0.03	0.46	-0.06	0.46	0.21
1A4	Comm-Coal	CO_2	2.56	103.59	5	10	11.18	0.02	0.00	0.00	0.00	0.01	0.02	0.02	0.00
1A4	Comm-Peat	CO_2	135.73	1.61	10	20	22.36	0.00	0.00	0.00	0.00	0.00	-0.06	0.06	0.00
1A4	Comm-Gas	CO_2	223.65	799.65	2.5	2.5	3.54	0.04	0.00	0.01	0.01	0.05	0.02	0.06	0.00
1A4	Res-Liquid	CO_2	1101.79	3328.73	10	5	11.18	0.53	0.28	0.04	0.06	0.85	0.18	0.87	0.75
1A4	Res-Coal	CO_2	2483.57	876.50	5	10	11.18	0.14	0.02	-0.04	0.02	0.11	-0.40	0.42	0.18
1A4	Res-Petcoke	CO_2	87.88	113.95	5	10	11.18	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.00
1A4	Res-Peat	CO_2	3123.37	1215.57	10	20	22.36	0.39	0.15	-0.05	0.02	0.31	-0.98	1.02	1.05
1A4	Res-Gas	CO_2	269.73	1504.00	2.5	2.5	3.54	0.08	0.01	0.02	0.03	0.10	0.05	0.11	0.01
1A4	Agric Liquid	CO_2	660.30	825.46	10	5	11.18	0.13	0.02	0.00	0.01	0.21	0.00	0.21	0.04
1.B	Fugitive Emissions	CO_2	138.88	60.34	2.5	10	10.31	0.01	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
2.A.1	Cement Production	CO_2	884.00	2347.85	7.5	5	9.01	0.30	0.09	0.02	0.04	0.45	0.11	0.46	0.21
2.A.2	Lime Production	CO_2	214.08	180.30	5	5	7.07	0.02	0.00	0.00	0.00	0.02	-0.01	0.02	0.00
2.A.3	Limestone and Dolomite Use	CO_2	0.11	2.64	5	5	7.07	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	0.37	5	5	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.A.7	Other Mineral Products	CO_2	5.14	7.40	5	5	7.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.B.1	Ammonia Production	CO_2	989.17	0.00	1	5	5.10	0.00	0.00	-0.02	0.00	0.00	-0.11	0.11	0.01
3	Solvent and Other Product Use	CO_2	81.15	80.01	30	5	30.41	0.03	0.00	0.00	0.00	0.06	0.00	0.06	0.00
	Total CO_2		***32,545.20***	***47,319.68***				***1.18***	***1.39***					***1.80***	***3.24***
1A	Fuel Comb-All Fuels	CH_4	166.48	105.69	2	50	50.04	0.08	0.01	0.00	0.00	0.01	-0.09	0.09	0.01
1B	Fugitive Emissions	CH_4	131.08	102.02	2.5	10	10.31	0.02	0.00	0.00	0.00	0.01	-0.01	0.01	0.00
4A	Ent Ferm. Dairy Cattle	CH_4	2875.51	2545.88	1	15	15.03	0.55	0.30	-0.02	0.05	0.06	-0.29	0.30	0.09
4A	Ent Ferm.Other Cattle	CH_4	5546.63	5792.37	1	15	15.03	1.25	1.56	-0.02	0.10	0.15	-0.32	0.35	0.12
4A	Ent Ferm.Other Livestock	CH_4	1071.61	812.92	1	30	30.02	0.35	0.12	-0.01	0.01	0.02	-0.29	0.29	0.08
4B	Man. Manag.Dairy Cattle	CH_4	611.80	477.78	1	15	15.03	0.10	0.01	-0.01	0.01	0.01	-0.08	0.08	0.01
4B	Man. Manag.Other Cattle	CH_4	1255.57	1185.55	1	15	15.03	0.26	0.07	-0.01	0.02	0.03	-0.11	0.11	0.01
4B	Man. Manag.Other Livestock	CH_4	461.09	570.81	1	30	30.02	0.25	0.06	0.00	0.01	0.01	0.00	0.02	0.00
6A	Solid Waste	CH_4	1332.27	1669.41	41[a]	47[b]	62.37	1.49	2.23	0.00	0.03	1.74	0.00	1.74	3.04
6.B	Wastewater Handling	CH_4	14.73	24.26	10	30	31.62	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	Total CH_4		***13,466.77***	***13,286.68***				***2.09***	***4.35***					***1.83***	***3.36***

	Cumulative CO_2 and CH_4		***46,011.97***	***60,606.36***				***2.40***	***5.75***					***2.57***	***6.60***
1A3	Fuel Comb-Road Traffic	N_2O	54.33	188.85	1	25	25.02	0.07	0.00	0.00	0.00	0.00	0.05	0.05	0.00
1A	Fuel Comb-Other Sectors	N_2O	867.32	1043.80	2	50	50.04	0.75	0.56	0.00	0.02	0.05	-0.04	0.07	0.00
2B	Nitric Acid	N_2O	1035.40	0.00	1	10	10.05	0.00	0.00	-0.02	0.00	0.00	-0.23	0.23	0.05
4B	Liquid System	N_2O	55.57	55.46	11.2[c]	100	100.63	0.08	0.01	0.00	0.00	0.02	-0.03	0.03	0.00
4B	Solid Storage and dry lot	N_2O	341.48	343.04	11.2[c]	100	100.63	0.49	0.24	0.00	0.01	0.10	-0.15	0.18	0.03
4D	Direct Soil Emissions	N_2O	2862.46	2591.34	11.2[c]	100	100.63	3.74	13.97	-0.02	0.05	0.74	-1.81	1.96	3.82
4D	Pasture Range and Paddock	N_2O	2802.31	2782.97	11.2[c]	100	100.63	4.01	16.11	-0.01	0.05	0.79	-1.33	1.55	2.40
4D	Indirect Emissions	N_2O	1344.53	1289.40	11.2[c]	50	51.24	0.95	0.90	-0.01	0.02	0.37	-0.36	0.51	0.27
6B	Wastewater Handling	N_2O	114.00	137.75	10	10	14.14	0.03	0.00	0.00	0.00	0.04	0.00	0.04	0.00
	Total N_2O		***94,77.40***	***8,432.62***				***5.64***	***31.79***					***2.57***	***6.58***
	Cumulative CO_2, CH_4, N_2O		***55,489.37***	***69,038.98***				***6.13***	***37.54***					***3.63***	***13.18***
2F	Halocarbons & SF_6	HFC	0.69	506.45	20	10	22.36	0.16	0.03	0.01	0.01	0.21	0.09	0.22	0.05
2F	Halocarbons & SF_6	PFC	0.09	148.32	10	2.5	10.31	0.02	0.00	0.00	0.00	0.03	0.01	0.03	0.00
2F	Halocarbons & SF_6	SF_6	35.40	68.60	15	5	15.81	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	Total HFC, PFC and SF_6		**36.19**	**723.37**				**0.16**	**0.03**					**0.23**	**0.05**
	Total all gases		**55,525.56**	**69,762.35**					**37.56**						**13.24**
					Level Uncertainty in Emissions			**6.13**				***Trend Uncertainty***		**3.64**	

Type A Sensitivity — *the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions of a given source category/gas combination in both the base year and the current year*

Type B Sensitivity — *the change in the difference in overall emissions between the base year and the current year, expressed as a percentage, resulting from a 1 percent increase in emissions of a given source category/gas combination in the current year only*

a Based on Equation 6.4 of IPCC GPG with uncertainties of 25%, 25% and 20% for MSW quantity, MSW composition and DOC, respectively

b Based on Equation 6.4 of IPCC GPG with uncertainties of 30%, 30% and 20% for fraction DOC dissimilated, MCF and time of CH_4 release, respectively

c Based on Equation 6.4 of IPCC GPG with uncertainties of 20% and 30% for nitrogen excretion and AWMS proportion, respectively

Table 1.9 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**
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 1990-2006. The estimates reported here show some changes on those reported in the 2007 submission, which reflect recalculations that are fully described in subsequent chapters. The trends in the principal emission components within the six IPCC sectors as CO_2 equivalents are shown on Figure 2.2 through Figure 2.8. Total emissions of the six greenhouse gases in Ireland (excluding net emissions from *Land Use Land Use Change and Forestry*) increased steadily from 55,525.56 Gg CO_2 equivalent in 1990 to 70,734.70 Gg CO_2 equivalent in 2001 and then decreased slightly to 68,646.20 Gg CO_2 equivalent in 2003. The emissions increased again in 2004 and 2005 to 68,700.97 and 70,345.06 Gg CO_2 equivalent. In 2006 emissions decreased by 0.8 percent to 69,762.35, which is 25.6 percent higher than in 1990.

In 2006, the *Energy* sector accounted for 66.1 percent of total emissions, *Agriculture* contributed 26.4 percent while a further 4.7 percent emanated from *Industrial Processes* and 2.6 percent 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*.

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 45.5 percent over these 12 years. The bulk of this increase occurred in the years between 1995 and 2001, during which Ireland experienced a period of unprecedented economic growth and energy emissions grew by an average of 5.5 percent 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 and 2003. The sustained increase over the period 2003 - 2005 was due largely to increased emissions from road transport and from electricity generation where two new peat-fired stations entered service. The small reduction seen in 2006 can be largely attributed to the reduction in the use of a large coal fired electricity generating station due to the installation of emission controls at the plant.

Table 2.1. Greenhouse Gas Emissions 1990-2006 (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
CO_2 (inc net CO_2 from LULUCF)	32,716.90	33,712.69	33,654.27	33,628.81	34,700.14	35,719.12	37,471.53	38,885.81	40,573.34	42,201.10	44,974.77	47,299.82	45,753.86	44,803.98	45,753.88	47,267.54	46,795.93
CO_2 (exc net CO_2 from LULUCF)	32,545.20	33,377.59	33,258.47	33,404.38	34,653.88	35,447.90	37,105.56	38,584.40	40,650.72	42,313.98	44,846.84	47,303.72	45,865.93	45,125.65	45,991.76	47,722.66	47,319.68
CH_4 emissions (inc CH_4 from LULUCF)	13,468.57	13,612.35	13,705.33	13,794.38	13,762.11	13,801.34	14,047.11	14,109.33	14,366.43	14,045.37	13,540.74	13,291.26	13,363.76	13,946.65	13,358.95	13,262.47	13,288.57
CH_4 emissions (exc CH_4 from LULUCF)	13,466.77	13,610.55	13,703.53	13,792.67	13,760.21	13,799.26	14,045.11	14,108.05	14,366.17	14,045.12	13,539.47	13,288.04	13,362.58	13,942.35	13,355.63	13,261.81	13,286.68
N_2O emissions (inc N_2O from LULUCF)	9,492.52	9,336.83	9,326.26	9,468.37	9,728.02	9,937.44	9,992.10	9,889.43	10,487.49	10,542.94	10,073.58	9,553.07	9,076.77	8,913.57	8,750.44	8,693.90	8,465.48
N_2O emissions (exc N_2O from LULUCF)	9,477.40	9,321.34	9,310.11	9,449.16	9,708.42	9,917.36	9,969.72	9,866.94	10,464.87	10,520.20	10,050.52	9,525.98	9,047.55	8,880.74	8,717.62	8,661.24	8,432.62
HFCs	0.69	5.27	6.17	9.44	19.97	44.85	76.11	132.28	190.71	197.13	230.22	251.49	276.52	349.98	386.44	435.06	506.45
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
SF_6	35.40	40.64	45.87	55.35	64.83	82.83	102.06	132.10	94.28	69.01	55.96	69.49	70.31	118.69	67.09	95.96	68.60
Total including LULUCF	**55,714.19**	**56,715.40**	**56,753.04**	**56,986.56**	**58,320.34**	**59,660.96**	**61,792.00**	**63,279.77**	**65,774.12**	**67,251.49**	**69,180.68**	**70,761.10**	**68,753.62**	**68,361.66**	**68,499.23**	**69,923.26**	**69,273.35**
Total excluding LULUCF	**55,525.56**	**56,363.01**	**56,339.30**	**56,741.22**	**58,252.58**	**59,367.58**	**61,401.65**	**62,954.59**	**65,828.63**	**67,341.38**	**69,028.42**	**70,734.70**	**68,835.28**	**68,646.20**	**68,700.97**	**70,345.06**	**69,762.35**

Table 2.1 contd. Greenhouse Gas Emissions 1990-2006 (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
1. Energy	31,590.77	32,558.08	32,498.58	32,681.60	33,730.22	34,612.23	36,235.26	37,417.44	39,677.20	41,426.38	43,479.30	45,720.72	44,392.83	44,672.55	44,826.36	46,561.00	46,141.47
2. Industrial Processes	3,164.08	2,875.82	2,802.93	2,791.42	3,067.68	3,060.67	3,202.85	3,655.26	3,494.17	3,560.10	4,185.50	4,290.09	3,719.40	3,039.29	3,142.50	3,250.97	3,261.94
3. Solvent and Other Product Use	81.15	82.87	83.19	83.51	84.36	86.05	86.77	87.20	88.28	84.96	80.29	79.61	77.28	76.28	76.09	77.89	80.01
4. Agriculture	19,228.56	19,350.23	19,413.31	19,597.79	19,733.80	19,920.06	20,249.54	20,362.41	21,059.58	20,719.60	19,639.90	19,162.51	18,993.87	19,063.18	18,863.94	18,681.68	18,447.52
5. LULUCF	188.63	352.39	413.74	245.34	67.76	293.38	390.35	325.19	-54.51	-89.89	152.26	26.41	-81.66	-284.54	-201.74	-421.80	-489.00
6. Waste	1,461.00	1,496.02	1,541.30	1,586.91	1,636.52	1,688.56	1,627.23	1,432.27	1,509.40	1,550.34	1,643.43	1,481.77	1,651.90	1,794.90	1,792.08	1,773.52	1,831.42
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total including LULUCF	**55,714.19**	**56,715.40**	**56,753.04**	**56,986.56**	**58,320.34**	**59,660.96**	**61,792.00**	**63,279.77**	**65,774.12**	**67,251.49**	**69,180.68**	**70,761.10**	**68,753.62**	**68,361.66**	**68,499.23**	**69,923.26**	**69,273.35**

2.2 Trends by Gas

Emissions of CO_2 accounted for 67.8 percent of the total (excluding LULUCF) of 69,762.35 Gg CO_2 equivalent in 2006, with CH_4 and N_2O contributing 19.0 percent and 12.1 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for approximately 1 percent of total emissions in 2006. In 1990 emissions of CO_2, CH_4, N_2O and the combined emissions of HFCs, PFCs and SF_6 accounted for 58.6, 24.3, 17.1 and 0.1 percent, respectively of total emissions of 55,525.56 Gg CO_2 equivalent.

Emissions of CO_2 increased from 32,545.20 Gg in 1990 to 47,319.68 Gg in 2006, which equates to an increase of 45.4 percent. 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 are largely accounted for by road traffic increased by 167.6 percent. This trend is exaggerated somewhat in later years by so-called fuel-tourism whereby approximately 15 percent of automotive fuel sold in Ireland is used in vehicles in the UK and other countries. Over the time-series, emissions of CO_2 from energy industries have increased by 33.6 percent 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 accounted for only 8.2 percent of total emissions in 2006, nevertheless, these emissions increased by 43.3 percent between 1990 and 2006.

Methane is the second most significant contributor to greenhouse gas emissions in Ireland after CO_2, due mainly to large cattle populations. In 2006 emissions of CH_4 were 13,286.68 Gg CO_2 equivalent, a decrease of 1.3 percent on the 1990 level of 13,466.77 Gg CO_2 equivalent. Emissions of CH_4 increased progressively from 1990, reaching a peak in 1998 of 14,366.17 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*. Since 1998 CH_4 emissions have decreased as a result of falling livestock numbers due to reform of the Common Agricultural Policy (CAP). Emission levels in the period 2001-2006 have however fluctuated 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*, which have fluctuated on a yearly basis over this period. In addition, emissions from sector *6.A Solid Waste Disposal on Land* have increased by 5.4 percent over the same period.

Emissions of N_2O have decreased by 11 percent from their 1990 level of 9,477.40 Gg CO_2 equivalent in 1990 to 8,432.62 Gg in 2006. Similar to CH_4, emissions of N_2O increased during the 1990's to reach peak levels in 1999 reflecting increased use of synthetic fertilisers and increased amounts of organic 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 manure applications as a result of the effect of CAP reform on animal numbers.

Emissions of the F-gases (HFCs, PFCs and SF_6) were 731.24 Gg CO_2 equivalent in 2006 compared to 36.19 Gg CO_2 equivalent in 1990, a 20-fold increase over the time series. However F-gas emissions only account for approximately one percent 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 of PFCs show an increasing trend 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 2001. Semiconductor manufacturers continue to investigate various reduction initiatives through the use of gas substitution and new process technologies. As a result the downward trend in emissions between 2000 and 2006 may continue into the future. 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 35.41 Gg CO_2 equivalent and 68.60 Gg CO_2 equivalent in 1990 and 2006, respectively. However, emissions of SF_6 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 2006 contributes 66.1 percent of total greenhouse gas emissions (excluding *LULUCF*). The second largest sector is *Agriculture*, which accounted for 26.4 percent of total emissions in 2006. Emissions from *Industrial Processes, Solvent and Other Product Use* and *Waste* accounted for 4.7 percent, 0.1 percent and 2.6 percent, respectively of total emissions in 2006. 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 have increased by 46.1 percent from 31,590.77 Gg CO_2 equivalent in 1990 to 46,141.47 Gg CO_2 equivalent in 2006. This is largely due to the continued used of carbon intensive fuels in *1.A.1 Energy Industries*, *1.A.2 Manufacturing Industries and Construction, 1.A.3 Transport* and *1.A.4 Other Sectors*. Total greenhouse gas emissions from *1.A.1 Energy Industries* increased by 54.9 percent from 11,576.40 Gg in 1990 to 17,926.82 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 in category 1.A.1 decreased to 15,813.75 Gg CO_2 equivalent in 2004. Emissions in this category subsequently increased in 2005 to 16,219.72 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 have decreased to 15,427.79 Gg CO_2 equivalent due to a reduction in the use of Moneypoint coal-fired station for the installation of pollutant control measures. Overall drivers and trends in emissions from the *Energy* sector are presented in Figure 2.1 and Figure 2.2.

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 7.4 percent and 8.4 percent of total national greenhouse gas emissions in 1990 and 2006, respectively. However, the trend shows an increase of 43.4 percent 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*.

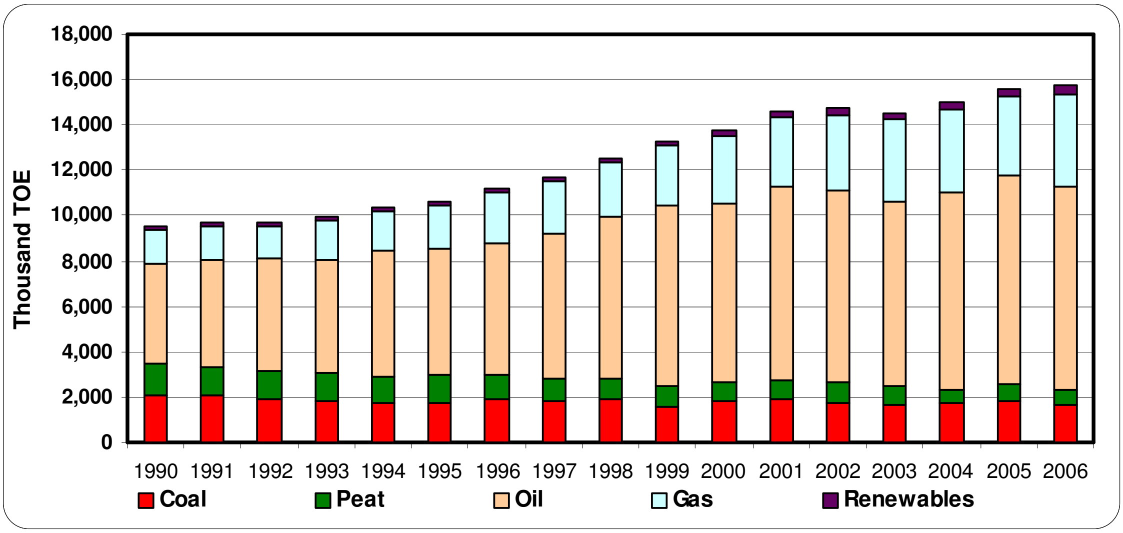

Figure 2.1 Total Primary Energy Requirement (TPER) 1990-2006

Fuel combustion emissions in *1.A.3 Transport* have increased by 165.4 percent from 5,168.23 Gg CO_2 equivalent in 1990 to 13,718.94 Gg CO_2 equivalent in 2006. This is largely accounted for by a 177.2 percent 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. The proportion is estimated to account for 15 percent of automotive fuels in 2006. It is worth noting that in the years 1990-1995 inclusive there was cross border movement of automotive fuels into the Republic of Ireland. Even though emissions from civil aviation have approximately doubled over since 1990, their overall effect on emission trends is negligible.

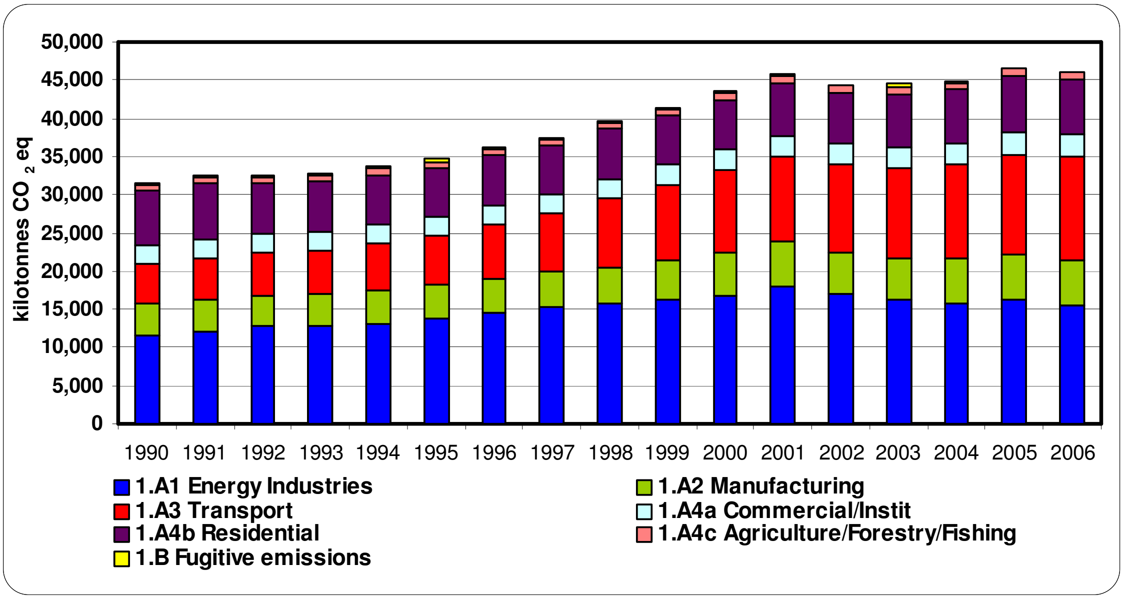

Figure 2.2 Trend in Emissions from Energy 1990-2006

Emissions from category *1.A.4 Other Sectors* increased by 4.5 percent from 10,468.92 Gg CO_2 equivalent in 1990 to 10,943.74 Gg CO_2 equivalent in 2006. Emissions from the Commercial (1.A.4 b) and Agriculture (1.A.4 c) sub-categories increased by 14.9 and 25.0 percent respectively, whilst those in the Residential (1.A.4 a) sub-category decreased by 0.8 percent. Although residential energy consumption increased by 20.4 percent from 1990 to 2006 there has been a decline in the use of carbon-intensive fuels, such as peat and coal, and greater use of oil and natural gas. The emissions of CO_2 from coal and peat use in the residential sector decreased by 62.7 percent between 1990 and 2006 while those from oil and natural gas more than doubled over this period.

2.3.2 Trends in Industrial Processes (IPCC Sector 2)

The contribution from *Industrial Processes* is relatively small accounting for 5.7 percent of total greenhouse gases in 1990 and 4.7 percent in 2006. Total emissions from the sector were 3,164.08 Gg CO_2 equivalent in 1990 and 3,269.81 Gg CO_2 equivalent in 2006. This small increase in emissions over the time series of 3.1 percent is not fully reflective of a number of important underlying trends in the sector. Overall trends in emissions from *Industrial Processes* is presented in Figure 2.3.

In the early 1990's the contribution of *2.B Chemical Industry* to overall sectoral emissions was on average 64.0 percent. By the late 1990's this proportion had fallen to approximately 45 percent of total emissions from the sector. In 1990 emissions from *2.B. Chemical Industry* were 2,024.57 Gg CO_2 equivalent, however by 2000 they had reduced by 16.2 percent to 1,695.74 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 percent. Economic growth was sustained into the early years of the new millennium with subsequent increases in emissions from the sector. In fact two new cement production plants were commissioned with one opening in 2000 and the other in 2003.

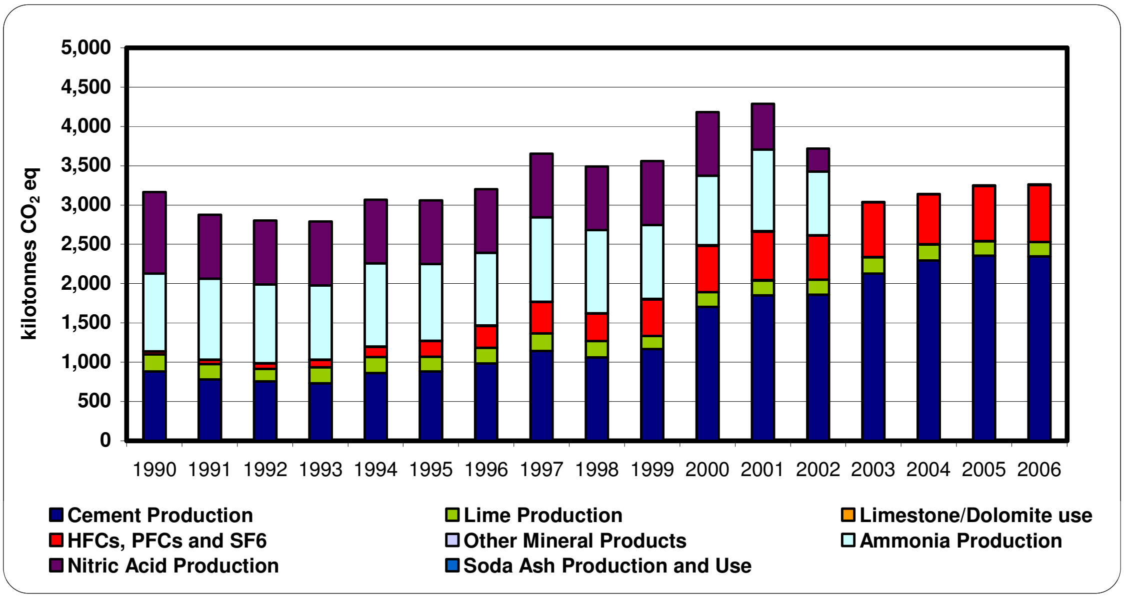

Figure 2.3 Trend in Emissions from Industrial Processes 1990-2006

The closure of Ireland's ammonia and nitric acid plants in 2002 signalled the use of the notation key "NO" in CRF tables for *2.B Chemical Industry* for subsequent years. As a result

CO_2 emissions from cement manufacture account for approximately 72 percent of total emissions from *Industrial Processes* in 2006. 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 5.8 percent of total sectoral emissions in 2006 and their effect on overall trends is negligible.

Emissions from *2.F Consumption of Halocarbons and SF_6* were estimated to be 723.37 Gg CO_2 equivalent in 2006, compared to 36.19 Gg CO_2 equivalent in 1990. This represents a 20-fold increase over the time series and a rise to 22.3 percent of the sectoral total for Industrial Processes in 2006. The contribution of F-gases in 2006 approximates that of N_2O from nitric acid production at the time this activity ceased in 2002. Trends in the emission of industrial gases are discussed in section 2.2.

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

Solvents and Other Product Use derived emissions do not affect the overall trend in greenhouse gases in Ireland. The CO_2 emissions from this source were estimated to be 80.96 Gg CO_2 in 1990 and 80.81 Gg CO_2 in 2006. 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 percent 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 26.7 percent in 1990 to 36.9 percent in 2006 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 5.2 percent and 9.2 percent, respectively of total over all emissions in the sector in 2006. Emissions from both sub-categories show downward trends over the time-series 1990-2006. A graphical representation of the trends in emissions from *Solvent and Other Product Use* is presented in Figure 2.4.

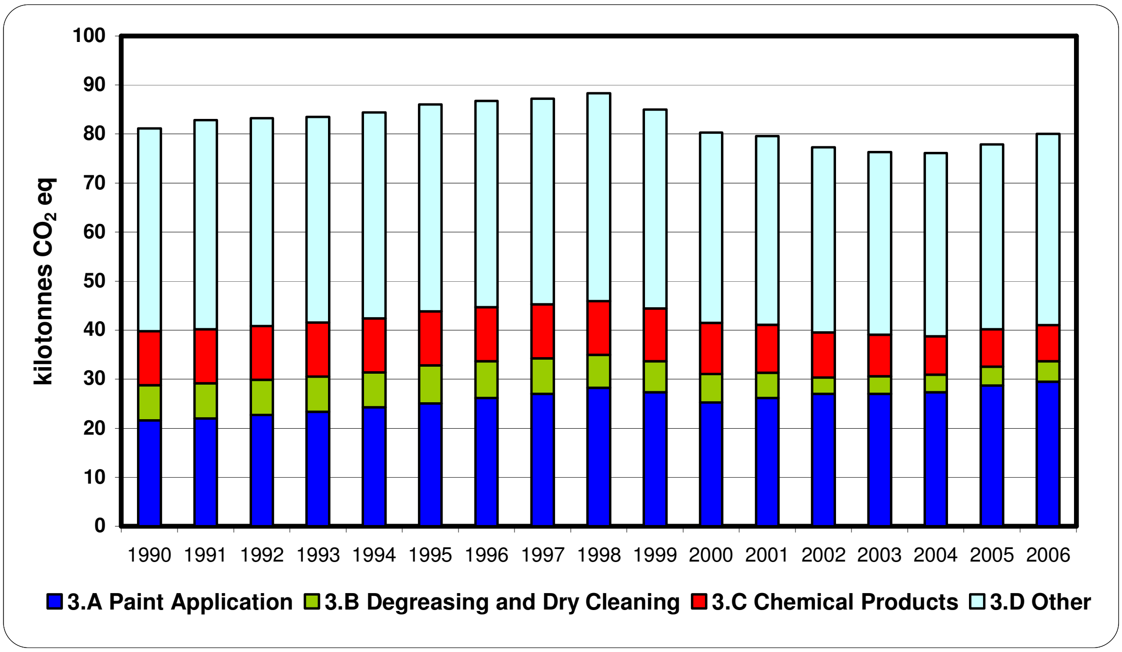

Figure 2.4 Trend in Emissions from Solvents and Other Product Use 1990-2006

2.3.4 Trends in Agriculture (IPCC Sector 4)

The trend in emissions from the *Agriculture* sector is presented in Figure 2.5 with the main drivers of the emissions presented in Figure 2.6. Emissions of greenhouse gases from the *Agriculture* sector amounted to 19,228.56 Gg CO_2 equivalent in 1990 and 18,447.52 Gg CO_2 equivalent in 2006, a reduction of 4.1 percent. Total emissions from the *Agriculture* sector increased by 9.5 percent in the period 1990-1998, reflecting an increase in animal numbers and increased synthetic nitrogen use on farms. Following this peak in emission levels, the annual emissions from the sector decreased by 12.4 percent 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 dependant 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 11,822.21 Gg CO_2 equivalent in 1990. This increased by 7.9 percent to reach 12,757.80 Gg CO_2 equivalent in 1998 and subsequently decreased by 10.8 percent to 11,385.30 Gg CO_2 equivalent in 2006. Cattle account for almost 90 percent of annual CH_4 emissions in 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 by 12.1 percent in the period 1990-1999 with emissions in 1999 totalling 8,305.24 Gg CO_2 equivalent. Nitrous oxide emissions totalling 7,062.22 Gg CO_2 equivalent in 2006 represent a reduction of 15.0 percent on the 1999 level.

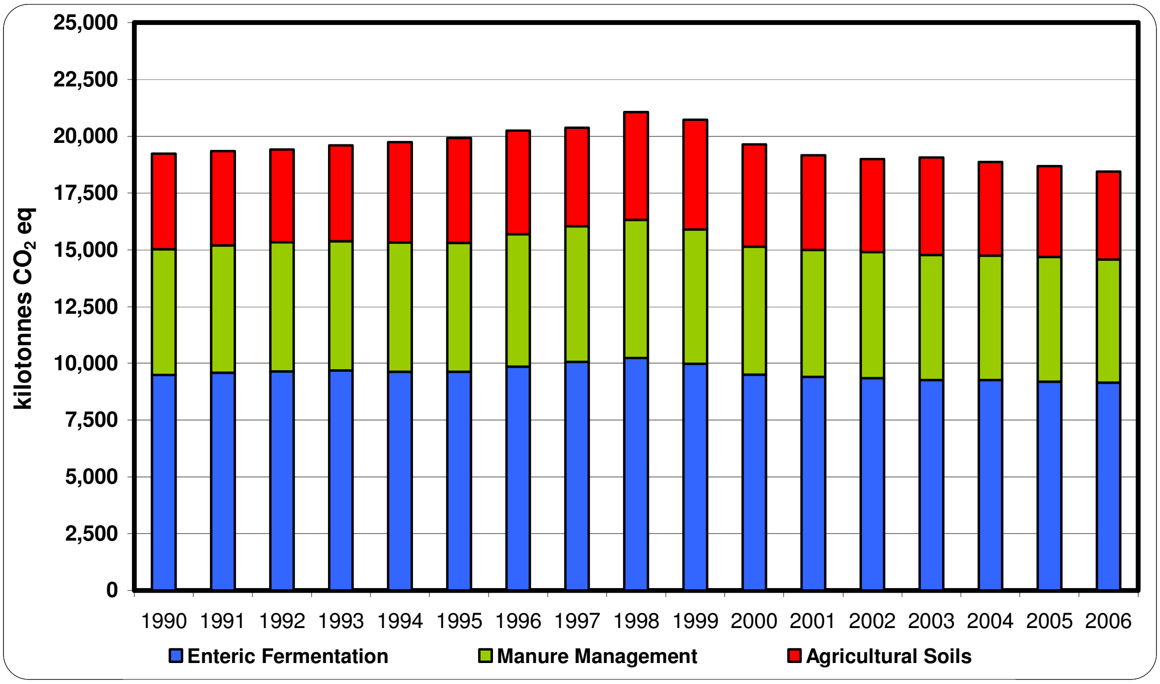

Figure 2.5 Trend in Emissions from Agriculture 1990-2006

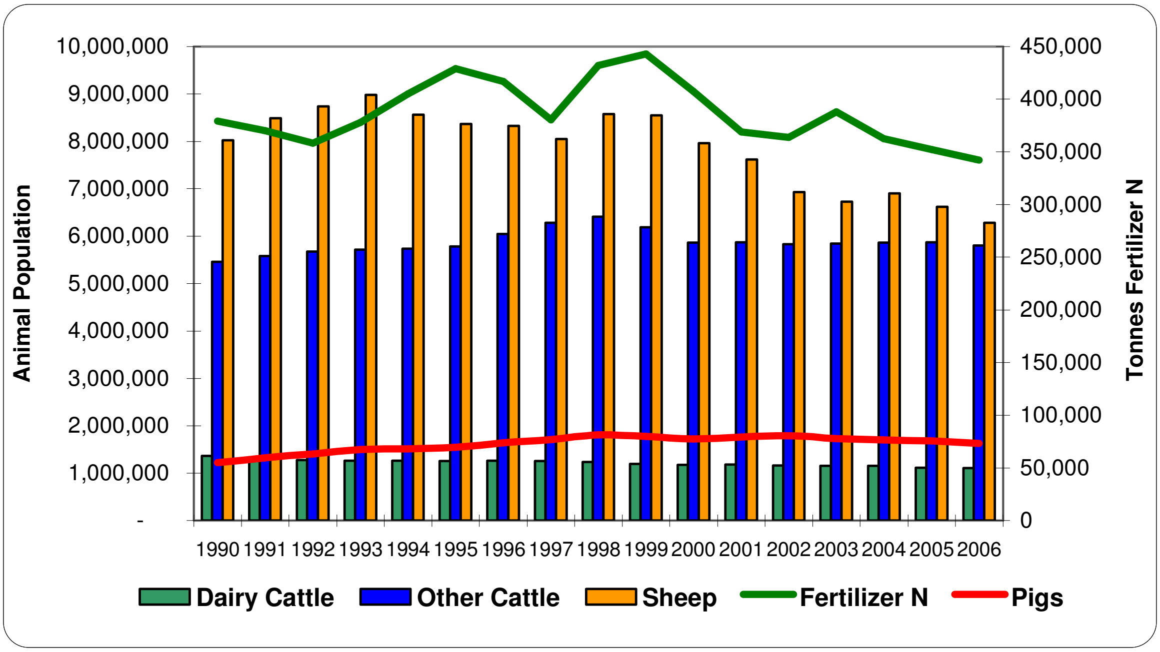

Figure 2.6 Principal Drivers of Emissions from Agriculture 1990-2006

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 source of emissions in some years and a net sink of carbon in other years (Table 2.1 and Figure 2.7). This result is determined largely by the balance between *5.A Forest Land*, which is a major carbon sink, and *5.C Grassland*, where soil disturbance and liming of agricultural lands generate relatively large emissions of CO_2. 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 1990-2006.

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.

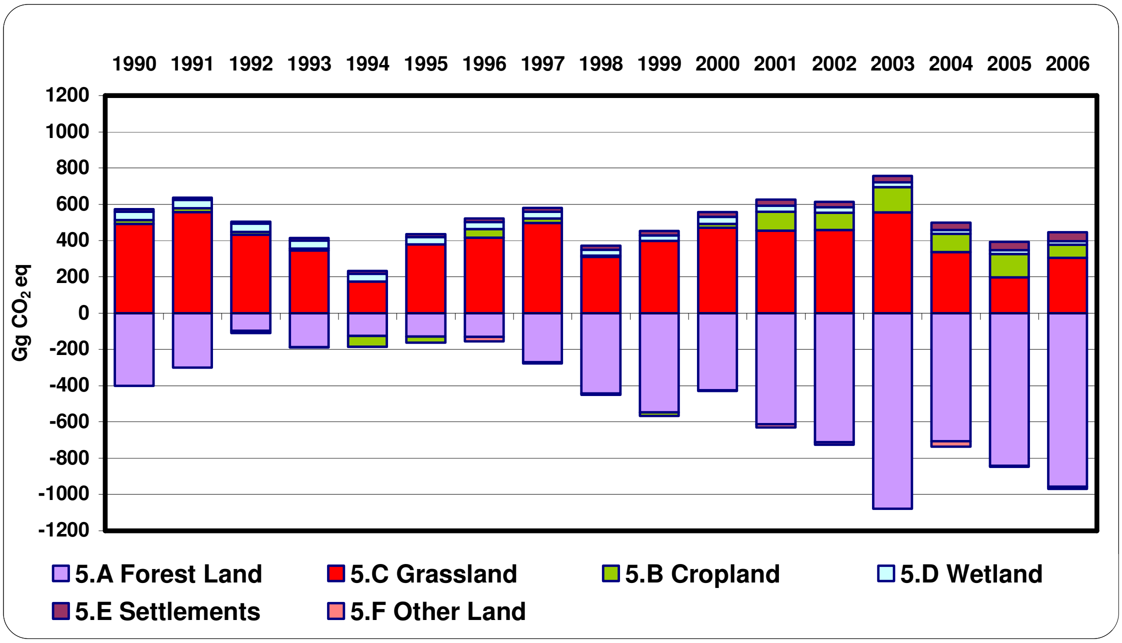

Figure 2.7 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2006

2.3.6 Trends in Waste (IPCC Sector 6)

The *Waste* sector is an important source of CH_4 emissions, the contribution of which is increasing steadily (Figure 2.8) due to the continued dominance of landfill as a means of solid waste disposal in Ireland. Emissions from the waste sector have increased by 25.4 percent from 1,461.00 Gg CO_2 equivalent in 1990 to 1,831.42 Gg CO_2 equivalent in 2006. This increase in emission levels takes into account the recovery of landfill gas for energy production and flaring at landfill sites, without which emissions of this sector would be considerably larger.

The main contributor to trends in the *Waste* sector is CH_4 emissions from municipal solid wastes (MSW) disposed of at solid waste disposal sites (SWDS) or landfills (*6.A Solid Waste Disposal on Land*). The emission of CH_4 from SWDS in a particular year is the cumulative contribution for that year arising from MSW deposited over a period of 21 years that ends in the year concerned. The quantities of MSW deposited at SWDS are dependent on a number of factors, of which population trends and the quantities and MSW and its constituents are the most important. There have been minor changes in the constituent proportions of MSW over the period 1990-2006. The proportion of organic materials has increased from 34 percent in 1990 to 37 percent in 2006. The proportions of paper and textiles have changed from 29 percent and 3 percent, respectively in 1990 to 24 percent and 8 percent respectively in 2006. As the quantities of MSW increase in line with increasing population the consequences of these proportional changes in MSW characteristics become more pronounced due to the differing degradable organic carbon contents of the waste streams and their associated CH_4 production potentials. Since 1990 the population of the Republic of Ireland has increased by 20.9 percent with an associated increase in the quantity of MSW produced of 124.6 percent. However, even though recycling has become a part of every day life in Irish households and businesses, the quantity of MSW disposed of in SWDS has increased by 74.8 percent over the same period.

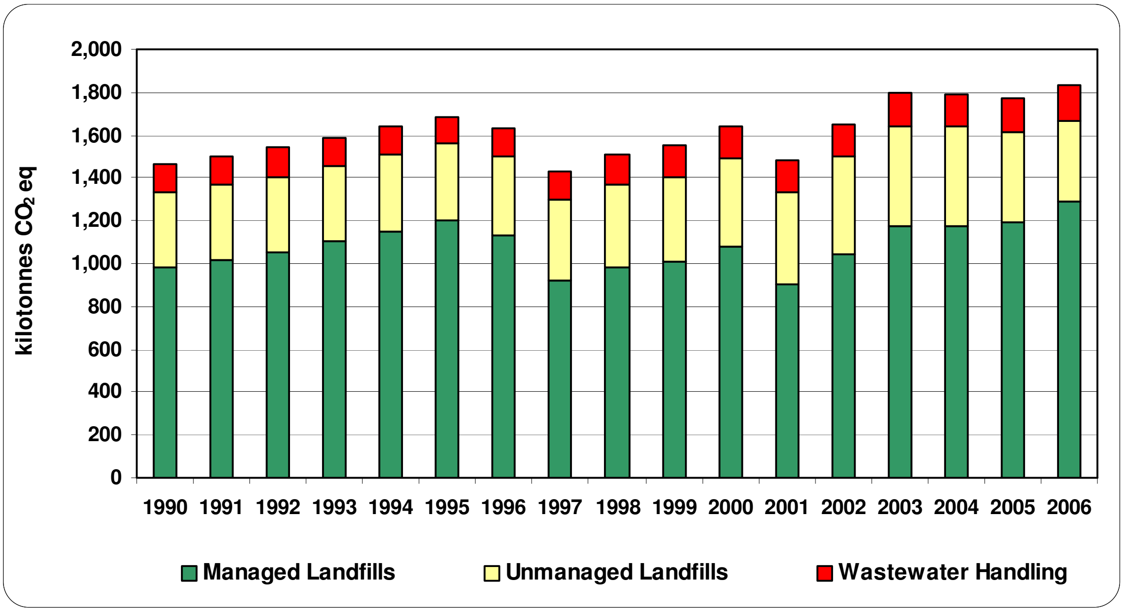

Figure 2.8 Trend in Emissions from Waste 1990-2006

Landfill gas recovery for energy production or flaring has become an important element in the accounting of emissions form the *Waste* sector. Since 1996 a small number of landfill sites have utilised landfill gas for electricity production. In addition, since 2001 CH_4 flaring has become an important part of management practices at landfill sites. The combined effect of these measures has offset the significant increase in CH_4 emission estimates associated with increased quantities of MSW disposed of at SWDS.

Emissions of CH_4 and N_2O from *6.B Wastewater Handling* accounted for 128.73 Gg CO_2 equivalent in 1990 and 162.01 Gg CO_2 equivalent in 2006 which equates to 8.8 percent of total emissions from the sector in both years. The contribution of this sub-category to overall sectoral trends is negligible.

2.4 Emissions of Indirect Greenhouse Gases

The total emissions of SO_2, NO_X, NMVOC and CO for the years 1990 to 2006 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 VOC emissions are generated by road traffic and solvent use. Substantial decreases have occurred in the emissions of SO_2 and CO. Some reductions have also taken place in NMVOC emissions but emissions of NO_X in 2006 were similar to that in 1990.

Total SO_2 emissions decreased by approximately 67.2 percent, from 182,840 tonnes in 1990 to 59,890 tonnes in 2006. Power stations remain the principal source of SO_2 emissions, contributing approximately 61.4 percent of the total in 2006. Combustion sources in the industrial and residential/commercial sectors largely account for the remainder of emissions, with contributions of 11.4 percent and 22.2 percent, respectively in 2006. In 1990, coal combustion accounted for 51.4 percent of SO_2 emissions and fuel oil contributed 30.7 percent. By 2006, the share of SO_2 emissions from coal had decreased slightly to 47.0 percent and that from fuel oil had decreased to 29.9 percent.

Table 2.2. Emissions of SO_2, NO_X, VOC and CO 1990-2006 (Tonnes)

	SO_2	NO_X	NMVOC	CO
1990	182,840	126,562	108,548	406,913
1991	180,007	128,513	110,156	404,774
1992	168,517	137,156	111,624	385,985
1993	159,529	124,708	110,039	358,387
1994	174,083	125,613	106,570	335,282
1995	160,031	127,772	104,544	308,171
1996	148,657	131,981	110,709	314,369
1997	165,220	132,284	111,909	298,702
1998	176,694	137,040	113,329	307,633
1999	157,669	136,373	91,431	274,438
2000	137,155	139,100	81,172	246,705
2001	129,635	140,659	78,041	236,585
2002	99,643	131,050	71,182	218,241
2003	77,942	126,228	67,154	206,459
2004	72,143	125,731	63,202	196,820
2005	70,897	127,282	61,761	187,178
2006	59,890	122,438	60,629	178,386

Unlike SO_2, total NO_X emissions show only a small reduction after 2001. Road transport is the principal source of NO_X emissions, contributing approximately 40.4 percent of the total in 2006. The power generation sector is the other main source of NO_X emissions, accounting for 24.4 percent of emissions in 2006. 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 sources typically produce about 80 per cent of the annual total of NMVOC emissions in Ireland. Coal burning in the residential sector is another important source. Technological controls for VOCs 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. However, NMVOC emissions from paint application and the domestic use of various solvent-based products are still increasing with the result that overall NMVOC emissions reductions are not large for the period 1990-2006.

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 implements programmes to comply with the requirements of the National Emission Ceilings Directive (EP and CEU, 2001).

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 sufficiently detailed completion of the CRF tables. The overall approach and methodologies used to estimate emissions in the *Energy* sector for 2006 remain largely as described in the 2007 NIR. As for 2005, CO_2 estimates reported under the ETS for 2006 are used to achieve complete bottom-up results in respect of some important sub-categories in this sector for the 2006 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 *Energy*.

Table B.1 of Annex B shows the national energy balance sheets for 2006, published by Sustainable Energy Ireland (SEI). The energy statistics are compiled using a combination of top-down and bottom-up methods and the 2006 example indicates the same form of expanded balance sheet as previously used for 1990 and - 2005. The improved balance sheets reflect revisions made by SEI as part of 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 Irish energy balances incorporate additional sectoral disaggregation specific to the needs of the greenhouse gas inventory, following close collaboration between SEI and the inventory agency over recent years. The annual submission of up-to-date energy balances from SEI 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 1990-2006 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 2006 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	NO	NA
b. Natural gas	All	All	NA
c. Venting and Flaring	All	All	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 64.0 percent of total emissions in 2006 (Chapter Two). 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.

The Irish 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 2006 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, except those for petroleum coke and biomass, are country-specific values, determined directly from information on the carbon content and net calorific value of the fuels used in stationary and mobile sources. Where ETS data are used for the 2006 inventory, they provide more precision on CO_2 emission factors on an individual plant basis. 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 import of natural gas from the UK began around 1993 and imported gas accounted for almost 90 percent of the total in 2006. The CO_2 emission factor appropriate to the split between domestic and imported natural gas, which is more carbon intensive, was first applied for the 2004 inventory. The same approach is now used for all years from 1993 to 2006.

The combustion CO_2 emission factors adopted for use by participants in ETS take account of the fact that a very small fraction of fuel carbon may remain unoxidised and IPCC oxidation factors appropriate to solid, liquid and gaseous fuels are applied to compute the emissions. For other combustion sources, where activity data are in general top-down fuel use 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 for petroleum coke and biomass, the latter almost invariably referring to wood and wood wastes. For stationary sources and all mobile sources except road traffic, Ireland has to date 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).

3.2.1.1 Energy Industries (1.A.1)

The returns from ETS participants in respect of their emissions and fuel combustion in 2006 under Directive 2003/87/EC (EP and CEU, 2003) to the EPA's Emission Trading Unit (ETU) were used to compile the complete inventory for category 1.A.1. The data from a total of only 18 individual installations – 15 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) – were sufficient to compute 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 was used to estimate CH_4 and N_2O emissions using the emission factors as previously applied in these sub-categories.

The bottom-up CO_2 emission estimates received from the ETS participants, along with the emissions of CH_4 and N_2O estimated by the inventory agency, are aggregated on the basis of four main fuel types (peat, coal, oil and natural gas) in the calculation sheets 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 energy balance, rather than from the ETS returns, following established practice to always reflect the published national energy data in emission inventories. The differences between ETS energy amounts and those given by the energy balance are very small for 2006 as the inventory agency communicated the ETS data to SEI so that the energy use in respect of category 1.A.1 could be compared and reconciled with that being compiled through SEI's own surveys and procedures.

Figure 3.1 shows the trend in emissions from 1.A.1(a) Public Electricity and Heat Production over the period 1990-2006, which account for almost 97 percent of the total for category 1.A.1. It may be noted that CO_2 emissions from coal, peat and oil all decreased in 2006. Emissions of CO_2 from Ireland's only coal fired power plant decreased by over 720 kilotonnes in 2006 due to ongoing improvements in emission abatement technologies at this plant. Emissions from natural gas increased by 558 kilotonnes as gas-fired plant were used more in favour of those using other fuels and a new combined cycle gas turbine plant entered service in 2006.

One small oil refinery accounts for the emissions reported under 1.A.1(b) Petroleum Refining using ETS data and country-specific emission factors. 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 2006 values for CO_2 are also taken from ETS returns while CH_4 and N_2O estimates are computed by the inventory agency.

The inventory experts are collaborating with colleagues to fully consolidate and formalise data gathering for this important sub-set of emissions using prescribed monitoring and verification mechanisms to ensure consistency with reporting under the Convention and Decision 280/2004/EC.

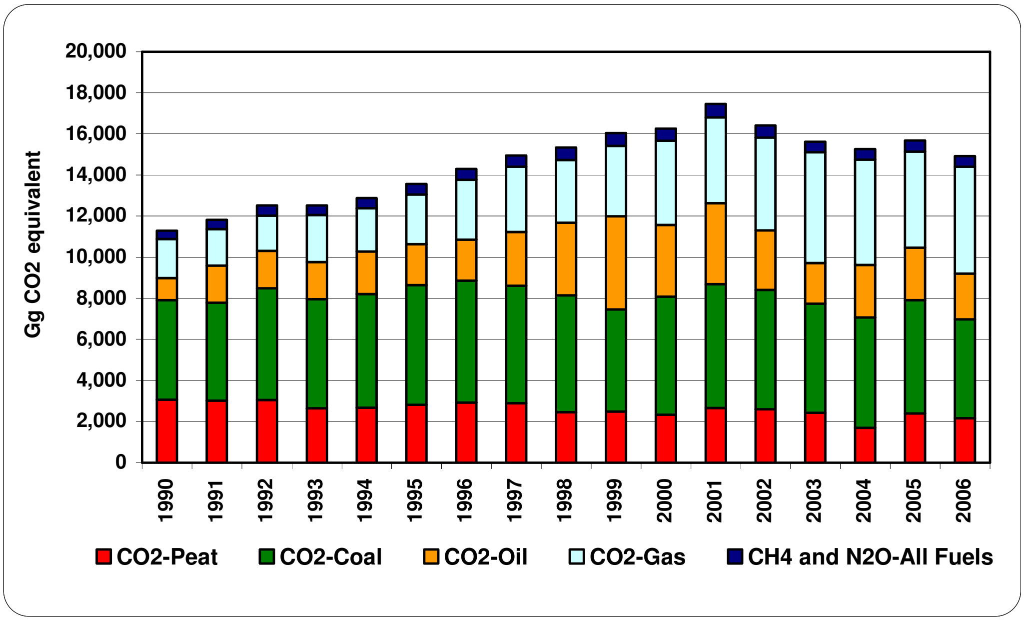

Figure 3.1 Trend in Emissions from 1.A.1 Energy Industries 1990-2006

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

The revised and expanded energy balance sheets developed by SEI 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 (a) through (f). Information on fuel consumption in 2006 was obtained from ETS returns in respect of a small number of energy intensive industries (e.g. alumina production and cement manufacture) allowing their respective energy use amounts to be incorporated into the national energy balance. Emissions are estimated on a top-down basis using the country-specific emission factors as shown in Table C.1 of Annex C.

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 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.

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 energy balance sheet 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 the State, even though a significant proportion of automotive fuels purchased in Ireland is used in the UK. The CH_4 and N_2O emissions from road traffic are estimated in the COPERT 4 model (Gkatzoflias et al., 2007), developed within the CORINAIR programme for estimating a range of emissions from this important source. This is the first submission which uses this new version of the COPERT model resulting in recalculations to CH_4 and N_2O emissions for all years 1990-2005. Road traffic is an important source of N_2O from fuel combustion and the emissions are increasing in line with the increasing share of catalyst-controlled vehicles in the national fleet. The COPERT 4 model estimates these emissions 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 2006 emission factors have been converted to national average values per fuel type for the purpose of Table C.1 in Annex C.

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 and the country specific emission factors for oil. The emissions reported in sub-category 1.A.3(e) Other Transportation refer to the use of natural gas 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 energy balance sheet (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.

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 sector remains the most important source of emissions in this sub-category in Ireland. This is evident from Figure 3.2, which shows the trend in the principal components of emissions in 1.A.4 Other Sectors over the period 1990-2006. While the shift from carbon-intensive fuels, such as coal and peat, to oil and natural gas has been sufficient to maintain emissions relatively constant up to 2006, the benefits from fuel switching are now fully realised and the emissions from oil and gas are increasing in line with higher fuel consumption resulting from greater housing stock and population.

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 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.

3.2.2 Fugitive Emissions (1.B)

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

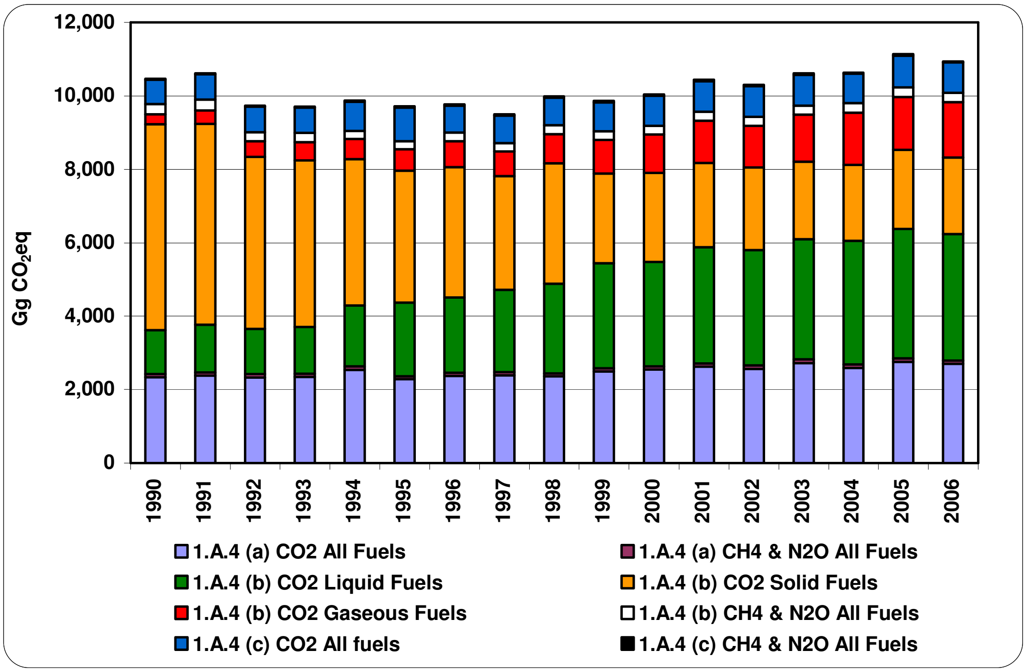

Figure 3.2 Trend in Emissions from 1.A.4 Other Sectors 1990-2006

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 off-shore gas production platforms are reported to the Department of Communications Marine and Natural Resources under the OSPAR Convention. Such reports have been obtained for several years in the 1990-2006 time series and the estimates of CO_2 and CH_4 emissions given therein are used directly for the years concerned. 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 for 2006.

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 2006 CRF) is reproduced as Table C.4 of Annex C of this report. The apparent consumption of fuels, the basic activity data in this case, is determined as

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

where production applies only to primary fuels. Naphtha was previously the only petroleum product to be considered in relation to non-energy fuel-use, where the carbon is not fully released as in combustion. The IPCC default value of 0.50, 0.75 and 1.0 are used for the proportion of carbon stored in lubricants, naphtha and bitumen respectively. Ireland's only oil refinery is a small hydroskimming refinery where there is no production of other petroleum products normally used for non-energy purposes, such as bitumen, lubricants, plastics and asphalt. The expanded SEI 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 2002 and there is consequently no feedstock use of natural gas since 2002.

3.4 Comparison of CO_2 Estimates from the 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. Differences of -0.45 percent and –0.32 percent are indicated for total energy and CO_2 emissions, respectively in 2006. The differences are largely due to those for solid fuels, where they amount to 2.55 percent for energy and 2.84 percent for CO_2 emissions. This is due to the "statistical difference" in peat fuels (milled, sod and briquettes) in the 2006 energy balance between the primary energy supply (PER) and total final consumption (TFC).

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 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 2006 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 2006, the amount of fuel allocated to domestic aviation was approximately 3.8 percent of the total recorded under air transport in the energy balance.

3.6 Quality Assurance and Quality Control

Extensive QA/QC procedures have been followed for the Energy sector during the present reporting cycle by fully implementing the plan that underpins Ireland's formal national system. This involved the designation of a QA/QC manager within the inventory agency and the application of a system of quality control checks and documentation spreadsheets to the front of all calculation workbooks. These workbooks were restructured to correspond directly to the disaggregation given by the CRF sectoral background data tables and 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 SEI, 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 now completed by SEI. This work, together with further collaboration with inventory experts and thorough evaluation of the SEI 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 2006 included in the present submission. In recognition of its role as a key data provider, SEI is continuing to develop its own procedures to ensure that energy balances fully harmonised with Eurostat and IEA requirements will be 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 SEI. Plans are being formulated to supplement traditional approaches to energy accounting by undertaking surveys of greater frequency and increased bottom-up detail.

The formal application of ETS data in the Energy sector for 2006 is a timely and important step towards improved reliability and accuracy of the estimates. Thorough checking of this input was achieved in collaboration with colleagues in the Emissions Trading Unit of the EPA. Having received the raw ETS data from ETU, the inventory experts allocated the CO_2 estimates and corresponding energy amounts to the appropriate sub-categories for CRF reporting and then returned the compilation to the ETU contact for final checking and accounting of any amendments following the ETS verification process.

3.7 Recalculations in Energy

Recalculations have been undertaken in the Energy sector to account for the following

- Revision of the national energy balance for years 1990-2005 to reduce the "statistical differences" (between TPER and TFC) in the national oil balance. The most significant recalculations occurred in 2004 and 2005 and were trivial in most other years;
- Revision of natural gas consumption for 2004 and 2005 in sectors *Manufacturing Industries and Construction (1.A.2)* and *Other Sectors (1.A.4.b)*;
- Revised methodology for estimating emissions of CH_4 and N_2O from *Road Transport sector (1.A.3.b)* by adoption of COPERT 4 version 4.0;
- Revision to include estimates of N_2O from Gasoil use in the *Energy Industries sector (1.A.1.a),* which were incorrectly omitted in Submission 2007.

This work together with some other minor modifications is now reflected in the results of the recalculations as given in Tables 3.2, 3.3, 3.4 and 3.5. The overall effects on total GHG emissions are very small, between –0.54 and 0.38 percent.

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
Sub-category total in 2007 Submission (Gg CO_2 equivalent)																	
1.A.1.	Energy Industries (Gg CO_2 eq)	11,575.12	12,071.35	12,767.59	12,775.62	13,134.27	13,832.80	14,558.23	15,245.41	15,683.33	16,355.46	16,642.75	17,922.27	16,941.83	16,165.93	15,799.47	16,207.40
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	4,107.55	4,243.55	3,919.16	4,133.76	4,415.30	4,524.75	4,320.83	4,755.42	4,767.00	4,921.39	5,889.53	5,870.91	5,569.77	5,570.26	5,648.23	5,660.60
1.A.3.	Transport (Gg CO_2 eq)	5,182.11	5,387.76	5,849.62	5,833.74	6,092.78	6,320.77	7,402.31	7,769.83	9,169.85	10,178.66	10,951.43	11,483.10	11,684.06	11,879.48	12,592.37	13,460.87
1.A.4.	Other Sectors (Gg CO_2 eq)	10,468.63	10,615.77	9,738.80	9,714.67	9,879.80	9,717.59	9,772.29	9,502.91	9,988.05	9,866.09	10,043.25	10,441.69	10,304.02	10,612.63	10,636.97	10,938.34
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	269.96	269.71	263.59	281.68	280.61	280.93	270.84	246.54	199.94	206.42	156.53	226.07	134.55	685.34	137.35	117.06
1. Total (Gg CO_2 eq)		31,603.37	32,588.14	32,538.75	32,739.47	33,802.76	34,676.83	36,324.52	37,520.10	39,808.17	41,528.02	43,683.48	45,944.03	44,634.23	44,913.64	44,814.39	46,384.29
Sub-category total in 2008 Submission (Gg CO_2 equivalent)																	
1.A.1.	Energy Industries	11,576.40	12,072.50	12,769.06	12,776.66	13,137.67	13,835.56	14,559.97	15,247.30	15,685.84	16,359.98	16,648.12	17,926.82	16,945.58	16,170.87	15,813.75	16,219.72
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	4,107.26	4,226.52	3,902.11	4,116.66	4,398.18	4,507.61	4,303.67	4,738.14	4,749.50	4,973.69	5,872.80	5,854.17	5,553.02	5,570.25	5,967.12	6,051.94
1.A.3.	Transport (Gg CO_2 eq)	5,168.23	5,373.65	5,824.70	5,791.57	6,034.36	6,270.94	7,329.20	7,683.37	9,054.55	10,021.40	10,760.40	11,274.04	11,457.75	11,635.66	12,270.47	13,036.90
1.A.4.	Other Sectors (Gg CO_2 eq)	10,468.92	10,615.70	9,739.12	9,715.03	9,879.39	9,717.19	9,771.56	9,502.10	9,987.37	9,864.89	10,041.46	10,439.61	10,301.93	10,610.44	10,637.66	11,135.41
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	269.9621	269.7106	263.5889	281.6794	280.6129	280.9286	270.8442	246.5355	199.9436	206.4197	156.5263	226.0672	134.5483	685.3434	137.3451	117.0397
1. Total (Gg CO_2 eq)		31,590.77	32,558.08	32,498.58	32,681.60	33,730.22	34,612.23	36,235.26	37,417.44	39,677.20	41,426.38	43,479.30	45,720.72	44,392.83	44,672.55	44,826.36	46,561.00
Percentage change in total GHG Emissions from Energy																	
1.A.1.	Energy Industries	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.03	0.09	0.08
1.A.2.	Manufacturing Industries and Construction	-0.01	-0.40	-0.44	-0.41	-0.39	-0.38	-0.40	-0.36	-0.37	1.06	-0.28	-0.29	-0.30	0.00	5.65	6.91
1.A.3.	Transport	-0.27	-0.26	-0.43	-0.72	-0.96	-0.79	-0.99	-1.11	-1.26	-1.54	-1.74	-1.82	-1.94	-2.05	-2.56	-3.15
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	0.01	1.80
1.B.	Fugitive Emissions from Fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
1. Total		-0.04	-0.09	-0.12	-0.18	-0.21	-0.19	-0.25	-0.27	-0.33	-0.24	-0.47	-0.49	-0.54	-0.54	0.03	0.38

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
		Sub-category total in 2007 Submission (Gg CO_2 equivalent)															
1.A.1.	Energy Industries (Gg CO_2 eq)	11,158.62	11,617.34	12,279.74	12,297.59	12,634.28	13,317.47	14,031.86	14,692.87	15,080.53	15,732.98	16,050.38	17,266.57	16,345.34	15,643.44	15,283.51	15,657.29
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	3,969.76	4,101.01	3,785.02	3,994.43	4,259.72	4,365.44	4,172.23	4,588.25	4,599.87	4,748.00	5,682.10	5,660.99	5,371.49	5,371.09	5,444.89	5,453.71
1.A.3.	Transport (Gg CO_2 eq)	5,045.02	5,245.42	5,694.65	5,653.42	5,891.79	6,123.46	7,162.07	7,504.93	8,847.83	9,810.93	10,535.34	11,041.74	11,237.21	11,419.24	12,101.91	12,942.05
1.A.4.	Other Sectors (Gg CO_2 eq)	10,064.90	10,198.47	9,377.33	9,354.88	9,523.50	9,374.17	9,413.81	9,158.46	9,626.52	9,507.14	9,681.31	10,068.53	9,935.22	10,232.99	10,260.41	10,549.80
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	138.88	142.34	140.78	159.92	162.67	166.75	160.75	141.04	107.85	117.06	70.82	134.00	65.40	58.88	71.30	60.20
1. Total (Gg CO_2 eq)		30,377.18	31,304.58	31,277.51	31,460.23	32,471.95	33,347.29	34,940.73	36,085.55	38,262.60	39,916.11	42,019.95	44,171.82	42,954.66	42,725.64	43,162.02	44,663.05
		Sub-category total in 2008 Submission (Gg CO_2 equivalent)															
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
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	3,969.48	4,084.32	3,768.32	3,977.67	4,242.95	4,348.64	4,155.42	4,571.32	4,582.72	4,797.69	5,665.71	5,644.59	5,355.08	5,371.09	5,758.41	5,836.54
1.A.3.	Transport (Gg CO_2 eq)	5,039.39	5,242.11	5,685.51	5,646.50	5,880.60	6,109.25	7,147.40	7,485.36	8,828.98	9,787.53	10,516.88	11,021.64	11,219.60	11,401.15	12,032.62	12,796.74
1.A.4.	Other Sectors (Gg CO_2 eq)	10,065.19	10,198.77	9,377.64	9,355.23	9,523.86	9,374.57	9,414.22	9,158.99	9,627.27	9,507.93	9,681.31	10,068.53	9,935.22	10,232.99	10,263.29	10,742.40
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	138.88	142.34	140.78	159.92	162.67	166.75	160.75	141.04	107.85	117.06	70.82	134.00	65.40	58.88	71.30	60.18
1. Total (Gg CO_2 eq)		30,371.56	31,284.88	31,251.99	31,436.91	32,444.36	33,316.68	34,909.64	36,049.59	38,227.34	39,943.19	41,985.09	44,135.32	42,920.65	42,707.54	43,409.13	45,093.15
		Percentage change in CO_2 Emissions from Energy															
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
1.A.2.	Manufacturing Industries and Construction	-0.01	-0.41	-0.44	-0.42	-0.39	-0.38	-0.40	-0.37	-0.37	1.05	-0.29	-0.29	-0.31	0.00	5.76	7.02
1.A.3.	Transport	-0.11	-0.06	-0.16	-0.12	-0.19	-0.23	-0.20	-0.26	-0.21	-0.24	-0.18	-0.18	-0.16	-0.16	-0.57	-1.12
1.A.4.	Other Sectors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.03	1.83
1.B.	Fugitive Emissions from Fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04
1. Total		-0.02	-0.06	-0.08	-0.07	-0.08	-0.09	-0.09	-0.10	-0.09	0.07	-0.08	-0.08	-0.08	-0.04	0.57	0.96

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
		Sub-category total in 2007 Submission (Gg CO_2 equivalent)															
1.A.1.	Energy Industries (Gg CO_2 eq)	0.86	0.68	0.59	0.60	0.69	0.63	0.63	0.45	0.74	0.72	0.80	1.06	1.34	1.51	1.38	0.97
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	24.74	25.99	15.49	17.53	11.51	13.81	16.29	16.64	15.69	14.56	22.83	27.24	25.70	26.96	29.36	32.27
1.A.3.	Transport (Gg CO_2 eq)	36.39	37.49	40.45	40.60	42.50	43.12	47.22	50.89	57.14	55.61	54.98	54.84	52.27	49.29	47.35	45.50
1.A.4.	Other Sectors (Gg CO_2 eq)	94.99	97.02	77.63	76.61	66.12	58.13	63.99	56.18	59.93	49.87	51.33	50.35	48.40	49.65	48.13	49.88
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	89.36	85.71	92.07	69.14	626.46	66.05	56.86
1. Total (Gg CO_2 eq)		288.06	288.56	256.97	257.11	238.75	229.86	238.22	229.66	225.59	210.13	215.65	225.57	196.86	753.87	192.25	185.49
		Sub-category total in 2008 Submission (Gg CO_2 equivalent)															
1.A.1.	Energy Industries	0.86	0.68	0.59	0.60	0.69	0.63	0.63	0.45	0.74	0.72	0.80	1.06	1.34	1.51	1.38	0.97
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	24.74	25.98	15.48	17.52	11.49	13.80	16.27	16.63	15.68	14.81	22.82	27.23	25.69	26.96	29.59	32.52
1.A.3.	Transport (Gg CO_2 eq)	45.88	47.59	51.18	46.33	44.46	48.14	49.55	48.02	49.21	47.89	43.14	40.90	36.58	33.82	31.50	29.53
1.A.4.	Other Sectors (Gg CO_2 eq)	94.99	96.90	77.63	76.61	65.85	57.86	63.61	55.73	59.44	49.20	50.73	49.65	47.69	48.91	47.38	49.39
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	131.08	127.37	122.81	121.76	117.94	114.18	110.09	105.50	92.09	89.36	85.71	92.07	69.14	626.46	66.05	56.86
1. Total (Gg CO_2 eq)		297.56	298.52	267.69	262.83	240.44	234.60	240.15	226.33	217.16	201.99	203.19	210.91	180.45	737.67	175.89	169.27
		Percentage change in CH_4 Emissions from Energy															
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	-0.08
1.A.2.	Manufacturing Industries and Construction	0.00	-0.05	-0.09	-0.08	-0.12	-0.10	-0.08	-0.08	-0.09	1.75	-0.06	-0.05	-0.05	0.00	0.79	0.78
1.A.3.	Transport	26.10	26.94	26.53	14.12	4.61	11.64	4.93	-5.63	-13.88	-13.89	-21.54	-25.43	-30.01	-31.38	-33.48	-35.11
1.A.4.	Other Sectors	0.00	-0.13	0.00	0.00	-0.39	-0.46	-0.60	-0.81	-0.81	-1.35	-1.17	-1.39	-1.46	-1.49	-1.54	-0.99
1.B.	Fugitive Emissions from Fuels	0.00	0.00	0.00	0.00	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		3.30	3.45	4.17	2.23	0.71	2.06	0.81	-1.45	-3.73	-3.87	-5.78	-6.50	-8.33	-2.15	-8.51	-8.74

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
								Sub-category total in 2007 Submission (Gg CO_2 equivalent)									
1.A.1.	Energy Industries (Gg CO_2 eq)	415.64	453.33	487.25	477.42	499.30	514.70	525.74	552.09	602.06	621.75	591.57	654.64	595.14	520.98	514.59	549.14
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	113.05	116.55	118.64	121.80	144.07	145.50	132.32	150.52	151.43	158.83	184.59	182.68	172.58	172.21	173.98	174.62
1.A.3.	Transport (Gg CO_2 eq)	100.70	104.84	114.52	139.72	158.49	154.19	193.02	214.01	264.88	312.12	361.11	386.52	394.58	410.95	443.11	473.32
1.A.4.	Other Sectors (Gg CO_2 eq)	308.73	320.28	283.85	283.18	290.19	285.29	294.49	288.27	301.61	309.07	310.61	322.81	320.41	329.99	328.43	338.66
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1. Total (Gg CO_2 eq)		938.13	994.99	1,004.27	1,022.12	1,092.05	1,099.68	1,145.57	1,204.88	1,319.99	1,401.78	1,447.88	1,546.64	1,482.71	1,434.13	1,460.11	1,535.74
								Sub-category total in 2008 Submission (Gg CO_2 equivalent)									
1.A.1.	Energy Industries	416.92	454.48	488.72	478.47	502.71	517.46	527.49	553.98	604.57	626.28	596.95	659.20	598.89	525.92	528.87	561.45
1.A.2.	Manufacturing Industries and Construction (Gg CO_2 eq)	113.04	116.22	118.31	121.47	143.74	145.17	131.98	150.19	151.10	161.19	184.27	182.35	172.26	172.21	179.12	182.88
1.A.3.	Transport (Gg CO_2 eq)	82.96	83.94	88.01	98.73	109.29	113.55	132.25	149.98	176.36	185.98	200.37	211.51	201.57	200.68	206.36	210.63
1.A.4.	Other Sectors (Gg CO_2 eq)	308.74	320.03	283.85	283.19	289.67	284.77	293.74	287.38	300.66	307.76	309.42	321.43	319.02	328.54	326.99	343.61
1.B.	Fugitive Emissions from Fuels (Gg CO_2 eq)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1. Total (Gg CO_2 eq)		921.65	974.67	978.90	981.86	1,045.41	1,060.95	1,085.46	1,141.53	1,232.69	1,281.20	1,291.02	1,374.49	1,291.73	1,227.34	1,241.34	1,298.58
								Percentage change in N_2O Emissions from Energy									
1.A.1.	Energy Industries	0.31	0.25	0.30	0.22	0.68	0.54	0.33	0.34	0.42	0.73	0.91	0.70	0.63	0.95	2.78	2.24
1.A.2.	Manufacturing Industries and Construction	0.00	-0.28	-0.28	-0.27	-0.23	-0.23	-0.25	-0.22	-0.22	1.49	-0.17	-0.18	-0.19	0.00	2.95	4.73
1.A.3.	Transport	-17.62	-19.93	-23.15	-29.33	-31.04	-26.35	-31.48	-29.92	-33.42	-40.41	-44.51	-45.28	-48.92	-51.17	-53.43	-55.50
1.A.4.	Other Sectors	0.00	-0.08	0.00	0.00	-0.18	-0.18	-0.26	-0.31	-0.31	-0.43	-0.38	-0.43	-0.43	-0.44	-0.44	1.46
1.B.	Fugitive Emissions from Fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1. Total		-1.76	-2.04	-2.53	-3.94	-4.27	-3.52	-5.25	-5.26	-6.61	-8.60	-10.83	-11.13	-12.88	-14.42	-14.98	-15.44

Chapter Four

Industrial Processes

4.1 Overview of 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 ammonia and nitric acid plants, both operated by Irish Fertilizer Industries, ceased production in June 2002. A small amount of limestone is used to abate SO_2 emissions in peat-fired electricity generating stations and is also used by a number of companies as a raw material thus 2*.A.3 Limestone and Dolomite Use* is a relevant activity in Ireland. The associated CO_2 emissions from this minor source were included in the annual inventories for the first time in the 2006 submission.

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 (Table 4.1), as described below.

Table 4.2 presents the estimates of greenhouse gas emissions for *Industrial Processes* over the period 1990-2006 for the relevant sources in Ireland. They indicate contributions of 5.7 percent and 4.7 percent to total emissions in 1990 and 2006, 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 two-thirds of the total, but the plants ceased operation in 2002, leaving cement production as the dominant process emission source thereafter. The combined contributions 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, largely due to the influence of the air conditioning and refrigeration sub-categories while the emissions of PFC continue to follow the downward trend post 2000 evident in previous submissions. Emissions of SF_6 remain variable from year to year. The estimates given in Table 4.2 for the period 1990-2006 include recalculated values in several sub-categories for many of these years, which are further described in the following sections.

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 June 2002

4.2 Emissions from Mineral Products (2.A)

The IPCC Level 3 emission source categories relevant under *2.A Mineral Products* in 2006 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* and *2.A.7 Other Mineral Products*. Total CO_2 emissions from these activities amounted to 2538.57 Gg, in 2006 of which cement production accounted for 92.5 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.

An emission factor of 0.5 tonne CO_2 per tonne of cement clinker had been used to estimate CO_2 emissions from cement production for all years up to 2002 using the Tier 1 method. The activity data for the years 1990-2002 were recognised as unreliable, mainly due to reasons of confidentiality, as only one company produced cement during this period. Information that the company supplied to the EPA during 2004 for the development of Ireland's National Allocation Plan under Directive 2003/87/EC (EP and CEU, 2003) on emissions trading included the company's estimates of process emissions for the period 1990-2002 and provided a basis for detailed examination of the emission factor used to estimate process CO_2 from cement production. Similar information was obtained from a number of additional cement producers who had entered the Irish market in 2000, which facilitated complete analysis of the process emissions from cement plants in Ireland. The revised estimates of process CO_2 emissions that were included in the 2006 submission are those supplied by the company. The associated amounts of clinker production were not made available for confidentiality reasons. The values that are reported in the CRF were estimated by the inventory agency based on the relationship between clinker production and process emissions at the same plants in 2003 and 2004.

As the emission estimates from the individual cement plants 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 was achieved again in respect of the four cement plants in operation in 2006, allowing for accurate accounting of combustion emissions and process emissions separately. The process CO_2 emissions from these plants are calculated using the Tier 2 method given in Decision 2004/156/EC, which is fully consistent with the Tier 2 method in the IPCC good practice guidance, based on reliable data on clinker production, corrected as appropriate for CKD, and CaO content of the clinker. These data are reported to the Emissions Trading Unit in the EPA and transmitted to the inventory team for systematic inclusion in the national inventory. The process emission factors in 2006 ranged from 0.528 t CO_2/ t clinker to 0.537 t CO_2/ t clinker with a weighted average of 0.534 t CO_2/t for all clinker production. Total process emissions for cement production in 2006 were 2,347.85 Gg CO_2.

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 1998 and two companies thereafter). The CORINAIR default value for CO_2 emissions from lime production (0.75 t CO_2/t lime) was used consistently to estimate process emissions from this source using the Tier 1 method for all inventory years up to 2003. This default value is also given for high-calcium lime in the IPCC good practice guidance and it was considered appropriate for Ireland as high-grade limestone is the standard raw material available for high calcium quicklime manufacture (at least 95 percent CaO content).

Table 4.2. Emissions from Industrial Processes 1990-2006

	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
INDUSTRIAL PROCESSES	All	Gg CO_2 eq	3,164.08	2,875.82	2,802.93	2,791.42	3,067.68	3,060.67	3,202.85	3,655.26	3,494.17	3,560.10	4,185.50	4,290.09	3,719.40	3,039.29	3,142.85	3,250.97	3,261.94
2.A. Mineral Products																			
Cement Production	CO_2	Gg	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
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
Limestone and Dolomite Use	CO_2	Gg	0.11	0.10	0.09	0.07	0.09	0.13	0.12	0.17	0.16	0.18	0.18	4.50	2.17	2.38	3.56	4.29	2.64
Soda Ash Production and Use			NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	0.35	0.37
Other Mineral Products			5.14	4.94	4.84	4.54	4.84	5.54	5.34	6.34	6.19	6.49	6.66	6.30	6.04	6.24	6.36	6.44	7.40
2.B. Chemical Industry																			
Ammonia Production*	CO_2	Gg	989.17	1,030.58	1002.97	945.46	1,055.81	972.996	922.46	1,074.21	1,058.1	943.09	883.287	1,037.4	809.68	NO	NO	NO	NO
Nitric Acid Production*	N_2O	Gg CO_2 eq	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
2.F. Consumption of Halocarbons and SF_6																			
Emissions of HFC	HFC	Gg CO_2 eq	0.69	5.27	6.17	9.44	19.97	44.85	76.11	132.28	190.71	197.13	230.22	251.49	276.52	349.98	386.44	435.06	506.45
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
Emissions of SF_6	SF_6	Gg CO_2 eq	35.40	40.64	45.87	55.35	64.83	82.83	102.06	132.10	94.28	69.01	55.96	69.49	70.31	118.69	67.09	95.96	68.60
Implied Emission Factor for CO_2 in Cement Production		t CO_2/t clinker	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.54	0.54	0.54	0.54	0.53
Implied Emission Factor for CO_2 in Lime Production		t CO_2/t lime	0.84	0.83	0.75	0.84	0.83	0.84	0.83	0.88	0.83	0.82	0.77	0.78	0.79	0.86	0.82	0.78	0.78

* Ammonia and nitric acid plants ceased production in 2002

As in the case of cement production, lime producers have provided their own estimates of CO_2 emissions from lime manufacture calculated in accordance with the methods described in 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*. Similar to cement production, the CO_2 estimates for lime production have been obtained from the Emissions Trading Unit for the most recent years and these have been used to confirm the estimates for previous years of the time-series, as given in Table 4.2. They indicate implied emission factors in the range 0.75 to 0.88 t CO_2/t lime produced.

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

Up to 2006 Ireland had not reported emissions arising from this activity. Information became available in 2005 to allow for the inclusion of CO_2 emissions associated with the use of carbonates in the manufacture of building bricks and ceramics from individual plants that are included in the Emissions Trading Scheme and are subject to verification under Directive 2003/87/EC. Carbon dioxide emissions reported by individual companies are used in inventory estimates, similar to the approach undertaken in *2.A.1 Cement Production*.

Limestone has also been used to capture sulphur emitted from peat burning in one new electricity generating station since 2001. The CO_2 emissions from this use of limestone are estimated on the basis of limestone quantity reported by the company and an emission factor of 0.44 t CO_2/t limestone, which is the stoichiometric ratio of CO_2 to $CaCO_3$. The reported emissions for *2.A.3 Limestone and Dolomite Use* refer to limestone used in the manufacture of bricks and ceramics only up to the year 2000 and thereafter also include the emissions from limestone use for the absorption of SO_2 emitted in one new peat-fired power plant.

A further use of limestone in Ireland is in the production of sugar from sugar beet. As cleaned sugar beet enters the production process the beet is thinly sliced and passed through a diffuser, which uses hot water to draw out the sugar. The resultant liquid is then passed through a purifier to remove non-sugars, which is achieved, by adding lime and carbon dioxide, which causes many of these non-sugars to be removed. Similar to the other uses of limestone, information is provided by the Emissions Trading Scheme. In early 2006 the last remaining sugar production plants ceased operation, therefore in future submissions emissions from this source will not occur.

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. Soda ash is used in Ireland as a raw material in the manufacture of glass and glass related products. Emissions from this sector are reported for the first time in this submission and only for the years 2005 and 2006. Information on activity data and emission estimates have been taken from plants that are included in the Emissions Trading Scheme and have undergone verification procedures under Directive 2003/87/EC.

4.2.5 Other Mineral Products (2.A.7)

The emission of CO_2 as a result of the use of clays and shale as a raw material in the manufacture of bricks and ceramics is reported under this CRF sector for the first time in this submission. Previously all process emissions from the manufacture of bricks and ceramics were reported under *2.A.3 Limestone and Dolomite Use*. Similar to sectors *2.A.1 Cement Production* and *2.A.3 Limestone and Dolomite Use* information from individual plants that are participants in the Emissions Trading Scheme is utilised in inventory estimates.

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

4.3.1 Special Studies

The compilation of emissions 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 this country, 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 1990-2006 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. This trend largely reflects the increasing use of HFCs across a range of applications (e.g. often as replacements in applications where the use of CFC and HCFCs is no longer permitted under the Montreal Protocol) and hence the presence of larger fluid banks from which operational leakage potentially occurs. In contrast, PFC emissions have decreased while emissions of SF_6 fluctuate significantly. This trend is determined principally by their use in the manufacture of semiconductors, for which the reported emissions received directly from manufacturing companies in Ireland show annual fluctuations reflecting changing manufacturing activity in response to the global trends in this market. For the years 1999-2006, this sub-category produced much higher combined emissions of HFC, PFC and SF_6 than any other (in terms of CO_2 equivalent emissions), accounting for half of the annual emissions in these years.

4.3.2 HFC, PFC and SF_6 Time-Series 1990-2006

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 1990-2006. 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 CRF.

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

HFC's and HFC blends have been widely used as replacement refrigerants for CFC and HCFC refrigerants across virtually all refrigeration sub-sectors (i.e. domestic refrigeration, small commercial distribution systems, industrial systems, building air conditioning systems and refrigerated transport). In terms of stationary refrigeration data on the quantities of industrial gases supplied to the refrigeration sector is obtained from chemical suppliers and manufacturers of refrigeration units. Sales data is provided for a range of HFCs and blends corresponding to the individual HFC species HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a and HFC-152a. Potential emissions are calculated from the sector using a Tier 1 approach as follows:

Potential emissions = production + import – export – destruction

As there is no manufacture of fluorinated gases in Ireland the production term above is zero. Imported HFCs are calculated using the data supplied as described above. Exports are calculated on the basis of refrigeration unit manufacturers share of exports. In Ireland there is no known destruction of HFCs. Recovered gas is used either in other equipment or exported for recycling or destruction.

A bottom-up approach is not feasible for estimating actual emissions from stationary refrigeration and air conditioning in Ireland due to the lack of data available on equipment types and HFC sales data 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.

4.3.2.2 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.

4.3.2.3 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. 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.

4.3.2.4 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.

4.3.2.5 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 1990-2006.

4.3.2.6 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.

4.3.2.7 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 is assumed to have been discontinued in window insulation since 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, as the market share of such products is assumed to similar to that in the UK. Emissions are therefore derived based on UK sales data for sporting goods multiplied by the ratio of the Irish population (CSO) to the UK population (ONS) in each year of the time series 1990-2006.

The remaining minor uses of SF_6 in Ireland are as a tracer gas from 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.

4.4 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 1995-2006 and are therefore consistent over this period. Estimates of F gases 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 do 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.

4.5 Recalculations for *Industrial Processes*

An outcome of the in-country review of Ireland's greenhouse gas inventory for 2004 which was undertaken in 2007 was the recommendation that emissions associated with the use of clays in bricks and ceramics production be reallocated from sector *2.A.3 Limestone and Dolomite Use* to *2.A.7 Other Mineral Products* in order to improve time-series consistency of emission estimates and comparability with other Parties inventories. The net effect of this reallocation is shown in Table 4.4. The use of limestone as a raw material in the manufacture of bricks and ceramics continues to be reported under sector *2.A.3 Limestone and Dolomite Use*.

As part of on-going inventory development and QA/QC procedures the F-gas inventory was reviewed by the inventory team in 2007. It was found that a number of correspondence errors existed between internal calculation sheets and in the data values for previous years appearing in the CRF tables. As a number of studies (discussed in previous sections) have been undertaken for developing F-gas estimates and which cover different time frames within the time series 1990-2006, the applicability of activity data and underlying assumptions were investigated in the context of the study deliverables and previous recalculations. In previous submissions, inventory estimates were made from a number of different spreadsheets, which may have lead to transcription errors in the use of CRF Reporter. All inventory estimates are now performed in one calculation workbook and QA/QC procedures as used for the other greenhouse gas source sectors in this NIR are applied in full for this workbook. The time-series is consistent. The effects of these changes on emission estimates are shown in Table 4.4. The sub-category *2.F.7 Semiconductor Manufacture* is the largest contributor to revisions from these recalculations with significant differences between the new estimates and those previously reported for the years 1990-1994 inclusive. Significant changes are also evident in category *2.F.4 Metered Dose Inhalers* for the years 1996-2000 inclusive.

4.6 Improvements in *Industrial Processes*

The inventory 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.

Table 4.3. Emissions of HFC, PFC and SF_6 from Industrial Processes 1990-2006 (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
HFCs																	
2.F.1 Refrigeration and Air-Conditioning	NO	3.32	3.51	3.69	3.98	4.48	7.14	20.51	41.14	48.13	51.64	47.53	62.88	110.61	133.09	150.97	193.98
2.F.1 Mobile Air Conditioning	NO	NO	NO	1.22	5.07	10.14	16.36	25.08	38.23	54.12	70.46	83.36	96.38	110.15	126.12	145.63	166.54
2.F.2 Foams	NO	0.00	0.02	0.06	0.30	0.64	1.11	1.78	3.62	5.22	6.28	9.21	11.50	14.10	18.31	21.58	23.91
2.F.3 Fire-extinguishers	0.22	0.70	1.18	1.68	2.23	2.84	3.50	4.21	4.99	5.83	6.76	7.81	9.03	10.39	11.91	13.64	15.57
2.F.4 Aerosols	0.01	0.65	0.72	1.78	7.10	24.92	45.05	76.01	98.78	73.35	80.03	86.35	77.86	83.88	77.24	79.27	81.67
2.F.4 Metered Dose Inhalers	NO	NO	NO	NO	NO	NO	0.02	0.06	0.08	1.05	2.69	14.13	16.99	18.21	18.41	21.74	21.64
2.F.7 Semiconductor manufacture	0.47	0.60	0.74	1.01	1.28	1.83	2.94	4.63	3.88	9.42	12.38	3.10	1.88	2.64	1.36	2.23	3.16
TOTAL HFC	**0.69**	**5.27**	**6.17**	**9.44**	**19.97**	**44.85**	**76.11**	**132.28**	**190.71**	**197.13**	**230.22**	**251.49**	**276.52**	**349.98**	**386.44**	**435.06**	**506.45**
PFCs																	
2.F.7 Semiconductor manufacture	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34	148.32
TOTAL PFC	**0.09**	**7.62**	**15.15**	**30.21**	**45.27**	**75.38**	**103.09**	**130.82**	**61.87**	**195.93**	**305.41**	**295.98**	**212.40**	**228.79**	**182.43**	**168.34**	**148.32**
SF_6																	
2.F.7 Semiconductor manufacture	0.48	4.73	8.99	17.49	26.00	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55	27.52
2.F.8 Electrical equipment	21.51	22.47	23.42	24.38	25.33	26.29	26.39	37.28	25.24	34.99	7.79	32.05	22.79	38.45	21.55	23.52	28.11
2.F.9 Other - window soundproofing	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.59	0.46	0.33	0.19	0.19	0.19	0.19	0.19	0.19
2.F.9 Other - medical applications	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
2.F.9 Other - sporting goods	NO	NO	NO	NO	NO	NO	NO	NO	2.89	3.84	3.79	3.82	5.76	7.15	5.81	5.90	11.99
2.F.9 Other - gas-air tracers	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	12.19	6.09	NO	NO
TOTAL SF_6	**35.40**	**40.64**	**45.87**	**55.35**	**64.83**	**82.83**	**102.06**	**132.10**	**94.28**	**69.01**	**55.96**	**69.49**	**70.31**	**118.69**	**67.09**	**95.96**	**68.60**
TOTAL HFCs, PFCs and SF_6	**36.19**	**53.53**	**67.18**	**95.00**	**130.07**	**203.06**	**281.26**	**395.20**	**346.86**	**462.08**	**591.59**	**616.95**	**559.23**	**697.46**	**635.96**	**699.35**	**723.37**

Table 4.4. Recalculated Emission Estimates for Industrial Processes 1990-2005 (Gg CO_2 eq)

IPCC Source Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Previously Reported Values																	
2.A.3 Limestone and Dolomite Use	CO_2	7.59	7.39	7.29	6.99	7.29	7.99	7.79	8.79	8.64	8.94	9.34	13.48	10.95	11.37	12.55	13.14
2.A.4 Soda Ash Production and Use	CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.A.7 Other Mineral Products	CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.F.1 Mobile Air Conditioning	HFC	NO	3.32	3.51	3.69	3.98	4.48	7.14	20.06	40.62	47.66	51.21	47.53	62.88	110.61	133.09	150.97
2.F.2 Foams	HFC	NO	0.00	0.02	0.06	0.30	0.64	1.11	1.78	3.62	5.22	6.28	9.21	11.50	13.71	15.86	18.04
2.F.4 Aerosols	HFC	0.01	0.65	0.72	1.78	7.11	24.96	45.14	76.20	97.50	72.34	78.88	86.37	77.89	83.81	77.29	79.27
2.F.4 Metered Dose Inhalers	HFC	NO	NO	NO	NO	NO	NO	6.10	6.70	7.50	8.30	9.80	14.13	16.99	18.21	18.41	21.74
2.F.7 Semiconductor manufacture	HFC	0.47	0.47	0.47	0.47	1.83	1.83	2.94	4.63	3.88	9.42	12.38	3.10	1.88	2.64	1.36	1.74
2.F.7 Semiconductor manufacture	PFC	0.09	0.09	0.09	0.09	75.38	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	186.84	173.95
2.F.7 Semiconductor manufacture	SF_6	0.48	0.48	0.48	0.48	43.02	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55
2.F.9 Other - sporting goods	SF_6	NO	NO	NO	NO	NO	NO	NO	NO	2.85	3.79	3.73	3.82	5.76	7.14	5.81	5.90
Recalculated Values																	
2.A.3 Limestone and Dolomite Use	CO_2	0.11	0.10	0.09	0.07	0.09	0.13	0.12	0.17	0.16	0.18	0.18	4.50	2.17	2.38	3.56	4.29
2.A.4 Soda Ash Production and Use	CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	0.35
2.A.7 Other Mineral Products	CO_2	5.14	4.94	4.84	4.54	4.84	5.54	5.34	6.34	6.19	6.49	6.66	6.30	6.04	6.24	6.36	6.44
2.F.1 Mobile Air Conditioning	HFC	NO	3.32	3.51	3.69	3.98	4.48	7.14	20.51	41.14	48.13	51.64	47.53	62.88	110.61	133.09	150.97
2.F.2 Foams	HFC	NO	0.00	0.02	0.06	0.30	0.64	1.11	1.78	3.62	5.22	6.28	9.21	11.50	14.10	18.31	21.58
2.F.4 Aerosols	HFC	0.01	0.65	0.72	1.78	7.10	24.92	45.05	76.01	98.78	73.35	80.03	86.35	77.86	83.88	77.24	79.27
2.F.4 Metered Dose Inhalers	HFC	NO	NO	NO	NO	NO	NO	0.02	0.06	0.08	1.05	2.69	14.13	16.99	18.21	18.41	21.74
2.F.7 Semiconductor manufacture	HFC	0.47	0.60	0.74	1.01	1.28	1.83	2.94	4.63	3.88	9.42	12.38	3.10	1.88	2.64	1.36	2.23
2.F.7 Semiconductor manufacture	PFC	0.09	7.62	15.15	30.21	45.27	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	182.43	168.34
2.F.7 Semiconductor manufacture	SF_6	0.48	4.73	8.99	17.49	26.00	43.02	62.14	81.26	52.58	16.73	31.07	20.43	28.58	59.92	32.65	65.55
2.F.9 Other - sporting goods	SF_6	NO	NO	NO	NO	NO	NO	NO	NO	2.89	3.84	3.79	3.82	5.76	7.15	5.81	5.90

Table 4.4.contd: Recalculated Emission Estimates for Industrial Processes 1990-2005 (Gg CO_2 eq)

IPCC Source Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
% Change in Emission																	
2.A.3 Limestone and Dolomite Use	CO_2	-98.61	-98.72	-98.77	-98.94	-98.77	-98.42	-98.51	-98.08	-98.14	-98.02	-98.09	-66.60	-80.18	-79.08	-71.64	-67.34
2.A.4 Soda Ash Production and Use	CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.A.7 Other Mineral Products	CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2.F.1 Mobile Air Conditioning	HFC	NO	0.00	0.01	-0.01	0.01	0.00	0.00	2.26	1.29	1.00	0.83	0.00	0.00	0.00	0.00	0.00
2.F.2 Foams	HFC	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	15.42	19.64
2.F.4 Aerosols	HFC	NO	0.00	-0.04	-0.07	-0.11	-0.17	-0.21	-0.25	1.31	1.40	1.46	-0.02	-0.04	0.08	-0.06	0.00
2.F.4 Metered Dose Inhalers	HFC	NO	NO	NO	NO	NO	NO	-99.68	-99.13	-98.93	-87.31	-72.59	0.00	0.00	0.00	0.00	0.00
2.F.7 Semiconductor manufacture	HFC	0.00	29.00	58.00	116.00	-29.74	0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.95
2.F.7 Semiconductor manufacture	PFC	0.11	8095.69	16191.27	32382.43	-39.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.36	-3.23
2.F.7 Semiconductor manufacture	SF_6	0.00	890.00	1780.00	3560.00	-39.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.F.9 Other - sporting goods	SF_6	NO	NO	NO	NO	NO	NO	NO	NO	1.31	1.40	1.46	-0.02	-0.04	0.08	-0.06	0.00

Chapter Five

Solvent and Other Product Use

5.1 Overview of *Solvent and Other Product Use* Sector

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 VOC 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 VOC 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). The CO_2 emissions are derived by assuming that 85 percent of the mass emissions of NMVOC in the four categories 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 Control (IPC) and the Solvents Directive (CEC, 1999). In these circumstances, the inventories of VOC 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.*

A bottom-up approach was possible for activities subject to IPC 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 IPC 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 IPC and non-IPC 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 1990-2006 are presented in Table 5.1. The largest contributor to overall emissions is the domestic solvent use sub-category. It is also to be noted that emissions from this sub-category have increased while those from the majority of sub-categories are decreasing. The main drivers are considered to be the increased number of vehicles, growth in the number of individual households, and higher per-capita consumption of non-aerosol automotive products, cosmetics, toiletries, and household products. It should be noted that UK emission factors together with Irish statistics for number of vehicles, persons and households were used in the absence of any other data. One of the only two other significant sub-categories for which emissions are increasing is industrial application of paint in the wood products sector. This is as a result of an expansion in activity in the sub-category as well as the continued use of conventional high solvent content coatings. The vast majority of these companies are small operations outside the remit of IPC.

Emissions from architectural paint use are decreasing (even while paint sales are increasing) as a result of an increased market share for water-based paints and a reduction in the VOC content of water based paints (VOC content of solvent based paints remains more or less static). From discussions with industry, one of the key drivers for the decrease in solvent use in architectural paint has been as a result of pressure from some of the larger retailers. The decrease in VOC emissions from architectural painting should be set to continue with the advent of the deco-paints Directive (EP and CEU, 2004b) and can only benefit from continued and expanded retailer/consumer pressure. There have been significant drops in both printing and wood impregnation. The decrease in printing is principally due to the installation of abatement equipment in the plant, which is the largest user of solvents. The decrease in the use of wood preservatives can be attributed to several site closures and to the switch from solvent-borne to water-borne wood preservatives.

Other industrial paint application and other manufacturing taken together show a decrease in emissions between 1998 and 2006. The diversity within these sectors is very large in terms of the type of process, the products made, and the scale involved. There have been closures, particularly of a few of the large emitters, which have decreased emissions, but there has also been some new processes licensed. In addition there is a large degree of uncertainty associated with the non-IPC element of the emissions estimates for these sources. However, the study found that there are specific instances of IPC licensed sites reducing VOC emissions through prevention at source or through abatement.

5.3 Recalculations for Solvents and Other Product Use

In the compilation of emission estimates for 2006, it was found that underlying UK population statistics for the period 1990 to 2004 inclusive used as scaling factors in the calculation of Irish emissions from sub-categories 3A (Paint Application) and 3D (Other Use of Solvents) were not consistent with UK published statistics. This anomaly has been rectified. In addition the key data suppliers who supplied data for the in-depth analysis carried out for the

2006 submission (CTC, 2005) were contacted and any new activity data or assumptions affecting VOC emissions have been taken into account in this submission. A comparison of these recalculated totals for VOC emissions in the four sub-categories with those in the 2007 submission is presented in Table 5.2.

Table 5.1 Estimates of NMVOC and CO_2 Emissions from Solvent and Other Product Use 1990-2006

Year	3A Paint Application	3B Degreasing, dry cleaning, electronics	3C Chemical Products Manufacturing & Processing	3D Other Use of Solvents	Total NMVOC Emissions	Estimated CO_2 emissions from NMVOC
Mg NMVOC						Gg
1990	6,941	2,304	3,534	13,259	26,038	81.15
1991	7,058	2,304	3,534	13,694	26,590	82.87
1992	7,285	2,304	3,534	13,569	26,692	83.19
1993	7,494	2,304	3,534	13,462	26,794	83.51
1994	7,778	2,291	3,534	13,463	27,066	84.36
1995	8,047	2,496	3,534	13,532	27,609	86.05
1996	8,385	2,423	3,534	13,499	27,840	86.77
1997	8,676	2,311	3,534	13,460	27,980	87.20
1998	9,058	2,158	3,534	13,573	28,324	88.28
1999	8,771	2,043	3,433	13,014	27,261	84.96
2000	8,091	1,883	3,332	12,455	25,761	80.29
2001	8,394	1,660	3,132	12,356	25,542	79.61
2002	8,673	1,067	2,932	12,123	24,795	77.28
2003	8,669	1,141	2,732	11,932	24,475	76.28
2004	8,765	1,155	2,532	11,962	24,414	76.09
2005	9,217	1,222	2,453	12,099	24,991	77.89
2006	9,459	1,344	2,374	12,495	25,673	80.01

Table 5.2 Recalculations for Solvent and Other Product Use 1990-2005

	3A Paint Application	3B Degreasing, dry cleaning, electronics	3C Chemical Products Manufacturing & Processing	3D Other Use of Solvents	Total NMVOC Emissions	Estimated CO_2 from NMVOC
	Mg NMVOC					Gg
2007 Submission						
1990	6878	2304	3534	13228	25944	80.86
1991	7036	2304	3534	13674	26548	82.74
1992	7231	2304	3534	13550	26619	82.96
1993	7485	2304	3534	13444	26767	83.42
1994	7782	2291	3534	13446	27053	84.32
1995	8082	2496	3534	13517	27629	86.11
1996	8406	2423	3534	13485	27848	86.79
1997	8687	2311	3534	13447	27979	87.20
1998	9053	2158	3534	13508	28253	88.06
1999	8761	2043	3442	12947	27193	84.75
2000	8071	1883	3350	12386	25690	80.07
2001	8375	1660	3168	12356	25560	79.66
2002	8649	1067	2986	12123	24826	77.37
2003	8625	1141	2804	11801	24371	75.96
2004	8700	1155	2622	11811	24288	75.70
2005	8785	1079	2440	11901	24206	75.44
2008 Submission						
1990	6941	2304	3534	13259	26038	81.15
1991	7058	2304	3534	13694	26590	82.87
1992	7285	2304	3534	13569	26692	83.19
1993	7494	2304	3534	13462	26794	83.51
1994	7778	2291	3534	13463	27066	84.36
1995	8047	2496	3534	13532	27609	86.05
1996	8385	2423	3534	13499	27840	86.77
1997	8676	2311	3534	13460	27980	87.20
1998	9058	2158	3534	13573	28324	88.28
1999	8771	2043	3433	13014	27261	84.96
2000	8091	1883	3332	12455	25761	80.29
2001	8394	1660	3132	12356	25542	79.61
2002	8673	1067	2932	12123	24795	77.28
2003	8669	1141	2732	11932	24475	76.28
2004	8765	1155	2532	11962	24414	76.09
2005	9217	1222	2453	12099	24991	77.89
% Change in Emission						
1990	0.91	0.00	0.00	0.24	0.36	0.36
1991	0.31	0.00	0.00	0.15	0.16	0.16
1992	0.74	0.00	0.00	0.14	0.27	0.27
1993	0.12	0.00	0.00	0.13	0.10	0.10
1994	-0.05	0.00	0.00	0.12	0.05	0.05
1995	-0.43	0.00	0.00	0.11	-0.07	-0.07
1996	-0.25	0.00	0.00	0.10	-0.03	-0.03
1997	-0.13	0.00	0.00	0.09	0.01	0.01
1998	0.06	0.00	0.00	0.48	0.25	0.25
1999	0.12	0.00	-0.26	0.52	0.25	0.25
2000	0.25	0.00	-0.54	0.56	0.28	0.28
2001	0.22	0.00	-1.14	0.00	-0.07	-0.07
2002	0.27	0.00	-1.81	0.00	-0.12	-0.12
2003	0.52	0.00	-2.57	1.11	0.43	0.43
2004	0.75	0.00	-3.43	1.28	0.52	0.52
2005	4.92	13.20	0.53	1.66	3.25	3.25

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 Three). The inventory time-series for the years 1990-2006 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 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 now being 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 conducted in recent years. This research, together with other relevant work related to the development of an elaborate new NH_3 inventory for agriculture in 2005 and guidelines on the implementation of the EU Nitrates Directive (CEC, 1991) has facilitated the application of a large amount of country-specific information underlying the various estimates of emissions. The same method is used for the purposes of this submission but further development and minor updating of the underlying activity data remains part of the ongoing work and assessment in relation to agricultural emissions.

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 and Food (DAF). The CSO and DAF are key data providers whose annual statistical inputs to the inventory agency are covered by MOU in Ireland's national system (Figure 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 D. It may be noted that in the case of cattle, the populations related to housing (Table D.1 (a)) are different to those for pasture (Table D.1 (b)) to take full account of the respective production systems as they affect emissions. The manner in which the cattle populations are applied makes best use of the available activity data and is explained in the documentation boxes of the CRF tables.

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)*

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 Irelands inventory submissions to the UNFCCC. As a result a research project was undertaken which was funded by the EPA to provide appropriate annual Tier 2 emission factors for the Irish cattle herd. The results of this research (O'Mara, 2006) were applied for the first time in the 2006 submission and continue to be used.

In brief, the Irish cattle herd is characterised by 11 principal animal categories as shown in Table 6.2 for which annual census data are published by 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 were analysed for suckler cows, while up to 30 systems were examined for both male and female beef cattle. The exercise to develop Tier 2 emission factors for the 11 animal categories shown in Table 6.2 was initially carried out for the 2003 herd and then repeated for 1990. The approach has been continued for this submission with country-specific emission factors developed for 2006 by the inventory team using the methodologies derived in the research project. The following paragraphs outline the approach and a detailed description of the comprehensive study and the analysis underlying the emission factors is available (O'Mara, 2006).

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 the Nitrates Directive Action Programme (SI No 378 of 2006). This 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 regions identified above using the Cattle Movement Monitoring System (CMMS) reports published by the Department of Agriculture and Food (DAF, 2007) on an annual basis. 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 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 (INRA, 1989). In this system, net energy requirement is defined in terms of units of feed for lactation (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, 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 important equations are:

Maintenance NE_l requirements (MJ) = 9.96 + (0.6 x LW/100), where LW is liveweight.
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;

Liveweight change: each kg liveweight lost contributed 24.9 MJ NE_l to energy requirements, while each kg of liveweight 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 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 Cattle Movement Monitoring System (CMMS) reports published by the Department of Agriculture and Food (DAF, 2007). 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 liveweight gain as it directly affects the energy requirement and thus the feed intake. There is little statistical information on the liveweight gain of the different types of cattle in the Irish 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 liveweight 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 liveweight and liveweight 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 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 forrige viande*) where 1 UFV 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 heifer's 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 value for animals in this category is determined by an applicable period of 310 days in their second year, which is adjusted upwards using the full period of 365 days for 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 3^{rd} 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 2006, 2005 and 1990 are summarised in Table 6.3 for the 11 principal categories chosen to characterise the Irish cattle herd. Emission factors for the full time series 1990–2006 in respect of the 11 principal categories are presented in Table D.2 of Annex D. 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 2006 indicates an increase of 8.2 percent from 1990 in line with increased milk yield, which is not captured by the Tier 1 approach previously used. As such, annual milk yield may be used as a convenient basis for deriving aggregate weighted emission factors for dairy cattle in other years. The emission factors for beef cattle indicate an overall weighted average of approximately 40 kg/head, compared to the value of 50 kg/head previously used. Little change is indicated between 1990 and 2006, 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, 2005 and 2006

	Enteric Fermentation (kg/head/year)			Manure Management (kg/head/year)		
	2006	2005	1990	2006	2005	1990
Dairy cows	109.70	107.84	101.38	20.59	20.41	21.57
Suckler cows	74.28	74.12	74.03	13.88	13.86	14.02
Male cattle < 1 year	29.58	29.72	30.46	8.56	8.60	9.73
Male cattle 1 - 2 years	59.93	58.96	62.22	14.09	13.82	16.68
Male cattle > 2 years	37.80	37.67	55.08	1.92	1.91	4.57
Female cattle < 1 year	27.74	27.86	27.05	8.28	8.29	8.79
Female cattle 1 - 2 years	46.46	45.64	53.54	9.77	9.63	14.74
Female cattle > 2 years	22.46	22.46	21.65	0.34	0.34	0.33
Bulls for breeding	81.55	81.55	86.38	18.95	18.95	23.79
Dairy in-calf heifers	50.16	50.16	51.82	10.93	10.93	13.40
Beef in-calf heifers	53.68	53.68	55.42	12.87	12.87	15.61

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 D.2 of Annex D. As a result, the implied emission factors produced by the CRF related to total sheep and swine are lower than the default values.

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. New information obtained from a national farm facilities survey (Hyde et al., in prep) 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 D4 Annex D 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 categories that characterise the national herd, 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), a B_O (the methane production potential of animal waste) value of 0.24 m^3 CH_4/kg VS, 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. 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, swine, horses and poultry. The allocations to animal waste management system are again based on the farm facilities survey and appropriate values of B_O and VS are taken from the IPCC Guidelines while MCF is again as given in Table 4.10 of the IPCC good practice guidance. The application of the manure management emission factors for sheep, horses and poultry means that all CH_4 emissions from livestock are included in current estimates. The CH_4 emissions from manure management in 2006 amounted to 24.4 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. These rates of nitrogen excretion 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. 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 as the basis of CRF Table 4.B (b).

Approximately two-thirds of animal waste 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 wastes excreted at pasture are unmanaged and the associated emissions are accounted for under agricultural soils (Section 6.5.1). The bulk of animal wastes in housing are managed in liquid storage systems (93.8 percent and 67.0 percent for dairy cattle and other cattle, respectively and 100 percent for swine) for eventual spreading on agricultural lands. The remainder of animal wastes produced in-house is treated in solid systems. The emission factors given by the IPCC good practice guidance indicate that 1 kg of nitrogen per tonne of nitrogen handled in liquid systems is lost as N_2O while the corresponding loss is 20 kg per tonne for nitrogen in solid storage systems. These default emission factors, for which uncertainty ranges of 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 2005 amounted to 1.29 Gg.

6.5 N_2O Emissions from Agricultural Soils (4.D)

Agricultural soils are the principal source of N_2O emissions in many countries. The IPCC methodologies for the source categories concerned are essentially an accounting of all inputs of nitrogen to agricultural soils and the subsequent application of default rates of nitrogen for losses 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 1990-2006 are presented in Table D.3 of Annex D.

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 1990-2006 take into account the nitrogen inputs from all these sources, except that due to the cultivation of organic soils. Tillage farming in Ireland is concentrated in the 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

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

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

$F_S = SS_l * NSSF$

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

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

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 (0.016 in 2006)
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 2006)
$Frac_{GASM1}$ = fraction of animal manure nitrogen that volatilizes as NH_3 during housing, manure storage and landspreading (0.486 in 2006)
$N_2O\text{-}N_{hs}$ = amount of animal manure nitrogen emitted as N_2O in housing and storage (kg N_2O-N)
SS_l = quantity of sewage sludge spread on agricultural lands (kt)
NSSF = nitrogen fraction of sewage sludge (3 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 from the analysis in the previous section in relation to manure management. 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 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 2006 values of $Frac_{GASM1}$ and $Frac_{GASM2}$ are 0.486 and 0.036, respectively indicating an overall volatilisation rate of 0.190 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 0.016 and 0.486, respectively in 2006 from the NH_3 inventory. Published estimates of sludge production (Smith et al, 2007) 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 2006.

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 2006 for category *4.D.1 Direct Soil Emissions* amounted to 8.36 Gg, of which synthetic fertilizers accounted for 6.61 Gg, 1.53 Gg was due to land spreading of animal manures and crops produced 0.22 Gg.

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 value of 0.66 for $Frac_{GRAZ}$ in 2006, 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 2006 was 8.98 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 2006)
$Frac_{LEACH}$ = fraction of synthetic fertilizer nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2006)

EF_4 = N_2O emission factor for nitrogen inputs from atmospheric deposition
EF_5 = N_2O emission factor for nitrogen leaching

The expressions for $N_2O_{indirect-dep}$ and $N_2O_{indirect-leach}$ are slightly modified to be consistent with those for estimating direct emissions in section 6.5.1 and to account for the two separate volatilisation fractions $Frac_{GASM1}$ and $Frac_{GASM2}$. There is no contribution to $N_2O_{indirect-dep}$ from F_S, the nitrogen input from sludge spreading, but F_S increases $N_2O_{indirect-leach}$ through its inclusion in F_{AW}. The default value for $Frac_{LEACH}$, the fraction of nitrogen lost through leaching, in the IPCC Guidelines is 30 percent. Estimates of the nitrogen loads in Irish rivers reported under the OSPAR Convention (NEUT, 1999) suggest that approximately 10 percent of all applied nitrogen in Irish agriculture is lost through leaching. This level of leaching is also indicated by farm budget studies where the nitrogen runoff equivalent to 60 kg N/ha has been measured in streams adjoining farmland receiving 200 kg N/ha from chemical fertilizer and 100 kg N/ha from animal manures per year. The value of 0.1 is considered to be a more realistic estimate of $Frac_{LEACH}$ than the default value of 0.3 and it is used for 2006, 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 2006 amounted to 4.16 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 GHG's from the agriculture sector have been reduced through the use of Tier 2 methods for the calculation of CH_4 emissions from enteric fermentation and manure management. In addition, 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 1990–2006 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 1990-2006.

Table 6.4 Activity data and emission factor uncertainty prior and post 2006 submission

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

6.7 Quality Assurance and Quality Control

The inventory agency has discontinued the use of the IPCC software in the compilation of the CH_4 and N_2O emissions in Agriculture. Instead, a new spreadsheet system developed for the 2006 submission is used to estimate these emissions in a more efficient and transparent manner, which takes into account the strong links to Ireland's Tier II 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 new 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 and calculations as well as internal checks on the calculations and the outputs are directly compatible with the CRF Reporter Tool. The entire compilation for 2006 and all-previous years was reviewed externally by a technical person from the Department of Agriculture and Food as an important element of quality assurance for the 2008 submission.

In 2007 a member of the inventory team undertook a re-examination of some of the underlying assumptions in relation to some of the animal disaggregations and animal number statistics and the activity data underlying Tier 2 CH_4 estimates. In addition, the results of a farm facilities survey which provides activity data to the inventory process was re-analysed. The effect of these QA/QC procedures is described in detail in the following section (section 6.8).

This intensive 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. The assessment and endorsement of the outcomes by other experts in TEAGASC and the DoEHLG according to the IPCC good practice guidance and is an important part of the overall QA/QC procedures being undertaken on an annual basis.

6.8 Recalculations in Agriculture

Recalculated estimates of emissions in the Agriculture sector are due to the following inventory revisions carried out in the 2008 reporting cycle for the years 1990-2005.

a) Animal population statistics over the full time series were examined with some minor errors found in calculations for pig, horses, asses and mule populations.
b) Turkey production cycles were not accounted for in previous submissions with the result that population statistics were over estimated.
c) As a result of a technical review of the inventory by a member of staff of the Department of Agriculture in 2007, CH_4 estimates from other cattle in the categories less than 1 year, 1-2 years old and greater than two years old were separated into male and female sub-divisions and appropriate emission factors applied.
d) The underlying activity data used in Tier 2 CH_4 emission calculations were re-examined resulting in slightly revised emission factor estimates for the years 2003, 2004 and 2005.
e) A re-analysis of farm facilities data resulted in revised estimates associated with manure management practices and indirect emissions due to NH_3 volatilization.

The recalculations undertaken as a result of items (a) to (e) on emission estimates from the agricultural sector are presented in Table 6.5. Accounting for items (a) to (e) above resulted in recalculations in all categories of the agriculture inventory across the full time series 1990-2005. The largest quantitative effect was due to item (c), which resulted in an increase in emission estimates for CH_4 from enteric fermentation and manure management of 1.7 and 1.3 percent, respectively for 2005. When expressed in terms of CO_2 equivalent, net emissions from *Agriculture* were increased by between 0.0 and 1.2 percent over the period 1990-2005 inclusive.

6.9 Improvements in the Agriculture Sector

Clearly, it is important that high priority is given to emissions of CH_4 and N_2O from agricultural sources in Ireland so that they may be quantified as reliably as possible, given their large overall contributions to the national total (Chapter Three). 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 parameters have an important bearing on the outcome. 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. The inventory agency is continually developing emission estimates so that they fully reflect national circumstances within the availability of reliable statistics.

The inventory agency made substantial improvement in the overall inventory compilation for *Agriculture* during 2005, particularly with respect to CH_4 emissions, and now achieves closer compliance with the IPCC good practice guidance by the use of Tier 2 methods for CH_4 emissions from enteric fermentation and manure management in cattle. Research is ongoing in this area through funding by the EPA and the Department of Agriculture. As the results of this research become available, the inventory team will collaborate with the researchers involved so that the agriculture inventory will take account of new information for this important source of emissions. The agency has also been intensively engaged with researchers working on N_2O emissions from soils. Over the last number of years some work has been conducted by researchers on the use of the DNDC model (Li et al, 1994, 1996), which quantifies N_2O emissions from soils with a view to adopting a methodology for such emissions 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 precluded its routine application. Currently both the DNDC model and other models are being investigated by the research community in Ireland.

Both The EPA and the Department of Agriculture are actively pursuing the opportunities for N_2O emissions research in Ireland with a number of projects being currently funded. Recently published research at both field and lysimeter scales conducted in Ireland suggest that N_2O emission rates from agricultural soils may be substantially higher than the value of 1.25 percent given by the current IPCC default emission factor. The high inter-annual and spatial variability in emission estimates found in these studies requires further investigation and long-term emission datasets are required.

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
2007 submission																	
4.A. Enteric Fermentation	CH_4	444.66	450.75	453.21	455.89	454.91	455.63	468.56	479.11	485.23	469.83	448.00	446.43	440.91	438.28	439.65	430.91
4.B Manure Management	CH_4	110.19	111.44	112.39	112.72	112.10	111.77	116.15	118.94	120.25	115.04	109.56	109.92	109.14	107.39	107.28	105.92
4.B Manure Management	N_2O	1.31	1.36	1.37	1.39	1.38	1.41	1.42	1.45	1.49	1.51	1.43	1.38	1.34	1.33	1.33	1.32
4.D.1 Direct Soil emissions	N_2O	9.23	9.07	8.84	9.18	9.74	10.25	10.03	9.33	10.40	10.63	9.86	9.03	8.91	9.43	8.99	8.67
4.D.2 Pasture Range and Paddock	N_2O	9.03	9.18	9.34	9.33	9.31	9.30	9.55	9.77	10.01	9.75	9.30	9.20	9.09	9.09	9.08	8.94
4.D.3 Indirect emissions	N_2O	4.34	4.35	4.35	4.45	4.55	4.66	4.70	4.62	4.90	4.92	4.65	4.40	4.33	4.40	4.29	4.23
Total CH_4 (Gg CH_4)	CH_4	554.84	562.19	565.60	568.61	567.01	567.40	584.71	598.04	605.48	584.87	557.56	556.35	550.06	545.67	546.93	536.83
Total N_2O (Gg N_2O)	N_2O	23.91	23.97	23.90	24.35	24.99	25.62	25.70	25.17	26.80	26.81	25.25	24.02	23.67	24.26	23.69	23.16
Total (Gg CO_2 eq)	CO_2 eq	19,063.03	19,235.61	19,286.82	19,488.13	19,652.85	19,857.05	20,247.02	20,362.83	21,024.43	20,594.83	19,535.86	19,128.74	18,889.41	18,978.92	18,830.02	18,453.44
2008 submission																	
4.A. Enteric Fermentation	CH_4	452.08	456.28	459.15	461.09	458.89	458.81	469.30	479.58	487.14	475.28	452.70	448.05	445.00	441.10	440.89	438.11
4.B Manure Management	CH_4	110.88	111.89	112.98	113.21	112.44	112.02	115.94	118.77	120.37	115.88	110.14	110.10	110.12	108.38	107.64	107.28
4.B Manure Management	N_2O	1.28	1.32	1.33	1.35	1.35	1.37	1.38	1.41	1.45	1.47	1.39	1.34	1.31	1.30	1.29	1.29
4.D.1 Direct Soil emissions	N_2O	9.23	9.07	8.85	9.19	9.74	10.26	10.03	9.34	10.41	10.65	9.87	9.05	8.93	9.45	9.02	8.71
4.D.2 Pasture Range and Paddock	N_2O	9.04	9.19	9.35	9.34	9.33	9.32	9.57	9.79	10.03	9.77	9.33	9.23	9.12	9.13	9.11	9.10
4.D.3 Indirect emissions	N_2O	4.34	4.35	4.34	4.44	4.54	4.64	4.69	4.60	4.88	4.90	4.63	4.38	4.31	4.39	4.27	4.22
Total CH_4 (Gg CH_4)	CH_4	562.96	568.17	572.13	574.30	571.33	570.83	585.25	598.35	607.51	591.16	562.84	558.14	555.12	549.48	548.53	545.39
Total N_2O (Gg N_2O)	N_2O	23.89	23.93	23.87	24.31	24.95	25.59	25.68	25.15	26.78	26.79	25.23	24.00	23.67	24.27	23.69	23.32
Total (Gg CO_2 eq)	CO_2 eq	19,228.56	19,350.23	19,413.31	19,597.79	19,733.80	19,920.06	20,249.54	20,362.41	21,059.58	20,719.60	19,639.90	19,162.51	18,993.87	19,063.18	18,863.94	18,681.68

Table 6.5 (contd.) 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
% Change in Emission																	
4.A. Enteric Fermentation	CH_4	1.67	1.23	1.31	1.14	0.88	0.70	0.16	0.10	0.39	1.16	1.05	0.36	0.93	0.65	0.28	1.67
4.B Manure Management	CH_4	0.63	0.40	0.52	0.44	0.30	0.22	-0.18	-0.14	0.11	0.73	0.53	0.16	0.89	0.92	0.33	1.28
4.B Manure Management	N_2O	-2.20	-2.66	-2.70	-2.89	-2.80	-2.84	-2.83	-2.82	-2.71	-2.81	-2.86	-2.80	-2.61	-2.62	-2.68	-2.32
4.D.1 Direct Soil emissions	N_2O	0.05	-0.02	0.06	0.06	0.05	0.05	0.04	0.11	0.09	0.15	0.15	0.20	0.21	0.18	0.32	0.44
4.D.2 Pasture Range and Paddock	N_2O	0.12	0.07	0.08	0.15	0.17	0.20	0.22	0.26	0.25	0.22	0.24	0.28	0.31	0.47	0.30	1.74
4.D.3 Indirect emissions	N_2O	-0.06	-0.10	-0.22	-0.26	-0.29	-0.27	-0.27	-0.36	-0.37	-0.38	-0.39	-0.39	-0.41	-0.26	-0.46	-0.16
Total CH_4 (Gg CH_4)	CH_4	1.46	1.06	1.15	1.00	0.76	0.60	0.09	0.05	0.34	1.08	0.95	0.32	0.92	0.70	0.29	1.59
Total N_2O (Gg N_2O)	N_2O	-0.07	-0.15	-0.14	-0.13	-0.13	-0.11	-0.11	-0.09	-0.09	-0.09	-0.09	-0.05	-0.03	0.06	0.01	0.67
Total (Gg CO_2 eq)	CO_2 eq	0.87	0.60	0.66	0.56	0.41	0.32	0.01	0.00	0.17	0.61	0.53	0.18	0.55	0.44	0.18	1.24

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 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 1990-2006 in all IPCC land categories, as indicated by Table 7.1, whereas in previous submissions (pre 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 use of default methods to estimate emissions and removals for the relevant land categories in the time-series 1990-2006. 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	NO*	All	Part, IE
2. Land converted to Forest Land	All	All	All	NA	IE
B. Cropland					
1. Cropland remaining Cropland	NO	NO	NO*	NA	NE
2. Land converted to Cropland	All	NO	All	NA	All
C. Grassland					
1. Grassland remaining Grassland	NO	NO	NO*	NO	NE
2. Land converted to Grassland	All	NO	All	NO	NE
D. Wetlands					
1. Wetlands remaining Wetlands	All	NO	All	NO	NE
2. Land converted to Wetlands	NO	NO	NO	NO	All
E. Settlements					
1. Settlements remaining Settlements	NO	NO	NA	NO	NE
2. Land converted to Settlements	All	NO	All	NO	NE
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 2006 inventory for LULUCF follows the same approach and methodologies as those used for the 2007 submission. In addition, this submission includes estimates for a number of sources that were not reported in 2007 and there are some minor revisions and the use of updated datasets where appropriate. These revisions are outlined in section 7.10. Following recommendations of the 2007 in-country review of Ireland's national inventory, emissions of N_2O and CH_4 are reported by Ireland for the first time in this 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 in agriculture and therefore all N_2O emissions from fertilization are reported in the *Agriculture* sector and the notation IE is used in CRF Table 5(I). Additionally, information has been sourced regarding the occurrence of forest wildfires in Ireland, which facilitates the reporting of CH_4 and N_2O emissions from biomass burning in CRF Table 5(V) for the first time. In previous submissions, this activity had been assumed not to occur.

The estimates of emissions and removals from LULUCF over the period 1990-2006 are presented in Table 7.2 for all land-use categories. The LULUCF sector was a significant net source of emissions in the first half of the time-series and was a net sink of carbon in most years thereafter as shown in Table 7.2. This outcome 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 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. The inclusion of CH_4 and N_2O by coverage of additional emission sources has a very minor effect on emissions from LULUCF. The results contained in the 2008 submission for the years 1990-2006 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 category and the areas converted to the category. The IPCC *Wetlands* category has been split into natural unexploited wetlands, and peatlands, the latter being wetlands drained for the purpose of commercial and domestic harvesting of peat for combustion or horticultural use. While estimates of emissions and removals are included for peatlands in the Irish analysis, the much larger area of wetlands does not contribute to emissions and removals. The estimate of the *Other Land* area is effectively the residual land area of the country once all other categories of land use have been accounted. As such, the estimate includes a certain degree of misclassification of lands which are fit for agricultural utilisation, but which have not been reported to the Central Statistics Office as agricultural land in a given year. This occurs mostly commonly for grazing grassland “let rest” for a period. The situation does not arise for cropland as it is covered under the setaside programme.

Table 7.4 records the land-use changes among the various land categories over the period 1990-2006 in the form of land-use change matrices for the individual years. 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 as contributors 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 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 categories and because different lengths of transition period apply to organic and mineral soils. *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 18.3 percent. The *Other Land* category is the next largest at 11.2 percent, followed by C*ropland* at 5.69 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 wetland to forest land. The area of forests has increased by 64 percent between 1990 and 2006, however the proportion of *Forest Land* to total land in the country remains less than 10 percent, which is low compared to many other Annex I Parties.

Table 7.2. Emissions[a] and Removals[a] from Land Use Land-Use Change and Forestry 1990-2006 (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
A. Forest Land	-399.99	-300.80	-96.69	-188.82	-124.83	-129.01	-132.47	-270.97	-444.47	-548.77	-425.70	-613.08	-711.66	-1,078.63	-706.28	-841.38	-957.61
1. Forest Land remaining Forest Land	-1,059.21	-1,143.69	-864.71	-857.86	-566.71	-390.46	-343.93	-235.80	-518.53	-563.53	-77.03	-24.13	-307.78	-1,244.77	-739.13	-833.67	-838.99
2. Land converted to Forest Land	659.22	842.89	768.03	669.04	441.89	261.45	211.47	-35.17	74.06	14.76	-348.67	-588.95	-403.88	166.14	32.85	-7.71	-118.63
Biomass burning	21.64	21.64	21.64	20.43	22.84	24.93	23.99	15.33	3.16	2.97	15.27	38.57	14.13	51.61	39.83	7.87	22.63
B. Cropland	21.62	21.40	16.73	10.36	-59.38	-34.79	47.84	25.26	6.42	-17.84	22.94	103.53	94.38	138.86	100.98	128.86	73.25
1. Cropland remaining Cropland	21.62	21.40	9.60	-59.80	-87.34	-62.75	-25.92	-19.86	-38.70	-62.96	-22.18	-29.49	-35.23	-36.47	-25.60	2.29	-53.33
2. Land converted to Cropland	NE,NO	NE,NO	7.13	70.16	27.96	27.96	73.76	45.12	45.12	45.12	45.12	133.02	129.61	175.33	126.58	126.58	126.58
Agricultural Lime Application[b]	38.28	32.72	26.25	36.05	27.69	50.39	49.50	44.55	31.84	39.48	37.31	39.21	29.17	42.04	27.15	29.28	25.80
Emissions from soil disturbance	NA,NO	NA,NO	0.30	3.10	3.10	3.10	5.00	5.00	5.00	5.00	5.00	8.64	10.78	14.01	14.01	14.01	14.01
C. Grassland	491.91	556.77	431.68	345.93	174.71	379.29	416.08	497.19	310.55	398.86	469.57	454.83	459.24	555.27	335.84	196.64	303.76
1. Grassland remaining Grassland	620.33	583.02	529.94	619.33	523.02	718.34	708.53	648.32	543.13	613.14	598.45	615.46	513.51	612.88	479.65	503.47	494.00
2. Land converted to Grassland	-128.42	-26.25	-98.26	-273.40	-348.31	-339.05	-292.45	-151.13	-232.57	-214.27	-128.88	-160.62	-54.27	-57.61	-143.81	-306.83	-190.24
Agricultural Lime Application[b]	316.76	282.43	229.35	321.24	241.95	444.21	434.53	378.94	273.74	343.75	329.07	346.07	244.72	344.72	213.64	237.46	229.06
D. Wetlands	46.61	46.00	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.80	21.69	21.27	20.85
1. Wetlands remaining Wetlands	46.61	46.00	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.80	21.69	21.27	20.85
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
Drainage of soils	3.60	3.57	3.55	3.52	3.49	3.45	3.40	3.36	3.32	3.28	3.24	3.19	3.15	3.11	3.07	3.03	2.99
E. Settlements	12.80	11.72	11.94	12.74	15.69	15.81	19.86	21.65	23.12	24.74	26.09	34.33	30.53	37.23	39.18	46.06	48.29
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
2. Land converted to Settlements	12.80	11.72	11.94	12.74	15.69	15.81	19.86	21.65	23.12	24.74	26.09	34.33	30.53	37.23	39.18	46.06	48.29
F. Other Land	-1.24	NE,NO	-13.26	-0.57	-2.31	NE,NO	-22.82	-6.75	-5.59	NE,NO	-3.11	-17.53	-14.46	-0.20	-29.29	-6.58	-12.29
1. Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Land converted to Other Land	-1.24	NO	-13.26	-0.57	-2.31	NO	-22.82	-6.75	-5.59	NO	-3.11	-17.53	-14.46	-0.20	-29.29	-6.58	-12.29
G. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
TOTAL LULUCF	188.63	352.39	413.74	245.34	67.76	293.38	390.35	325.19	-54.51	-89.89	152.26	26.41	-81.66	-284.54	-201.74	-421.80	-489.00

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 2006 (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	370,123	608,079	FIPS (Forest Inventory and Planning System) 1995 COILLTE database Forest Service Premiums database LPIS (Land Parcels information System) CORINE Land Cover General Soil Map		Grassland
Cropland	Permanent crops and tillage areas (including setaside) recorded by the Central Statistics Office (CSO)	404,563	344,500	CSO, CORINE Land Cover LPIS (Land Parcels information System		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	3,879,500	CSO, CORINE Land Cover LPIS (Land Parcels information System) CORINE Land Cover General Soil Map		Other Land
Wetlands	Natural unexploited wetlands	1,226,142	1,136,006	CORINE Land Cover General Soil Map	Peatlands	
Peatland	Wetland areas commercially exploited for public and private extraction of peat and areas used for domestic harvesting of peat	74,149	60,044	Bord na Mona (BNM) area statistics; Expert opinion		
Settlements	Urban areas, roads, airports and the footprint of industrial, commercial/institutional and residential buildings	98,152	110,872	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	798,272	972,784	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	**370,123**	**4,140,385**	**404,563**	**74,149**	**1,226,142**	**98,152**	**798,272**	**7,111,785**
Forest Land	370,092					31		370,123
Grassland	10,062	4,130,053				270		4,140,385
Cropland	435	2,410	401,694			24		404,563
Peatland	320	61		73,550	219			74,149
Wetland	9,689				1,216,453			1,226,142
Settlements						98,152		98,152
Other Land		17,729				18	780,525	798,272
1991	**389,236**	**4,150,253**	**401,694**	**73,550**	**1,216,671**	**98,495**	**781,887**	**7,111,785**
Forest Land	389,204					32		389,236
Grassland	8,680	4,119,655	1,303			274	20,340	4,150,253
Cropland	356		401,313			25		401,694
Peatland	320	61		72,950	219			73,550
Wetland	8,847				1,207,825			1,216,671
Settlements						98,495		98,495
Other Land						18	781,869	781,887
1992	**405,898**	**4,119,716**	**402,616**	**72,950**	**1,208,044**	**98,844**	**803,718**	**7,111,785**
Forest Land	405,864					34		405,898
Grassland	8,372	4,099,263	11,551			293	238	4,119,716
Cropland	355		402,235			26		402,616
Peatland	320	61		72,350	219			72,950
Wetland	7,649				1,200,395			1,208,044
Settlements						98,844		98,844
Other Land						19	803,699	803,718
1993	**421,855**	**4,099,324**	**413,785**	**72,350**	**1,200,614**	**99,216**	**804,641**	**7,111,785**
Forest Land	421,813					42		421,855
Grassland	10,408	4,085,948				361	2,607	4,099,324
Cropland	486	2,966	410,301			32		413,785
Peatland	320	61		71,751	219			72,350
Wetland	9,449				1,191,165			1,200,614
Settlements						99,216		99,216
Other Land						24	804,617	804,641
1994	**441,267**	**4,088,974**	**410,301**	**71,751**	**1,191,384**	**99,675**	**808,434**	**7,111,785**
Forest Land	441,224					42		441,267
Grassland	12,910	4,075,699				365		4,088,974
Cropland	647	345	409,277			33		410,301
Peatland	140	30		70,938	643			71,751
Wetland	12,100				1,179,283			1,191,384
Settlements						99,675		99,675
Other Land		11,772				24	796,638	808,434
1995	**464,928**	**4,087,847**	**409,277**	**71,151**	**1,179,926**	**100,138**	**798,518**	**7,111,785**
Forest Land	464,874					54		464,928
Grassland	11,586	4,032,277	7,928			461	35,595	4,087,847
Cropland	611		408,624			42		409,277
Peatland	140	30		70,291	690			71,151
Wetland	10,636				1,169,290			1,179,926
Settlements						100,138		100,138
Other Land						30	798,488	798,518
1996	**485,847**	**4,032,307**	**416,552**	**70,127**	**1,169,980**	**100,725**	**836,247**	**7,111,785**
Forest Land	485,788					59		485,847
Grassland	6,523	4,015,147				507	10,130	4,032,307
Cropland	383	2,023	414,100			46		416,552
Peatland	140	30		69,267	690			70,127
Wetland	5,380				1,164,600			1,169,980
Settlements						100,725		100,725
Other Land						33	836,214	836,247
1997	**497,211**	**4,017,200**	**414,100**	**69,102**	**1,165,290**	**101,369**	**847,513**	**7,111,785**

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

	Forest Land	Grassland	Cropland	Peatland	Wetland	Settlements	Other Land	Total
1997	**497,211**	**4,017,200**	**414,100**	**69,102**	**1,165,290**	**101,369**	**847,513**	**7,111,785**
Forest Land	497,148					63		497,211
Grassland	7,112	4,001,089				546	8,453	4,017,200
Cropland	370	5,681	408,000			49		414,100
Peatland	140	30		68,242	690			69,102
Wetland	6,066				1,159,224			1,165,290
Settlements						101,369		101,369
Other Land						36	847,477	847,513
1998	**510,059**	**4,006,800**	**408,000**	**68,078**	**1,159,914**	**102,063**	**856,871**	**7,111,785**
Forest Land	509,991					68		510,059
Grassland	7,234	3,998,979				587		4,006,800
Cropland	426	6,621	400,900			53		408,000
Peatland	140	30		67,218	690			68,078
Wetland	4,929				1,154,986			1,159,914
Settlements						102,063		102,063
Other Land		11,770				38	845,063	856,871
1999	**522,642**	**4,017,400**	**400,900**	**67,053**	**1,155,676**	**102,809**	**845,306**	**7,111,785**
Forest Land	522,569					72		522,642
Grassland	8,914	4,007,864				621		4,017,400
Cropland	517	227	400,100			56		400,900
Peatland	327	75		65,107	1,544			67,053
Wetland	6,389				1,149,287			1,155,676
Settlements						102,809		102,809
Other Land		33,734				41	811,532	845,306
2000	**538,245**	**4,041,900**	**400,100**	**66,193**	**1,150,831**	**103,598**	**810,917**	**7,111,785**
Forest Land	538,150					96		538,245
Grassland	8,934	3,994,425	15,019			823	22,698	4,041,900
Cropland	545		399,481			74		400,100
Peatland	327	75		64,249	1,542			66,193
Wetland	6,139				1,144,692			1,150,831
Settlements						103,598		103,598
Other Land						54	810,864	810,917
2001	**553,584**	**3,994,500**	**414,500**	**65,352**	**1,146,235**	**104,645**	**832,969**	**7,111,785**
Forest Land	553,498					86		553,584
Grassland	8,696	3,948,525	8,797			738	27,744	3,994,500
Cropland	531		413,903			66		414,500
Peatland	327	75		63,408	1,542			65,352
Wetland	5,577				1,140,658			1,146,235
Settlements						104,645		104,645
Other Land						48	832,921	832,969
2002	**568,531**	**3,948,600**	**422,700**	**64,511**	**1,142,200**	**105,583**	**859,661**	**7,111,785**
Forest Land	568,426					105		568,531
Grassland	5,263	3,929,127	13,304			905		3,948,600
Cropland	323		422,296			81		422,700
Peatland	327	75		62,567	1,542			64,511
Wetland	3,310				1,138,890			1,142,200
Settlements						105,583		105,583
Other Land		4,698				59	854,904	859,661
2003	**577,497**	**3,933,900**	**435,600**	**63,670**	**1,140,432**	**106,734**	**853,953**	**7,111,785**
Forest Land	577,386					111		577,497
Grassland	5,208	3,868,530				954	59,208	3,933,900
Cropland	319	12,395	422,800			86		435,600
Peatland	327	75		61,726	1,542			63,670
Wetland	3,223				1,137,209			1,140,432
Settlements						106,734		106,734
Other Land						62	853,890	853,953
2004	**586,347**	**3,881,000**	**422,800**	**62,829**	**1,138,751**	**107,947**	**912,112**	**7,111,785**

Table 7.4 (continued) Land Use Matrices 2004-2006 (ha)

	Forest Land	Grassland	Cropland	Peatland	Wetland	Settlements	Other Land	Total
2004	**586,347**	**3,881,000**	**422,800**	**62,829**	**1,138,751**	**107,947**	**912,112**	**7,111,785**
Forest Land	586,217					130		586,347
Grassland	8,101	3,774,123				1,123	97,653	3,881,000
Cropland	497	53,902	368,300			101		422,800
Peatland	327	75		60,885	1,542			62,829
Wetland	3,164				1,135,587			1,138,751
Settlements						107,947		107,947
Other Land						73	912,039	912,112
2005	**600,179**	**3,828,100**	**368,300**	**61,988**	**1,137,129**	**109,374**	**1,006,716**	**7,111,785**
Forest Land	600,042					137		600,179
Grassland	4,753	3,822,170				1,178		3,828,100
Cropland	293	23,401	344,500			106		368,300
Peatland	327	75		60,044	1,542			61,988
Wetland	2,664				1,134,464			1,137,129
Settlements						109,374		109,374
Other Land		33,855				77	972,784	1,006,716
2006	**608,079**	**3,879,500**	**344,500**	**60,044**	**1,136,006**	**110,872**	**972,784**	**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 (GPG Tables 3.2.4, 3.3.3 and 3.4.4). 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

Mineral Soils

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

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

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

where

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

The factors F_{LU}, F_{MG} and F_I account for changes in SOC due to management practices that impact on soil carbon. Table 7.6 shows the adjustment factors derived from the product of F_{LU}, F_{MG} and F_I taken from GPG Table 3.3.4 for the land uses defined for Ireland in 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 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

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 are adopted for Ireland. Some information is available to suggest that a transition period shorter than the default duration of 20 is appropriate for some land-use conversions on organic soil, which is taken into account in the analysis described in the following sections.

7.3 Forest Land (Category 5.A)

7.3.1 Carbon Stock Change in Living Biomass

Previous NIRs have described a well-established country-specific 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) is available (Gallagher et al, 2004). The output from the model has been updated to include 2006 forestry data. The model 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 LUCF 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 regime.

Given that it fully quantifies annual change in forest biomass, the CARBWARE model is retained as the basic methodology 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 and 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 area, afforestation, harvest, etc) and the estimated carbon stock changes in biomass for *5.A Forest Land* are compiled in Table E.1 of Annex E for the years 1990-2006.

Forest Area and Species
A time series of forest strata by area and age was constructed for the years 1990-2006 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 and private forests. The young crop (7 to 25 years of age inclusive) and mature crop (greater than 25 years) categories in FIPS were broken down by species to provide nine individual strata. A third broad category of cleared/unclassified areas (age up to 7 years) was included so that the total Forest Service area was accounted for in

all years. This 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 2006 were obtained by growing the forest estate forward in time, using annual data on planting and clear felling rates (Annex E), while 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 E.

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).

Harvest
Coillte records are the main source of data for wood harvesting. These data (Annex E) 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.

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. The carbon stock change estimates for living biomass in forests are slightly revised on those given in the 2007 submission due to the effect of some updated information for afforestation in 2004 provided by the National Council for Forest Research and Development (COFORD).

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 default net litter accumulation values for wet temperate forests are adopted, as outlined in Table 3.2.1 of the good practice guidance for LULUCF and the stock change is estimated with reference to young and mature forests separately. The values from Table 3.2.1 are 0.3 t C/ha/yr for broadleaves and 0.5 t C/ha/yr for conifers in young forests (less than 20 years) and 0.8 t C/ha/yr for broadleaves and 1.3 t C/ha/yr for conifers in mature forests (greater than 20 years).

It is assumed that afforested and reforested areas less than 7 years old do not contribute to the dead organic 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 to conifer split for old forests is 31 percent and 69 percent, respectively, again on the basis of the 1995 FIPS baseline year distribution.

For comparison it may be noted that experimental data for Sitka spruce stands up to 20 years old show a net accumulation (net decomposition) of 0.8 to 3 t C/ha/year and about 2 t C/ha/year for older stands, based on litter inputs of 1 to 4 t C/ha/year. The decomposition was based on a mean residence time (total litter/annual input rate) for litter on wet mineral gley soils for Sitka spruce of about 5 to 7 years (i.e. 14-20 percent of the litter is decomposed annually). These values are slightly higher than the IPCC defaults but the default values are adopted because sufficient country-specific data is not available.

7.3.3 Net Carbon Stock Change in 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* remains constant, regardless of changes in forest management, forest type and disturbance. The notation key NO is therefore used under this item in CRF Table 5.A.

Land Converted to Forest Land (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 E.1 of Annex E) with *5.A.2.3 Wetlands Converted to Forest Land* accounting for 57 percent of the 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 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. Although there is evidence that afforestation on mineral soils has little or no impact on the carbon stock within mineral soils under Irish conditions, there is not sufficient published data to apply a country-specific or region-specific emissions scheme. Therefore the Tier 1 IPCC defaults in the good practice guidelines were used. Accordingly, afforestation on mineral soils has been assigned the default transition period of 20 years, requiring evaluation of new forests on mineral soils from 1970 onwards. Carbon stock changes for afforested areas on mineral soils were estimated using Equation 7.1.

Previously, it was assumed that afforestation occurs on mineral and organic soils at a ratio of approximately 60:40. The allocation to mineral and organic soils is now determined separately for each year using LPIS data. Recent forest research in the UK (Hargreaves et al, 2003) under climatic and organic soil conditions similar to those in Ireland suggests that following plantation, organic soils emit carbon at an elevated rate of approximately 16 t C/ha over a typical period of 4-5 years. This implies an emission rate of 4 t C/ha annually over a transition period of 4 years. Thereafter the emission from afforested organic soils reduces to zero, or indeed the soil may become a modest sink of carbon. While the emission rate is large compared to the default rate of 0.68 t C/ha/year for organic soils in cold wet temperate conditions, the transition period is much shorter than the 20-year default period. The accumulated default emission of 13.6 t C/ha over 20 years is only 15 percent less than total emissions according to the UK findings (Hargreaves et al, 2003). A country specific transition period of four years is therefore considered appropriate to afforested areas on organic soils.

7.3.4 Emissions from Biomass Burning

Estimates of emissions from forest biomass burning in Ireland are included in this submission following recommendations made during the in-country review carried out in 2007. These emissions are associated with forest wildfires. For the 2008 submission, COFORD compiled estimates of forested areas subjected to fires for the years 1993 to 2006 based on data from Coillte and the Forest Service and modified the CARBWARE model to account for emissions of CO_2, CH_4 and N_2O from forest fires. The emissions are estimated using equation 3.2.19 on page 3.51 of the IPCC good practice guidance for LULUCF and the estimates appear in CRF Table 5(V). In order to incorporate the effect of fires into CARBWARE, the following assumptions were made:

1) All fires occur in the young forest category under *5.A.1 Forest Land Remaining Forest Land*. 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 category under *5.A.1 Forest Land Remaining Forest Land* is equally distributed among all species cohorts;
3) 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 (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 431 ha per year for the period 1993-2006 was assumed.
5) The indirect effect of fires on carbon stock changes included those associated with loss of productivity of the area after fire and re-growth following re-planting, assumed to occur 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 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 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 IE is therefore used in CRF Table 5(I).

7.3.6 Emissions of N_2O from Drainage

In previous submissions, no estimates were reported for N_2O emissions associated with the drainage of forest soils, as this is an optional reporting category in the LULUCF sector, and the notation key NA was used in CRF Table 5(II). This position was reviewed for the 2008 submission. Tier 1 estimates of N_2O emissions due to the drainage of organic soils and mineral soils in forest lands are now reported.

7.4 Cropland (Category 5.B)

7.4.1 Cropland Areas

Cropland areas are based on CSO annual statistics for tillage crops, revised by the inventory agency to account for inconsistencies due to the impact of changes in total farmed area reported in 1997, as described in the 2007 NIR. At the time of submission of the 2007 NIR, revised Cropland data for 2005 were unavailable, therefore an estimate of the 2005 figure was included. The analysis included for this submission utilizes a complete CSO data set for cropland areas for the period 1990-2006 and includes the correction of the 2005 figures compared to the previous submission.

In previous submissions, it was maintained that a small area of peatland, approximately 3,000ha 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. Following discussion with national experts in agricultural practices and GIS analysis, it has been agreed, pending the results of proposed research, that the existing expert opinion would prevail. Therefore, it is assumed 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 previous submissions 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 classes, as new cropland areas on organic soils are no longer required to transfer to, or from, grasslands, with an equivalent change in the dynamics of transfer of mineral soils between classes.

Croplands are assumed to revert to natural grassland status during set-aside (the temporary exclusion of tillage areas from production) but stay within the category *5.B Croplands Remaining Croplands*, as a land parcel that is given over to set-aside in one year will probably be tilled in subsequent years. 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 to *5.A Forest Land* and *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 forest lands and 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*. Land converted to cropland remains as cropland for at least the full transition period of 20 years. Therefore the area of land in transition to cropland increases only in those years were there is a net increase in cropland reported by the CSO statistics. The corollary is that in years where there is a reported net decrease in cropland, the change is limited to a decrease in cropland remaining cropland. As a result, the cropland areas in Table 7.3 tend to follow the CRF data quite closely. 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 I 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 GPG Table 3.3.8 is adopted for the carbon stock in crop biomass after one year. The carbon stock change in biomass on the area A converted to cropland is then calculated from Equation 3.3.8 of the IPCC good practice guidance as follows:

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

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

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 are reported in this 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 (Category 5.C)

7.5.1 Grassland Areas

Grassland is the dominant land-use category in Ireland. Area estimates are based principally on CSO annual statistics for improved grassland (pastures and areas harvested for silage and hay) and unimproved grassland, which refers to rough grazing. As with croplands, at the time of submission of the 2007 NIR, grassland area data for 2005 were unavailable, therefore an estimate of the 2005 figure was included at that time. The analysis undertaken for this submission utilizes a complete CSO dataset for grassland areas for the years 1990-2006, and includes the correction of the 2005 figures compared to the previous submission. The methodology for estimating Grassland area has not changed from the previous submission. Any revisions are due to the knock-on effects of changes in other land classes.

It is important to note that both improved and unimproved grassland areas are estimates of grasslands *in use* for agricultural purposes. Rough grazing areas *in use* are native grasslands that are unmanaged with regard to drainage or other inputs, such as fertilizer, 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 un-used 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 which 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. There is little data available on conversion of forest land to grassland. For the purposes of this submission it is assumed that the amount of deforestation is negligible, especially as there has been an annual increase in forest over recent decades. However, deforestation is an issue to be addressed in future submissions.

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.*

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 will invariably be subject to ploughing and reseeding. This is accounted for through Equation 7.2 as a loss of 6 t C/ha for standing biomass followed by a gain of 6.0 t C/ha through growth in the first year, using default values.

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 have been applied.

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 (Category 5.D)

7.6.1 Wetland Areas

Wetlands as applied to Ireland refer to natural unexploited wetlands while peatlands are those wetland areas drained for the purpose of commercial exploitation and harvesting of peat. The national wetland area is therefore split into two types, wetland and 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 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 activities and for private industrial and domestic harvesting of peat. 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 average value obtained from this total is used for each of the five years to obtain the full time series. Private industrial exploitation of peatlands is of the order of one-eighth that of the commercial activity of Bord na Mona. As similar harvesting methods are used, the areas have been extrapolated from the Bord na Mona values for individual years. 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. Current estimates are that approximately 1Mt of peat are extracted each year by hand cutting. This represents a bog area of about 400 hectares per year.

Table 7.7 Area Statistics for Peatlands (ha)

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

7.6.2 Carbon Stock Changes in *Wetland*

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).

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.

7.6.3 Emissions of Non-CO_2 Gases

In previous submissions 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 Irelands GHG inventory in 2007. Emissions of N_2O due to the drainage of peatlands are reported in this submission for the first time and utilise the IPCC Tier 1 approach.

7.7 Settlements (Category 5.E)

7.7.1 Areas of Settlements

The area of settlements in 1990 is that given by CORINE 1990. Land converted to settlements is the area taken up by new road building, available from the National Roads Authority, and the area covered by new residential, commercial and industrial construction based on CSO annual statistics, which are extracted from floor area records for permitted development. An incomplete time series of housing types (for the years 1995-2000) 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. Section 7.10 outlines a significant revision of the area of land taken by dwellings, which has been incorporated into this submission.

The identification of the land use from which settlement areas are converted is based on an analysis of the distribution of land use classes given by CORINE 1990, with the exclusion of wetland, water bodies, existing continuous urban fabric and other marginal unsuitable land types. Conversions of the different types of land area to settlement areas are assumed to occur in the proportions under which the respective categories existed in 1990. For example, as 80 percent of the land is grassland, it is reasonable to assume that 80 percent of new buildings and road construction takes place on grasslands.

7.7.2 Carbon Stock Changes in Settlements

The assumption is made of complete removal of biomass in the year of the planning permission for buildings constructed or in the year of completion of road projects. 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. Based on the carbon estimates in Section 7.3, the average biomass of forested lands in Ireland is of the order of 42 t C/ha. No account has been made of the potential increased carbon stock in biomass in urban areas. 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.

7.8 Other Land (Category 5.F)

7.8.1 Areas of Other Land

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

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.

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 the reporting of additional source categories and minor changes in the areas assigned to some land use categories. The following are the principal items leading to recalculations for the years 1990-2005

a) Revised allocation between organic and mineral soils *for 5.A.2 Land Converted to Forest Land*. The allocation for each year is determined from LPIS data instead of using a fixed 60:40 split in all years;

b) Inclusion of CH_4 and N_2O estimates for biomass burning in *5.A.1 Forest Land Remaining Forest Land*;

c) Inclusion of N_2O estimates for drainage in *5.A. Forest Land*;

d) Inclusion of N_2O estimates for drainage in *5.D Wetlands*;

e) Exclusion of inversion tillage on organic soils in *5.B Cropland;*

f) Inclusion of N2O estimates associated with soil disturbance for land converted to cropland;

g) Revision of total area of exploited peatland in *5.D Wetlands*;

h) Revision of the annual rates of biomass loss due to conversion of peatland;

i) Revised estimates of footprint areas for new dwellings in *5.E.2 Land Converted to Settlements* to take account of soil sealing due to the construction of access roads and driveways in housing developments.

The effects of the recalculations is shown in Table 7.8. Items a) and f), together with the inclusion of the estimates for N2O account for the bulk of the change.

7.11 Improvements in LULUCF

The coverage of sources of emissions and removals by Ireland in LULUCF is complete for the years 1990-2006. Even though a rather simplified approach has had to be followed 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 data treatment for this submission. 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 is being expanded so that it may devote more resources to integrating the available datasets and to undertaking the level of spatial analysis needed to improve the land area activity data.

The results of an extensive new forest inventory are now available for use in the LULUCF inventory. COFORD is funding a new series of projects on climate change and forestry over the period from 2007 to 2012. The CARBWARE project will develop forest carbon stock change reporting tools and software, building on work begun in 2000, which used FIPS and Forest Service planting data. It will also access data from the new CARBiFOR II project and other research projects, to refine estimates of carbon stock change for reporting purposes. Data from IFORIS and NFI will be needed to fulfil reporting requirements. An initial data provision and analysis framework has been developed for CARBWARE, which is being extensively enhanced to make available an integrated system that will meet the reporting needs of the Convention and the Kyoto Protocol.

Work on developing a single forest cover and attribute data set has been progressing in the Forest Service over the past two years. 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. The land use conversion to settlements, particularly as regards new construction, remains a coarse estimate.

Table 7.8 Percentage Change in Emissions and Removals from LULUCF due to Recalculations

(a) 2007 Submission (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Forest Land	-478.02	-391.91	-201.01	-275.98	-207.58	-245.02	-216.91	-349.44	-505.17	-591.85	-474.15	-624.88	-738.42	-1,060.00	-665.77	-811.38
1. Forest Land remaining Forest Land	-1,078.90	-1,163.38	-884.4	-876.45	-587.48	-437.51	-358.95	-238.61	-521.46	-579.24	-116.18	-37.62	-358.01	-1,258.08	-724.25	-845.19
2. Land converted to Forest Land	600.89	771.47	683.39	600.46	379.9	192.5	142.05	-110.82	16.29	-12.61	-357.96	-587.26	-380.41	198.08	58.48	33.81
Biomass burning	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
B. Cropland	46.83	46.34	42.3	37.46	-32.34	-7.85	75.02	51.66	32.55	8.39	48.39	129.77	120.66	165.77	126.57	148.09
1. Cropland remaining Cropland	46.83	46.34	34.6	-33.48	-60.91	-36.42	-0.27	5.46	-13.66	-37.82	2.19	-5.00	-10.85	-11.88	-2.23	19.29
2. Land converted to Cropland	NE,NO	NE,NO	7.7	70.95	28.58	28.58	75.3	46.2	46.2	46.2	46.2	134.77	131.52	177.65	128.8	128.8
Agricultural Lime Application[b]	38.28	32.72	26.25	36.05	27.69	50.39	49.5	44.55	31.84	39.48	37.32	39.21	29.17	42.04	27.15	26.71
Emissions from soil disturbance	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
C. Grassland	491.91	559.29	433.02	347.37	176.32	383.12	417.93	500.31	313.87	402.46	473.67	458.89	463.29	559.32	340.65	56.57
1. Grassland remaining Grassland	620.07	582.8	529.72	619.22	522.83	718	708.21	648.16	542.97	612.98	598.29	615.3	513.35	612.72	479.5	477.79
2. Land converted to Grassland	-128.16	-23.51	-96.71	-271.84	-346.51	-334.88	-290.28	-147.86	-229.09	-210.51	-124.63	-156.41	-50.05	-53.39	-138.85	-421.22
Agricultural Lime Application[b]	316.76	282.43	229.35	321.25	241.95	444.21	434.53	378.94	273.74	343.75	329.07	346.07	244.72	344.72	213.64	214.09
D. Wetlands	46.61	46	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.8	21.69	21.27
1. Wetlands remaining Wetlands	46.61	46	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.8	21.69	21.27
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
Drainage of soils	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
E. Settlements	13.69	12.91	13.81	15.24	17.8	18.28	22.81	25.91	29.04	31.18	33.04	44.88	38.29	46.39	52.99	59.38
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
2. Land converted to Settlements	13.69	12.91	13.81	15.24	17.8	18.28	22.81	25.91	29.04	31.18	33.04	44.88	38.29	46.39	52.99	59.38
F. Other Land	-0.21	NE, NO	-12.31	-12.4	-13.93	-6.73	-28.27	-34.33	-39.34	-32.07	-10.79	-23.69	-39.7	-35.98	-70.7	-131.16
1. Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Land converted to Other Land	-0.21	NO	-12.31	-12.4	-13.93	-6.73	-28.27	-34.33	-39.34	-32.07	-10.79	-23.69	-39.7	-35.98	-70.7	-131.16
G. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
TOTAL LULUCF	120.81	272.64	321.21	156.48	-17.36	181.73	308.06	229.14	-136.47	-151.76	108.29	18.99	-125.96	-298.7	-194.58	-657.22

(b) 2008 Submission (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Forest Land	-399.99	-300.80	-96.69	-188.82	-124.83	-129.01	-132.47	-270.97	-444.47	-548.77	-425.70	-613.08	-711.66	-1,078.63	-706.28	-841.38
1. Forest Land remaining Forest Land	-1,059.21	-1,143.69	-864.71	-857.86	-566.71	-390.46	-343.93	-235.80	-518.53	-563.53	-77.03	-24.13	-307.78	-1,244.77	-739.13	-833.67
2. Land converted to Forest Land	659.22	842.89	768.03	669.04	441.89	261.45	211.47	-35.17	74.06	14.76	-348.67	-588.95	-403.88	166.14	32.85	-7.71
Biomass burning	21.64	21.64	21.64	20.43	22.84	24.93	23.99	15.33	3.16	2.97	15.27	38.57	14.13	51.61	39.83	7.87
B. Cropland	21.62	21.40	16.73	10.36	-59.38	-34.79	47.84	25.26	6.42	-17.84	22.94	103.53	94.38	138.86	100.98	128.86
1. Cropland remaining Cropland	21.62	21.40	9.60	-59.80	-87.34	-62.75	-25.92	-19.86	-38.70	-62.96	-22.18	-29.49	-35.23	-36.47	-25.60	2.29
2. Land converted to Cropland	NE,NO	NE,NO	7.13	70.16	27.96	27.96	73.76	45.12	45.12	45.12	45.12	133.02	129.61	175.33	126.58	126.58
Agricultural Lime Application[b]	38.28	32.72	26.25	36.05	27.69	50.39	49.50	44.55	31.84	39.48	37.31	39.21	29.17	42.04	27.15	29.28
Emissions from soil disturbance	NA,NO	NA,NO	0.30	3.10	3.10	3.10	5.00	5.00	5.00	5.00	5.00	8.64	10.78	14.01	14.01	14.01
C. Grassland	491.91	556.77	431.68	345.93	174.71	379.29	416.08	497.19	310.55	398.86	469.57	454.83	459.24	555.27	335.84	196.64
1. Grassland remaining Grassland	620.33	583.02	529.94	619.33	523.02	718.34	708.53	648.32	543.13	613.14	598.45	615.46	513.51	612.88	479.65	503.47
2. Land converted to Grassland	-128.42	-26.25	-98.26	-273.40	-348.31	-339.05	-292.45	-151.13	-232.57	-214.27	-128.88	-160.62	-54.27	-57.61	-143.81	-306.83
Agricultural Lime Application[b]	316.76	282.43	229.35	321.24	241.95	444.21	434.53	378.94	273.74	343.75	329.07	346.07	244.72	344.72	213.64	237.46
D. Wetlands	46.61	46.00	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.80	21.69	21.27
1. Wetlands remaining Wetlands	46.61	46.00	45.39	44.79	42.37	39.92	37.48	35.03	32.58	30.13	38.13	34.02	29.91	25.80	21.69	21.27
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
Drainage of soils	3.60	3.57	3.55	3.52	3.49	3.45	3.40	3.36	3.32	3.28	3.24	3.19	3.15	3.11	3.07	3.03
E. Settlements	12.80	11.72	11.94	12.74	15.69	15.81	19.86	21.65	23.12	24.74	26.09	34.33	30.53	37.23	39.18	46.06
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
2. Land converted to Settlements	12.80	11.72	11.94	12.74	15.69	15.81	19.86	21.65	23.12	24.74	26.09	34.33	30.53	37.23	39.18	46.06
F. Other Land	-1.24	NE,NO	-13.26	-0.57	-2.31	NE,NO	-22.82	-6.75	-5.59	NE,NO	-3.11	-17.53	-14.46	-0.20	-29.29	-6.58
1. Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Land converted to Other Land	-1.24	NO	-13.26	-0.57	-2.31	NO	-22.82	-6.75	-5.59	NO	-3.11	-17.53	-14.46	-0.20	-29.29	-6.58
G. Other	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
TOTAL LULUCF	188.63	352.39	413.74	245.34	67.76	293.38	390.35	325.19	-54.51	-89.89	152.26	26.41	-81.66	-284.54	-201.74	-421.80

(b) Percentage Change

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Forest Land	-16.32	-23.25	-51.90	-31.58	-39.87	-47.35	-38.93	-22.46	-12.02	-7.28	-10.22	-1.89	-3.62	1.76	6.09	3.70
1. Forest Land remaining Forest Land	-1.82	-1.69	-2.23	-2.12	-3.53	-10.76	-4.18	-1.18	-0.56	-2.71	-33.70	-35.85	-14.03	-1.06	2.05	-1.36
2. Land converted to Forest Land	9.71	9.26	12.39	11.42	16.32	35.82	48.87	-68.26	354.63	-217.05	-2.60	0.29	6.17	-16.12	-43.83	-122.80
Biomass burning	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B. Cropland	-53.83	-53.81	-60.46	-72.34	83.61	543.18	-36.23	-51.10	-80.28	-312.63	-52.60	-20.22	-21.78	-16.23	-20.22	-12.98
1. Cropland remaining Cropland	-53.83	-53.81	-72.26	78.61	43.39	72.30	9,500.00	463.74	183.31	66.83	-1,112.79	489.80	224.70	206.99	1,047.98	-88.14
2. Land converted to Cropland	NA	NA	-7.43	-1.11	-2.18	-2.18	-2.04	-2.34	-2.34	-2.34	-2.34	-1.30	-1.46	-1.30	-1.73	-1.73
Agricultural Lime Application[b]	0.00	-0.01	0.02	0.01	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	0.00	0.02	0.01	0.01	9.61
Emissions from soil disturbance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C. Grassland	0.00	-0.45	-0.31	-0.41	-0.91	-1.00	-0.44	-0.62	-1.06	-0.89	-0.86	-0.88	-0.87	-0.72	-1.41	247.61
1. Grassland remaining Grassland	0.04	0.04	0.04	0.02	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	5.37
2. Land converted to Grassland	0.21	11.64	1.60	0.57	0.52	1.25	0.75	2.21	1.52	1.79	3.41	2.69	8.43	7.90	3.57	-27.16
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	10.91
D. Wetlands	-0.01	0.00	0.01	0.00	0.01	0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.01
1. Wetlands remaining Wetlands	-0.01	0.00	0.01	0.00	0.01	0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.01
2. Land converted to Wetlands	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Drainage of soils	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
E. Settlements	-6.48	-9.24	-13.51	-16.44	-11.85	-13.50	-12.95	-16.43	-20.38	-20.65	-21.02	-23.50	-20.27	-19.75	-26.07	-22.42
1. Settlements remaining Settlements	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Land converted to Settlements	-6.48	-9.24	-13.51	-16.44	-11.85	-13.50	-12.95	-16.43	-20.38	-20.65	-21.02	-23.50	-20.27	-19.75	-26.07	-22.42
F. Other Land	492.66	NA	7.71	-95.42	-83.39	NA	-19.30	-80.33	-85.78	NA	-71.21	-26.00	-63.58	-99.45	-58.58	-94.98
1. Other Land remaining Other Land	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2. Land converted to Other Land	492.66	NA	7.71	-95.42	-83.39	NA	-19.30	-80.33	-85.78	NA	-71.21	-26.00	-63.58	-99.45	-58.58	-94.98
G. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL LULUCF	56.14	29.25	28.81	56.79	-490.32	61.44	26.71	41.92	-60.06	-40.77	40.60	39.05	-35.17	-4.74	3.68	-35.82

Chapter Eight

Waste

8.1 Overview of Waste Sector

The main activities 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 most important of these sources is solid waste disposal where CH_4 is the gas concerned. Landfills represent a key emission category in Ireland (Chapter Three) and the emission estimates are reasonably well quantified in current inventories. The treatment of wastewaters and sludge in anaerobic systems may also be an important source of CH_4. Only a very small proportion of wastewater treatment in Ireland is anaerobic and consequently this is a minor source of CH_4 emissions. However, the estimates together with estimates of CH_4 emissions from sludge treatment are included. The N_2O emissions arising from the production of human sewage continue to be reported following the inclusion of first estimates for this source as part of the recalculations undertaken for the 2002 submission.

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 burning of clinical wastes was discontinued around 1995. The practice 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 may be negligible. The incineration of municipal waste may become an additional source of emissions for inclusion in annual inventories in the coming years following the granting of waste licences for two incinerators by the EPA.

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	NE
2. Domestic and Commercial Wastewater	NA	All	All
3. Other	NO	NO	NO
C. Waste Incineration	NE	NE	NE
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)

The anaerobic decomposition of organic matter in solid waste disposal sites (SWDS) is a major source of CH_4 in developed countries. The CH_4 production potential of SWDS in a particular year depends on the cumulative solid waste disposal over many previous years, the composition of the wastes disposed of and the level of management applied to the disposal sites concerned. Well managed deep landfills in which the wastes receive constant compaction and cover material have a much greater capacity for CH_4 production than shallow unmanaged sites or open dumps where aerobic conditions may dominate. Methane production within landfills occurs in a number of distinct phases with virtually all CH_4 usually being realised within a period of approximately 20 years following waste disposal.

8.2.1 Methodology for CH_4 Emissions from Solid Waste Disposal

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 results obtained from this methodology were included as an important component of the recalculations reported in the 2002 submission. The same method continues to be used but further development and minor updating of the underlying activity data remains part of the ongoing work and assessment in relation to this source of CH_4 emissions. In this regard, sewage sludge placed in landfills was taken into account as an additional source of degradable organic matter for the estimation of emissions in 2004, which is in line with good practice guidance.

The approach underlying the quantification of CH_4 from solid waste disposal uses the relationship given in Figure 8.1 to describe the CH_4 production from all contributing solid waste deposited in landfills in a particular year. A full analysis of the relationship given in Figure 8.1 is provided in Annex F.

Figure 8.1. Typical CH_4 Production Pattern in Solid Waste Disposal Sites

This relationship is based on a two-stage first-order model (Cossu et al, 1996) for landfill gas production, incorporating a lag period of one year before CH_4 generation commences, followed by active CH_4 production over 20 years. Landfill gas is in general produced in five distinct stages (ICRCL Guidance Note 17/78, 1990). Details of these distinct stages are as follows:

Phase I: Aerobic decomposition of biodegradable materials during which entrained oxygen is converted to CO_2.
Phase II: Anaerobic decomposition commences as oxygen is used up. The CO_2 concentration increases and some hydrogen is produced. No methane is produced at this stage.
Phase III: Anaerobic CH_4 production commences and rises to a peak as the concentration of CO_2 declines while hydrogen production ceases.
Phase IV: Steady state CH_4 and CO_2 production in proportions of between 50-70% and 30-50% respectively.
Phase V: Steady decline in generation of CH_4 and CO_2 with a gradual return to aerobic conditions.

The length of the individual phases are dependant on the method of waste placement, the type of waste containment provided and environmental factors including oxygen, hydrogen, pH, alkalinity, nutrients, inhibitors, temperature and moisture content. For the purposes of emission calculations it is assumed that the individual phases are estimated to be completed when the following periods have elapsed:

Phase I: 3 months,
Phase II: 1 year,
Phase III: 5 years
Phase IV: 15 years,
Phase V: Decades

The CH_4 production estimates take account of a variable allocation of wastes between well-managed landfills, where the full CH_4 potential is realised, and shallow unmanaged landfills for which 40 percent of the potential CH_4 is assumed to be emitted. To estimate annual emissions for the years 1990 to 2006, the CH_4 potential of wastes landfilled in each year from 1969 (21 years prior to 1990) is first determined. These annual CH_4 potentials are then assigned as emissions over 20 subsequent years (with an initial lag of 1 year) according to the proportions depicted in Figure 8.1 and Table F.3 Annex F and their cumulative contributions for the 20 year period give the total emissions for the end year in that period.

8.2.2 CH_4 Production Potential of Solid Wastes

The CH_4 production potential of solid wastes is determined by the amount of degradable organic carbon (DOC) in wastes, which in turn depends on the amount and composition of the waste material. The IPCC Guidelines use municipal solid waste (MSW), which usually refers to household and commercial refuse, as the basic parameter from which the amount of DOC is established for the purposes of estimating CH_4 potential. However, it is recognised that some industrial wastes, sewage sludge and street cleansings may also contribute to degradable organic matter in landfills and therefore they should be taken into account to the extent possible.

The EPA commenced the development of the National Waste Database in the early 1990s to address a severe lack of information on waste production and waste management practices in Ireland. The database is 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, are the primary basis for establishing the historical time-series of MSW placed in landfills in Ireland for the purpose of estimating CH_4 emissions from this source. These publications provide detailed descriptions of the methods employed to compile the waste database. The results of other less comprehensive 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 Database reports for 1995 (Carey et al, 1996), 1998 (Crowe et al, 2000), 2001 (Meaney et al, 2003), and 2004 (Collins et al, 2005) and interim reports for 2002 (Collins et al, 2004a), 2003 (Collins et al, 2004b), 2005 (Le Bolloch et al, 2006) and 2006 (Le Bolloch et al, 2007) are used to establish the MSW time-series up to 2006 and the corresponding annual CH_4 emission estimates. The time-series estimates given in the present submission also account for the inclusion of sewage sludge and are fully consistent over the period 1990-2006. The historical time series of wastes placed in solid waste disposal sites up to 2006, along with their associated DOC contents, used as the basis of CH_4 emission estimates from this source are provided in Table F.1 of Annex F. The following paragraphs describe the steps and assumptions made in developing these data from the available National Waste Database statistics:

- the waste material contributing to DOC includes MSW (household and commercial refuse) and street cleansings, as given in the National Waste Database reports together with sludge from municipal wastewater treatment that are deposited in landfills;
- the per-capita MSW generation rates indicated for 2001, 1998 and 1995, along with those implied by the earlier surveys, are used to assign the rate of MSW production in intervening years and pre 1995;
- similarly, the proportion of MSW that is placed in landfills in 1995, 1998, 2001, is used to assign the corresponding value in intervening years and pre 1995;
- the per-capita MSW generation rate and the proportion of MSW that is placed in landfills are assumed to remain constant at 1 kg/cap/day and 75 percent, respectively prior to 1985;
- the historical amount of street cleansings is estimated from the ratio of street cleansings to MSW given by the 1995, 1998, 2001, waste reports data;
- the waste constituents of MSW that contribute to DOC are organics, paper, textiles and the category other (fine elements, unclassified materials and wood wastes), are identified in the available breakdown for 1995, 1998, and 2001 through 2006
- the IPCC default proportions of DOC are used for organics, paper and textiles (15, 40 and 40 percent, respectively);
- DOC contents of 25 percent and 15 percent have been assumed for street cleansings and the category other, respectively;
- the DOC contribution of sludge is determined from information on the BOD content, the BOD removal rate and the proportion of sludge disposed to landfill.

The potential CH_4 available from the annual DOC in SWDS, determined as described above, is estimated as follows;

- in accordance with the IPCC good practice guidance, 60 per cent of the total available DOC in solid waste is dissimilated on an eqi-molar basis to CH_4 and CO_2;

- in the period 1990 - 1995, 60 percent of DOC is assigned a methane correction factor (MCF) of 1, on the basis that the MSW from all major population centres (60 percent of the population) is deposited in managed landfills (Carey et al, 1996) and the full CH_4 potential is ultimately realised;

- in the period 1990 - 1995, 40 percent of DOC is assigned a MCF of 0.4, on the assumption that 40 percent of MSW is placed in unmanaged SWDS of less than 5 m depth;

- the MSW split between managed and unmanaged sites in 1969 is taken to be the reverse of that adopted for the years 1990 -1995 and appropriate adjustment is made for the intervening years and for the years after 1995 to reflect a gradual increase for managed landfills;

- The MSW split adopted for 2005 is 0.96 for managed sites and 0.04 for unmanaged sites on the basis that over the coming years all landfills in Ireland will be classified in the managed category as defined by the IPCC.

8.2.3 CH_4 Emissions from Solid Waste in 2006

The final estimates of CH_4 emissions from the IPCC source-category *6.A.1 Solid Waste Disposal on Land* are derived for the years 1990-2006 from the time-series data on CH_4 potential given in Table F.2 of Annex F, using the time-dependent rate of release shown in Figure 8.1 and Table F.3 of Annex F. The emissions in a particular year are simply the cumulative contribution for that year arising from managed landfills and from unmanaged landfills separately over the period of 21 years that ends in the year concerned.

Landfill gas has been recovered at a small number of landfill sites in Ireland since 1996. The amount of CH_4 utilised for electricity production at these sites is known from annual reports on renewable energy use. In this top-down analysis, the amount of CH_4 captured for energy use is estimated from the reported electricity production from this source in the national energy balance, assuming assigned percentage conversion efficiency factors. As part of the implementation of Directive 1999/31/EC (CEU, 1999) and reporting to the European Pollution Emissions Register (EPER), the EPA made estimates of CH_4 emissions from 65 individual landfills in Ireland for 2004 using either the LANDGEM model developed by the USEPA or the GASSIM model used in the UK. These were considered to be all the landfills that were producing CH_4 in any appreciable quantities in that year and the exercise was a repeat of that undertaken for EPER in 2001. The landfills identified which burn-off or flare CH_4 produced in 2004 were contacted by inspectors in early 2007 to provide data for methane flaring for 2005 for inclusion in the 2007 NIR. Currently no data are available for 2006, therefore it is assumed that the quantity of CH_4 flared in 2006 is similar to that in 2005. The total CH_4 flared is added to the total utilised for energy production to derive a total quantity of CH_4 that must be deducted from CH_4 production to obtain the emission estimates.

Figure 8.2 shows the trend in emissions from solid waste disposal over the period 1990-2006 achieved from the analysis described above and using the results of flaring and utilisation of landfill gas for the years 1996 to 2006. The estimates indicate CH_4 emissions of 63.441 Gg in 1990 from an annual average of 0.92 million tonnes of contributing municipal waste over the preceding period of 20 years. In 2006, emissions had increased to 79.496 Gg after recovery and flaring and the average contributing wastes were approximately 1.46 million tonnes annually.

It is evident from Figure 8.2 that emissions from solid waste disposal are increasing significantly even though a substantial part of CH_4 production is offset by flaring and utilisation. The implied emission factors for CH_4 production are typically 0.1 to 0.11 t CH_4/t MSW for managed landfills. These values may not be comparable to those for other Parties as the activity data reported for a particular year is the 20-year average MSW for the period contributing to emissions in that year. This gives an IEF approximately 30 percent higher than those based on MSW for the year concerned, e.g. range 0.056-0.080 compared to 0.101-0.115 over the period 1990-2006.

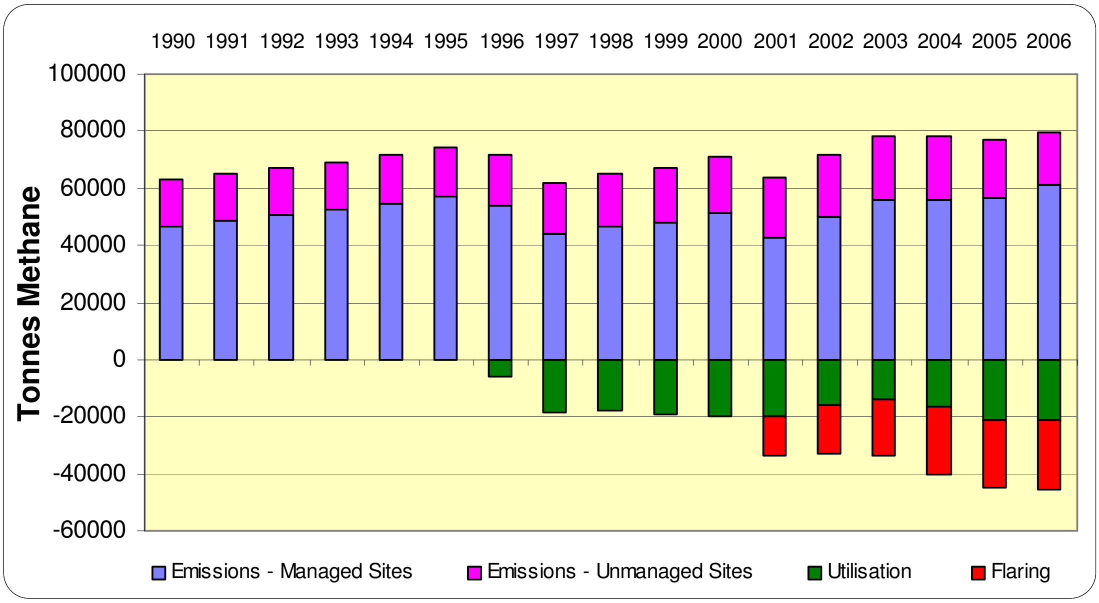

Figure 8.2. Methane Emissions from Solid Waste Disposal Sites 1990-2006

8.3 Emissions from Wastewater Handling (6.B)

8.3.1. CH_4 Emissions from Wastewater and Sludge (6.B.2.1)

Wastewater treatment systems are used to chemically or biologically stabilise wastewater before disposal. Wastewater treatment methods can be classified as primary, secondary and tertiary treatment. In primary treatment, physical barriers remove larger solids from the wastewater with remaining particles allowed to settle. Secondary treatment consists of a combination of biological processes that promote biodegradation by micro organisms and generally includes settlement of remaining solids. Tertiary treatment processes are used to further purify the wastewater of contaminants and pathogens. Sludge is produced in both the primary and secondary stages of treatment. The most common methods of wastewater handling are aerobic wastewater treatment plants and lagoons. In general wastewater treatment plants are used for the treatment of wastewater from urban areas, however, many large industrial facilities also have their own wastewater treatment plants on site to deal with the large quantities of wastewater produced by their facilities. The type of treatment facilities required is dependant on the size of the agglomeration (an area where the population and/or economic activities are sufficiently concentrated for wastewater to be collected and treated), the type of receiving water body and the sensitivity of the receiving water body to quality objectives and provisions.

For the purposes of inventory estimates it is assumed that all wastewaters sent to wastewater treatment plants are treated aerobically in both urban and industrial situations and as a result emissions of CH_4 do not occur. Furthermore a third of the population, mostly in rural areas, treat wastewater using septic tanks (Smith et al., 2004). Septic tanks consist of a watertight container that separates liquids and solids and provides a limited amount of organic digestion to the wastewater that enters it. The liquid overflow from these systems is released to a percolation area. The temperature, which exists within such systems, is not conducive to the occurrence of methanogenesis, therefore there is no emissions of CH_4 from this type of treatment system. Consequently the notation key “NO” is reported under wastewater in sub-sectors 6.B.1 and 6.B.2 of the CRF.

The sludge produced during primary and secondary treatment of wastewaters must be treated further before it can be safely disposed of. The sludge produced in primary wastewater treatment consists of the solids that are removed from the wastewater. Sludge produced in secondary treatment is as a result of biological growth in the biomass as well as the collection of small particles, which remain in the wastewater after primary treatment. In order to be safely disposed of sludge must undergo further treatment, which include aerobic and anaerobic stabilisation, conditioning, centrifugation, composting and drying. The anaerobic stabilisation of sludge is a source of CH_4. In Ireland 3 percent of sludge is anaerobically treated (O’Leary and Carty, 1998) and is therefore an emission source. Emissions are derived from national statistics, country specific values and the IPCC Guidelines. The most important parameters are presented in Table 8.2.

Table 8.2 Parameters for Estimation of CH_4 Emissions from Wastewater and Sludge 2006

Parameter	**Source**	**Value**
Population Equivalent	National Statistic (Incl. Dom/Commercial and Some Industry)	5,808.09
Kg BOD/1000 people/yr of wastewater	IPCC Guidelines; 0.06*1000*365	21,900
Total Organic Waste from Dom/Comm/Some Industry (Gg Dc/yr)	21900*PE (National Statistic)	157.84
Total amount of sludge (Tonnes of DS)	National Statistic for some years	61,747
Total Wet Sludge (Gg Dc/yr)(20% solids)	Tonnes of DS * 100/20	308,737
Fraction of Sludge (wet weight) comes off Wastewater	Total Wet Sludge (M^3) /Total Wastewater (M^3)	0.0008
Bo Maximum Methane Producing Potential CH_4kg/kgBOD	Default IPCC	0.6
SBF is the Fraction of BOD that readily settles	Country Specific	0.4
Organic Content of Industrial Sludge (BOD kg/m^3)	0.4 of Ave.BOD of Treated Ind. WW- 150kg/m^3	60
Fraction of BOD in sludge degrades anaerobically (FTA)	Country Specific	3%
Emission Factor for Sludge (3% Anaerobic)	0.03*0.6	0.018

Following initial treatment, sludge may be disposed of in landfill, spread on agricultural lands or used in composting. The quantity of sludge that is disposed of in landfill contributes to CH_4 emissions from SWDS and is included in emission estimates for CRF sector *6.A.1 Solid Waste Disposal on Land*. The proportion of sludge disposed of in SWDS has reduced significantly from 42% of sludge produced (tonnes of dry solids) in 1990 to 17.2 percent in 2005 (data for 2006 is currently not available). Where sludge is spread on agricultural land it contributes to N_2O emissions from soils and is included in emission estimates for CRF sector *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 increased from 12 percent in 1990 to 76.1 percent in 2005 (data for 2006 is currently not available).

8.3.2 N_2O Emissions from Human Sewage (6.B.2.2)

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, seepage into the soil through percolation areas or discharged to a water body. Nitrous oxide can be produced during these processes through nitrification and denitrification. Estimates of emissions of N_2O from human sewage discharges are made using the IPCC methodology. This source of emissions was first included as part of the recalculation exercise undertaken for the 2002 submission. In previous submissions, the body weight and average protein intake of the population were taken as 80 kg and 0.75 g/kg body weight per day, respectively, to estimate annual protein consumption based on information provided by the Food Safety Authority of Ireland (FSAI, 1999). The 2003 in-country review of Ireland's 2001 submission identified that FAO statistics indicate a typical protein intake of about 114 g/capita/day for the population of Ireland, compared to the 60 g/capita/day suggested by the FSAI recommendations. Ireland adopted the FAO estimate of protein intake in the estimates for 2003 and the corresponding emissions in other years were recalculated on this basis for the purpose for the 2005 submission. The emissions in 2006 are estimated using the same approach. The N_2O emissions are computed by taking the IPCC default proportion of 0.16 for the nitrogen content in protein and applying the default emission factor of 0.01 to obtain the quantity of nitrogen in sewage ultimately entering the atmosphere as N_2O.

8.4 Uncertainties and Time-Series Consistency

Consistent methodologies are used in the derivation of emissions estimates from the waste sector. The methodologies used are employed for each year of the time series 1990-2006 and in the case of emissions from source category 6.A, a historical time series has been developed to account for the long term nature of emissions from SWDS. However due to the lack of data available historically and for the early part (pre 1995) of the time series, various assumptions have been made as discussed in previous sections.

The IPCC Good Practice Guidance recognises that the overall uncertainty associated with estimating CH_4 emissions from source category 6.A are likely to be very high, even when national data are well characterised as is the case in Ireland in terms of the quantities and types of municipal solid wastes disposed of at SWDS. Uncertainty estimates for the source category are calculated using equation 6.4 of the Good Practice Guidance and assume uncertainties of 25%, 25% and 20% in relation to the quantity of MSW, its composition and DOC contents, respectively and uncertainties of 30%, 30% and 20% for the fraction of DOC dissimilated, MCF and the time of CH_4 release respectively. This equates to an uncertainty in activity data estimates of 41% and an emission factor uncertainty of 47% as presented in Table 1.8 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 Chemical/Biological oxygen demand, the methane producing capacity and its treatment. The only source of emissions from wastewater handling in Ireland is from the anaerobic treatment of sludge. Uncertainty estimates of 10% and 30% are assigned to the activity data and emission factor used, respectively.

8.5 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 estimates are prepared by various teams within the EPA in various reports as outlined in the previous sections. Quality control procedures are undertaken by the teams involved through yearly reviews of data collection methods and collation and aggregation and disaggregation methodologies. In addition where any anomalies exist in reported data, corrected activity data is published in the following years reports and thus forms part of any recalculations in emission estimates. The inventory team also has close collaboration with specialists in the waste sector.

8.6 Recalculations in Waste

During 2007, in response to issues raised in the in-country review of Ireland's inventory, the expert review team suggested that the description of the methodology to estimate emissions from *6.B Wastewater Handling* could be improved. As part of that process underlying activity data and assumptions were analysed. It was found that some minor inconsistencies existed as a result of the structure of the reports that provide the necessary activity data for this sector. This also has a knock-on effect to *6.A. Solid waste disposal on land* due to the quantities of sludge that are disposed of in SWDS in a particular year. The effect of this minor recalculation to waste sector emissions is shown in Table 8.3.

8.7 Improvements in Waste

Radical changes in waste management have taken place in Ireland through the EPA waste licensing system and Government initiatives designed to implement waste management policies that favour prevention, minimisation and recycling options at the expense of waste disposal on land. Many landfills have been closed down and new landfills operate only to best practice in terms of management and pollution control and in their capacity to track waste streams for much larger contributing areas than was previously the case, in accordance with Directive 1999/31/EC (CEU, 1999). Waste management has improved to the stage where virtually all solid landfills may be currently regarded as fully managed.

These changes have major implications for the evolution of the time-series of municipal solid waste as it is applied to the estimation of CH_4 emissions from landfill sites. Major assumptions and generalisations are inherent to the determination of these emissions using the approach described above that has been used now for many years. The huge variety of landfill sites that is represented by calculations at the national scale and the lack of good historical data for the extended period that must be taken into account mean that the emissions baseline relative to this new waste management regime is already highly uncertain. It is difficult for the methodology to adequately reflect major changes relating to landfills in a robust and transparent manner that maintains consistency in the emissions time series.

The inventory team is currently seeking to establish a survey of landfill sites in Ireland. The project proposal aims to undertake a detailed study of the use of flaring and utilisation plants in both closed and operating landfill sites throughout the country to quantify landfill gas capture in a systematic manner. The recovery of landfill gas has become increasingly important in emission estimates over the last decade as the quantity of MSW disposed of at SWDS increased. One of the proposed outcomes of the project is a methodology whereby flaring and utilisation estimates will be reported to the EPA on a yearly basis as part of annual reporting under the Pollutant Release and Transfer Register (PRTR) guidelines.

Table 8.3. Recalculations for Waste 1990-2005

IPCC Source Category		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Emissions 2007 Submission (Gg CO_2 eq)																	
6.A.1 Managed Waste Disposal on Land	CH_4	980.17	1,015.35	1,056.52	1,103.41	1,151.95	1,201.60	1,130.96	919.23	985.23	1,009.03	1,078.35	896.77	1,042.48	1,169.06	1,174.12	1,192.72
6.A.2 Unmanaged Waste Disposal Sites	CH_4	351.88	350.09	349.46	350.81	354.52	360.81	368.84	376.79	385.50	397.00	413.17	432.08	454.47	470.47	461.87	425.46
6.B.2.1 Domestic and Commercial Wastewater	CH_4	14.70	14.78	14.90	14.98	15.03	14.88	14.73	18.13	20.52	21.31	22.23	22.86	23.48	23.85	24.69	25.22
6.B.2.2 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
Total		1,460.75	1,495.77	1,541.04	1,586.65	1,636.26	1,688.55	1,626.97	1,429.97	1,509.46	1,548.90	1,640.45	1,477.36	1,647.70	1,792.65	1,792.06	1,777.61
Emissions 2008 Submission (Gg CO_2 eq)																	
6.A.1 Managed Waste Disposal on Land	CH_4	980.33	1,015.51	1,056.69	1,103.58	1,152.12	1,201.77	1,131.14	919.33	985.18	1,009.76	1,080.73	900.13	1,045.86	1,172.00	1,174.97	1,190.10
6.A.2 Unmanaged Waste Disposal Sites	CH_4	351.94	350.15	349.52	350.87	354.57	360.86	368.89	376.82	385.50	397.20	413.81	432.96	455.32	471.26	462.22	425.33
6.B.2.1 Domestic and Commercial Wastewater	CH_4	14.73	14.81	14.93	15.02	15.06	14.67	14.77	20.31	20.52	21.82	22.19	23.02	23.44	22.37	23.51	23.88
6.B.2.2 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
Total		1,461.00	1,496.02	1,541.30	1,586.91	1,636.52	1,688.56	1,627.23	1,432.27	1,509.40	1,550.34	1,643.43	1,481.77	1,651.90	1,794.90	1,792.08	1,773.52
% Change due to recalculation																	
6.A.1 Managed Waste Disposal on Land	CH_4	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.00	0.07	0.22	0.37	0.32	0.25	0.07	-0.22
6.A.2 Unmanaged Waste Disposal Sites	CH_4	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.05	0.15	0.20	0.19	0.17	0.08	-0.03
6.B.2.1 Domestic and Commercial Wastewater	CH_4	0.22	0.22	0.22	0.22	0.22	-1.46	0.22	11.99	0.00	2.39	-0.17	0.73	-0.17	-6.21	-4.80	-5.31
6.B.2.2 Human Sewage	N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total		0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.16	0.00	0.09	0.18	0.30	0.25	0.13	0.00	-0.23

Chapter Nine

Recalculations and Improvements

Increasing demands for more complete and more accurate estimates of greenhouse gas emissions means that the methodologies being used are subject to constant 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 guidelines provide for the reporting of recalculations as part of the annual submissions from Annex I Parties. Justification for the recalculations are required, 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.

9.1 Explanations and Justifications for Recalculations

The foregoing chapters describe recalculations and improvements for the individual Level 1 source sectors of the inventory and they present the corresponding changes in emissions and removals within the sectors. This chapter summarises the recalculations and assesses their effect in relation to total national emissions to record the updates and the available emissions time-series as they appear in the 2008 submission. The original and revised numerical values of the emissions estimates for the years 1990-2005, along with the changes related to methods, activity data and emission factors are detailed in the respective Tables 8(a) and 8(b) of the CRF time-series. The principal changes that result in recalculated estimates for the years 1990-2005 included in the 2008 submission are as follows:

1.A.1 Energy Industries

- Revision to include estimates of N_2O from Gasoil use, which were incorrectly omitted in the 2007 Submission.

1.A.2 Manufacturing Industries and Construction

- Revision of natural gas consumption for 2004 and 2005.
- Revision of the national energy balance for years 1990-2005 to reduce the “statistical differences” (between TPER and TFC) in the national oil balance. The most significant recalculations occurred in 2004 and 2005 and were trivial in most other years

1.A.3 Transport

- Revised methodology for estimating emissions of CH_4 and N_2O from *Road Transport sector (1.A.3.b)* by adoption of COPERT 4 version 4.0.

1.A.4 Other Sectors

- Revision of natural gas consumption for 2004 and 2005.
- Revision of the national energy balance for years 1990-2005 to reduce the "statistical differences" (between TPER and TFC) in the national oil balance. The most significant recalculations occurred in 2004 and 2005 and were trivial in most other years

2.A Mineral Products

- The use of clays in brick and ceramic manufacture reallocated to *2.A.7 Other Mineral Products*. Previously reported under *2.A.3 Limestone and Dolomite Use*.
- *2.A.4.2 Soda Ash Production and Use* is reported for the first time in this submission.

2.F Consumption of Halocarbons and SF_6

- Correction of transcription errors between calculation sheets and CRF Reporter.
- Re-analysis of underlying activity data and assumptions.

3. Solvent and Other Product Use

- Correction of population statistics and updated information from data providers.

4.A Enteric Fermentation

- Minor errors in pig population estimates corrected.
- Cattle sub-categories revised to included estimates from both male and female beef cattle separately.
- Underlying activity data revised and updated in country-specific emission factor calculations.

4.B Manure Management

- Minor errors in pig, horse, asses and mule population estimates corrected.
- Cattle sub-categories revised to included estimates from both male and female beef cattle separately.
- Underlying activity data revised and updated in country-specific emission factor calculations.
- Revised animal waste management system allocations.
- Turkey flock statistics revised to take account of production cycle estimates.

4.D Agricultural Soils

- Minor errors in pig, horse, asses and mule population estimates corrected.
- Revised animal waste management system allocations.
- Revised estimates of indirect emissions due to NH_3 volatilization.

5.A. Forest Land

- Revised allocation between organic and mineral soils *for 5.A.2 Land Converted to Forest Land*. The allocation for each year is determined from LPIS data instead of using a fixed 60:40 split in all years;
- Inclusion of CH_4 and N_2O estimates for biomass burning in forest land;
- Inclusion of N_2O estimates associated with drainage of forest land

5.B Cropland

- Organic soils reported under cropland allocated to mineral soils pending research results, i.e. cultivation of organic soils does not occur;
- Inclusion of N_2O estimates associated with soil disturbance for land converted to cropland

5.D Wetlands

- Revised wetland area statistics.

5.E Settlements

- Revised estimates of new dwelling footprint areas to take account of soil sealing due to the construction of access roads and driveways within housing developments.

5.F Other Land

- Revised area due to minor changes in areas for other land categories.

6.A Solid Waste Disposal on Land

- Revised estimates of sludge disposed of in solid waste disposal sites.

6.B Wastewater Handling

- Revised estimates of wastewater production.

9.2 Implications for emission levels, trends and time-series consistency

Tables 9.1 and 9.2 outline the effect of recalculations according to greenhouse gas and IPCC sector. The overall effect on total emissions excluding LULUCF is less than 1 percent across the time-series, which fluctuates from increase to decrease due to the large number of minor recalculations. More significant changes are evident for some individual gases and sectors. The major change for gases in Table 9.1 is the effect of recalculations on the industrial gases, HFCs, PFCs and SF_6. Significant change is evident in the early part of the time-series. However, the combined total of emissions of HFCs, PFCs and SF_6 account for approximately 1 percent of total national emissions and therefore the effect of overall trends is negligible. The largest sectoral change occurs in the case of *Land Use, Land Use Change and Forestry* where recalculations reflect revised allocations between organic and mineral soils in afforested areas, revised land area statistics for peatlands and revision of the footprint for new dwellings for estimating areas under *5.E.2 Land Converted to Settlements*.

The recalculations reported in this submission are insignificant in terms of their effect on emission levels in Ireland or on the trends in emissions over the period 1990-2006. However, they improve time-series consistency and take account of the inventory review process by implementing the inventory-specific recommendations of the latest review reports. It may be said that fully consistent greenhouse gas inventories are available for the years 1990 - 2006. The 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 most of the important elements of good practice are taken into account in the current approaches to estimating their emissions

9.3 Response to the review process and planned improvements to the inventory

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 have been implemented in the 2008 submission. It may be stated therefore that the inventory material being submitted in 2008 broadly meets the principles of transparency, completeness, consistency, comparability and accuracy laid down in the UNFCCC reporting guidelines.

Further general improvements to greenhouse gas inventories are continually taking place through consolidation and implementation of the national system, which is fully operational, and through application of formal QA/QC procedures that have been put into operation as an integral part of the national system. The consultant's Scoping Report (Thistlethwaite *et al*, 2005) on Ireland's national system proposed that a series of Memoranda of Understanding define the relationships between the inventory agency and key data providers, outlining the responsibilities that are conferred to the data providers under the national system, including their involvement in the annual inventory review process. These Memoranda of Understanding have been implemented in this reporting cycle and they underpin the national system in Ireland in the years ahead. An updated national climate change strategy was published in 2007 providing a framework in which internal review of annual inventories will take place among all stakeholders to monitor progress on the strategy, thereby fulfilling another important requirement of national system implementation.

Formal QA/QC activities were lacking in Ireland's work on emission inventories up to 2005. The implementation of comprehensive QA/QC procedures in this reporting cycle according to the plan supporting the national inventory system represents an important step towards 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 foreseen 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. Ireland continues to avail of this provision.

Table 9.1 Recalculations by Gas 1990-2005

(a) Emissions by Gas 1990 –2005 in 2007 Submission (Gg CO2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2 (inc net CO_2 from LULUCF)	32,673.69	33,672.17	33,607.34	33,586.49	34,666.43	35,662.63	37,447.07	38,851.78	40,551.58	42,137.21	44,992.27	47,361.95	45,776.82	44,847.48	45,552.30	46,635.04
CO_2 (exc net CO_2 from LULUCF)	32,552.88	33,399.53	33,286.13	33,430.00	34,683.79	35,480.90	37,139.01	38,622.65	40,688.06	42,288.97	44,883.98	47,342.95	45,902.78	45,146.17	45,746.89	47,292.25
CH_4 emissions (inc CH_4 from LULUCF)	13,286.51	13,474.80	13,555.44	13,667.18	13,667.56	13,722.62	14,031.64	14,102.74	14,331.89	13,919.70	13,438.10	13,260.61	13,268.48	13,881.23	13,338.46	13,102.32
CH_4 emissions (exc CH_4 from LULUCF)	13,286.51	13,474.80	13,555.44	13,667.18	13,667.56	13,722.62	14,031.64	14,102.74	14,331.89	13,919.70	13,438.10	13,260.61	13,268.48	13,881.23	13,338.46	13,102.32
N_2O emissions (inc N_2O from LULUCF)	9,498.85	9,352.58	9,346.12	9,499.28	9,764.81	9,964.97	10,038.59	9,937.06	10,559.77	10,648.13	10,214.20	9,702.05	9,240.36	9,083.32	8,935.99	8,849.96
N_2O emissions (exc N_2O from LULUCF)	9,498.85	9,352.58	9,346.12	9,499.28	9,764.81	9,964.97	10,038.59	9,937.06	10,559.77	10,648.13	10,214.20	9,702.05	9,240.36	9,083.32	8,935.99	8,849.96
HFCs	0.69	5.14	5.90	8.90	20.52	44.89	76.23	132.09	189.01	194.82	228.95	251.50	276.55	349.52	384.04	431.03
PFCs	0.09	0.09	0.09	0.09	75.38	75.38	103.09	130.82	61.87	195.93	305.41	295.98	212.40	228.79	186.84	173.95
SF_6	35.40	36.38	37.36	38.33	81.85	82.83	102.06	132.10	94.24	68.96	55.91	69.49	70.31	118.68	67.09	95.96
Total including LULUCF	**55,495.25**	**56,541.16**	**56,552.24**	**56,800.28**	**58,276.56**	**59,553.31**	**61,798.67**	**63,286.59**	**65,788.37**	**67,164.75**	**69,234.83**	**70,941.58**	**68,844.92**	**68,509.03**	**68,464.72**	**69,288.26**
Total excluding LULUCF	**55,374.43**	**56,268.52**	**56,231.04**	**56,643.80**	**58,293.92**	**59,371.58**	**61,490.61**	**63,057.46**	**65,924.84**	**67,316.51**	**69,126.54**	**70,922.59**	**68,970.89**	**68,807.72**	**68,659.31**	**69,945.48**

(b) Recalculated Emissions by Gas 1990 –2005 in 2008 Submission (Gg CO2eq)

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2 (inc net CO_2 from LULUCF)	32,716.90	33,712.69	33,654.27	33,628.81	34,700.14	35,719.12	37,471.53	38,885.81	40,573.34	42,201.10	44,974.77	47,299.82	45,753.86	44,803.98	45,753.88	47,267.54
CO_2 (exc net CO_2 from LULUCF)	32,545.20	33,377.59	33,258.47	33,404.38	34,653.88	35,447.90	37,105.56	38,584.40	40,650.72	42,313.98	44,846.84	47,303.72	45,865.93	45,125.65	45,991.76	47,722.66
CH_4 emissions (inc CH_4 from LULUCF)	13,468.57	13,612.35	13,705.33	13,794.38	13,762.11	13,801.34	14,047.11	14,109.33	14,366.43	14,045.37	13,540.74	13,291.26	13,363.76	13,946.65	13,358.95	13,262.47
CH_4 emissions (exc CH_4 from LULUCF)	13,466.77	13,610.55	13,703.53	13,792.67	13,760.21	13,799.26	14,045.11	14,108.05	14,366.17	14,045.12	13,539.47	13,288.04	13,362.58	13,942.35	13,355.63	13,261.81
N_2O emissions (inc N_2O from LULUCF)	9,492.52	9,336.83	9,326.26	9,468.37	9,728.02	9,937.44	9,992.10	9,889.43	10,487.49	10,542.94	10,073.58	9,553.07	9,076.77	8,913.57	8,750.44	8,693.90
N_2O emissions (exc N_2O from LULUCF)	9,477.40	9,321.34	9,310.11	9,449.16	9,708.42	9,917.36	9,969.72	9,866.94	10,464.88	10,520.20	10,050.52	9,525.98	9,047.55	8,880.74	8,717.62	8,661.24
HFCs	0.69	5.27	6.17	9.44	19.97	44.85	76.11	132.28	190.71	197.13	230.22	251.49	276.52	349.98	386.44	435.06
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
SF_6	35.40	40.64	45.87	55.35	64.83	82.83	102.06	132.10	94.28	69.01	55.96	69.49	70.31	118.69	67.09	95.96
Total including LULUCF	**55,714.19**	**56,715.40**	**56,753.04**	**56,986.56**	**58,320.34**	**59,660.96**	**61,792.00**	**63,279.77**	**65,774.12**	**67,251.49**	**69,180.68**	**70,761.10**	**68,753.62**	**68,361.66**	**68,499.23**	**69,923.26**
Total excluding LULUCF	**55,525.56**	**56,363.01**	**56,339.30**	**56,741.22**	**58,252.58**	**59,367.58**	**61,401.65**	**62,954.59**	**65,828.63**	**67,341.38**	**69,028.42**	**70,734.70**	**68,835.28**	**68,646.20**	**68,700.97**	**70,345.06**

(c) Percentage Change in Emissions by Gas 1990-2005

GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2 (inc net CO_2 from LULUCF)	0.13	0.12	0.14	0.13	0.10	0.16	0.07	0.09	0.05	0.15	-0.04	-0.13	-0.05	-0.10	0.44	1.36
CO_2 (exc net CO_2 from LULUCF)	-0.02	-0.07	-0.08	-0.08	-0.09	-0.09	-0.09	-0.10	-0.09	0.06	-0.08	-0.08	-0.08	-0.05	0.54	0.91
CH_4 emissions (inc CH_4 from LULUCF)	1.37	1.02	1.11	0.93	0.69	0.57	0.11	0.05	0.24	0.90	0.76	0.23	0.72	0.47	0.15	1.22
CH_4 emissions (exc CH_4 from LULUCF)	1.36	1.01	1.09	0.92	0.68	0.56	0.10	0.04	0.24	0.90	0.75	0.21	0.71	0.44	0.13	1.22
N_2O emissions (inc N_2O from LULUCF)	-0.07	-0.17	-0.21	-0.33	-0.38	-0.28	-0.46	-0.48	-0.68	-0.99	-1.38	-1.54	-1.77	-1.87	-2.08	-1.76
N_2O emissions (exc N_2O from LULUCF)	-0.23	-0.33	-0.39	-0.53	-0.58	-0.48	-0.69	-0.71	-0.90	-1.20	-1.60	-1.81	-2.09	-2.23	-2.44	-2.13
HFCs	0.01	2.64	4.60	6.08	-2.68	-0.09	-0.15	0.14	0.90	1.18	0.56	-0.01	-0.01	0.13	0.63	0.93
PFCs	0.00	8,086.90	16,173.79	32,347.58	-39.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.36	-3.23
SF_6	0.00	11.69	22.78	44.39	-20.79	0.00	0.00	0.00	0.04	0.08	0.10	0.00	0.00	0.00	0.00	0.00
Total including LULUCF	**0.39**	**0.31**	**0.36**	**0.33**	**0.08**	**0.18**	**-0.01**	**-0.01**	**-0.02**	**0.13**	**-0.08**	**-0.25**	**-0.13**	**-0.22**	**0.05**	**0.92**
Total excluding LULUCF	**0.27**	**0.17**	**0.19**	**0.17**	**-0.07**	**-0.01**	**-0.14**	**-0.16**	**-0.15**	**0.04**	**-0.14**	**-0.26**	**-0.20**	**-0.23**	**0.06**	**0.57**

Table 9.2 Recalculations by IPCC Sector 1990-2005

(a) Emissions by IPCC Sector 1990 –2005 in 2007 Submission (Gg CO2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1. Energy	31,603.37	32,588.14	32,538.75	32,739.47	33,802.76	34,676.83	36,324.52	37,520.10	39,808.17	41,528.02	43,683.48	45,944.03	44,634.23	44,913.64	44,814.39	46,384.29
2. Industrial Processes	3,166.43	2,866.26	2,781.45	2,746.12	3,117.73	3,063.04	3,205.31	3,657.35	3,494.73	3,560.02	4,186.67	4,292.79	3,722.18	3,041.57	3,147.14	3,254.70
3. Solvent and Other Product Use	80.86	82.74	82.96	83.42	84.32	86.11	86.79	87.20	88.06	84.75	80.07	79.66	77.37	75.96	75.70	75.44
4. Agriculture	19,063.03	19,235.61	19,286.82	19,488.13	19,652.85	19,857.05	20,247.02	20,362.83	21,024.43	20,594.83	19,535.86	19,128.74	18,889.41	18,983.90	18,830.02	18,453.44
5. LULUCF	120.81	272.64	321.21	156.48	-17.36	181.73	308.06	229.14	-136.47	-151.76	108.29	18.99	-125.96	-298.70	-194.58	-657.22
6. Waste	1,460.75	1,495.77	1,541.04	1,586.65	1,636.26	1,688.55	1,626.97	1,429.97	1,509.45	1,548.90	1,640.45	1,477.36	1,647.69	1,792.65	1,792.06	1,777.61
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total excluding LULUCF	**55,374.43**	**56,268.52**	**56,231.04**	**56,643.80**	**58,293.92**	**59,371.58**	**61,490.61**	**63,057.46**	**65,924.84**	**67,316.51**	**69,126.54**	**70,922.59**	**68,970.89**	**68,807.72**	**68,659.31**	**69,945.48**

(b) Recalculated Emissions by IPCC Sector 1990 –2005 in 2008 Submission (Gg CO2eq)

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1. Energy	31,590.77	32,558.08	32,498.58	32,681.60	33,730.22	34,612.23	36,235.26	37,417.44	39,677.20	41,426.38	43,479.30	45,720.72	44,392.83	44,672.55	44,826.36	46,561.00
2. Industrial Processes	3,164.08	2,875.82	2,802.93	2,791.42	3,067.68	3,060.67	3,202.85	3,655.26	3,494.17	3,560.10	4,185.50	4,290.09	3,719.40	3,039.29	3,142.50	3,250.97
3. Solvent and Other Product Use	81.15	82.87	83.19	83.51	84.36	86.05	86.77	87.20	88.28	84.96	80.29	79.61	77.28	76.28	76.09	77.89
4. Agriculture	19,228.56	19,350.23	19,413.31	19,597.79	19,733.80	19,920.06	20,249.54	20,362.41	21,059.58	20,719.60	19,639.90	19,162.51	18,993.87	19,063.18	18,863.94	18,681.68
5. LULUCF	188.63	352.39	413.74	245.34	67.76	293.38	390.35	325.19	-54.51	-89.89	152.26	26.41	-81.66	-284.54	-201.74	-421.80
6. Waste	1,461.00	1,496.02	1,541.30	1,586.91	1,636.52	1,688.56	1,627.23	1,432.27	1,509.40	1,550.34	1,643.43	1,481.77	1,651.90	1,794.90	1,792.08	1,773.52
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total excluding LULUCF	**55,525.56**	**56,363.01**	**56,339.30**	**56,741.22**	**58,252.58**	**59,367.58**	**61,401.65**	**62,954.59**	**65,828.63**	**67,341.38**	**69,028.42**	**70,734.70**	**68,835.28**	**68,646.20**	**68,700.97**	**70,345.06**

(c) Percentage Change in Emissions by Sector 1990-2005

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1. Energy	-0.04	-0.09	-0.12	-0.18	-0.21	-0.19	-0.25	-0.27	-0.33	-0.24	-0.47	-0.49	-0.54	-0.54	0.03	0.38
2. Industrial Processes	-0.07	0.33	0.77	1.65	-1.61	-0.08	-0.08	-0.06	-0.02	0.00	-0.03	-0.06	-0.07	-0.08	-0.15	-0.11
3. Solvent and Other Product Use	0.36	0.16	0.27	0.10	0.05	-0.07	-0.03	0.01	0.25	0.25	0.28	-0.07	-0.12	0.43	0.52	3.25
4. Agriculture	0.87	0.60	0.66	0.56	0.41	0.32	0.01	0.00	0.17	0.61	0.53	0.18	0.55	0.42	0.18	1.24
5. LULUCF	56.13	29.25	28.81	56.78	-490.30	61.44	26.71	41.92	-60.06	-40.77	40.61	39.02	-35.17	-4.74	3.68	-35.82
6. Waste	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.16	0.00	0.09	0.18	0.30	0.25	0.13	0.00	-0.23
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total excluding LULUCF	**0.27**	**0.17**	**0.19**	**0.17**	**-0.07**	**-0.01**	**-0.14**	**-0.16**	**-0.15**	**0.04**	**-0.14**	**-0.26**	**-0.20**	**-0.23**	**0.06**	**0.57**

References

Adams, M., Wagner, A., Goodwin, J., O'Leary, E., Creedon, M., McHugh, M and Gibson, C. 2005. Compiling Emission Inventories of HFCs, PFCs and SF_6 for inclusion in Ireland's greenhouse gas submissions to the EU under Decision 280/2004/EC under the United National Framework Convention on Climate Change. Netcen/ ED48411/R1, AEA Technology UK.

Boyle, O. C., 1987. National Database on Waste. An Foras Forbartha, Dublin.

Carey, P. et al, 1996. National Waste Database Report 1998, Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

CEC (Council of the European Communities), 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources O.J. L167, July 1993.

CEC (Council of the European Communities), 1999. Council Directive 99/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations. O.J. L85, 29 March 1999.

CEC (Commission of the European Communities), 2004. Commission Decision 2004/156/EC of 29/01/2004 establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC. O.J. L59, 26 February 2004.

CEU (Council of the European Union), 1999. Council Directive 1999/31/EC on the landfill of waste. O.J. L182, July 1999.

Collins, C. et al, 2004a. National Waste Database Interim Report 2002. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Collins, C. et al, 2004b. National Waste Database Interim Report 2003. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Collins, C. et al, 2005. National Waste Report 2004. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Cossu, R., Andreottola, G. and Muntoni, A., 1996. Modelling Landfill Gas Production. In Landfilling of Waste Biogas. Edited by T. H. Christensen, R. Cossu and R. Stegman. E & FN Spon, London.

Crowe, M. et al, 2000. National Waste Database Report 1998, Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Crowley, A. M. 2001. Prediction of net energy requirements of beef cattle. M.Agr.Sc. Thesis, National University of Ireland, University College Dublin, November 2001, 145 pp.

Crowley, A. M., Keane, M.G., Agabriel, J. and O'Mara F. P. (2002). Prediction of net energy requirements of beef cattle. Proceedings of Agricultural Research Forum, 11 and 12 March 2002, Tullamore, p 19.

Cruickshank, M.M., Tomlinson, R.W. and Trew, S. 2000. Application of CORINE land-cover mapping to estimate the carbon stored in the vegetation of Ireland. Journal of Environmental Management, 58, 269-287.

CTC (Clean Technology Centre), 2005. NMVOC Inventory for Ireland (SNAP Sector 6 Solvent and Other Product Use). Report to the Environmental Protection Agency.

DAF (Department of Agriculture and Food), 2007. CMMS Statistics Report 2007. Department of Agriculture and Food, Dublin. www.agriculture.gov.ie.

DELG (Department of the Environment and Local Government), 1997. Sustainable Development. A Strategy for Ireland. Department of the Environment and Local Government, Custom House, Dublin.

DELG (Department of the Environment and Local Government), 1998. A Policy Statement. Waste Management. Changing our Ways. Department of the Environment and Local Government, Custom House, Dublin.

DOE (Department of the Environment), 1992. The Environmental Protection Agency Act, 1992. SI No 7 of 1992. Department of the Environment, Custom House, Dublin.

DOE (Department of the Environment), 1994. Recycling for Ireland. A Strategy for Recycling Domestic and Commercial Waste. Department of the Environment, Custom House, Dublin.

DOE (Department of the Environment), 1997. IRELAND : Second National Communication under the UN Framework Convention on Climate Change. Department of the Environment, Custom House, Dublin.

EP and CEU (European Parliament and Council of the European Union), 2001. Directive 2001/81/EC of 23 October 2001 on national emissions ceilings for certain atmospheric pollutants. O.J. L309, 27 November 2001.

EP and CEU (European Parliament and Council of the European Union), 2003. Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. O.J. L275, 25 October 2003.

EP and CEU (European Parliament and Council of the European Union), 2004a Decision 280/2004/EC of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol. O.J. L49, 19 February 2004.

EP and CEU (European Parliament and Council of the European Union), 2004b Directive 2004/42/CE on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC. O.J. L143, 30 April 2004.

ERL (Environmental Resources Limited), 1993. Towards a Recycling Strategy for Ireland. Department of the Environment, Custom House, Dublin.

Fehily Timoney and Company, 1985. Code of Good Practice for the Use of Biosolids in Agriculture. Guidelines for Farmers. Department of Environment and Local Government, Dublin.

Finn, J. et al, 2001. Estimation of Emissions of Non-Methane Volatile Organic Compounds from SNAP Sector 6: Solvent and Other Product Use for Ireland in 1998. Prepared for the Environmental Protection Agency by the Clean Technology Centre, Cork Institute of Technology. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Fogarty, G., Coggins, K and Gallagher, G., 1999, Forest Inventory and Planning System (FIPS). Irish Timber Growers Association Forestry Yearbook 2000. ITGA, Dublin.

Forest Service, 2000. Department of the Marine and Natural Resources Forestry Statistics. Internal publication.

FSAI (Food Safety Authority of Ireland), 1999. Recommended Dietary Allowances for Ireland. Food Safety Authority of Ireland, Dublin. http://www.fsai.ie/

Gallagher, G., Hendrick, E. and Byrne, K. Preliminary Estimates of Biomass Carbon Stock Changes in Managed Forests in the Republic of Ireland over the period 1990-2000. In Irish Forestry Vol. 61 No 1, 2004.

Gardiner, M. J. and Radford, T., 1980. Soil Associations of Ireland and their Land Use Potential. Explanatory Bulletin to Soil Map of Ireland 1980, Soil Survey Bulletin No 36, An Foras Taluntais, Dublin.

Gkatzoflias, D., Kourdis, C, Ntziachristos, L. and Samaras, Z., 2007. Copert 4. Computer programme to calculate emissions from road transport. Laboratory of Applied Thermodynamics, Mechanical Engineering Department, Aristotle University Thessaloniki.

Hamilton, G.J. 1975. Forest Mensuration Handbook. Forestry Comission Booklet 39, HMSO, London.

Hargreaves, K., Milne, R. and Cannell, M. 2003. Carbon balance of afforested peatland in Scotland. Forestry, 76, 299-317.

Hyde, B., Carton, O.T. and Murphy, W.E. (2008). Manure Management Practices on Irish Farms. (In prep).

ICRL, 1990. Notes on the development and after-use of landfill sites. Guidance Note 17/78. Eight Edition, December, 1990. Interdepartmental Committee on the Redevelopment of Contaminated Land.

INRA, 1989. Ruminant Nutrition. Recommended Allowances and Feed Tables. R. Jarrige, Ed. John Libbey Eurotext, London and Paris.

IPCC (Intergovernmental Panel on Climate Change), 1997. Revised 1996 Guidelines for National Greenhouse Gas Inventories. OECD, Paris.

IPCC (Intergovernmental Panel on Climate Change), 2000. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IGES (Institute for Global Environmental Strategies), Kanagawa, Japan.

IPCC (Intergovernmental Panel on Climate Change), 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. IGES (Institute for Global Environmental Strategies), Kanagawa, Japan.

IUCC (Information Unit on Climate Change), 1998. The Kyoto Protocol to the Framework Convention on Climate Change. UNEP, Geneva.

Le Bolloch, Meaney, B., Copoe, J and Doyle, M., 2006. National Waste Report 2005: Data Update. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Le Bolloch, O., Cope, J., Meaney, B and Kurz, I., 2007. National Waste Report 2006. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Li, C., Frolking, S. and Harriss, R. 1994. Modelling carbon biogeochemistry in agricultural soils. Global Biogeochemical Cycles, 8, 237-254.

Li, C., Narayanan, V. and Harriss, R.C. 1996. Model estimates of nitrous oxide emissions from agricultural lands in the United States. Global Biogeochemical Cycles 10, 297-306.

Meaney, B. et al, 2003. National Waste Database Report 2001, Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

MCOS (M. C. O'Sullivan), 1994. Report on Solid Waste Recycling (Packaging). Department of the Environment, Custom House, Dublin.

McInnes, G. (editor), 1996. CORINAIR/EMEP Atmospheric Emission Inventory Guidebook. First Edition. European Environment Agency, Copenhagen.

NEUT(Working Group on Nutrients and Eutrophication under the OSPAR Convention), 1999. Screening Procedure for Irish Coastal Waters with Regard to Eutrophication Status.

O'Brien, P. 2007. Data Analysis and Estimation of Greenhouse Gas Emissions and Removals for the IPCC Sector Land Use Land-Use Change and Forestry in Ireland. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland (in preparation).

O'Doherty, S. and McCulloch, A. 2002. Emission Inventories of HFC, PFC and SF6. RTDI Project L.S.-5.1.3(a) Final Report. Environmental Protection Agency, Johnstown Castle, Wexford.

O'Leary, G. and Carty, G. Urban Waste Water Discharges in Ireland. A Report for the years 1996 and 1997.

O'Leary, E., Finn, J. and Cunningham, D., 2002. Emission Inventories for HFCs, PFCs and SF6 for Ireland 1998. RTDI Project L.S.-5.1.3(b) Final Report. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

O'Leary, E., 2002. Emission Inventories for HFCs, PFCs and SF6 for Ireland 1995-2000. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

O'Mara, F. P., Caffrey, P. J. and Drennan, M. J. 1997. Net energy values of grass silage determined from comparative feeding trials. Irish Journal of Agricultural and Food Research, 36, 110.

O'Mara, F. 2006. Development of Emission Factors for the Irish Cattle Herd. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Purcell, T. 1979. Inventory of Private Woodlands – 1973. Forest and Wildlife Service, Dublin.

Richardson, S. (editor), 1999. CORINAIR/EMEP Atmospheric Emission Inventory Guidebook. Second Edition. European Environment Agency, Copenhagen.

SBSTA (Subsidiary Body for Scientific and Technological Advice), 1999. Guidelines for the Preparation of National Communications by Parties included in Annex I to the Convention. Part I: UNFCCC Reporting Guidelines on Annual Inventories. FCCC/SBSTA/1999/6/Add.1. UNFCCC Secretariat, Bonn.

SBSTA (Subsidiary Body for Scientific and Technological Advice), 2002. Guidelines for the Preparation of National Communications by Parties included in Annex I to the Convention. Part I: UNFCCC Reporting Guidelines on Annual Inventories. FCCC/SBSTA/2002/L.5/Add.1, UNFCCC Secretariat, Bonn.

Smith, D., O'Neill, N.,Doris, Y. and Moriarty, J., 2004. Urban Waste Water Discharges in Ireland. A Report for the Years 2002/2003. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Thistlethwaite, G., Baggott, S. L. and Goodwin, J., 2005. National Inventory System Scoping Report for the Greenhouse Gas Emission Inventory in Ireland. AEAT/ENV/R/1990 Issue 1, NETCEN, UK.

Tomlinson, R.W., Cruickshank, M.M., Cruickshank, J.G., Mallon, G., McStravick, A., Byrne, K., Collins, J., O'Toole, P., Farrell, E., Cunningham, D., Milne, R. and Walsh, M. 2005. Impact of land use and land-use change on carbon emission/fixation. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

UNECE (United Nations Economic Commission for Europe), 1999. Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication and Ground Level Ozone. UNECE Secretariat, Geneva.

UNFCCC (United Nations Framework Convention on Climate Change). 2003a. FCCC/SBSTA/2003/L.22/Add.1. UNFCCC Secretariat, Bonn.

UNFCCC (United Nations Framework Convention on Climate Change). 2007.: Report on the Individual Review of the Greenhouse Gas Inventory of Ireland Submitted in 2006. FCCC/ARR/2006/IRL (UNFCCC Secretariat, Bonn.
http://unfccc.int/resource/docs/2007/arr/irl.pdf

UNFCCC (United Nations Framework Convention on Climate Change). 2004 FCCC/SBSTA/2004/8 UNFCCC Secretariat, Bonn.

Yan, T., Agnew, R. E., Gordon, F. J. and Porter, M. G. (2000). Prediction of methane energy output in dairy and beef cattle offered grass silage-based diets. Livestock Production Science, 64: 253-263.

Glossary

Annex 1 Parties	Countries listed in Annex I to the United Nations Framework Convention on Climate Change
Base year	The year or period for which quantified emissions reduction or limits are established under the Kyoto Protocol.
BOD	Biochemical Oxygen Demand
CARBWARE	A national forest model to calculate carbon stock change and increment for forests
CFCs	Chlorofluorocarbon
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 emissions reductions or limits, as well as other commitments, are established under the Kyoto Protocol
COP	Conference of the Parties
CORINAIR	Co-ordinated Information on the environment in the European /community-AIR. CORINAIR was one of several collaborative exercises initiated under the CORINE programme to harmonise the collection and dissemination of information on the environment in the EU.
CRF	Common Reporting Format
DAF	Department of Agriculture and Food
Decision 13/CP.9	Decision No 13 at Ninth Session of the COP in Milan, December 2003
Decision 18/CP.9	Decision No 18 at Ninth Session of the COP in Milan, December 2003
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
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
GasSim	A model that estimates landfill gas emissions from managed or unmanaged landfill sites (Golder Associates, UK)

GDP	Gross Domestic Product
Gg	Gigagram (10^9 g) = kilo tonne = 1,000 tonnes
Greenhouse Gas	A gas in the atmosphere that allows solar radiation through to the earth's surface, but traps some of the heat radiated back from the earth's surface
GWP	The cumulative warming over a specified time period, e.g. 100 years, resulting from a unit mass of a greenhouse gas emitted at the beginning of that time period, expressed relative to an absolute GWP of 1 for CO_2
HCFCs	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbons
HGV	Heavy Goods Vehicle
IEA	International Energy Agency
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
LandGEM	Landfill Gas Emissions model (USEPA)
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
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
PFCs	Perfluorocarbons
SBSTA	Subsidiary Body for Scientific and Technological Advice
SEI	Sustainable Energy Ireland
SF_6	Sulphur Hexafluoride
Sink	The reservoir or pool in which sequestered carbon is stored; the process of sequestration
SO_2	Sulphur Dioxide
Teagasc	Irish Agriculture and Food Development Authority
TPER	Total Primary Energy Requirement
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compounds

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 2006

Table B.1 Expanded Energy Balance Sheet 2006

2006 Units = ktoe	NACE	COAL	Bituminous Coal	Anthracite + Manuf Ovoids	Coke	Lignite	PEAT	Milled Peat	Sod Peat	BRIQUETTES	OIL	Crude	Refinery Gas	Gasoline	Kerosene	JET Kerosene
Indigenous Production		**0**	**0**				**766**	571	196		**0**					
Imports		**1,635**	**1,590**	**39**		6	**0**				**10,826**	3,254		1,269	450	1,214
Exports		**4**	**0**	**4**		0	**10**			10	**1,397**			101	8	0
Mar. Bunkers		**0**					**0**				**130**					
Stock Change		**0**	**6**	-5		-2	**-49**	-40	0	-10	**-31**	-47		4	-34	64
Primary Energy Supply (incl non-energy)		**1,631**	**1,596**	**31**	**0**	**4**	**707**	**531**	**196**	**-20**	**9,268**	**3,207**	**0**	**1,173**	**408**	**1,278**
Primary Energy Requirement (excl. non-energy)		**1,631**	**1,596**	**31**	**0**	**4**	**707**	**531**	**196**	**-20**	**8,978**	**3,207**	**0**	**1,173**	**408**	**1,278**
Transformation Input		**1,265**	**1,265**	**0**	**0**	**0**	**552**	**552**	**0**	**0**	**3,900**	**3,207**	**7**	**0**	**0**	**0**
Public Thermal Power Plants		**1,265**	1,265				**437**	437	0		**686**					
Combined Heat and Power Plants		**0**	0				**8**	8			**7**		7			
Pumped Storage Consumption																
Briquetting Plants		**0**					**108**	108			**0**					
Oil Refineries & other energy sector		**0**					**0**				**3,207**	3,207				
Transformation Output		**0**	**0**	**0**	**0**	**0**	**98**	**0**	**0**	**98**	**3,322**	**0**	**98**	**677**	**241**	**0**
Public Thermal Power Plants		**0**					**0**				**0**					
Combined Heat and Power Plants - Electricity		**0**					**0**				**0**					
Combined Heat and Power Plants - Heat																
Pumped Storage Generation																
Briquetting Plants							**98**			98	**0**					
Oil Refineries							**0**				**3,322**		98	677	241	0
Exchanges and transfers		**13**	-11	24	0	0	**0**	0	0	0	**-24**	0	0	-12	275	-275
Electricity																
Heat																
Other		**13**	-11	24							**-24**			-12	275	-275
Own Use and Distribution Losses		**0**					**11**	11			**130**		91			
Available Final Energy Consumption		**379**	**320**	**55**	**0**	**4**	**243**	**-32**	**196**	**79**	**8,535**	**0**	**0**	**1,838**	**924**	**1,004**
Non-Energy Consumption		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**290**	**0**	**0**	**0**	**0**	**0**
Final non-Energy Consumption (Feedstocks)		0					0				290					
Total Final Energy Consumption		**378**	**316**	**57**	**0**	**4**	**284**	**0**	**196**	**88**	**8,367**	**0**	**0**	**1,884**	**916**	**988**
Industry*		**133**	**133**	**0**			**0**	**0**	**0**	**0**	**987**	**0**	**0**	**0**	**124**	**0**
Non-Energy Mining	13-14	**0**	0				**0**				**44**				1	
Food, beverages and tobacco	15 - 16	**13**	13				**0**				**114**				16	
Textiles and textile products	17 - 18	**6**	6				**0**				**10**				1	
Wood and wood products	20	**0**	0				**0**				**12**				2	
Pulp, paper, publishing and printing	21 - 22	**0**	0				**0**				**7**				1	
Chemicals & man-made fibres	24	**0**	0				**0**				**44**				7	
Rubber and plastic products	25	**0**	0				**0**				**6**				0	
Other non-metallic mineral products	26	**113**	113				**0**				**285**				3	
Basic metals and fabricated metal products	27 - 28	**0**	0				**0**				**367**				89	
Machinery and equipment n.e.c.	29	**0**	0				**0**				**8**				1	
Electrical and optical equipment	30 - 33	**0**	0				**0**				**73**				2	
Transport equipment manufacture	34 - 35	**0**	0				**0**				**3**				0	
Other manufacturing	36 - 37, 1	**0**	0				**0**			0	**16**				2	
Transport		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5,383**	**0**	**0**	**1,884**	**0**	**988**
Road Freight		**0**					**0**				**1,186**					
Road Private Car		**0**					**0**				**2,022**			1,555		
Public Passenger Services		**0**					**0**				**162**			42		
Rail		**0**					**0**				**40**					
Domestic Aviation		**0**					**0**				**51**			2		49
International Aviation		**0**					**0**				**938**					938
Fuel Tourism		**0**					**0**				**903**			286		
Unspecified		**0**					**0**				**80**			0		
Residential		**219**	**159**	57		**4**	**284**		**196**	**88**	**1,142**			**0**	**792**	
Commercial/Public Services		**26**	**24**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**586**	**0**	**0**	**0**	**0**	**0**
Commercial Services		**26**	24	1		1	**0**				**382**				0	
Public Services		**0**					**0**		0	0	**203**					
Agricultural		**0**	**0**				**0**				**269**			**0**	**0**	
Statistical Difference		**1**	**4**	**-3**	**0**	**0**	**-41**	**-32**	**0**	**-10**	**-122**	**0**	**0**	**-47**	**8**	**16**

Table B.1 (continued) Expanded Energy Balance Sheet 2006

2006 Units = ktoe	NACE	Fueloil	LPG	Gasoil / Diesel /DERV	Petroleum Coke	Naphta	Bitumen	White Spirit	Lubricants	NATURAL GAS	RENEWABLES	HYDRO	Wind	Biomass	Landfill Gas	Biogas	Liquid Biofuel	Solar	Geothermal	ELECTRICITY	Heat	TOTAL
Indigenous Production										**410**	**420**	62	139	181	25	7	3	1	1			1,596
Imports		1,037	132	2,828	274	0	238	120	10	**3,610**	**2**			2						154		16,226
Exports		1,065	18	124	0	3	0	71	6	**0**	**0**			0						1		1,411
Mar. Bunkers		49		81							**0**											130
Stock Change		-15	-2	-4	6	-4	0	0	0	**-0**	**0**			-0			0					-80
Primary Energy Supply (incl non-energy)		**-92**	**112**	**2,619**	**279**	**-7**	**238**	**48**	**4**	**4,019**	**422**	**62**	**139**	**183**	**25**	**7**	**3**	**1**	**1**	**153**	**0**	**16,200**
Primary Energy Requirement (excl. non-energy)		**-92**	**112**	**2,619**	**279**	**-7**	**0**	**0**	**0**	**4,019**	422	**62**	**139**	**183**	**25**	**7**	**3**	**1**	**1**	**153**	**0**	**15,910**
Transformation Input		**611**	**0**	**75**	**0**	**0**	**0**	**0**	**0**	**2,417**	**30**	**0**	**0**	**2**	**25**	**2**	**0**	**0**	**0**	**62**	**0**	**8,227**
Public Thermal Power Plants		611		75						**2,233**	**25**			0	25							4,646
Combined Heat and Power Plants		0	0	0						**184**	**5**			2		2						204
Pumped Storage Consumption																				49		49
Briquetting Plants											**0**											108
Oil Refineries & other energy sector											**0**									12		3,220
Transformation Output		**1,083**	**56**	**1,158**	**0**	**9**	**0**	**0**	**0**	**0**	**11**	**0**	**0**	**1**	**9**	**1**	**0**	**0**	**0**	**2,151**	**0**	**5,582**
Public Thermal Power Plants											**9**				9					1,984		1,993
Combined Heat and Power Plants - Electricity											**2**			1		1				135		137
Combined Heat and Power Plants - Heat											**0**											0
Pumped Storage Generation																				31		31
Briquetting Plants											**0**											98
Oil Refineries		1,083	56	1,158		9					**0**											3,322
Exchanges and transfers		3	0	-2	-13	0	0	0	0	**0**	**-213**	-62	-139	-1	-9	-1	0	0	0	**213**	**0**	-11
Electricity											**-213**	-62	-139	-1	-9	-1				**213**		0
Heat																						0
Other		3		-2	-13						**0**											-11
Own Use and Distribution Losses		32	6	1						**66**	**0**									**303**		510
Available Final Energy Consumption		**351**	**162**	**3,699**	**266**	**2**	**238**	**48**	**4**	**1,536**	**190**	**0**	**0**	**181**	**0**	**4**	**3**	**1**	**1**	**2,152**	**0**	**13,034**
Non-Energy Consumption		**0**	**0**	**0**	**0**		**238**	**48**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**290**
Final non-Energy Consumption (Feedstocks)							238	48	4	0	0											290
Total Final Energy Consumption		**381**	**162**	**3,778**	**257**	**1**	**0**	**0**	**0**	**1,567**	**187**	**0**	**0**	**180**	**0**	**4**	**3**	**1**	**1**	**2,225**	**0**	**13,008**
Industry*		**372**	**71**	**190**	**230**	**1**	**0**	**0**	**0**	**629**	**164**	**0**	**0**	**162**		**2**	**0**	**0**	**0**	**772**	**0**	**2,685**
Non-Energy Mining	13-14	4	0	38	0					37	**0**									64		144
Food, beverages and tobacco	15 - 16	49	4	45	0					177	**58**			56		2				189		551
Textiles and textile products	17 - 18	2	2	5	0					2	**0**									9		27
Wood and wood products	20	5	0	5	0					4	**106**			106						33		155
Pulp, paper, publishing and printing	21 - 22	2	1	3	0					23	**0**									35		65
Chemicals & man-made fibres	24	20	1	16	0					125	**0**									113		281
Rubber and plastic products	25	1	0	5	0					10	**0**									35		51
Other non-metallic mineral products	26	8	3	40	230					187	**0**									60		646
Basic metals and fabricated metal products	27 - 28	268	3	7	0					13	**0**									48		428
Machinery and equipment n.e.c.	29	2	2	3	0					13	**0**									19		40
Electrical and optical equipment	30 - 33	5	54	13	0					28	**0**									127		228
Transport equipment manufacture	34 - 35	0	0	2	0					9	**0**									10		21
Other manufacturing	36 - 37, 1	6	1	7	0	1				2	**0**									29		47
Transport		**0**	**1**	**2,509**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**8**	**0**	**5,393**
Road Freight				1,186							**0**											1,186
Road Private Car			1	466							**3**						3					2,024
Public Passenger Services				121							**0**											162
Rail				40							**0**									8		48
Domestic Aviation											**0**											51
International Aviation											**0**											938
Fuel Tourism				617							**0**											903
Unspecified		0		80							**0**											80
Residential		**0**	**78**	**245**	**27**					**632**	**17**			**17**				**1**	**0**	**695**		**2,989**
Commercial/Public Services		**10**	**12**	**564**	**0**	**0**	**0**	**0**	**0**	**306**	**3**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**1**	**698**	**0**	**1,619**
Commercial Services		1	9	373						**134**	**3**			0		3				500		1,046
Public Services		9	3	191						**172**	**0**									198		573
Agricultural			**0**	**269**						**0**	**0**									**53**		**322**
Statistical Difference		**-30**	**-0**	**-79**	**9**	**1**	**0**	**0**	**0**	**-32**	**3**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**-73**	**0**	**-264**

Annex C

Calculation Sheets for Energy 2006

Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2006 (continued on following pages)

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
				CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
	Sector/Fuel	kTOE	TJ	kg/TJ	kg/TJ	kg/TJ	Gg	Mg	Mg
	1A1a Public Electricity								
1	Coal	1265.14	52968.76	90533	NO	14	4795.42	NO	741.56
2	Peat	436.60	18279.76	118754	NO	12	2170.79	NO	219.36
3	Fuel Oil and Gas Oil	685.58	28704.05	77411	NO	14	2222.00	NO	401.86
4	Natural Gas	2233.24	93501.39	55855	NO	3	5222.55	NO	280.50
5	Landfill Gas	25.41	1063.95	54940	NO	3	58.45	NO	3.19
	Public Electricity Total	**4645.98**	**194517.90**				**14410.77**	**0.00**	**1646.47**
	1A1b Refinery Fuel								
6	Refinery Gas	98.47	4122.81	53143	0	3	219.10	NO	12.37
7	Fuel Oil	32.21	1348.45	76596	0	10	103.29	NO	13.48
8	LPG	5.78	242.15	210225	2	3	50.91	0.48	0.73
9	Gasoil/Diesel/DERV	1.09	45.47	71279	2	10	3.24	0.09	0.45
	Refinery Total	**137.55**	**5758.89**				**376.53**	**0.58**	**27.03**
	1A1c Manufacture of Briquettes								
10	Peat	**18.45**	**772.33**	154958	50	5	**119.68**	**38.62**	**3.86**
	1A2a-1A2f Industry Fuel								
11	Bituminous Coals	132.91	5564.57	94600	100	3	526.41	556.46	16.69
12	Kerosene	124.01	5192.23	71400	5	10	370.73	25.96	51.92
13	Fuel Oil	371.58	15557.22	76000	0	10	1182.35	NO	155.57
14	LPG	71.15	2978.77	63700	2	3	189.75	5.96	8.94
15	Gasoil/Diesel/DERV	190.16	7961.55	73300	5	10	583.58	39.81	79.62
16	Pet Coke	230.35	9644.40	100800	50	12	972.16	482.22	115.73
17	Naptha								
18	Natural Gas	783.27	32794.10	56803	2	3	1862.81	65.59	98.38
19	Biomass	163.91	6862.65	110000	30	4	754.89	205.88	27.45
20	Biogas			84200	0	0	0.00	0.00	0.00
	Industry Total	**2067.34**	**86555.50**				**5687.78**	**1381.87**	**554.31**
	1A3a Aviation								
21	Civil Aviation Kerosene	37.95	1588.77	71363	1	2	113.38	1.77	3.89
	1A3b Road Transport Fuel								
22	Gasoline	1882.63	78821.98	69960	13.70	4.26	5514.39	1079.88	335.52
23	Gasoil/Diesel/DERV	2468.46	103349.35	73300	2.17	2.65	7575.51	224.75	273.52
24	LPG	1.05	43.81	63700	12.10	3.65	2.79	0.53	0.16
	Road Transport Total	**4352.13**	**182215.13**				**13092.68**	**1305.16**	**609.20**

Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2006 (continued from previous page)

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors			Emissions		
				CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
	Sector/Fuel	kTOE	TJ	kg/TJ	kg/TJ	kg/TJ	Gg	Mg	Mg
	1A3c-1A3e Other Transport Fuel								
25	Railway Diesel	39.78	1665.70	73300	5	30	122.10	8.33	49.97
26	Navigation Fuel Oil	0.00	0.00	76000	5	30	0.00	0.00	0.00
27	Navigation Gasoil	1.26	52.65	73300	5	30	3.86	0.26	1.58
28	Gas Distribution Use Gasoil	63.60	2662.68	56832	5	2	151.33	13.31	5.33
	Other Transport Total	**104.64**	**4381.03**				**277.28**	**21.91**	**56.88**
	1A4a Commercial/Institutional Fuel								
29	Bituminous Coal	24.49	1025.41	94600	100	12	97.00	102.54	12.30
30	Anthracite + Manufactured Ovoids	0.88	37.02	98260	100	12	3.64	3.70	0.44
31	Lignite	0.70	29.13	101200	50	12	2.95	1.46	0.35
32	Briquettes	0.39	16.30	98860	50	5	1.61	0.82	0.08
33	Fuel Oil	9.85	412.36	76000	0	10	31.34	0.00	4.12
34	LPG	11.51	481.86	63700	0	2	30.69	0.00	0.96
35	Gasoil / Diesel/ DERV	564.22	23622.76	73300	5	10	1731.55	118.11	236.23
36	Natural Gas	336.07	14070.42	56832	5	2	799.65	70.35	28.14
37	Biomass	0.43	17.93	110000	30	4	1.97	0.54	0.07
38	Biogas	2.94	123.29	84200	0	0	10.38	NO	NO
	Commercial/Institutional Total	**951.48**	**39836.48**				**2698.43**	**297.52**	**282.71**
	1A4b Residential Fuel								
39	Bituminous Coal	158.64	6642.07	94600	100	12	628.34	664.21	79.70
40	Anthracite + Manufactured Ovoids	56.54	2367.23	98260	100	12	232.60	236.72	28.41
41	Lignite	3.67	153.71	101200	50	12	15.56	7.69	1.84
42	Sod Peat	195.54	8186.76	104000	50	5	851.42	409.34	40.93
43	Briquettes	87.98	3683.46	98860	50	5	364.15	184.17	18.42
44	Kerosene	791.78	33150.40	71400	5	10	2366.94	165.75	331.50
45	LPG	78.47	3285.41	63700	0	2	209.28	0.00	6.57
46	Gasoil / Diesel/ DERV	245.20	10266.21	73300	5	10	752.51	51.33	102.66
47	Petroleum Coke	27.00	1130.48	100800	50	12	113.95	56.52	13.57
48	Natural Gas	632.08	26464.10	56832	5	2	1504.00	132.32	52.93
49	Biomass	16.78	702.41	110000	30	4	77.27	21.07	2.81
	Residential Total	**2293.69**	**96032.24**				**7038.76**	**1929.13**	**679.35**
	1A4c Agriculture Fuel								
50	Gasoil	**268.97**	**11261.40**	73300	5	10	**825.46**	**56.31**	**112.61**
	Total Energy	**14878.18**	**622919.66**				**44640.76**	**5032.85**	**3976.31**

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**	**201049.1135**				**14906.9837**	**0.0392**	**1.6774**
B	Solid Fuels	72020.8393	98.3867	0.5362	13.3959	7085.8934	0.0386	0.9648
C	Liquid Fuels	34462.9345	75.4009	0.0167	12.4450	2598.5355	0.0006	0.4289
D	Gaseous Fuels	93501.3893	55.8554	NO	3.0000	5222.5549	NO	0.2805
E	Biomass	1063.9504	54.9400	NO	3.0000	58.4534	NO	0.0032
F	**1.A.2 Manufacturing Industries and Construction**	**86555.4967**				**5687.7822**	**1.3819**	**0.5543**
G	Solid Fuels	5564.5723	94.6000	100.0000	3.0000	526.4085	0.5565	0.0167
H	Liquid Fuels	41334.1775	79.8022	13.4017	9.9622	3298.5594	0.5539	0.4118
I	Gaseous Fuels	32794.0956	56.8033	2.0000	3.0000	1862.8142	0.0656	0.0984
J	Biomass	6862.6513	110.0000	30.0000	4.0000	754.8916	0.2059	0.0275
K	**1.A.3 Transport**	**188184.9313**				**13483.3421**	**1.3288**	**0.6700**
L	Solid Fuels	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
M	Liquid Fuels	185522.2504	71.8621	7.0909	3.5826	13332.0169	1.3155	0.6646
N	Gaseous Fuels	2662.6809	56.8319	5.0000	2.0000	151.3252	0.0133	0.0053
O	Biomass	NO	NO	NO	NO	NO	NO	NO
P	**1.A.4 Other Sectors**	**147130.1169**				**10562.6510**	**2.2830**	**1.0747**
Q	Solid Fuels	22141.1036	99.2395	72.7444	8.2420	2197.2713	1.6106	0.1825
R	Liquid Fuels	83610.8666	72.4993	5.3585	9.6666	6061.7265	0.4480	0.8082
S	Gaseous Fuels	40534.5218	56.8319	5.0000	2.0000	2303.6532	0.2027	0.0811
T	Biomass	843.6250	106.2296	25.6158	3.4154	89.6179	0.0216	0.0029
U	**1.A.5 Other** *(Not specified elsewhere)* [(6)]	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
V	**1.A. Fuel Combustion**	**622919.6584**				**44640.7590**	**5.0329**	**3.9763**
	Memo Items							
W	Air Bunkers	39835.9837	71.3686	0.0009	0.0023	2843.0400	0.0378	0.0933
X	Marine Bunkers	5438.3195	74.3082	NE,NO	NE,NO	404.1120	NE,NO	NE,NO
Y	CO_2 from Biomass	8770.2267	102.9578			902.9630	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)**	
G	(a) Solid Fuels	11
H	(b) Liquid Fuels	12+13+14+15+16+17
I	(c) Gaseous Fuels	18
J	(d) Biomass	19+20
K	**1.A.3 Transport (K = L+M+N+O)**	
L	(a) Solid Fuels	NO
M	(b) Liquid Fuels	21+22+23+24+25+26+27
N	(c) Gaseous Fuels	28
O	(d) Biomass	NO
P	**1.A.4 Other Sectors (P = Q+R+S+T)**	
Q	(a) Solid Fuels	29+30+31+32+39+40+41+42+43
R	(b) Liquid Fuels	33+34+35+44+45+46+47+50
S	(c) Gaseous Fuels	36+48
T	(d) Biomass	37+38+49
U	**1.A.5 Other**	**NO**
V	**1.A Fuel Combustion (V = A+F+K+P+U)**	

Table C.4 Emissions of CO_2 from the Reference Approach in 2006 [CRF 2006 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	3,182.1796	NO		45.8208	3,136.3589	42.1842	NCV	132,304.7890	20.0000	2,646.0958	NA	2,646.0958	1.0000	9,702.3512
		Orimulsion		NO	NO	NO		NO	NO	41.8680	NCV	NO	NO	NO	NO	NO	NO	NO
		Natural Gas Liquids	kt	87.4294	NO	NO		NO	87.4294	47.1559	NCV	4,122.8120	17.7270	73.0851	NA	73.0851	1.0000	267.9787
	Secondary Fuels	Gasoline	kt		1,191.8431	95.0659	NO	-4.1918	1,100.9690	44.5890	NCV	49,091.1064	19.0800	936.6583	NA	936.6583	1.0000	3,434.4138
		Jet Kerosene	kt		1,152.3803	NO	903.3192	-61.0329	310.0939	44.1000	NCV	13,675.1426	19.4730	266.2961	NA	266.2961	1.0000	976.4189
		Other Kerosene	kt		426.3060	7.8845	NO	32.0705	386.3510	44.1960	NCV	17,075.1696	19.4727	332.4997	NA	332.4997	1.0000	1,219.1654
		Shale Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Gas / Diesel Oil	kt		2,734.4325	119.6395	78.6804	-8.8334	2,544.9460	43.3082	NCV	110,217.0288	19.9909	2,203.3376	NA	2,203.3376	1.0000	8,078.9045
		Residual Fuel Oil	kt		1,052.9030	1,081.7727	49.2486	15.4295	-93.5479	41.2357	NCV	-3,857.5131	20.7272	-79.9554	NA	-79.9554	1.0000	-293.1700
		Liquefied Petroleum Gas (LPG)	kt		117.0770	15.7650		1.6517	99.6603	47.1559	NCV	4,699.5710	17.3727	81.6442	NA	81.6442	1.0000	299.3622
		Ethane			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Naphtha	kt		NO	3.0040		3.4682	-6.4722	41.8680	NCV	-270.9763	20.0000	-5.4195	NO	-5.4195	1.0000	-19.8716
		Bitumen	kt		264.0000	NO		NO	264.0000	37.6979	NCV	9,952.2456	22.0000	218.9494	218.9494	0.0000	1.0000	0.0000
		Lubricants	kt		10.0000	6.0000	NO	NO	4.0000	42.2867	NCV	169.1468	20.0000	3.3829	1.6915	1.6915	1.0000	6.2020
		Petroleum Coke	kt		328.4590	NO		-6.7420	335.2010	34.8719	NCV	11,689.0958	27.4909	321.3438	NO	321.3438	1.0000	1,178.2605
		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												2,024.1380		40.4828	NO	40.4828		NO
Aviation Gasoline			kt	NO	NO	NO	NO	NO	NO	44.5890	NCV	NO	19.0800	NO	NO	NO	1.0000	NO
Other non-specified			kt	NO	114.0000	68.0000	NO	NO	46.0000	44.0030	NCV	2,024.1380	20.0000	40.4828	NO	40.4828	NO	NO
Liquid Fossil Totals												350,891.7563		7,038.4006	220.6409	6,817.7597		24,850.0156
Solid Fossil	Primary Fuels	Anthracite (2)	kt	NO	56.3730	NO		6.1040	50.2690	27.8422	NCV	1,399.5996	26.7982	37.5067	NO	37.5067	1.0000	137.5247
		Coking Coal		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA	NA,NO	NO	NA,NO
		Other Bituminous Coal	kt	NO	2,531.0650	3.0000	NO	-9.6370	2,537.7020	27.8422	NCV	70,655.2066	25.8000	1,822.9043	NA	1,822.9043	1.0000	6,683.9825
		Sub-bituminous Coal		NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Lignite	kt	NO	12.8030	NO		3.5760	9.2270	19.8161	NCV	182.8432	27.6000	5.0465	NO	5.0465	1.0000	18.5037
		Oil Shale		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Peat	kt	3,068.8730	NO	NO		213.0530	2,855.8200	7.7874	NCV	22,239.4127	29.8630	664.1356	NA	664.1356	1.0000	2,435.1638
	Secondary Fuels	BKB(3) and Patent Fuel	kt		NO	21.7550		NO	-21.7550	18.5475	NCV	-403.5009	26.9618	-10.8791	NA	-10.8791	1.0000	-39.8901
		Coke Oven/Gas Coke			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Other Solid Fossil												8,199.3487		232.5630	NO	232.5630		852.7312
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Sod Peat			kt	625.2000	NO	NO	NO	-0.4800	625.6800	13.1047	NCV	8,199.3487	28.3636	232.5630	NO	232.5630	1.0000	852.7312
Solid Fossil Totals												102,272.9098		2,751.2771	NA,NO	2,751.2771		10,088.0159
Gaseous Fossil		Natural Gas (Dry)	ktoe	409.9495	3,609.6435	NO		0.1127	4,019.4803	41.8680	NCV	168,287.6003	15.4918	2,607.0778	NO	2,607.0778	1.0000	9,559.2854
Other Gaseous Fossil												NO		NO	NO	NO		NO
	Other non-specified			NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
Gaseous Fossil Totals												168,287.6003		2,607.0778	NO	2,607.0778		9,559.2854
Total												621,452.2665		12,396.7555	220.6409	12,176.1147		44,497.3170
Biomass total												6,362.6968		174.6649	NO	174.6649		640.4378
		Solid Biomass	TJ	5,223.2613	NO	NO		NO	5,223.2613	1.0000	NCV	5,223.2613	30.0000	156.6978	NO	156.6978	1.0000	574.5587
		Liquid Biomass	ktoe	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Gas Biomass	TJ	1,139.4355	NO	NO		NO	1,139.4355	1.0000	NCV	1,139.4355	15.7684	17.9670	NO	17.9670	1.0000	65.8791

Table C.5 Comparison of Results from Sectoral Approach and Reference Approach for 2006 (CRF 2006 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)	350.8918	340.8549	24,850.0156	344.9302	25,290.8383	-1.1815	-1.7430
Solid Fuels (excluding international bunkers) [5]	102.2729	102.2729	10,088.0159	99.7265	9,809.5732	2.5534	2.8385
Gaseous Fuels	168.2876	168.2876	9,559.2854	169.4927	9,540.3475	-0.7110	0.1985
Other [5]	NO	NO	NO	NA,NO	NA,NO		
Total [5]	*621.4523*	*611.4154*	*44,497.3170*	*614.1494*	*44,640.7590*	*-0.4452*	*-0.3213*

Annex D

Agricultural activity Data, Methane emission factors and input data for the calculation of Nitrous oxide emissions from soils

Year 1990-2006

Table D.1 (a) Activity Data for Agriculture

Housing and Storage (1000's)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Cattle	5,969.10	6,100.40	6,147.30	6,236.40	6,263.90	6,343.80	6,450.70	6,661.00	6,881.60	6,951.80	6,557.70	6,330.10	6,408.10	6,332.90	6,223.50	6,211.50	6,191.80
Dairy Cows	1,341.60	1,322.20	1,288.00	1,246.20	1,248.30	1,233.00	1,220.80	1,215.60	1,201.40	1,198.80	1,173.80	1,152.80	1,148.00	1,128.70	1,135.70	1,121.80	1,101.10
All Other Cattle(exclud.Dairy Cows)	4,627.50	4,778.20	4,859.30	4,990.20	5,015.60	5,110.80	5,229.90	5,445.40	5,680.20	5,753.00	5,383.90	5,177.30	5,260.10	5,204.20	5,087.80	5,089.70	5,090.70
Other Cows	659.20	729.40	784.00	916.70	936.60	968.70	1,004.60	1,083.40	1,163.80	1,196.20	1,166.80	1,155.20	1,159.70	1,150.80	1,144.20	1,150.80	1,150.00
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
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
Cattle < 1 yrs	1,436.20	1,477.00	1,491.00	1,472.30	1,564.90	1,556.50	1,631.40	1,735.00	1,828.60	1,789.60	1,648.90	1,689.90	1,879.40	1,805.70	1,751.10	1,746.00	1,693.30
Cattle < 1 yrs - male	775.30	794.80	796.10	799.40	849.60	842.20	888.10	952.90	1,012.80	983.10	892.20	927.10	1,007.40	1,001.10	948.60	924.20	885.60
Cattle < 1 yrs - female	660.90	682.20	694.90	672.90	715.30	714.30	743.30	782.10	815.80	806.50	756.70	762.80	872.00	804.60	802.50	821.80	807.70
Cattle 1 - 2 yrs	1,311.70	1,347.60	1,399.30	1,379.00	1,361.40	1,403.90	1,380.20	1,424.60	1,481.90	1,548.90	1,446.40	1,269.30	1,329.00	1,363.80	1,319.90	1,253.40	1,261.70
Cattle 1 - 2 yrs - male	813.80	824.00	846.00	857.50	841.20	850.60	853.00	894.70	943.60	976.10	904.80	798.10	841.40	885.60	856.20	782.00	762.00
Cattle 1 - 2 yrs - female	497.90	523.60	553.30	521.50	520.20	553.30	527.20	529.90	538.30	572.80	541.60	471.20	487.60	478.20	463.70	471.40	499.70
Cattle > 2 yrs	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
Cattle > 2 yrs - male	638.70	623.90	591.20	608.50	551.80	571.40	563.30	531.40	521.90	546.40	491.10	452.30	288.00	278.60	258.20	283.20	311.90
Cattle > 2 yrs - female	283.90	296.20	290.30	265.30	251.30	257.70	247.20	246.60	241.20	272.50	247.60	217.50	197.30	192.60	191.30	216.00	231.60
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
Total Sheep	8,020.98	8,483.65	8,735.75	8,977.22	8,559.06	8,363.83	8,329.04	8,050.87	8,572.21	8,547.15	7,957.34	7,615.85	6,925.31	6,722.29	6,902.84	6,617.08	6,279.46
Ewes Lowland	2,396.60	2,542.54	2,621.99	2,576.45	2,511.11	2,426.99	2,369.07	2,389.75	3,056.41	2,936.12	2,814.25	2,704.31	2,637.25	2,552.34	2,463.79	2,626.72	2,414.32
Ewes Upland	1,960.85	2,080.26	2,145.26	2,108.00	2,054.54	1,985.72	1,938.33	1,955.25	1,309.89	1,258.34	1,206.11	1,158.99	1,130.25	1,093.86	1,055.91	656.68	603.58
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
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
Lambs	3,248.30	3,563.50	3,680.70	3,988.50	3,676.50	3,625.80	3,716.30	3,375.00	3,845.00	4,021.10	3,621.60	3,463.80	2,868.70	2,768.00	3,083.70	3,082.30	3,016.10
Total Pigs	1,220.85	1,325.95	1,405.50	1,503.60	1,513.40	1,546.15	1,642.70	1,708.30	1,809.75	1,774.90	1,726.80	1,760.50	1,790.80	1,728.65	1,703.80	1,679.20	1,631.60
Gilts in Pig	20.80	22.30	25.60	22.75	21.45	24.00	24.50	26.85	25.60	24.85	21.25	22.65	20.05	20.00	21.55	19.75	21.65
Gilts not yet Served	11.85	14.00	14.75	14.60	15.05	17.40	16.85	17.70	18.70	16.20	17.85	18.95	19.55	17.80	19.00	19.55	18.65
Sows in Pig	83.35	91.05	96.30	100.55	98.70	99.90	103.15	107.95	109.10	108.60	109.65	107.30	110.00	103.95	102.25	99.80	96.40
Other Sows for Breeding	30.30	31.20	33.85	32.30	29.60	30.95	35.80	37.05	38.00	37.70	32.00	36.50	32.85	32.30	30.40	33.60	30.50
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
Pigs 20 Kg +	749.15	802.65	836.50	904.95	917.65	951.95	1,015.75	1,063.90	1,144.35	1,094.10	1,037.90	1,036.30	1,061.95	1,043.20	1,027.85	1,010.30	1,033.95
Pigs Under 20 Kg	319.15	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
Total Poultry	11,412.83	12,338.21	12,913.07	12,712.41	13,674.55	14,078.45	15,015.62	15,189.04	15,326.96	15,130.48	15,320.50	15,663.15	15,182.57	15,787.87	16,610.57	16,094.68	15,775.34
Layer	1,868.25	1,800.00	2,231.00	1,831.50	1,730.00	1,370.50	1,701.00	1,580.00	1,558.50	1,537.00	1,572.00	1,676.00	1,613.00	1,906.60	1,906.27	1,950.00	1,970.00
Broiler	8,035.13	8,904.90	9,066.82	9,522.47	10,392.54	11,092.18	11,729.88	12,096.34	12,286.79	12,200.11	12,426.10	12,628.89	12,321.96	12,672.21	13,242.90	12,817.70	12,708.69
Turkey	1,509.45	1,633.30	1,615.26	1,358.44	1,552.01	1,615.77	1,584.74	1,512.70	1,481.67	1,393.37	1,322.41	1,358.26	1,247.60	1,209.06	1,461.40	1,326.98	1,096.65
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
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
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
Fertiliser (tonnes N)	379,311	370,121	358,302	377,985	404,811	428,826	416,918	380,350	431,999	442,916	407,598	368,667	363,513	388,080	362,525	352,165	342,137

Table D.1 (b) Activity Data for Agriculture
Pasture(1000's)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Cattle	6,816.10	6,912.10	6,951.40	6,981.70	6,996.30	7,034.00	7,313.50	7,532.80	7,639.90	7,387.00	7,037.40	7,049.70	6,992.20	6,999.70	7,015.70	6,982.60	6,915.80
Dairy Cows	1,359.70	1,330.80	1,277.90	1,263.50	1,260.60	1,256.20	1,266.40	1,251.70	1,233.80	1,200.60	1,177.50	1,182.50	1,164.10	1,155.60	1,156.10	1,113.70	1,109.20
All Other Cattle(exclud.Dairy Cows)	5,456.40	5,581.30	5,673.50	5,718.20	5,735.70	5,777.80	6,047.10	6,281.10	6,406.10	6,186.40	5,859.90	5,867.20	5,828.10	5,844.10	5,859.60	5,868.90	5,806.60
Other Cows	731.30	817.30	889.10	979.70	1,011.00	1,039.10	1,112.70	1,201.90	1,247.90	1,217.30	1,187.00	1,196.80	1,154.20	1,187.30	1,207.10	1,227.80	1,215.40
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
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
Cattle < 1 yrs	1,716.10	1,764.70	1,694.50	1,737.50	1,736.20	1,746.10	1,852.10	1,938.20	1,965.00	1,820.70	1,751.90	1,824.40	1,799.30	1,761.20	1,771.40	1,689.50	1,631.20
Cattle < 1 yrs - male	903.20	918.70	888.90	913.80	903.80	915.30	974.30	1,023.00	1,054.80	965.10	919.40	955.20	953.10	922.10	929.80	842.50	801.70
Cattle < 1 yrs - female	812.90	845.90	805.60	823.70	832.40	830.70	877.80	915.20	910.30	855.50	832.50	869.20	846.20	839.10	841.60	847.00	829.50
Cattle 1 - 2 yrs	1,663.10	1,692.00	1,637.60	1,587.00	1,585.70	1,586.10	1,639.40	1,717.00	1,782.60	1,706.00	1,517.10	1,515.00	1,593.20	1,577.20	1,534.80	1,575.60	1,553.80
Cattle 1 - 2 yrs - male	985.80	981.10	981.60	957.50	952.00	964.40	996.20	1,054.70	1,085.60	1,039.00	912.40	913.30	991.80	983.30	949.80	940.20	915.70
Cattle 1 - 2 yrs - female	677.30	710.90	656.10	629.50	633.70	621.70	643.20	662.30	697.00	667.10	604.70	601.70	601.40	593.90	585.00	635.30	638.10
Cattle > 2 yrs	1,092.60	1,098.80	1,151.80	1,077.90	1,057.70	1,022.90	1,036.20	985.70	1,002.10	1,057.70	1,016.20	941.10	844.70	901.50	910.60	929.40	951.20
Cattle > 2 yrs - male	826.40	797.50	829.60	773.20	739.80	711.60	732.20	690.20	708.10	736.70	721.60	642.10	560.40	598.70	605.40	619.30	639.70
Cattle > 2 yrs - female	266.20	301.30	322.20	304.70	318.00	311.30	304.00	295.60	294.00	321.00	294.70	299.00	284.30	302.80	305.20	310.20	311.50
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
Total Sheep	8,020.98	8,483.65	8,735.75	8,977.22	8,559.06	8,363.83	8,329.04	8,050.87	8,572.21	8,547.15	7,957.34	7,615.85	6,925.31	6,722.29	6,902.84	6,617.08	6,279.46
Lowland Ewes	2,396.60	2,542.54	2,621.99	2,576.45	2,511.11	2,426.99	2,369.07	2,389.75	3,056.41	2,936.12	2,814.25	2,704.31	2,637.25	2,552.34	2,463.79	2,626.72	2,414.32
Upland Ewes	1,960.85	2,080.26	2,145.26	2,108.00	2,054.54	1,985.72	1,938.33	1,955.25	1,309.89	1,258.34	1,206.11	1,158.99	1,130.25	1,093.86	1,055.91	656.68	603.58
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
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
Lambs	3,248.30	3,563.50	3,680.70	3,988.50	3,676.50	3,625.80	3,716.30	3,375.00	3,845.00	4,021.10	3,621.60	3,463.80	2,868.70	2,768.00	3,083.70	3,082.30	3,016.10
Total Pigs	1,220.85	1,325.95	1,405.50	1,503.60	1,513.40	1,546.15	1,642.70	1,708.30	1,809.75	1,774.90	1,726.80	1,760.50	1,790.80	1,728.65	1,703.80	1,679.20	1,631.60
Gilts in Pig	20.80	22.30	25.60	22.75	21.45	24.00	24.50	26.85	25.60	24.85	21.25	22.65	20.05	20.00	21.55	19.75	21.65
Gilts not yet Served	11.85	14.00	14.75	14.60	15.05	17.40	16.85	17.70	18.70	16.20	17.85	18.95	19.55	17.80	19.00	19.55	18.65
Sows in Pig	83.35	91.05	96.30	100.55	98.70	99.90	103.15	107.95	109.10	108.60	109.65	107.30	110.00	103.95	102.25	99.80	96.40
Other Sows for Breeding	30.30	31.20	33.85	32.30	29.60	30.95	35.80	37.05	38.00	37.70	32.00	36.50	32.85	32.30	30.40	33.60	30.50
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
Pigs 20 Kg +	749.15	802.65	836.50	904.95	917.65	951.95	1,015.75	1,063.90	1,144.35	1,094.10	1,037.90	1,036.30	1,061.95	1,043.20	1,027.85	1,010.30	1,033.95
Pigs Under 20 Kg	319.15	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
Total Poultry	11,412.83	12,338.21	12,913.07	12,712.41	13,674.55	14,078.45	15,015.62	15,189.04	15,326.96	15,130.48	15,320.50	15,663.15	15,182.57	15,787.87	16,610.57	16,094.68	15,775.34
Layer	1,868.25	1,800.00	2,231.00	1,831.50	1,730.00	1,370.50	1,701.00	1,580.00	1,558.50	1,537.00	1,572.00	1,676.00	1,613.00	1,906.60	1,906.27	1,950.00	1,970.00
Broiler	8,035.13	8,904.90	9,066.82	9,522.47	10,392.54	11,092.18	11,729.88	12,096.34	12,286.79	12,200.11	12,426.10	12,628.89	12,321.96	12,672.21	13,242.90	12,817.70	12,708.69
Turkey	1,509.45	1,633.30	1,615.26	1,358.44	1,552.01	1,615.77	1,584.74	1,512.70	1,481.67	1,393.37	1,322.41	1,358.26	1,247.60	1,209.06	1,461.40	1,326.98	1,096.65
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
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
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
Fertiliser (tonnes N)	379,311	370,121	358,302	377,985	404,811	428,826	416,918	380,350	431,999	442,916	407,598	368,667	363,513	388,080	362,525	352,165	342,137

Table D.2 (a) Emission factors used in the calculation of CH_4 emissions from enteric fermentation (kg/head/year)

Animal Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cattle																	
Dairy cows	101.38	101.92	102.47	103.01	103.56	104.10	104.64	105.19	105.73	106.28	106.82	107.37	107.91	108.45	108.36	107.84	109.70
Beef cows(Suckler Cows)	74.03	74.04	74.06	74.07	74.08	74.10	74.11	74.12	74.14	74.15	74.16	74.18	74.19	74.20	74.47	74.12	74.28
Dairy heifers	51.82	51.69	51.56	51.44	51.31	51.18	51.05	50.93	50.80	50.67	50.54	50.42	50.29	50.16	50.16	50.16	50.16
Beef heifers	55.42	55.29	55.15	55.02	54.89	54.75	54.62	54.48	54.35	54.22	54.08	53.95	53.82	53.68	53.68	53.68	53.68
Bulls for breeding	86.38	86.01	85.61	85.23	84.86	84.49	84.12	83.75	83.37	83.00	82.63	82.26	81.89	81.55	81.55	81.55	81.55
Male cattle																	
< 1 year	30.46	30.39	30.31	30.24	30.17	30.09	30.02	29.94	29.87	29.80	29.72	29.65	29.58	29.50	29.70	29.72	29.58
1 - 2 years	62.22	62.10	61.99	61.87	61.76	61.64	61.53	61.41	61.30	61.18	61.07	60.95	60.84	60.72	59.26	58.96	59.93
> 2 years*	55.08	53.47	51.85	50.24	48.63	47.01	45.40	43.79	42.17	40.56	38.94	37.33	35.72	34.10	35.23	37.67	37.80
Female cattle																	
< 1 year	27.05	27.11	27.17	27.22	27.28	27.34	27.40	27.46	27.51	27.57	27.63	27.69	27.75	27.80	27.88	27.86	27.74
1 - 2 years	53.54	52.85	52.17	51.48	50.79	50.10	49.42	48.73	48.04	47.36	46.67	45.98	45.30	44.61	44.49	45.64	46.46
> 2 years*	21.65	21.71	21.78	21.84	21.90	21.96	22.03	22.09	22.15	22.21	22.28	22.34	22.40	22.46	22.46	22.46	22.46
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
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
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
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
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
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
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
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
Pigs																	
Gilts in Pig	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Gilts not yet Served	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Sows in Pig	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Other Sows for Breeding	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Boars	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Pigs > 20 Kg	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Pigs < 20 Kg	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
Poultry	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 D.2 (b) Emission factors used in the calculation of CH_4 emissions from manure management (kg/head/yr)

Animal Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cattle																	
Dairy cows	21.57	21.49	21.40	21.32	21.24	21.15	21.07	20.99	20.91	20.82	20.74	20.66	20.57	20.49	20.46	20.41	20.59
Beef cows(Suckler Cows)	14.02	14.01	13.99	13.98	13.97	13.96	13.94	13.93	13.92	13.91	13.89	13.88	13.87	13.85	13.89	13.86	13.88
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
Beef heifers	15.61	15.40	15.19	14.98	14.77	14.56	14.35	14.14	13.93	13.71	13.50	13.29	13.08	12.87	12.87	12.87	12.87
Bulls for breeding	23.79	23.42	23.05	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
Male cattle																	
< 1 year	9.73	9.63	9.54	9.44	9.35	9.25	9.16	9.06	8.97	8.87	8.77	8.68	8.58	8.49	8.58	8.60	8.56
1 - 2 years	16.68	16.49	16.31	16.12	15.94	15.75	15.57	15.38	15.20	15.01	14.83	14.64	14.46	14.27	13.75	13.82	14.09
> 2 years*	4.57	4.33	4.09	3.85	3.61	3.37	3.13	2.89	2.65	2.41	2.17	1.93	1.69	1.46	1.60	1.91	1.92
Female cattle																	
< 1 year	8.79	8.75	8.71	8.67	8.63	8.60	8.56	8.52	8.48	8.44	8.40	8.36	8.32	8.28	8.30	8.29	8.28
1 - 2 years	14.74	14.33	13.91	13.50	13.08	12.67	12.25	11.84	11.42	11.01	10.59	10.18	9.77	9.35	9.11	9.63	9.77
> 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
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
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
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
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
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
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
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
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
Pigs																	
Gilts in Pig	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46
Gilts not yet Served	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17	17.17
Sows in Pig	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46
Other Sows for Breeding	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46
Boars	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46	21.46
Pigs > 20 Kg	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88	12.88
Pigs < 20 Kg	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58
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
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
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

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

Table D.3 Input data for the calculation of N_2O emissions from soils

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
$Frac_{GASF}$	0.015	0.015	0.016	0.016	0.016	0.015	0.020	0.021	0.018	0.018	0.021	0.020	0.017	0.015	0.015	0.016	0.016
$Frac_{GRAZ}$	0.659	0.658	0.660	0.657	0.657	0.655	0.657	0.658	0.657	0.650	0.650	0.656	0.655	0.657	0.658	0.659	0.657
$Frac_{GASM1}$	0.484	0.485	0.485	0.487	0.486	0.487	0.487	0.487	0.487	0.488	0.487	0.486	0.486	0.486	0.485	0.485	0.486
$Frac_{GASM2}$	0.043	0.042	0.041	0.041	0.041	0.040	0.041	0.040	0.040	0.040	0.040	0.038	0.038	0.038	0.038	0.036	0.036
$Frac_{GASM}$	0.194	0.194	0.192	0.194	0.194	0.194	0.193	0.193	0.193	0.197	0.197	0.192	0.193	0.191	0.191	0.189	0.190
F_{BN}	0.010	0.009	0.009	0.017	0.017	0.013	0.014	0.013	0.022	0.012	0.005	0.006	0.005	0.009	0.010	0.013	0.013
$Frac_{LEACH}$	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
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	356,974	346,638	336,525
F_{AM} (tonnes/year)	76,170	77,651	78,223	78,836	78,693	79,552	80,594	82,545	84,787	85,468	81,848	79,421	79,024	78,372	78,201	77,976	77,722
F_S (tonnes/year)	104.688	105.282	106.142	106.727	107.080	96.360	94.983	270.103	368.262	576.024	756.642	938.815	1,151.941	1,216.526	1,673.083	1,846.718	1,876.824
F_{CR} (tonnes/year)	19,692	19,001	19,335	16,201	17,934	19,439	20,848	19,969	19,919	21,128	21,683	19,742	17,757	19,962	23,568	18,046	10,628

Table D.4 Input data on manure management practices

Animal Catgeory	Days housed (mean)	% housed	% outwintered	Housing Type		Proportion to each animal waste management sytem		
				% Slurry based	% Straw based	Liquid	Solid	Pasture
Cattle								
Dairy Cows	161	98.18	1.82	93.75	6.25	0.405	0.027	0.567
Suckler Cows	131	83.76	16.24	72.73	27.27	0.220	0.080	0.700
In-calf heifers	137	95.87	4.13	80.02	19.98	0.290	0.070	0.640
Cattle under 1 year old	140	94.34	5.66	67.98	32.02	0.250	0.120	0.640
Cattle 1-2 years old	143	92.10	7.90	79.48	20.52	0.290	0.070	0.640
Cattle over 2 years old	146	86.43	13.57	58.70	41.30	0.200	0.140	0.650
Bulls	143	89.49	10.51	29.94	70.06	0.100	0.250	0.650
Sheep								
Lowland Ewes	61	47.07	52.93	0.00	100	0.000	0.078	0.922
Upland Ewes	85	44.34	55.66	0.00	100	NA	0.103	0.897
Rams	85	22.34	77.66	0.00	100	NA	0.052	0.948
Lambs	58	16.88	83.12	0.00	100	NA	0.027	0.973
Other sheep	61	47.07	52.93	0.00	100	NA	0.078	0.922
Pigs								
Gilts in pig	365	100	0.00	100	0.00	1.000	0.000	0.000
Gilts not yet served	365	100	0.00	100	0.00	1.000	0.000	0.000
Sows in pig	365	100	0.00	100	0.00	1.000	0.000	0.000
Other sows for breeding	365	100	0.00	100	0.00	1.000	0.000	0.000
Boars	365	100	0.00	100	0.00	1.000	0.000	0.000
Pigs < 20 kg	365	100	0.00	100	0.00	1.000	0.000	0.000
Pigs > 20 kg	365	100	0.00	100	0.00	1.000	0.000	0.000
Poultry								
Layers	365	88.00	12.00	84.20	15.80	0.741	0.139	0.120
Broilers	365	100.00	0.00	0.00	100.00	0.000	1.000	0.000
Turkeys	365	100.00	0.00	0.00	100.00	0.000	1.000	0.000
Horses	143	100.00	0.00	0.00	100.00	0.000	0.392	0.608
Mules and Asses	143	100.00	0.00	0.00	100.00	0.000	0.390	0.608
Goats	0.00	0.00	100.00	0.00	0.00	0.000	0.000	1.000

Annex E

Activity Data for the Carbon Stock Change Estimates of LULUCF Category 5.A Forest Land

Years 1990-2006

Table E.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
Year	Affor	Refor	Felling	Cleared and Unclassified	Forest Cover	Total Forest	Harvest Volume	Harvest Carbon Stock	Affor Carbon Stock	Carbon Stock in Young Forests	Carbon Stock in Mature Forests	Carbon Stock in Total Forests	Total Carbon Stock Change	5.A.1 Forest Land Remaining Forest Land	5.A.2 Land Converted to Forest Land	Cropland Converted to Forest Land	Grassland Converted to Forest Land	Wetland Converted to Forest Land	Other Land Converted to Forest Land
	ha	ha	ha	ha	ha	ha	1000 m^3	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C
1990	15,817	3,882	4,203	111,528	370,160	481,688	1,676	508.83	273.02	1,936.99	13,948.25	15,885.24	215.83	271.15	-55.32	-5.53	-16.60	-31.53	-1.66
1991	19,147	4,203	4,063	127,246	373,728	500,974	1,769	537.07	330.50	1,852.96	14,259.36	16,112.32	227.09	311.12	-84.03	-8.40	-25.21	-47.89	-2.52
1992	16,699	4,063	4,621	140,883	376,237	517,120	2,083	632.42	288.24	1,801.49	14,496.52	16,298.01	185.68	237.16	-51.47	-5.15	-15.44	-29.34	-1.54
1993	15,998	4,621	4,816	151,985	380,940	534,918	2,100	637.60	276.14	1,776.10	14,730.88	16,506.97	208.97	234.36	-25.39	-2.54	-7.62	-14.47	-0.76
1994	19,459	4,816	5,447	165,792	386,598	552,390	2,287	694.30	335.88	1,817.99	14,888.81	16,706.80	199.83	157.93	41.89	4.19	12.57	23.88	1.26
1995	23,710	5,447	6,203	180,777	394,853	575,630	2,382	723.28	409.26	1,920.28	14,999.87	16,920.15	213.35	111.07	102.29	10.23	30.69	58.30	3.07
1996	20,981	6,681	7,090	190,089	406,695	596,784	2,465	748.35	362.15	2,044.85	15,096.30	17,141.15	220.99	96.42	124.57	12.46	37.37	71.01	3.74
1997	11,434	7,395	7,185	189,009	419,451	608,460	2,322	705.11	197.36	2,231.04	15,163.96	17,395.00	253.85	67.66	186.19	18.62	55.86	106.13	5.59
1998	12,928	7,248	7,924	186,511	434,881	621,392	2,638	800.90	223.15	2,376.54	15,300.34	17,676.88	281.88	136.38	145.49	14.55	43.65	82.93	4.36
1999	12,668	8,033	7,747	186,164	447,651	633,815	2,777	843.12	218.66	2,517.01	15,451.97	17,968.98	292.10	151.63	140.47	14.05	42.14	80.07	4.21
2000	15,695	9,592	8,677	189,917	459,129	649,046	3,008	913.36	270.91	2,746.04	15,482.01	18,228.05	259.07	30.04	229.04	22.90	68.71	130.55	6.87
2001	15,465	9,573	9,132	190,239	475,220	665,459	2,836	861.01	266.94	3,045.28	15,501.33	18,546.61	318.56	19.32	299.24	29.92	89.77	170.56	8.98
2002	15,054	9,539	10,286	186,422	493,898	680,320	2,911	883.69	259.85	3,294.99	15,584.74	18,879.73	333.13	83.41	249.71	24.97	74.91	142.34	7.49
2003	9,097	11,391	9,289	177,146	513,031	690,177	3,000	910.80	157.02	3,388.36	15,924.96	19,313.31	433.58	340.22	93.36	9.34	28.01	53.22	2.80
2004	9,739	10,082	9,828	177,884	523,081	700,965	2,846	864.19	168.10	3,513.72	16,135.23	19,648.95	335.63	210.27	125.37	12.54	37.61	71.46	3.76
2005	10,096	10,085	9,781	177,585	533,565	711,150	2,942	893.19	174.27	3,641.90	16,362.12	20,004.02	355.07	226.89	128.18	12.82	38.45	73.06	3.85
2006	8,037	10,232	9,811	174,732	544,869	719,600	2,968	901.02	138.73	3,792.54	16,592.83	20,385.36	381.35	230.71	150.64	15.06	45.19	85.86	4.52

K The value 3,792.54 Gg is the afforestation carbon stock for the years 1987 to 2000 inclusive, similarly 3,641.90 is the afforestation carbon stock for the years 1986 to 1999 inclusive, etc

N Carbon stock change after harvest (corresponding in 2006 to difference between carbon stocks of 20,385.36 Gg in 2006 and 20,004.02 Gg in 2005)

P Carbon stock change for young forests (corresponding in 2006 to difference between carbon stocks of 3,792.54 Gg in 2006 and 3,641.90 Gg in 2005)

Q, R, S, T The total for 5.A.2 (column P) is split as Cropland – 0.10; Grassland – 0.30; Wetland – 0.57; Settlements – 0.00; Other Land – 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.

<u>YOUNG CROPS</u>

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

<u>MATURE CROPS</u>

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

<u>CLEARED/UNCLASSIFIED AREAS</u>
The category cleared/unclassified represents total identified forest area by Forest Service less covered forest as located by remote sensing and classified in FIPS. This would include felled areas in which forest cover had not been established, recent plantings not yet classified and other productive unforested sites. This category is assumed not to store carbon.

General Rule for years before 1995:
Current Year= (Current Year + 1 ha) - Afforestation[Current Year +1] - Felling[Current Year + 1] + ([Current Year + 1 - minimum age for young trees]Afforestation) + ([Current Year + 1 - minimum age for young trees]Reforestation)

Example:
1994 ha. = 1995 ha. - 1995 Afforestation -1995 Felling + 1988 Afforestation + 1988 Reforestation

General Rule for years after 1995:
Current Year= (Current Year - 1 ha) + Afforestation[Current Year)+ Felling[Current Year) - ([Current Year - minimum age for young trees]Afforestation) - ([Current Year - minimum age for young trees]Reforestation)

Example:
1996 ha. = 1995 ha. + 1996 Afforestation +1996 Felling - 1989 Afforestation - 1989 Reforestation

<u>The minimum age for young trees</u> is7 in all examples:

<u>Accretion rate</u> represents the movement of young categories into mature categories on the basis that a given percentage per annum reaches a given age. For example here (minimum age of 7 years assumed for young plantations and 25 years for mature plantations) the percentage is calculated as [1/(25-7)] or 0.056%.

Annex F

Activity Data for 6.A Solid Waste Disposal on Land

Years 1968 – 2006

Table F.1 Time Series of Solid Waste Disposal and Composition 1968-2006

Year	Pop	MSW Prod Rate kg/cap/day	MSW Production tonnes	MSW to SWDS %	MSW to SWDS tonnes	Street Cleansing tonnes	MSW Organic %	MSW Paper %	MSW Textiles %	MSW Other %	MSW Organic tonnes	MSW Paper tonnes	MSW Textiles tonnes	MSW Other tonnes	DOC in Sludge tonnes	DOC in MSW tonnes
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1968	2,912,200	1.00	1,062,953	0.75	797,215	21,259	0.36	0.28	0.03	0.19	286,997	223,220	23,916	151,471	13,594	183,534
1969	2,925,200	1.00	1,067,698	0.75	800,774	21,354	0.36	0.28	0.03	0.19	288,278	224,217	24,023	152,147	13,655	184,353
1970	2,949,900	1.00	1,076,714	0.75	807,535	21,534	0.36	0.28	0.03	0.19	290,713	226,110	24,226	153,432	13,770	185,909
1971	2,978,200	1.00	1,087,043	0.75	815,282	21,741	0.36	0.28	0.03	0.19	293,502	228,279	24,458	154,904	13,902	187,693
1972	3,024,400	1.00	1,103,906	0.75	827,930	22,078	0.36	0.28	0.03	0.19	298,055	231,820	24,838	157,307	14,118	190,605
1973	3,073,000	1.00	1,121,645	0.75	841,234	22,433	0.36	0.28	0.03	0.19	302,844	235,545	25,237	159,834	14,344	193,667
1974	3,123,900	1.00	1,140,224	0.75	855,168	22,804	0.36	0.28	0.03	0.19	307,860	239,447	25,655	162,482	14,582	196,875
1975	3,177,200	1.00	1,159,678	0.75	869,759	23,194	0.36	0.28	0.03	0.19	313,113	243,532	26,093	165,254	14,831	200,234
1976	3,227,800	1.00	1,178,147	0.75	883,610	23,563	0.36	0.28	0.03	0.19	318,100	247,411	26,508	167,886	15,067	203,423
1977	3,271,900	1.00	1,194,244	0.75	895,683	23,885	0.36	0.28	0.03	0.19	322,446	250,791	26,870	170,180	15,273	206,203
1978	3,314,000	1.00	1,209,610	0.75	907,208	24,192	0.36	0.28	0.03	0.19	326,595	254,018	27,216	172,369	15,469	208,856
1979	3,368,200	1.00	1,229,393	0.75	922,045	24,588	0.36	0.28	0.03	0.19	331,936	258,173	27,661	175,189	15,722	212,272
1980	3,401,000	1.00	1,241,365	0.75	931,024	24,827	0.36	0.28	0.03	0.19	335,169	260,687	27,931	176,895	15,876	214,339
1981	3,443,400	1.00	1,256,841	0.75	942,631	25,137	0.36	0.28	0.03	0.19	339,347	263,937	28,279	179,100	16,073	217,011
1982	3,480,000	1.00	1,270,200	0.75	952,650	25,404	0.36	0.28	0.03	0.19	342,954	266,742	28,580	181,004	16,244	219,318
1983	3,504,000	1.00	1,278,960	0.75	959,220	25,579	0.36	0.28	0.03	0.19	345,319	268,582	28,777	182,252	16,356	220,830
1984	3,529,000	1.00	1,283,556	0.75	962,667	25,671	0.36	0.28	0.03	0.19	346,560	269,547	28,880	182,907	16,473	221,682
1985	3,540,000	1.02	1,317,942	0.75	988,457	32,949	0.36	0.28	0.03	0.19	355,844	276,768	29,654	187,807	16,524	228,878
1986	3,540,600	1.04	1,344,012	0.75	1,008,009	33,600	0.35	0.28	0.03	0.19	352,803	282,242	30,240	191,522	16,527	231,569
1987	3,546,500	1.06	1,372,141	0.75	1,029,106	34,304	0.35	0.28	0.03	0.19	360,187	288,150	30,873	195,530	16,555	236,097
1988	3,530,700	1.09	1,404,689	0.75	1,053,517	35,117	0.34	0.28	0.03	0.19	358,196	294,985	31,606	200,168	16,481	239,651
1989	3,509,500	1.12	1,434,684	0.75	1,076,013	35,867	0.34	0.29	0.03	0.19	365,844	312,044	32,280	204,442	16,382	248,621
1990	3,505,800	1.15	1,471,560	0.77	1,133,101	36,789	0.34	0.29	0.03	0.19	385,254	328,599	33,993	215,289	16,365	260,680
1991	3,525,700	1.19	1,531,388	0.77	1,179,169	38,285	0.33	0.29	0.03	0.19	389,126	341,959	35,375	224,042	16,458	268,938
1992	3,554,500	1.24	1,608,767	0.78	1,254,838	40,219	0.33	0.30	0.03	0.18	414,097	376,451	31,371	225,871	16,592	285,771
1993	3,574,100	1.29	1,680,000	0.78	1,310,400	42,000	0.32	0.30	0.03	0.18	419,328	393,120	32,760	235,872	16,684	295,816
1994	3,585,900	1.33	1,740,775	0.80	1,392,620	43,519	0.32	0.30	0.02	0.18	445,638	417,786	27,852	250,672	16,739	310,320
1995	3,601,300	1.37	1,801,441	0.77	1,385,439	46,791	0.32	0.31	0.02	0.18	442,271	425,373	27,724	244,122	16,489	312,385
1996	3,626,100	1.41	1,866,172	0.80	1,492,938	55,985	0.32	0.31	0.02	0.18	476,588	458,379	29,875	263,064	16,798	337,044
1997	3,664,300	1.44	1,925,956	0.83	1,588,914	48,149	0.30	0.31	0.02	0.18	476,674	492,563	31,778	286,004	23,529	359,705
1998	3,703,100	1.46	1,975,653	0.85	1,685,766	80,999	0.27	0.32	0.02	0.19	455,204	547,850	36,142	323,463	24,213	394,859
1999	3,741,600	1.62	2,212,408	0.82	1,814,175	66,372	0.27	0.34	0.02	0.19	489,878	616,819	38,895	348,102	28,400	432,976
2000	3,789,500	1.77	2,448,206	0.79	1,934,083	73,446	0.28	0.36	0.03	0.19	541,543	696,270	48,352	371,110	31,588	484,696
2001	3,847,200	1.87	2,625,566	0.76	1,992,050	78,469	0.28	0.32	0.03	0.17	555,926	638,109	56,014	346,619	27,043	459,691
2002	3,917,200	1.86	2,654,812	0.72	1,901,864	65,573	0.28	0.31	0.03	0.18	541,125	583,430	55,998	344,080	21,706	426,651
2003	3,978,900	1.96	2,846,107	0.64	1,832,625	71,779	0.28	0.31	0.03	0.18	519,590	566,361	53,567	329,548	15,446	408,733
2004	4,043,800	1.99	2,930,977	0.62	1,818,536	69,661	0.37	0.25	0.08	0.11	667,081	446,310	146,987	206,469	10,696	396,462
2005	4,130,700	1.98	2,982,037	0.61	1,833,330	58,677	0.36	0.25	0.08	0.12	667,513	449,957	146,790	217,180	5,244	391,317
2006	4,239,848	2.14	3,305,784	0.60	1,980,618	78,822	0.37	0.24	0.08	0.12	723,670	475,284	166,623	229,253	5,327	424,734

Q = G*0.25 + L*0.15 + M*0.4 + N*0.4 + O*0.15 + P

D = Total MSW – street cleanings

Table F.2 Potential CH_4 Production from Solid Waste 1968-2006

Year	DOC in MSW tonnes	DOC Managed SWDS %	DOC Unmanaged SWDS %	Fraction DOC Dissimilated	Fraction CH4 in Landfill Gas	MCF Managed SWDS	MCF Unmanaged SWDS	Pot CH4 Managed SWDS tonnes	Pot CH4 Unmanaged SWDS tonnes	Pot CH4 Total SWDS tonnes
A	B	C	D	E	F	G	H	I	J	K
1968	183,534	0.40	0.60	0.60	0.50	1.00	0.40	29,365	17,619	46,985
1969	184,353	0.40	0.60	0.60	0.50	1.00	0.40	29,496	17,698	47,194
1970	185,909	0.40	0.60	0.60	0.50	1.00	0.40	29,746	17,847	47,593
1971	187,693	0.41	0.59	0.60	0.50	1.00	0.40	30,782	17,718	48,500
1972	190,605	0.42	0.58	0.60	0.50	1.00	0.40	32,022	17,688	49,710
1973	193,667	0.43	0.57	0.60	0.50	1.00	0.40	33,311	17,662	50,973
1974	196,875	0.44	0.56	0.60	0.50	1.00	0.40	34,650	17,640	52,290
1975	200,234	0.45	0.55	0.60	0.50	1.00	0.40	36,042	17,621	53,663
1976	203,423	0.46	0.54	0.60	0.50	1.00	0.40	37,430	17,576	55,006
1977	206,203	0.47	0.53	0.60	0.50	1.00	0.40	38,766	17,486	56,252
1978	208,856	0.48	0.52	0.60	0.50	1.00	0.40	40,100	17,377	57,477
1979	212,272	0.49	0.51	0.60	0.50	1.00	0.40	41,605	17,321	58,927
1980	214,339	0.50	0.50	0.60	0.50	1.00	0.40	42,868	17,147	60,015
1981	217,011	0.51	0.49	0.60	0.50	1.00	0.40	44,270	17,014	61,284
1982	219,318	0.52	0.48	0.60	0.50	1.00	0.40	45,618	16,844	62,462
1983	220,830	0.53	0.47	0.60	0.50	1.00	0.40	46,816	16,606	63,422
1984	221,682	0.54	0.46	0.60	0.50	1.00	0.40	47,883	16,316	64,199
1985	228,878	0.55	0.45	0.60	0.50	1.00	0.40	50,353	16,479	66,832
1986	231,569	0.56	0.44	0.60	0.50	1.00	0.40	51,871	16,302	68,174
1987	236,097	0.57	0.43	0.60	0.50	1.00	0.40	53,830	16,243	70,074
1988	239,651	0.58	0.42	0.60	0.50	1.00	0.40	55,599	16,105	71,704
1989	248,621	0.59	0.41	0.60	0.50	1.00	0.40	58,675	16,310	74,984
1990	260,680	0.60	0.40	0.60	0.50	1.00	0.40	62,563	16,684	79,247
1991	268,938	0.60	0.40	0.60	0.50	1.00	0.40	64,545	17,212	81,757
1992	285,771	0.60	0.40	0.60	0.50	1.00	0.40	68,585	18,289	86,874
1993	295,816	0.60	0.40	0.60	0.50	1.00	0.40	70,996	18,932	89,928
1994	310,320	0.60	0.40	0.60	0.50	1.00	0.40	74,477	19,861	94,337
1995	312,385	0.60	0.40	0.60	0.50	1.00	0.40	74,972	19,993	94,965
1996	337,044	0.60	0.40	0.60	0.50	1.00	0.40	80,890	21,571	102,461
1997	359,705	0.60	0.40	0.60	0.50	1.00	0.40	86,329	23,021	109,350
1998	394,859	0.61	0.39	0.60	0.50	1.00	0.40	96,346	24,639	120,985
1999	432,976	0.62	0.38	0.60	0.50	1.00	0.40	107,378	26,325	133,703
2000	484,696	0.63	0.37	0.60	0.50	1.00	0.40	122,143	28,694	150,837
2001	459,691	0.69	0.31	0.60	0.50	1.00	0.40	127,610	22,506	150,117
2002	426,651	0.76	0.24	0.60	0.50	1.00	0.40	129,361	16,520	145,881
2003	408,733	0.82	0.18	0.60	0.50	1.00	0.40	134,391	11,641	146,032
2004	396,462	0.89	0.11	0.60	0.50	1.00	0.40	140,506	7,231	147,738
2005	391,317	0.95	0.05	0.60	0.50	1.00	0.40	148,700	3,131	151,831
2006	424,734	0.96	0.04	0.60	0.50	1.00	0.40	163,098	2,718	165,816

E from GPG

G and H from IPCC Guidelines

I = B*C*E*F*G*16/12

J = B*D*E*F*H*16/12

K = I + J

Table F.3 Production of CH_4 from municipal solid waste disposed in SWDS

Years elapsed since waste deposition	Production rate of landfill Gas (LFG Units)	Proportion of CH_4 within LFG (%)	Methane Units (B x C)	Proportionate production rate of CH4 *	Percentage CH_4 contribution to 20-year CH_4 production cycle
A	B	C	D	E	F
1	0.12	0	0.000	0.0000	0.0
2	0.87	20	0.174	0.3330	6.0
3	1.05	45	0.473	0.9043	16.4
4	0.95	55	0.523	1.0000	18.1
5	0.35	65	0.228	0.4354	7.9
6	0.23	70	0.161	0.3081	5.6
7	0.22	70	0.154	0.2947	5.5
8	0.20	70	0.140	0.2679	4.9
9	0.18	70	0.126	0.2411	4.4
10	0.18	70	0.126	0.2411	4.4
11	0.16	70	0.112	0.2144	3.9
12	0.14	70	0.098	0.1876	3.4
13	0.14	70	0.098	0.1876	3.4
14	0.14	70	0.098	0.1876	3.4
15	0.12	70	0.084	0.1607	2.9
16	0.11	68	0.075	0.1432	2.6
17	0.10	65	0.065	0.1244	2.3
18	0.08	60	0.048	0.0919	1.7
19	0.07	55	0.039	0.0737	1.3
20	0.06	50	0.030	0.0574	1.0
21	0.06	50	0.030	0.0574	1.0

* The peak production of methane takes place in year 4, which is given a base value of 1. All methane production in other years is expressed as a proportion of the quantity produced in year 4.