IRELAND

NATIONAL INVENTORY REPORT 2006

GREENHOUSE GAS EMISSIONS 1990 - 2004
REPORTED TO THE UNITED NATIONS
FRAMEWORK CONVENTION
ON CLIMATE CHANGE

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CONTENTS

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List of Tables

List of Figures

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, background information and the entire process of inventory compilation for greenhouse gases and to give details of any recalculations of historical inventories. It is needed to assess the transparency, completeness and overall quality of the inventories as part of the rigorous ongoing review of submissions from Annex I Parties.

The present report constitutes Irelands NIR for 2006 and refers to the inventory time-series for the years 1990-2004. It is an update of the 2005 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). The inclusion of estimates of emissions and removals for the sector Land Use Land-Use Change and Forestry for the first time according to the requirements of Decision 13/CP.9 is a major improvement in relation to completeness of inventory reporting under the Convention. A comprehensive set of Annexes are part of the report, which include calculation sheets and other appropriate reference material to support the description of methods and achieve adequate transparency, as required by the UNFCCC Reporting Guidelines.

The Environmental Protection Agency performs the role of inventory agency in Ireland and has for many years been responsible for compiling the annual inventories and for submitting the results to meet UNFCCC and EU reporting requirements. Significant progress was achieved during 2005 to consolidate the Agency's role in this regard as part of general improvements to develop a formal national system for implementation of the Kyoto Protocol. In addition to complying with the UNFCCC reporting guidelines, the 2006 NIR is intended to inform 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 prepare for the challenge to comply with commitments under 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 allows data suppliers to become fully aware of the importance of their contributions to the inventory process and serves to identify areas where improvements in input data can be achieved.

ES.2 Emissions Profile and Key Categories

In 2004, total emissions of greenhouse gases in Ireland were 68.46 million tonnes CO_2 equivalent. The *Energy* sector accounted for 64.9 percent of total emissions, *Agriculture* contributed 27.7 percent while a further 4.6 percent emanated from *Industrial Processes* and 2.7 percent was due to *Waste*. Emissions of CO_2 accounted for 66 percent of the total of 68.46 million tonnes CO_2 equivalent in 2004, with CH_4 and N_2O contributing 19.4 percent and 13.5 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for approximately one percent of total emissions in 2004.

Tier 1 level assessment of emission source categories (ranking on the basis of their contribution to total emissions) at the level at which they could be targeted on an individual basis identified 26 key categories in 2004 (excluding the LULUCF sector). There were 13 key categories of CO_2, accounting for 64.8 percent of total emissions. There were seven key categories of CH_4 and five key categories of N_2O in level assessment, which accounted for 18.8 percent and 11.6 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 CO_2 emissions accounted for 15 out of 26 key categories identified by level assessment in 2004 and for 61 percent of total emissions. The top ten key source categories contributed almost 70 percent of total emissions in 2004 with emissions of CO_2 from the combustion of petrol and diesel by road traffic beings the single largest source, accounting for 17 percent of the total.

The application of uncertainty analysis for Irish greenhouse gas inventories indicates an overall level uncertainty of 6.66 percent in the 2004 inventory and a trend uncertainty of 3.4 percent for the period 1990 to 2004. These values represent some reductions on those in previous submissions due to improved methodologies for some major sources of CH_4. 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. Two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have an uncertainty of just over one percent. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2004 is negligible because they account for less than 1 percent of total emissions.

ES.3 Overview of Emissions Estimates and Trends

The EPA has compiled a consistent time-series of greenhouse gas inventories for the years 1990 through 2004 for submission to the UNFCCC secretariat in April 2006. The results are available as a complete set of Common Reporting Format files, generated by the CRF Reporter, the electronic reporting protocol adopted for annual data submissions. 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. Substantial recalculations have been undertaken for the purposes of the 2006 submission, with particular emphasis on the base year, and the latest inventories for the years 1990-2003 reflect these revisions.

Total emissions increased from 55.613 million tonnes CO_2 equivalent in 1990 to 70.55 million tonnes CO_2 equivalent in 2001. Following this period of sustained increase, the emissions decreased to 68.46 million tonnes CO_2 equivalent in 2004, a reduction of approximately three percent on their highest level in 2001. The decrease is to due a number of factors, including the closure of Irelands nitric acid plant and ammonia production plants in 2002, CO_2 reduction through increased energy efficiency the greater use of cleaner fuels in electricity generation and decreases in CH_4 and N_2O emissions in agriculture, resulting from a decline in both cattle populations and fertilizer use. The emissions in 2004 were 23.1 percent higher than in 1990.

Greenhouse gas emissions associated with road traffic, manufacturing industries especially cement production, solid waste disposal and the consumption of halocarbons and SF_6 are increasing steadily in Ireland. In contrast, emissions have decreased marginally in recent years in the major contributing sectors of agriculture and electricity generation. The coverage of sources of emissions and removals in LULUCF is now complete for the years 1990-2004. Even though a rather simplified approach has had to be followed due to the level and type of land area information available, the assessment of emissions and removals according to the reporting requirements of Decision 13/CP.9 has given a new understanding of the contribution of this sector to the overall inventory and it has identified a number of important CO_2 emission sources in the sector that offset carbon sequestration in Irish forests.

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 their annual emissions over the period 1990-2004 are included. 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 60 percent for SO_2 and 40 percent for CO and NMVOC. However, in the case of NO_X, the emissions reductions have been more difficult to achieve due to the large increase in road traffic with the result that emissions in 2004 were at the same level as in 1990, following a decrease of approximately 10 percent on their highest levels around 2001.

ES.5 Special Status of the 2006 Submission

The emissions inventory time-series presented in this NIR for the years 1990-2004 constitutes a key component of several other important national reports due to be submitted in 2006. These reports are the Fourth National Communication under the Convention, the report on demonstrable progress and the initial report under the Protocol for the purpose of determining assigned amount (allowable emissions in the first commitment period). The estimates of emissions in the base year (represented by CO_2, CH_4 and N_2O emissions in 1990 together with emissions of fluorinated gases in 1995) are of particular significance to the present submission because this reporting cycle is the final opportunity for revising such estimates, as they must become fixed for the purposes of the initial report. The base year estimates have therefore received special attention in the 2006 reporting cycle and they are revised significantly in some sectors to reflect major improvements to methodologies and data treatment that have been made to comply as closely as possible with the UNFCCC reporting guidelines and IPCC good practice guidance.

The 2006 NIR includes an additional chapter (Chapter Ten) on the calculation of proposed assigned amount for Ireland using the most recent and improved estimates of emissions in the base year. The revised estimate of emissions of greenhouse gases in Ireland in the base year according to this submission is 55.78 million tonnes CO_2 equivalent. The proposed assigned amount for Ireland in the first commitment period, calculated as five times this value of emissions and increased by 13 percent, is 315.16 million tonnes CO_2 equivalent. This corresponds to 63 million tonnes CO_2 equivalent per year over the period 2008-2012, which may be compared to the level of 68.46 million tonnes CO_2 equivalent in 2004.

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 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 reporting guidelines require that Parties submit a National Inventory Report (NIR) as one of 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 recalculations of historical inventories. It is needed to assess the transparency, completeness and overall quality of the inventories as part of the ongoing review of submissions from Annex I Parties.

The present report constitutes Irelands NIR for 2006 and refers to the inventory time-series for the years 1990-2004. It is an update of the 2005 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 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 information, including calculation sheets as appropriate, to facilitate replication of the emissions 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 guidelines, the report is intended to inform national agencies and Government departments of the state of the art of Irish greenhouse gas inventories as they face the challenge to curb the growth in emissions. 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 data suppliers, 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 being updated annually in accordance with the UNFCCC guidelines and is published on the web site of the EPA [http://coe.epa.ie/CRF2006/nirdownloads.html]. 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. 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.

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 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 coverage, methods, emissions and key source categories.

1.3 Institutional and Procedural Arrangements

1.3.1 Current Practice

The Irish Environmental Protection Agency (EPA) was established by the Environmental Protection Agency Act of 1992 (DOE, 1992). Under Section 52 of the EPA Act, 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. There are two other parallel projects dealing with emissions of other compounds.

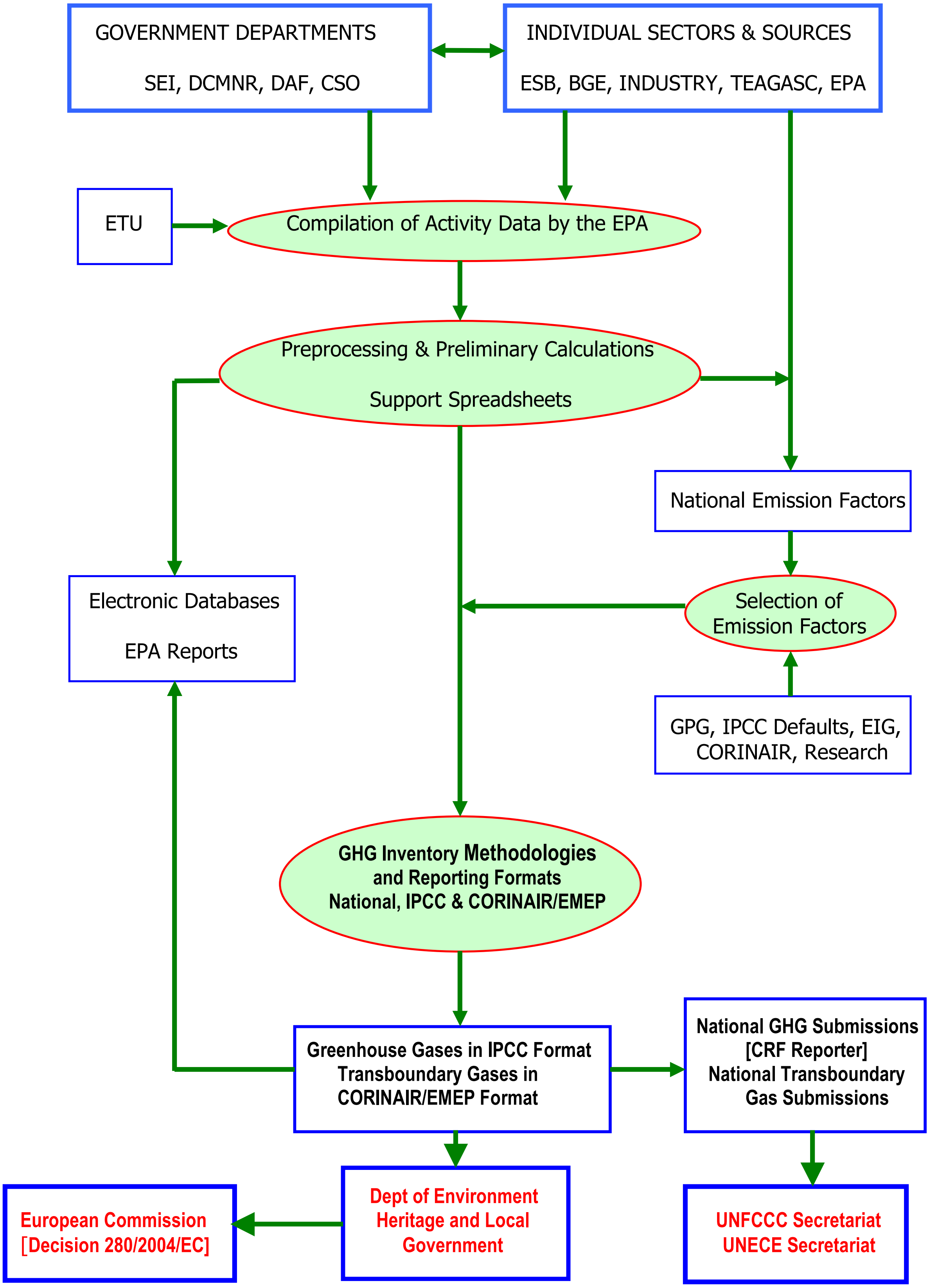
The Department of the Environment Heritage and Local Government (DEHLG) has designated the EPA as the inventory agency with responsibility for the submission of emissions data to the UNFCCC Secretariat and to the UNECE Secretariat. The Agency's Office of Environmental Assessment compiles the national 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, 2004), which has become the basis for EU Member States' reporting under the Convention and the Kyoto Protocol.

Figure 1.1 gives a schematic overview of the institutions and information flows involved in compiling Irish emission inventories for a variety of compounds emitted into the atmosphere, including greenhouse gases. The EPA receives the energy balance statistics from Sustainable Energy Ireland (SEI) while agricultural statistics are obtained from the Department of Agriculture and Food (DAF) and from the Central Statistics Office (CSO). These primary inputs are complemented by contributions from specific energy and industrial sub-sectors and by information from some of the EPA databases. The emissions of SO_2, NO_X and CO_2 from power plants are obtained on a plant-by-plant basis from electricity companies and similar data are available for a number of large industrial sources. Gas production and distribution companies supply estimates of the gas losses associated with natural gas.

As part of the EPA's implementation of a licensing system for Integrated Pollution Control (IPC), information on the emissions of a wide range of substances, including greenhouse gases, is now becoming more readily available for combustion and process emission sources in industry in general. The Annual Environmental Reports (AER) submitted by licensed companies provide useful information on emissions to air and they may be readily accessed within the Agency for inventory purposes. Information in the National Waste Database maintained by the EPA together with data on landfill gas utilisation and flaring is used as the primary inputs to estimate methane emissions from landfills.

The Emissions Trading Unit (ETU), established within the EPA in late 2003 to implement Directive 2003/87/EC (EP and CEU, 2003) in Ireland, is an important new source of activity-specific and company-specific data on emissions of greenhouse gases. Emissions trading covers approximately 100 plants and installations in Ireland with combined CO_2 equivalent emissions of approximately 24 million tonnes annually, equal to approximately 35 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, will consolidate and improve the information in relation to a substantial proportion of emissions for the purposes of reporting under the Convention. Although formal returns under the scheme will only begin in 2006, the inventory agency has been able to access some historical data for some sectors acquired in the preparation of National Allocation Plans under the Directive, which establishes an important new link in Figure 1.1.

Various preparatory calculations and conversions 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 CRF structure. Suitable emission factors are applied to the activity data to calculate emissions in a top-down manner and the results are combined with those already available in a bottom-up approach 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 offices in Dublin.



DCMNR : Department of Communications Marine & Natural Resources
ETU : Emissions Trading Unit
DAF : Department of Agriculture and Food
CSO : Central Statistics Office
IPCC : Intergovernmental Panel on Climate Change

ESB : Electricity Supply Board
EPA : Environmental Protection Agency
BGE : Bord Gais Eireann
EIG : Emissions Inventory Guidebook
SEI : Sustainable Energy Ireland

Figure 1.1. Inventory Institutional and Procedural Arrangements

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	NA	NA	NA	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 Change and Forestry						
A. Forest Land	Tier 1&3	NA	NA	NA	NA	NA
B. Cropland	Tier 1	NA	NA	NA	NA	NA
C. Grassland	Tier 1	NA	NA	NA	NA	NA
D. Wetlands	Tier 1	NA	NA	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	NA	NA	NA	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 Change and Forestry						
A. Forest Land	CS, D	NA	NA	NA	NA	NA
B. Cropland	D	NA	NA	NA	NA	NA
C. Grassland	D	NA	NA	NA	NA	NA
D. Wetlands	D	NA	NA	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

1.3.2 National System Development

During 2005 the EPA contracted UK consultants NETCEN to undertake 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 Agency 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 are benchmarked on systems in operation in other EU Member States and they prescribe how current arrangements can be enhanced within the existing statutory framework according to a plan of action that will make the system operational by the end of 2005, thereby meeting one of the key requirements set down in Decision 280/2004/EC. The scoping report also gives recommendations on internal inventory review and a database system to facilitate more efficient data management and reporting.

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 IPCC Guidelines and good practice 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 1990-2004. The current situation regarding data availability and national circumstances dictates the use of a combination of Tier 1 and Tier 2 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 in which country-specific methods and data dominate account for 75 percent of total emissions.

1.5 Overview of Key Categories

The IPCC good practice guidance defines a key category as one that is prioritised within the national inventory system because its emission estimate has a significant influence on the Party's total inventory in terms of the absolute level of emissions, the trend in emissions or both. Information about key categories is considered to be crucial to the choice of methodology for individual sources and to the management and reduction of overall inventory uncertainty. The identification of such categories is recommended in order that inventory agencies can give them priority in the preparation of annual inventories, especially in cases where resources may be limited. Information on key categories is clearly also vital for the development of policies and measures for emissions reduction. The IPCC good practice guidance provides several methods for undertaking an analysis of key sources that can be applied at any appropriate level of source aggregation, depending on the information available. The simplest approach is used for 2004 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, if 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 2004 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 86 percent of total emissions in 1990 and 2004, respectively. In the case of 2004 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 9.05 percent in 1990 to 17.66 percent in 2004, 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.

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	CO2	11,099.29	19.92	19.92
1.A.4	Other Sectors	CO2	9,997.67	17.94	37.86
4.A	Enteric Fermentation	CH4	9,337.80	16.76	54.62
4.D	Agricultural Soils	N2O	7,270.58	13.05	67.67
1.A.3	Transport	CO2	5,035.61	9.04	76.71
1.A.2	Manufacturing Industries and Construction	CO2	4,112.24	7.38	84.09
4.B	Manure Management	CH4	2,226.23	4.00	88.08
6.A	Solid Waste Disposal on Land	CH4	1,332.05	2.39	90.48
2.B.2	Nitric Acid Production	N2O	1,035.40	1.86	92.33
2.B.1	Ammonia Production	CO2	989.17	1.78	94.11
2.A.1	Cement Production	CO2	884.00	1.59	95.70

Table 1.4. Key Categories at IPCC Level 2 in 2004

IPCC Level 2 Source Category		GHG	Emissions in 2004 Gg CO_2 eq	2004 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO2	15,218.91	22.23	22.23
1.A.3	Transport	CO2	12,092.64	17.66	39.89
1.A.4	Other Sectors	CO2	10,594.83	15.48	55.37
4.A	Enteric Fermentation	CH4	9,232.58	13.49	68.86
4.D	Agricultural Soils	N2O	7,171.38	10.48	79.33
1.A.2	Manufacturing Industries and Construction	CO2	4,710.24	6.88	86.21
2.A.1	Cement Production	CO2	2,290.00	3.35	89.56
4.B	Manure Management	N2O	2,165.38	3.16	92.72
6.A	Solid Waste Disposal on Land	N2O	1,678.01	2.45	95.17

1.5.2 Disaggregated Key Categories

Ireland has used 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 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 2004 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 2004 are shown in Table 1.7. The results of the assessment for 2004 excluding LULUCF may be summarised as follows

(i) level assessment identifies 25 key categories;

(ii) there are 13 key categories of CO_2 in level assessment, accounting for 64.6 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 19 percent and 11.1 percent, respectively, of total emissions;

(iv) trend assessment identifies 23 key categories;

(v) there are 12 key categories of CO_2 in trend assessment, accounting for 76.9 percent of the total trend;

(vi) there are five key categories of CH_4 and four key categories of N_2O in trend assessment, which account for 9.4 percent and 6.9 percent, respectively, of the total trend;

(vii) all but two of the key categories identified by trend assessment (HFC emissions and PFC emissions under *2.F Consumption of Halocarbons and* SF_6) are also identified by level assessment;

(viii) in level assessment, *Energy* accounts for 13 key categories, *Agriculture* for nine while *Industrial Processes* contributes two and *Waste* contributes one;

(ix) in trend assessment, *Energy* accounts for 12 key categories, *Industrial Processes* for three and eight are given by *Agriculture*.

The list of key categories given by level assessment in 1990 is very similar to that for 2004 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 2004. The top ten key sources contributed approximately two-thirds of total emissions in both years. The closure of

Ireland's ammonia and nitric acid plants in 2002 means the loss of two key categories. The emissions 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 2004, accounting for 17 percent of the total.

1.5.3 Application of Results

The Tier 1 approach to the determination of key source 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 source 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 key categories in 2004 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 those sources 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 of sources 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 the increasing impact of CO_2 emissions from energy consumption on total emissions in Ireland. These emissions account for 12 of the key categories listed in Table 1.6 and for 61.2 percent of total emissions. While key categories determined by CO_2 emissions from energy consumption have a major bearing on total emissions in Ireland, the 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 in this submission 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 percent of the total are also known with probably their lowest possible respective uncertainties. 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 key categories in Table 1.6. The uncertainties in the estimates for these sources (Section 1.7) will remain high due to the large number of factors that influence the emissions and the relatively simple methods that must still be used.

1.6 Quality Assurance and Quality Control

The inventory preparation process employed in Ireland incorporates a number of activities that may be regarded as fundamental elements of quality control but they are not carried out in the context of a formal QA/QC process and there are no review procedures that qualify as quality assurance. This duplication given by the use of a number of calculation systems provides rigorous internal checking of the general calculation process and it ensures that there is consistency of application regarding units, aggregation, inputs that are common to several source categories and, in the case of the *Energy* sector, the inclusion of emissions estimates supplied by several external contributing bodies. Simple comparison of source category totals at IPCC Level 1 or Level 2 and at the national scale provides convenient completeness checks and immediate identification of gross errors or omissions.

In early 2005, 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 of a continuous improvement system for the inventory.

The inventory agency has used the 2006 reporting cycle to begin to implement the basic elements of the new approach to QA/QC. This involves 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.

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 2004 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 2004 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, the body responsible for compiling the national energy balance, has completed a process to expand and improve Irish energy balances, which provides further insight into uncertainty in the statistical data compiled from annual fuel-use questionnaires. The inventory experts have collaborated 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 Emissions Trading Unit within the EPA, were also investigated in an attempt to substantiate the quantitative estimates of uncertainty in activity data obtained in this way.

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 all 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 1.6 show how some of these revised uncertainty inputs were obtained. The application of the Tier 2 method for CH4 emissions from enteric fermentation in cattle and the use of improved country-specific information related to manure management (Chapter Seven) 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 more robust data are available through implementation of the EU emissions trading scheme (Chapter Three).

The Tier 1 uncertainty analysis for 2004 gives an overall uncertainty of 6.66 percent in total emissions and a trend uncertainty of 3.4 percent for the period 1990 to 2004. 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. Two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have a level uncertainty of just over one percent. When CH_4 is included, bringing the proportion of total emissions up to 86 percent, the total uncertainty is of the order of two 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 2004 and the relatively small share of this gas in total emissions. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2004 is 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 2004 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 has served to provide the information needed to fill a number of gaps in the inventories for Ireland, including F-gas estimates for the years 1990-1994 and estimates of emissions and removals for all years in the CRF tables for LULUCF adopted by Decision 13/CP.9. These improvements, together with the inclusion of some minor additional sources, result in full coverage with respect to sources, gases and years. In addition, the overall effect of improving the methodology and data application in some key areas with particular focus on the inventory year 2004 and the base year 1990, along with recalculation of the inventories for the extended intervening period on the same basis, is to bring greater internal consistency in the inventories for the 15 years. 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 CO2	1990 Emission inc LULUCF Gg CO2	1990 Emission inc LULUCF Gg CO2	1990 Level Assessment exc LULUCF %	Cumulative Level exc LULUCF %	1990 Level Assessment inc LULUCF %	Cumulative Level inc LULUCF %
1	1.A.1(ii)	Energy Industries-Solid Fuels	CO2	7950.72		7950.72	14.30	14.30	13.74	13.71
2	1.A.4(b)(ii)	Residential-Solid Fuels	CO2	5607.87		5607.87	10.08	24.38	9.69	23.37
3	4.A.2	Enteric Fermentation-Non-Dairy Cattle	CH4	5374.69		5374.69	9.66	34.04	9.29	32.64
4	1.A.3(b)(i)	Road Transport-Liquid fuels	CO2	4695.81		4695.81	8.44	42.49	8.11	40.73
5	4.D.1	Agricultural Soils-Direct Emissions	N2O	3047.92		3047.92	5.48	47.97	5.27	45.99
6	4.A.1	Enteric Fermentation-Dairy Cattle	CH4	2894.77		2894.77	5.21	53.17	5.00	50.98
7	4.D.2	Agricultural Soils-Pasture Range and Paddock	N2O	2835.57		2835.57	5.10	58.27	4.90	55.86
8	1.A.2	Manufacturing Industries and Construction-Liquid Fuels	CO2	2231.77		2231.77	4.01	62.28	3.86	59.71
9	1.A.4(a)(i)	Commercial/Institutional-Liquid Fuels	CO2	1977.23		1977.23	3.56	65.84	3.42	63.12
10	1.A.1(iii)	Energy Industries-Gaseous Fuels	CO2	1880.66		1880.66	3.38	69.22	3.25	66.36
11	4.D.3	Agricultural Soils-Indirect Emissions	N2O	1387.25		1387.25	2.49	71.72	2.40	68.75
12	6.A	Solid Waste Disposal on Land	CH4	1332.05		1332.05	2.40	74.11	2.30	71.05
13	1.A.1(i)	Energy Industries-Liquid Fuels	CO2	1267.91		1267.91	2.28	76.39	2.19	73.24
14	4.B(a).1	Manure Management-Non Dairy	CH4	1234.07		1234.07	2.22	78.61	2.13	75.36
15	1.A.4(b)(i)	Residential-Liquid Fuels	CO2	1193.78		1193.78	2.15	80.76	2.06	77.42
16	5.A.1	Forest Land Remaining Forest Land	CO2		-1078.90	1078.90			1.86	79.28
17	2.B.2	Nitric Acid Production	N2O	1035.40		1035.40	1.86	82.62	1.79	81.07
18	4.A.3	Enteric Fermentation-Sheep	CH4	1032.48		1032.48	1.86	84.48	1.78	82.85
19	1.A.2(ii)	Manufacturing Industries and Construction-Solid Fuels	CO2	999.48		999.48	1.80	86.27	1.73	84.57
20	2.B.1	Ammonia Production	CO2	989.17		989.17	1.78	88.05	1.71	86.27
21	2.A.1	Cement Production	CO2	884.00		884.00	1.59	89.64	1.53	87.80
22	1.A.2(iii)	Manufacturing Industries and Construction-Gaseous Fuels	CO2	880.99		880.99	1.58	91.22	1.52	89.32
23	1.A.4(c)(i)	Agriculture/Forestry/Fishing Liquid Fuels	CO2	659.82		659.82	1.19	92.41	1.14	90.45
24	4.B(a).1	Manure Management-Dairy Cattle	CH4	615.90		615.90	1.11	93.52	1.06	91.52
25	5.A.2	Land Converted to Forest Land	CO2		599.92	599.92			1.03	92.55
26	5(IV)	Agricultural Lime Application	CO3		355.04	355.04			0.61	93.16
27	4.B(b).13	Manure Management-Solid Storage	N2O	350.30		350.30	0.63	94.15	0.60	93.77
28	4.B(a).8	Manure Management-Pigs	CH4	327.77		327.77	0.59	94.74	0.57	94.33
29	1.A.1(ii)	Energy Industries-Solid Fuels	N2O	318.27		318.27	0.57	95.31	0.55	94.88
30	5.C.1	Grasssland Remaining Grassland	CO2		295.97	295.97			0.51	95.39

Table 1.6 Disaggregated Key Categories 2004

2004 Rank	IPCC Sub-Category	Emission Source/Activity	Gas	2004 Emission exc LULUCF Gg CO2	2004 Emission inc LULUCF Gg CO2	2004 Emission inc LULUCF Gg CO2	2004 Level Assessment exc LULUCF %	Cumulative Level exc LULUCF %	2004 Level Assessment inc LULUCF %	Cumulative Level inc LULUCF %
1	1.A.3(b)(i)	Road Transport-Liquid fuels	CO2	11674.62		11674.622	17.05	17.05	16.67	16.67
2	1.A.1(ii)	Energy Industries-Solid Fuels	CO2	7193.83		7193.83	10.51	27.56	10.27	26.94
3	4.A.1	Enteric Fermentation-Non-Dairy	CH4	5692.47		5692.47	8.32	35.88	8.13	35.07
4	1.A.1(iii)	Energy Industries-Gaseous Fuels	CO2	5118.79		5118.79	7.48	43.35	7.31	42.38
5	1.A.4(b)(i)	Residential-Liquid Fuels	CO2	3371.29		3371.292	4.92	48.28	4.81	47.19
6	1.A.2(I)	Manufacturing Industries and Construction-Liquid Fuels	CO2	3256.02		3256.02	4.76	53.03	4.65	51.84
7	4.D.1	Agricultural Soils-Direct Emissions	N2O	2985.61		2985.61	4.36	57.40	4.26	56.10
8	1.A.1(i)	Energy Industries-Liquid Fuels	CO2	2906.29		2906.29	4.25	61.64	4.15	60.25
9	4.D.2	Agricultural Soils-Pasture Range and Paddock	N2O	2814.80		2814.80	4.11	65.75	4.02	64.27
10	4.A.1	Enteric Fermentation-Dairy Cattle	CH4	2634.17		2634.17	3.85	69.60	3.76	68.03
11	2.A.1	Cement Production	CO2	2290.00		2290.00	3.35	72.94	3.27	71.30
12	1.A.4(a)(i)	Commercial/Institutional-Liquid Fuels	CO2	2126.28		2126.278	3.11	76.05	3.04	74.34
13	1.A.4(b)(ii)	Residential-Solid Fuels	CO2	2068.48		2068.476	3.02	79.07	2.95	77.29
14	6.A	Solid Waste Disposal on land	CH4	1678.01		1678.01	2.45	81.52	2.40	79.69
15	1.A.4(b)(iii)	Residential-Gaseous Fuels	CO2	1409.45		1409.448	2.06	83.58	2.01	81.70
16	4.D.3	Agricultural Soils-Indirect	N2O	1370.82		1370.82	2.00	85.58	1.96	83.66
17	1.A.2(iii)	Manufacturing Industries and Construction Gaseous Fuels	CO2	1256.16		1256.16	1.83	87.42	1.79	85.45
18	4.B(a).1	Manure Management-Non Dairy Cattle	CH4	1168.10		1168.10	1.71	89.13	1.67	87.12
19	4.A.3	Enteric Fermentation-Sheep	CH4	860.60		860.60	1.26	90.38	1.23	88.35
20	1.A.4(c)(i)	Agriculture/Forestry/Fishing Liquid Fuels	CO2	803.14		803.138	1.17	91.56	1.15	89.49
21	5.A.1	Forest Land Remaining Forest Land	CO2		-724.25	724.25			1.03	90.53
22	1.A.4(a)(iii)	Commercial/Institutional-Gaseous Fuels	CO2	713.65		713.65	1.04	92.60	1.02	91.55
23	4.B(a).1	Manure Management-Dairy Cattle	CH4	498.44		498.44	0.73	93.33	0.71	92.26
24	4.B(a).8	Manure Management-Pigs	CH4	444.35		444.35	0.65	93.98	0.63	92.89
25	1.A.3(b)(i)	Road Transport Liquid fuels	N2O	413.23		413.23	0.60	94.58	0.59	93.48
26	2.F	Consumption of Halocarbons and SF6	HFC	399.25		399.254	0.58	95.16	0.57	94.05
27	4.B(b).13	Manure Management-Solid Storage	N2O	356.19		356.19	0.52	95.68	0.51	94.56
28	1.A.1(ii)	Energy Industries-Solid Fuels	N2O	297.91		297.91	0.44	96.12	0.43	94.99
29	5.C.1	Grassland Remaining Grassland	CO2		262.68	262.68			0.38	95.36

Table 1.7 Key Category Trend Assessment 2004

Rank	Category	Emission Source	Gas	Emissions in 1990 Gg CO2	Emissions in 2004 Gg CO2	Level Assessment %	Trend Assessment	Contribution to Trend %	Cumulative Contribution to Trend %
1	1.A.3(b)(i)	Road Transport-Liquid fuels	CO2	4695.81	11674.62	17.05	6.9539	18.87	18.87
2	1.A.4(b)(ii)	Residential-Solid Fuels	CO2	5607.87	2068.48	3.02	5.7441	15.59	34.45
3	1.A.1(iii)	Energy Industries-Gaseous Fuels	CO2	1880.66	5118.79	7.48	3.3093	8.98	43.43
4	1.A.1(ii)	Energy Industries-Solid Fuels	CO2	7950.72	7193.83	10.51	3.1021	8.42	51.85
5	1.A.4(b)(i)	Residential-Liquid Fuels	CO2	1193.78	3371.29	4.92	2.2451	6.09	57.94
7	1.A.1(i)	Energy Industries-Liquid Fuels	CO2	1267.91	2906.29	4.25	1.5866	4.30	62.25
6	2.A.1	Cement Production	CO2	884.00	2290.00	3.35	1.4182	3.85	66.09
8	1.A.4(b)(iii)	Residential-Gaseous Fuels	CO2	269.13	1409.45	2.06	1.2745	3.46	69.55
9	1.A.2(ii)	Manufacturing Industries and Construction-Solid Fuels	CO2	999.48	198.06	0.29	1.2256	3.33	72.88
10	4.A.2	Enteric Fermentation-Non Dairy Cattle	CH4	5374.69	5692.47	8.32	1.1157	3.03	75.90
11	4.A.1	Enteric Fermentation-Dairy Cattle	CH4	2894.77	2634.17	3.85	1.1117	3.02	78.92
12	4.D.1	Agricultural Soils-Direct Emissions	N2O	3047.92	2985.61	4.36	0.9196	2.50	81.42
13	4.D.2	Agricultural Soils-Pasture, Range and Paddock	N2O	2835.57	2814.80	4.11	0.8115	2.20	83.62
14	1.A.2(i)	Manufacturing Industries and Construction-Liquid Fuels	CO2	2231.77	3256.02	4.76	0.5925	1.61	85.23
15	1.A.4(a)(iii)	Commercial/Institutional-Gaseous Fuels	CO2	216.22	713.65	1.04	0.5285	1.43	86.66
16	4.A.3	Enteric Fermentation-Sheep	CH4	1032.48	860.60	1.26	0.4899	1.33	87.99
17	2.F	Consumption of Halocarbons and SF6	HFC	0.69	399.25	0.58	0.4714	1.28	89.27
18	4.B(a).1	Manure Management-Non Dairy Cattle	CH4	1234.07	1168.10	1.71	0.4205	1.14	90.41
19	1.A.3(b)(i)	Road Transport-Liquid fuels	N2O	56.11	413.23	0.60	0.4070	1.10	91.51
20	4.D.3	Agricultural Soils-Indirect Emissions	N2O	1387.25	1370.82	2.00	0.4045	1.10	92.61
21	1.A.4(a)(i)	Commercial/Institutional-Liquid Fuels	CO2	1977.23	2126.28	3.11	0.3724	1.01	93.62
22	4.B(a).1	Manure Management-Dairy Cattle	CH4	615.90	498.44	0.73	0.3099	0.84	94.46
24	2.F	Consumption of Halocarbons and SF6	PFC	0.09	196.37	0.29	0.2322	0.63	95.09

Table 1.8 Tier 1 Uncertainty Estimates 2004 (continued on following page)

IPCC Source Category		Gas	Emissions in 1990	Emissions in 2004	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Emissions in 2004	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 CO2	*Gg CO2*	*%*	*%*	*%*	*%*		*%*	*%*	*%*	*%*	*%*	
1A1	Energy-Liquid Fuel	CO2	1267.91	2906.29	1	2.5	2.69	0.11	0.01	0.02	0.05	0.07	0.06	0.10	0.01
1A1	Energy-Solid Fuel	CO2	7950.72	7193.83	1	5	5.10	0.53	0.29	-0.05	0.13	0.18	-0.24	0.30	0.09
1A1	Energy-Gaseous Fuel	CO2	1880.66	5118.79	1	2.5	2.69	0.20	0.04	0.05	0.09	0.13	0.13	0.18	0.03
1A2	Industry-Liquid Fuel	CO2	2016.53	2268.30	10	2.5	10.31	0.34	0.12	0.00	0.04	0.58	-0.01	0.58	0.33
1A2	Industry-Coal	CO2	871.13	156.90	2	5	5.39	0.01	0.00	-0.02	0.00	0.01	-0.08	0.08	0.01
1A2	Industry-Pet Coke	CO2	215.24	987.72	5	10	11.18	0.16	0.03	0.01	0.02	0.13	0.13	0.18	0.03
1A2	Industry-Peat	CO2	128.35	41.16	1.5	5	5.22	0.00	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
1A2	Industry-Gaseous Fuel	CO2	880.99	1256.16	2.5	2.5	3.54	0.06	0.00	0.00	0.02	0.08	0.01	0.08	0.01
1A3	Transport-Oil	CO2	4987.31	11956.73	1	2.5	2.69	0.47	0.22	0.10	0.21	0.30	0.26	0.40	0.16
1A3	Transport-Gas	CO2	48.30	135.91	1	2.5	2.69	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4	Comm/Inst-Liquid Fuel	CO2	1977.23	2126.28	10	5	11.18	0.35	0.12	-0.01	0.04	0.54	-0.03	0.54	0.29
1A4	Comm/Inst-Coal Fuel	CO2	3.96	102.55	5	10	11.18	0.02	0.00	0.00	0.00	0.01	0.02	0.02	0.00
1A4	Comm/Inst-Peat	CO2	69.67	0.00	10	20	22.36	0.00	0.00	0.00	0.00	0.00	-0.03	0.03	0.00
1A4	Comm/Inst-Gaseous Fuel	CO2	216.22	713.65	2.5	2.5	3.54	0.04	0.00	0.01	0.01	0.05	0.02	0.05	0.00
1A4	Residential-Liquid Fuel	CO2	1105.15	3244.77	10	5	11.18	0.53	0.28	0.03	0.06	0.83	0.17	0.84	0.71
1A4	Residential-Coal	CO2	2484.38	928.02	5	10	11.18	0.15	0.02	-0.04	0.02	0.12	-0.38	0.40	0.16
1A4	Residential-Petcoke	CO2	88.63	126.52	5	10	11.18	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00
1A4	Residential-Peat	CO2	3123.47	1140.46	10	20	22.36	0.37	0.14	-0.05	0.02	0.29	-0.98	1.02	1.04
1A4	Residential-Gaseous Fuel	CO2	269.13	1409.45	2.5	2.5	3.54	0.07	0.01	0.02	0.03	0.09	0.05	0.10	0.01
1A4	Agric/Forestry/Fishing Liquid Fuel	CO2	659.82	803.14	10	5	11.18	0.13	0.02	0.00	0.01	0.20	0.00	0.20	0.04
1.B	Fugitive Emissions	CO2	138.90	71.30	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	CO2	884.00	2290.00	7.5	5	9.01	0.35	0.12	0.02	0.04	0.44	0.11	0.45	0.20
2.A.2	Lime Production	CO2	214.08	201.54	5	5	7.07	0.02	0.00	0.00	0.00	0.03	-0.01	0.03	0.00
2.A.3	Limestone and Dolomite Use	CO2	7.59	12.55	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	CO2	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	CO2	80.94	74.47	30	5	30.41	0.03	0.00	0.00	0.00	0.06	0.00	0.06	0.00
	Total CO2		*32559.46*	*45266.48*				*1.18*	*1.39*					*1.77*	*3.14*
1A	Fuel Combustion-All Fuels	CH4	154.48	106.72	2	50	50.04	0.08	0.01	0.00	0.00	0.01	-0.08	0.08	0.01
1B	Fugitive Emissions	CH4	150.70	78.31	2.5	10	10.31	0.01	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
4A	Ent Ferm. Dairy Cattle	CH4	2894.77	2634.18	1	15	15.03	0.58	0.33	-0.02	0.05	0.07	-0.25	0.26	0.07
4A	Ent Ferm.Other Cattle	CH4	5374.68	5692.47	1	15	15.03	1.25	1.55	-0.02	0.10	0.14	-0.26	0.29	0.09
4A	Ent Ferm.Other Livestock	CH4	1068.35	905.93	1	30	30.02	0.40	0.16	-0.01	0.02	0.02	-0.22	0.22	0.05
4B	Manure Manag.Dairy Cattle	CH4	615.91	498.44	1	15	15.03	0.11	0.01	0.00	0.01	0.01	-0.07	0.07	0.01
4B	Manure Manag.Other Cattle	CH4	1234.07	1168.10	1	15	15.03	0.26	0.07	-0.01	0.02	0.03	-0.10	0.10	0.01
4B	Manure Manag.Other Livestock	CH4	376.25	498.83	1	30	30.02	0.22	0.05	0.00	0.01	0.01	0.02	0.02	0.00
6A	Solid Waste	CH4	1332.05	1678.01	41[a]	47[b]	62.37	1.53	2.34	0.00	0.03	1.75	0.03	1.75	3.06
6.B	Wastewater Handling	CH4	14.70	24.23	10	30	31.62	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00
	Total CH4		*13215.94*	*13285.22*				*2.13*	*4527*					*1.81*	*3.28*

	Cumulative CO2 and CH4		*45775.40*	*58551.70*				*2.43*	*5.91*					*2.53*	*6.42*
1A3	Fuel Combustion-Road Traffic	N2O	86.80	438.34	1	25	25.02	0.16	0.03	0.01	0.01	0.01	0.15	0.15	0.02
1A	Fuel Combustion-Other Sectors	N2O	889.70	1089.34	2	50	50.04	0.79	0.63	0.00	0.02	0.06	-0.01	0.06	0.00
2B	Nitric Acid Production	N2O	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	Manure Man-Liquid System	N2O	55.18	56.11	11.2[c]	100	100.63	0.08	0.01	0.00	0.00	0.02	-0.02	0.03	0.00
4B	Manure Man-Solid Storage	N2O	350.30	356.19	11.2[c]	100	100.63	0.52	0.27	0.00	0.01	0.10	-0.14	0.17	0.03
4D	Direct Soil Emissions	N2O	3047.92	2985.61	11.2[c]	100	100.63	4.37	19.12	-0.01	0.05	0.85	-1.40	1.64	2.68
4D	Pasture Range and Paddock	N2O	2835.57	2814.80	11.2[c]	100	100.63	4.12	17.00	-0.01	0.05	0.80	-1.24	1.47	2.17
4D	Indirect Emissions	N2O	1387.25	1370.82	11.2[c]	50	51.24	1.02	1.05	-0.01	0.02	0.39	-0.31	0.50	0.25
6B	Wastewater Handling	N2O	114.08	131.44	10	10	14.14	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00
	Total N2O		*9802.20*	*9242.65*				*6.19*	*38.37*					*2.26*	*5.09*
	Cumulative CO2, CH4, N2O		*55577.60*	*67794.35*				*6.65*	*44.28*					*3.39*	*11.51*
2F	Halocarbons & SF6	HFC	0.69	399.25	20	10	22.36	0.13	0.02	0.01	0.01	0.16	0.07	0.18	0.03
2F	Halocarbons & SF6	PFC	0.09	196.37	10	2.5	10.31	0.03	0.00	0.00	0.00	0.04	0.01	0.04	0.00
2F	Halocarbons & SF6	SF6	35.39	70.00	15	5	15.81	0.02	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	Total HFC, PFC and SF6		*36.18*	*665.63*				*0.13*	*0.12*					*0.19*	*0.03*
	Total all gases		*55613.78*	*68459.98*					*44.30*						*11.54*
					Level Uncertainty in Emissions			***6.66***				***Trend Uncertainty***		***3.40***	

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 CH4 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 Change and Forestry						
A. Forest Land	All	NE	NE	NA	NA	NA
B. Cropland	All	NO	IE	NA	NA	NA
C. Grassland	All	NO	IE	NA	NA	NA
D. Wetlands	All	NE	NE	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 1990-2004. These time-series data are extracted from the trend tables of the 2004 CRF and they reflect a full series of inventory recalculations conducted for the 2006 submission, which are fully described in the following chapters of this report. The major outcome of the 2006 reporting cycle and recalculations is the completion of estimates for all gases and all source-sink categories according to the UNFCCC reporting guidelines. The trends in the principal emission components within the six IPCC sectors as CO_2 equivalents are shown on Figure 2.1 through Figure 2.6. Total emissions of the six greenhouse gases in Ireland (excluding net CO_2 from *Land Use Change and Forestry*) increased steadily from 55.614 million tonnes CO_2 equivalent in 1990 to 70.55 million tonnes CO_2 equivalent in 2001 and then decreased slightly to 68.46 million tonnes CO_2 equivalent in 2004. Total emissions in 2004 were 23.1 percent higher than in 1990 and three percent lower than the peak level of 2001. The estimated total for 2004 is 100 kilotonnes CO_2 equivalent higher than that for 2003.

In 2004, the *Energy* sector accounted for 64.9 percent of total emissions, *Agriculture* contributed 27.7 percent while a further 4.6 percent emanated from *Industrial Processes* and 2.7 percent was due to *Waste*. Emissions of CO_2 accounted for 66 percent of the total of 68.46 million tonnes CO_2 equivalent in 2004, with CH_4 and N_2O contributing 19.4 percent and 13.5 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for approximately 1 percent of total emissions in 2004. 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 trends in the principal drivers of emissions in the key sectors of *Energy* and *Agriculture* are shown in Figure 2.7 and Figure 2.8, respectively.

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 amounted to 43 percent over these 12 years. The bulk of this increase occurred in the years between 1995 and 2000, during which Ireland experienced a period of unprecedented economic growth and emissions grew by around 3 percent annually. The rate of economic growth slowed down from 2000 to 2004, which together with the closure of some major industrial plants and continued decline in cattle populations and fertilizer use, resulted in some reduction in the emission levels in 2002 and 2003.

2.2 Trends by Sector and Gas

Fuel combustion in *1.A.3 Transport* and in *1.A.1 Energy Industries* accounted for 28.3 million tonnes CO_2 in 2004 or approximately 41 percent of total greenhouse gas emissions (Figure 2.1). The largest increases in CO_2 emissions have taken place in the transport sector. The CO_2 emissions from transport sources, which are largely accounted for by road traffic in Ireland, increased by 144 percent between 1990 and 2004, due to sustained growth in the numbers and in the use of passenger cars and goods vehicles. This trend is exaggerated somewhat in latter years by so-called fuel-tourism, whereby a significant proportion of the automotive fuels sold in Ireland is used by vehicles in the UK and other countries. The proportion was estimated to be approximately 12 percent for petrol in 2001-2004 and averaged 25 percent in the case of diesel in the same period. It is worth noting that in 1990 there was significant cross-border movement of automotive fuels into Ireland.

There continues to be heavy reliance on carbon intensive fuels for electricity generation in Ireland and, as electricity demand increased steadily during the 1990s, the associated CO_2 emissions from 1.A.1 Energy Industries (electricity generation and oil refining) increased by 55 percent from 11.5 million tonnes in 1990 to 17.9 million tonnes in 2001. Some gains were achieved from energy efficiency and fuel switching as some new electricity producers entered the market in 2002 and 2003, with the result that CO_2 emissions from energy industries reduced to 15.8 million tonnes in 2004, which is approximately 35 percent higher than in 1990. Residential fuel combustion (CRF sub-category 1.A.4(b)) is another important source of emissions in the *Energy* sector (Figure 2.1). Although residential energy consumption increased by about 18 percent from 1990 to 2004, the CO_2 emissions in this sub-sector show a decrease of 3 percent due to the 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 63 percent between 1990 and 2004 while those from oil and natural gas trebled over this period.

Ireland has only a small number of energy intensive industries and CO_2 emissions from combustion in the industrial sector account for only 7 percent of total emissions but, nevertheless, these emissions increased by approximately 28 percent between 1990 and 2004. The contribution from *Industrial Processes* to total emissions is also relatively small and decreased significantly in 2003 following the closure of Ireland's ammonia and nitric acid plants in June 2002. This reduction is partly offset by sustained increases in emissions of CO_2 from cement manufacture (Figure 2.2). While HFC, PFC and SF_6 emissions account for only 1 percent of the national total, the proportion of these gases in the total for *Industrial Processes* is increasing. The small contribution from the sector *Solvents and Other Product Use* shows a steady decline since 1998.

The component emission trends in *Agriculture* are shown in Figure 2.4 and the main drivers of emissions are shown on Figure 2.8. Large livestock populations produce about 0.55 million tonnes of CH_4 annually through enteric fermentation and manure management while the sustained application of large amounts of chemical and organic nitrogen to soils results in the emission of approximately 25,000 tonnes N_2O. These emissions from *Agriculture,* equal to approximately 20 million tonnes CO_2 equivalent annually, account for a comparatively larger share of total emissions in Ireland than in most other Annex I Parties. However, according to the estimates given in this NIR, this share decreased from 35percent in 1990 to approximately 28 percent in 2004 due to the sustained CO_2 increase in *Energy* and a slight downturn in both CH_4 and N_2O emissions from agriculture after 1998, reflecting the decline in the cattle population and fertilizer use.

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 2.2 and Figure 2.5). 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 Irelatively large emissions of CO_2. The complex dynamics of land-use changes between categories lead to highly fluctuating estimates of emissions and removals over the period 1990-2004.

The *Waste* sector is an important source of CH_4 emissions, the contribution of which is increasing steadily (Figure 2.6) due to the continued dominance of landfill as a means of solid waste disposal in Ireland. The downward shift in the level of emissions after 1997 reflects the effect of landfill gas utilisation at a number of sites since 1997 and flaring since 2001 but nevertheless emissions in 2003 and 2004 had returned to the 1996 level.

2.3 Emissions of Indirect Greenhouse Gases

The total emissions of SO_2, NO_X, NMVOC and CO for the years 1990 to 2004 are summarised on Table 2.1. 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 emanate from 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 2004 were similar to that in 1990.

Total SO_2 emissions decreased by approximately 62 percent, from 185,140 tonnes in 1990 to 70,920 tonnes in 2004. Power stations remain the principal source of SO_2 emissions, contributing approximately 62 per cent of the total in 2004. Combustion sources in the industrial and residential/commercial sectors largely account for the remainder of emissions, with contributions of 10 percent and 22 percent, respectively in 2003. In 1990, coal combustion accounted for 51 per cent of SO_2 emissions and fuel oil contributed 31 per cent. By 2004, the share of SO_2 emissions from coal had decreased to 44 per cent and that from fuel oil had decreased to 26 per cent. This also reflects increased dependence on natural gas for electricity generation.

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 37 per cent of the total in 2004. The power generation sector is the other main source of NO_X emissions, accounting for 27 per cent of emissions in 2003. 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 but the corresponding emissions are included in the total for Ireland.

Table 2.1. Emissions of SO_2, NO_X, VOC and CO 1990-2004 (Mg)

	SO_2	NO_X	NMVOC	CO
1990	185138	121537	108485	415445
1991	180254	124435	107374	394045
1992	171679	135119	110312	394175
1993	160904	123671	104429	349999
1994	175381	122702	103852	331109
1995	161285	122282	100797	304168
1996	147454	126740	106816	306555
1997	166267	124910	109954	311276
1998	176124	128641	111408	317061
1999	157463	126366	90828	285101
2000	130911	132713	80101	278892
2001	126858	134926	77699	274076
2002	96422	125316	71208	255146
2003	76686	119855	66729	241908
2004	70922	118954	63436	239458

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 in 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. The emissions of CO have stabilised following major reductions due to catalysts in petrol cars, which is the principal source of CO, and large decrease in the use of solid fuels in residential combustion. Further reductions in the emissions of SO_2, NO_X and NMVOC will occur in the coming years as Ireland prepares to comply with the requirements of the National Emission Ceilings Directive (EP and CEU, 2001).

Table 2.2. Greenhouse Gas Emissions 1990-2004

(a) Emissions by Gas

GREENHOUSE GAS EMISSIONS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Net CO_2 emissions/removals	32,667.65	32,858.83	33,437.87	32,823.02	34,163.99	34,987.89	36,374.48	38,639.74	40,090.59	41,890.74	44,238.96	46,530.37	45,509.39	44,136.60	45,194.89
CO_2 emissions (without LUCF) [(6)]	32,559.48	32,556.64	33,088.07	32,701.35	34,115.79	34,782.67	36,081.48	38,503.75	40,305.53	42,136.03	44,240.93	46,704.25	45,700.51	44,519.38	45,266.48
CH_4	13,215.96	13,396.72	13,468.58	13,584.48	13,584.24	13,658.67	14,061.52	14,319.02	14,259.35	13,732.07	13,376.07	13,172.85	13,146.94	13,735.97	13,285.28
N_2O	9,801.99	9,632.70	9,654.21	9,779.97	10,086.57	10,279.24	10,361.68	10,320.58	10,905.14	11,034.23	10,521.43	10,054.19	9,565.64	9,399.85	9,243.07
HFCs	0.69	5.13	5.89	8.89	20.45	44.60	75.64	130.99	189.02	194.83	228.93	253.07	288.84	357.91	399.25
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	196.37
SF_6	35.40	36.38	37.36	38.33	81.85	82.83	102.06	132.10	94.24	68.96	55.91	69.43	70.22	118.59	70.01
Total (with net CO_2 emissions/removals)	**55,721.79**	**55,929.86**	**56,604.00**	**56,234.78**	**58,012.48**	**59,128.60**	**61,078.47**	**63,673.26**	**65,600.21**	**67,116.76**	**68,726.69**	**70,375.90**	**68,793.43**	**67,977.72**	**68,388.86**
Total (without CO_2 from LUCF) [(6)]	**55,613.62**	**55,627.66**	**56,254.20**	**56,113.11**	**57,964.28**	**58,923.38**	**60,785.47**	**63,537.27**	**65,815.15**	**67,362.05**	**68,728.67**	**70,549.78**	**68,984.55**	**68,360.50**	**68,460.46**

(b) Emissions by IPCC Category

SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	31,665.36	31,757.08	32,387.91	32,008.14	33,269.36	34,002.81	35,287.99	37,493.27	39,512.58	41,500.00	43,097.80	45,402.54	44,507.99	44,346.10	44,400.91
2. Industrial Processes	3,166.43	2,866.26	2,781.45	2,746.11	3,117.66	3,062.75	3,204.72	3,656.26	3,494.73	3,560.03	4,186.65	4,294.30	3,734.39	3,050.92	3,169.72
3. Solvent and Other Product Use	80.94	82.82	83.04	83.50	84.40	86.19	86.87	87.28	88.33	85.01	80.32	79.55	77.20	75.71	74.47
4. Agriculture	19,240.15	19,425.74	19,460.76	19,688.71	19,856.60	20,083.07	20,455.48	20,582.13	21,207.28	20,787.46	19,712.98	19,296.04	19,058.84	19,137.49	18,981.72
5. Land-Use Change and Forestry [(7)]	108.17	302.20	349.80	121.67	48.20	205.22	293.01	135.99	-214.94	-245.29	-1.98	-173.88	-191.12	-382.78	-71.60
6. Waste	1,460.75	1,495.77	1,541.04	1,586.65	1,636.26	1,688.55	1,750.39	1,718.33	1,512.23	1,429.55	1,650.92	1,477.36	1,606.13	1,750.28	1,833.63
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (including net CO_2 from LUCF)	**55,721.79**	**55,929.86**	**56,604.00**	**56,234.78**	**58,012.48**	**59,128.60**	**61,078.47**	**63,673.26**	**65,600.21**	**67,116.76**	**68,726.69**	**70,375.90**	**68,793.43**	**67,977.72**	**68,388.86**

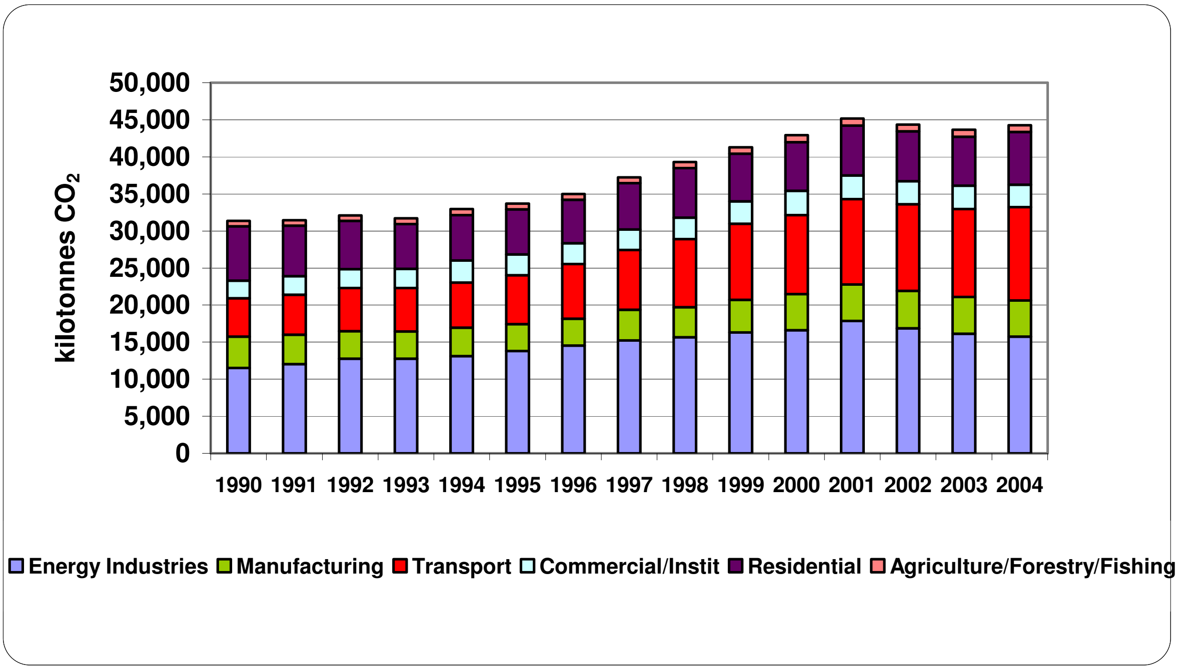


Figure 2.1 Trend in Emissions from Energy 1990-2004

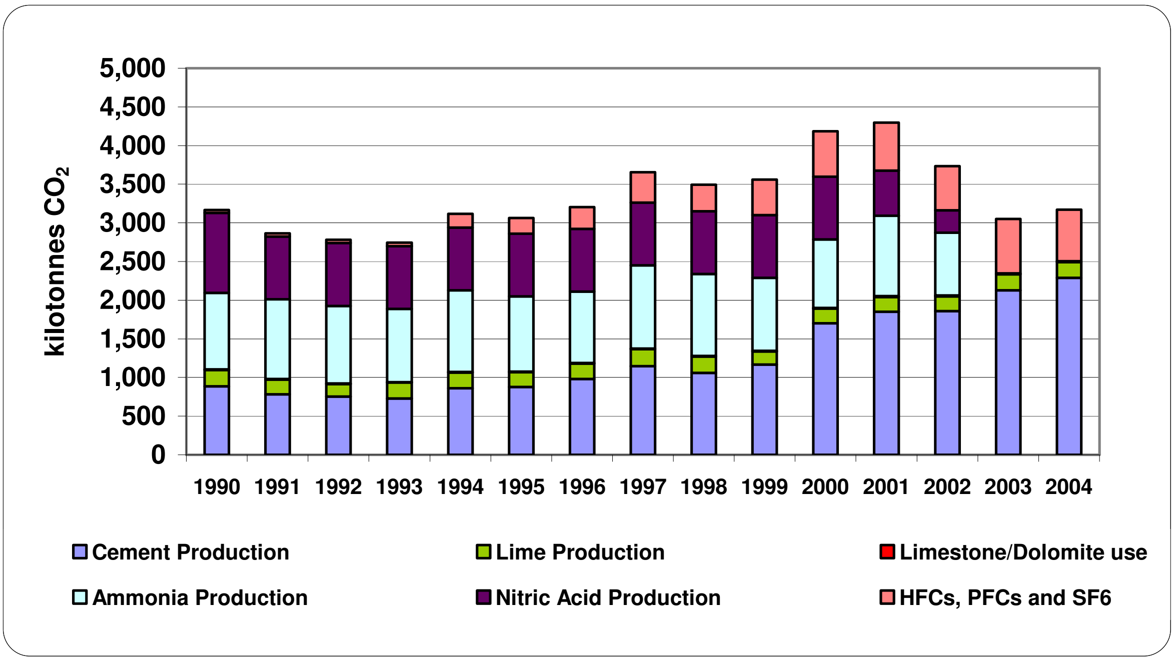


Figure 2.2 Trend in Emissions from Industrial Processes 1990-2004

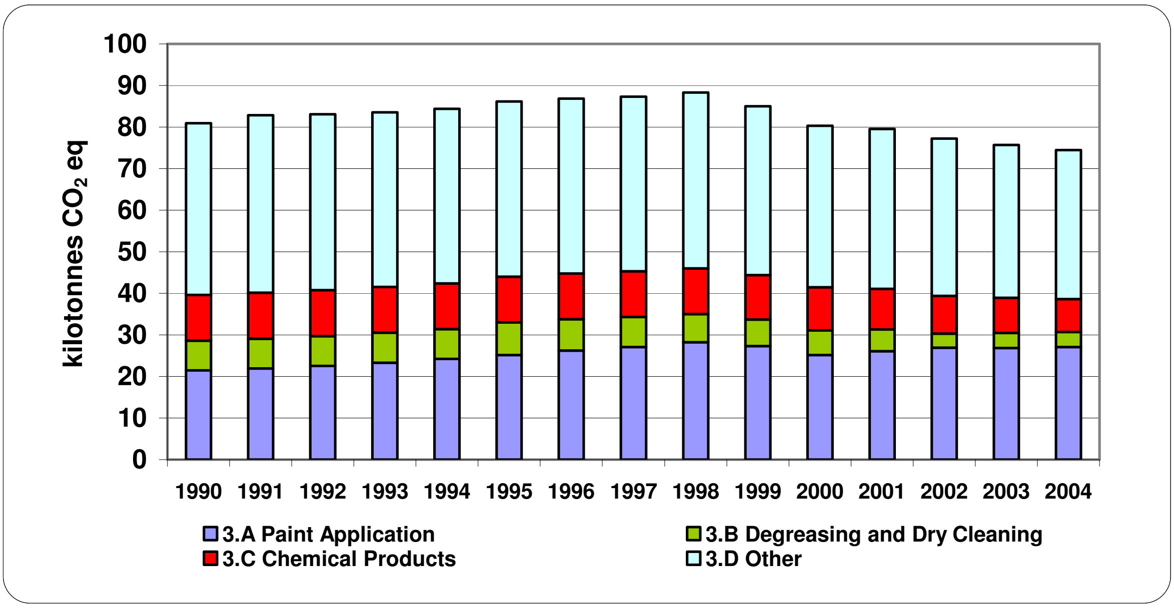


Figure 2.3 Trend in Emissions from Solvents and Other Product Use 1990-2004

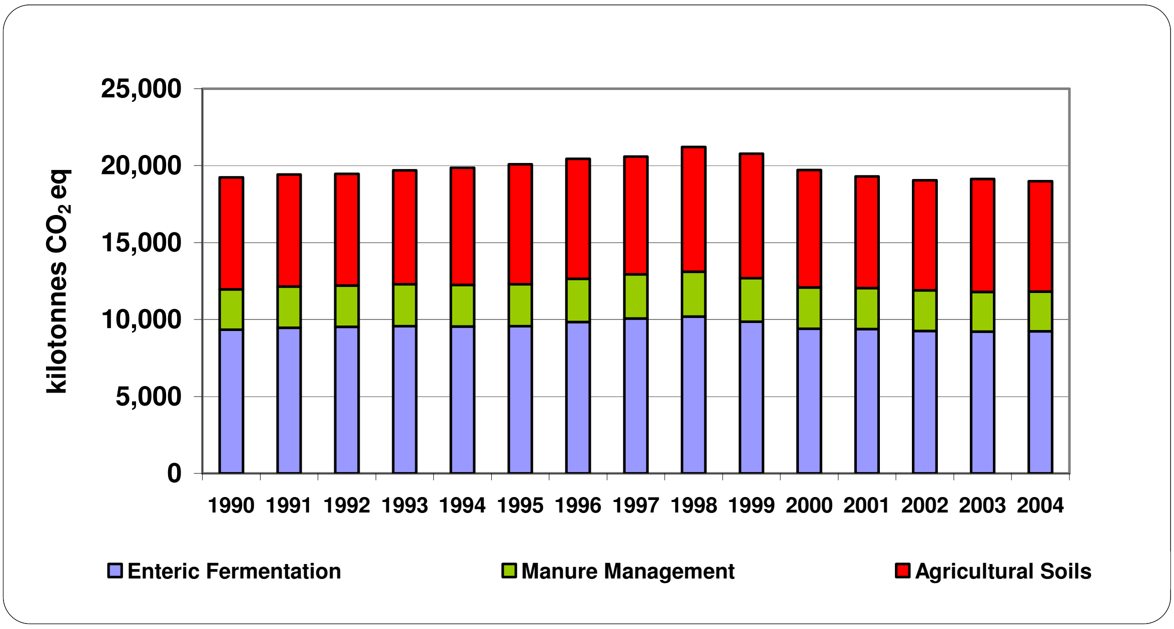


Figure 2.4 Trend in Emissions from Agriculture 1990-2004

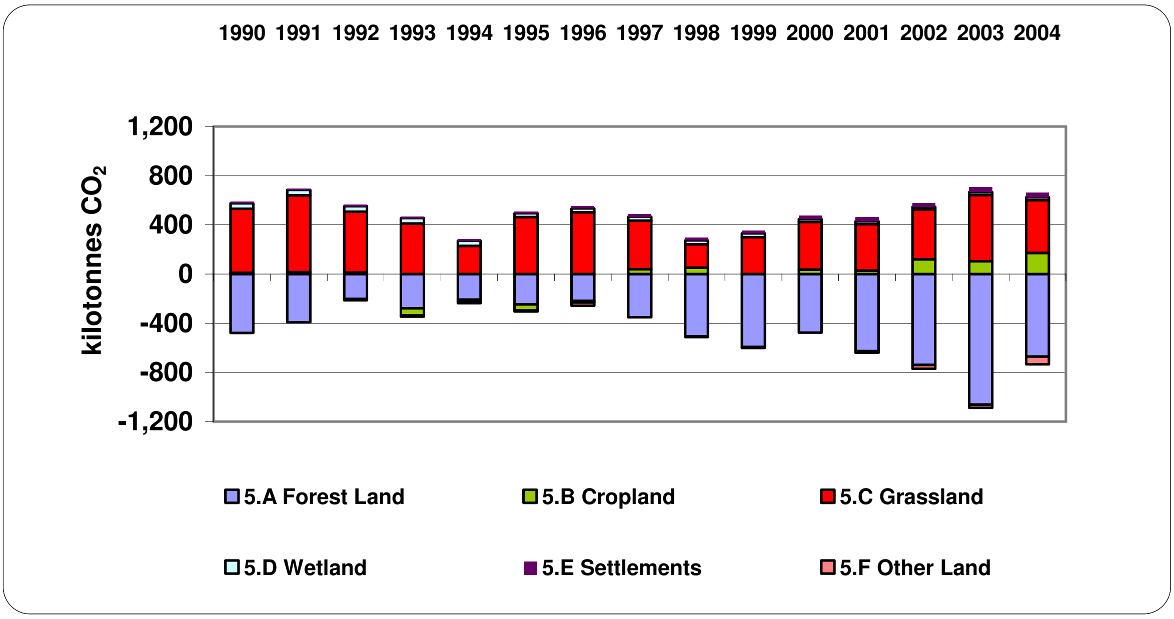


Figure 2.5 Trend in Emissions and Removals from Land Use Land-Use Change and Forestry 1990-2004

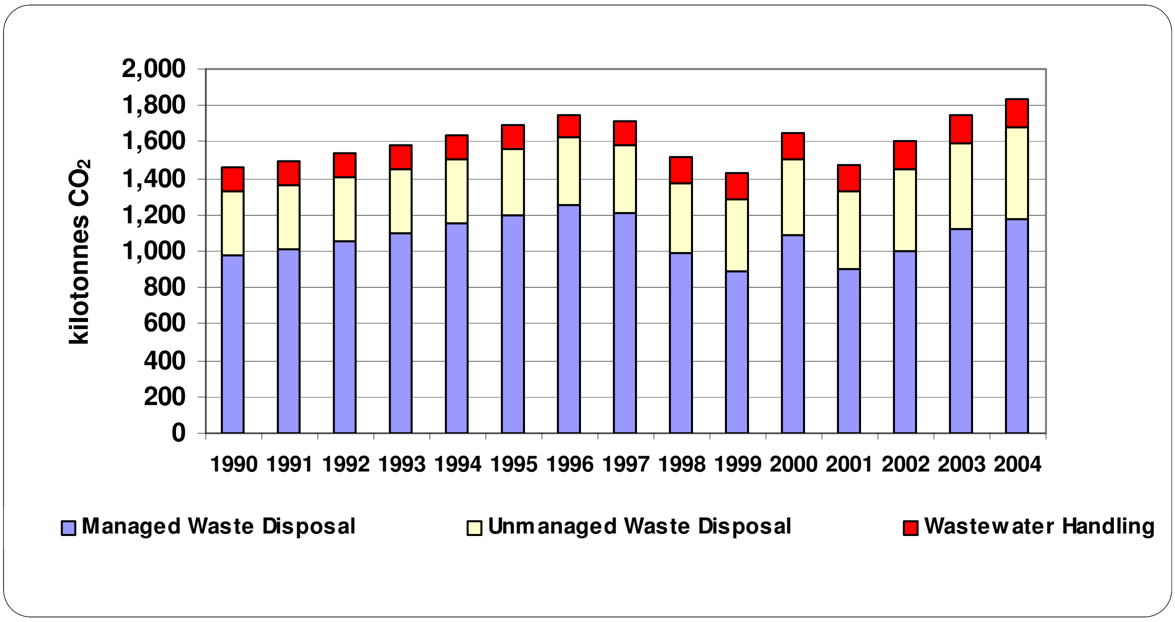


Figure 2.6 Trend in Emissions from Waste 1990-2004

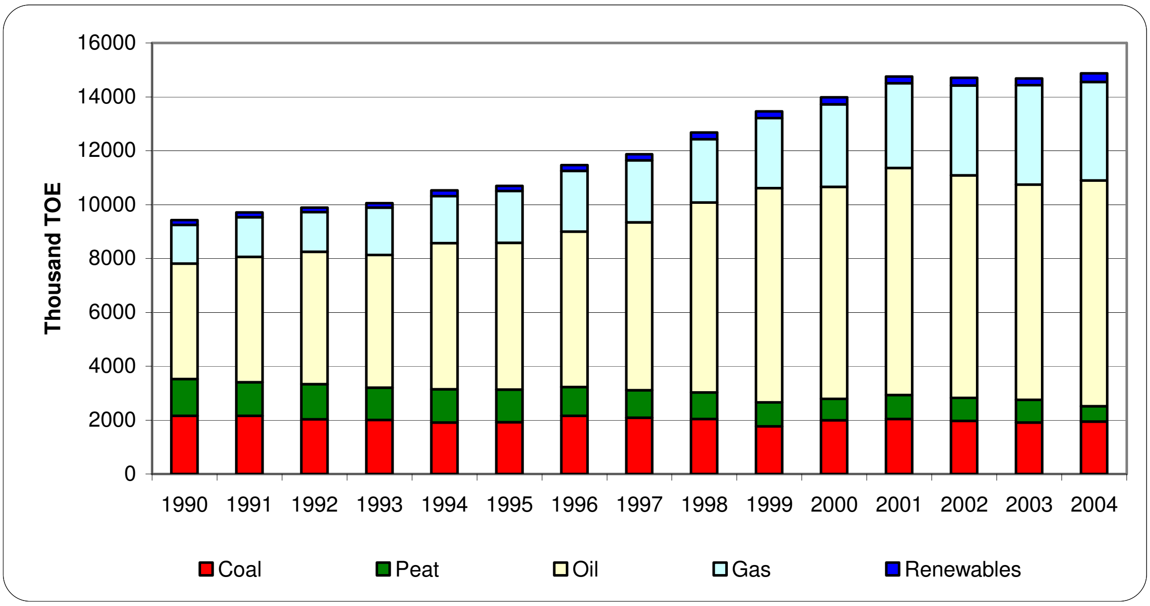


Figure 2.7 Total Primary Energy Requirement 1990-2004

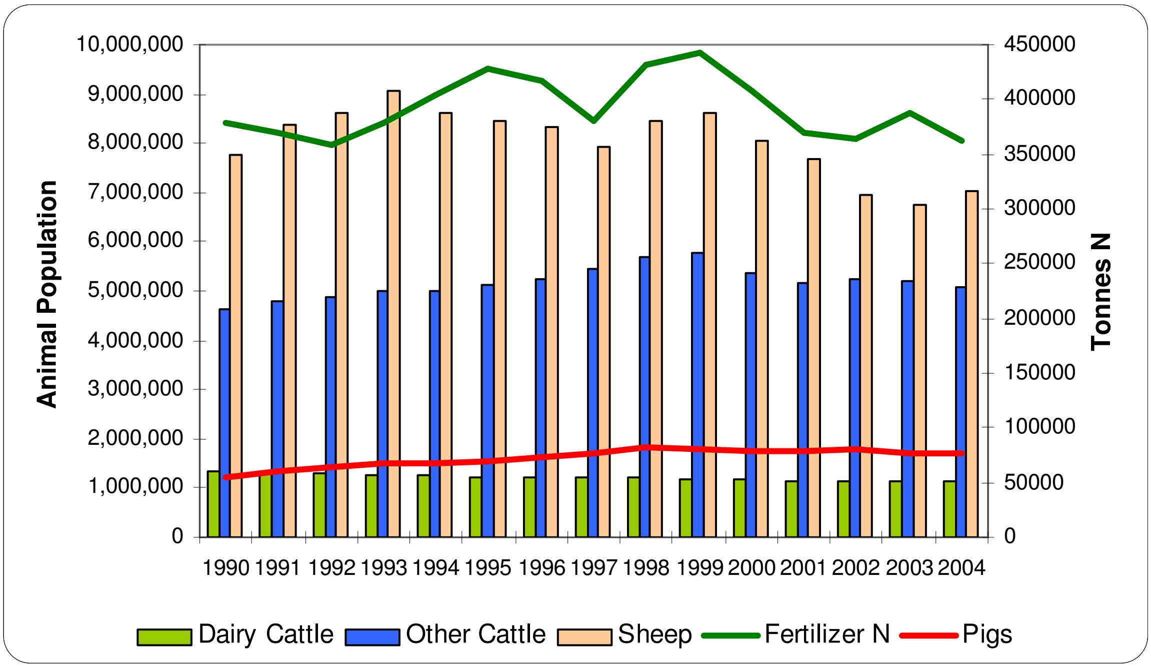


Figure 2.8 Principal Drivers of Emissions from Agriculture 1990-2004

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 2004 remain largely as described in previous NIRs. However, the availability of some additional or improved information for the sector allows for the inclusion of some minor additional sources compared to previous years thus increasing completeness and transparency. Together with the particular focus in this reporting cycle on improving the estimates of emissions in the base year, recalculations are therefore justified in a number of source/gas combinations in *Energy*. These are described in section 3.7 below.

The national energy balance forms the basis of all emission estimates related to the use of energy in Ireland. Table B.1 of Annex B shows the national energy balance sheets for 2004, published by SEI (Sustainable Energy Ireland). The energy statistics are compiled using a combination of top-down and bottom-up methods and the 2004 example indicate an expanded balance sheet compared to those included in previous NIRs. 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 are now more complete and they incorporate additional sectoral disaggregation more compatible with greenhouse gas inventory requirements, following close collaboration between SEI and the inventory agency over recent years. A revised 1990 energy balance consistent with that for 2004 has been used to make some recalculations for the 1990 inventory but those for the years 1991-2003 were not available in time to make corresponding revisions for period between 1990 and 2004. This will be done for the 2007 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 2004 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	CO2	CH4	N2O
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	All	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 this source contributed almost two-thirds of total emissions in 2004 (Chapter Two). The CO_2 emissions are relatively easy to quantify with reasonable accuracy as the fuel amounts are usually available from national energy agencies 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 2004 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. The CO_2 emission factor of 54.94 t/TJ has been used to date for natural gas and refers to indigenous production of this fuel only. The import of natural gas from the UK began around 1995 and by 2004 imported gas accounted for 80 percent of the total. The CO_2 emission factor appropriate to this split between domestic and imported natural gas, which is more carbon intensive, was 56.77 t/TJ in 2004. The emission factors for the years 1995-2003 have been revised in line with the 2004 value to account for the amount of gas imported in each year and will be applied in recalculations for these years for the next submission. The Irish CO_2 emission factors are assumed to account for the fact that a very small fraction of fuel carbon may remain unoxidised. Consequently, no specific allowance is made in the calculations for unoxidised carbon, which generally amounts to no more than one or two percent. Default CO_2 emission factors from IPCC are used for petroleum coke and biomass, the latter almost invariably referring to 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 1.A.1 Energy Industries

The Electricity Supply Board (ESB) was Ireland's only public electricity company up until the late 1990s and continues to operate the majority of power stations in the country. The emissions of CO_2 (as well as those of SO_2 and NO_X) for all power plants under *1.A.1(a) Public Electricity and Heat Production* operated by the ESB are estimated by the company on a plant-by-plant basis annually and are reported directly to the inventory agency. The liberalisation of the electricity market resulted in the construction of a number of new generating stations by other companies in recent years. Fuel use data and corresponding CO_2 emissions for these plants are obtained either by direct contact with the operators or from their Annual Environmental Reports (AER), submitted to the EPA in accordance with IPC licence conditions. While the emissions as reported are used directly in the annual inventory, the associated energy use for *1.A.1(a) Public Electricity and Heat Production* is that recorded in the national energy balance, which may not always match that indicated by the data returned directly by electricity producers to the inventory agency.

The bottom-up CO_2 emission estimates received from the electricity companies 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. The emissions of CH_4 and N_2O are estimated by the inventory agency and then aggregated for reporting in the same way. The national averaged emission factors for 2004 have been computed for presentation in this report. The implied emission factor for CO_2 appearing under solid fuels in sub-category *1.A.1(a) Public Electricity and Heat Production* is determined by weighting of the emissions factors for peat and coal. The high value for 2004 is due to an apparent incompatibility between peat energy use as given in the energy balance and the CO_2 emissions estimates received for peat-fired plants. This may be due to incomplete accounting of peat consumption on the part of SEI in respect of two new stations that came into operation during 2004. There are a number of small plants in Ireland that produce electricity from landfill gas extracted at some of the major landfill sites. The emissions from these plants are estimated using the emission factors for natural gas and are included in *1.A.1(a) Public Electricity and Heat Production*.

Figure 3.1 shows the trend in emissions from *1.A.1(a) Public Electricity and Heat Production* over the period 1990-2004. It may be noted that CO_2 emissions from peat use have decreased due to the phasing out of old peat-fired stations while new stations are largely using natural gas and therefore CO_2 emissions from gas consumption have increased. Coal is used only at the largest station in the country, which tends to be operated close to capacity giving a corresponding stable CO_2 output. Oil-fired plants are often used to replace downtime at other plants and to meet fluctuating electricity demand with the result that associated emissions are more variable. Two new peat-fired power stations came into operation in 2004.

Fuel consumption data for Ireland's only oil refinery are obtained from the company's AER and are useful for checking against the information that appears in the energy balance sheet (Table B.1 of Annex B). These data facilitate the estimation of emissions for reporting under *1.A.1(b) Petroleum Refining* using the country-specific emission factors. In the past, Ireland has not reported any emissions for *1.A.1(c) Manufacture of Solid Fuels and Other Energy Industries* with an indication that no such emissions occur. However, the energy balance records some fuel consumption and conversion in this source category, which refers to the production of peat briquettes from milled peat. The emissions concerned are now estimated for 2004 and a corresponding revision for 1990 is part of the recalculations for *Energy* described in section 3.7.

All major individual combustion plants, including 14 power stations, 1 oil refinery and 2 briquetting plants, that determine Irish emissions in *1.A.1 Energy Industries* are covered by Directive 2003/87/EC (EP and CEU, 2003) on emissions trading. The inventory experts are collaborating with colleagues in the Agency's Emission Trading Unit (ETU) to fully utilise the provisions of Directive 2003/87/EC to 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.

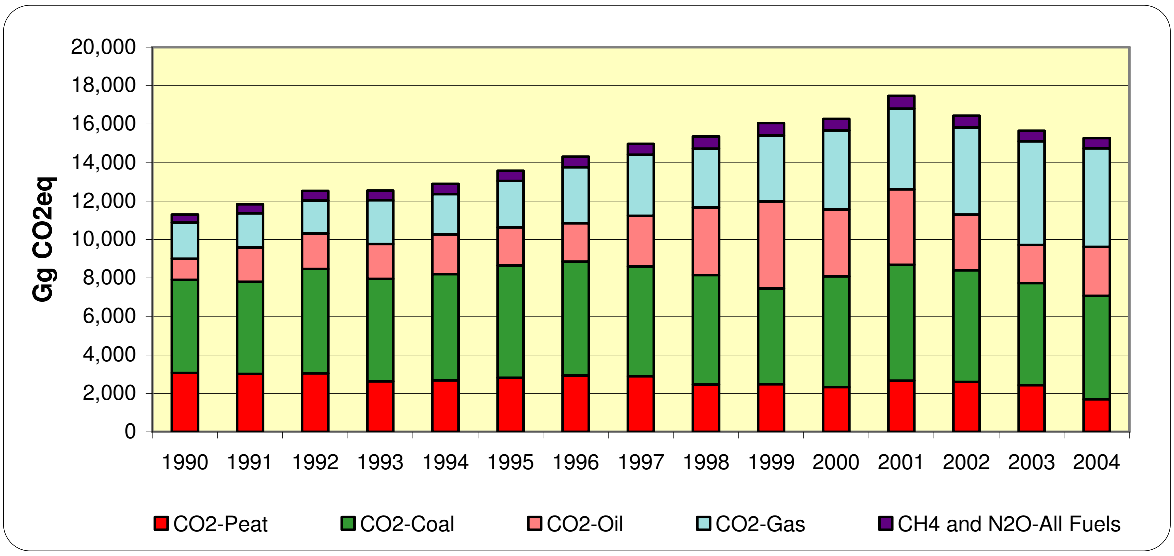


Figure 3.1 Trend in Emissions from 1.A.1 Energy Industries 1990-2004

3.2.1.2 1.A.2 Manufacturing Industries and Construction

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 emissions or fuel consumption is obtained in respect of a small number of energy intensive industries (e.g. alumina production and cement manufacture), either directly or from their respective AERs submitted to the EPA under their IPC licence conditions. This allows their respective estimates to be accounted for on a bottom-up basis. The energy amounts concerned are deducted from the known totals for sub-categories 1.A.2(a) through 1.A.2(f) and the remainder of the fuel quantities is used to compute emissions on a top-down approach using the country-specific emission factors as shown in Table C.1 of Annex C.

3.2.1.3 1.A.3 Transport

The fuel consumption within Ireland associated with sub-category *1.A.3(a) Civil Aviation* is calculated from the number of annual domestic LTO cycles 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 energy balance sheet for 2004 records the amount of fuel used in domestic air transport. However, there is only approximately 8 percent difference between the two values of fuel amount.

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 calculated in the COPERT III model (Ahlvik *et al*, 1997), developed within the CORINAIR programme for estimating a range of emissions from this important source. 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 III 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. The model is applied annually in Ireland to derive CH_4 and N_2O emissions estimates. The resultant 2004 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 1.A.4 Other Sectors

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 1990-2004. 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 2004, gains from fuel switching are 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

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.

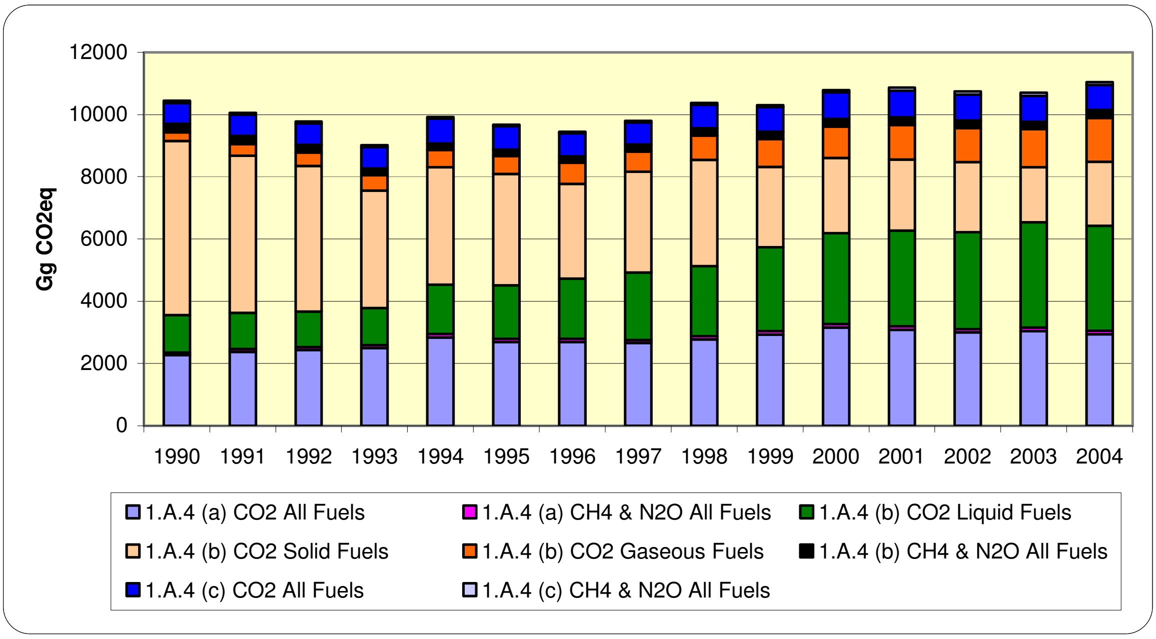


Figure 3.2 Trend in Emissions from 1.A.4 Other Sectors 1990-2004

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 4,840 tonnes of methane. 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 1998 value and the projections is applied to give an emission for all years of the inventory time-series referred to in this report. 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 1990-2004 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. The recalculations for *Energy* include a major revision in respect of the CH_4 emissions for this source in 2003. The estimate of CH_4 emissions supplied to the inventory agency for 2003 (27.035 Gg) was very high compared to that for previous years and was not substantiated until the information for 2004 was obtained. The high CH_4 emission in 2003 was due to the drilling and venting associated with a new gas well.

3.3 IPCC Reference Approach for CO_2 Emissions from Energy Use

The 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 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 2004 CRF) is reproduced as Table C.4 of Annex C 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 0.75 is used for the proportion of carbon stored in naphtha. 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 for 2004 and 1990 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 in 2004.

3.4 Comparison 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 2.6 percent and 1.4 percent are indicated for total energy and CO_2 emissions, respectively in 2004. The differences are largely due to those for liquid fuels, where they amount to 4.6 percent for energy and 2.3 percent for CO_2 emissions. The small differences are largely explained by the highly aggregated manner in which emission factors are applied in the Reference Approach.

3.5 Memo Items

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

The activity data for biomass appear under the heading other renewables in the Irish energy balance sheet (Table B.1 of Annex B). For the industrial, residential and agricultural sectors, this is known to refer to 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 *Energy* total 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 close in 2004 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. In 2004, the amount of fuel allocated to domestic aviation was approximately 4.7 percent of the total recorded under air transport in the energy balance.

3.6 QA/QC in Energy

Previous NIRs have mentioned that Sustainable Energy Ireland was engaged in a major revision exercise to address a number of shortcomings in Irish energy balance sheets following its own assessment of historical data and harmonisation of Irish energy statistics as reported to Eurostat and requests from the inventory agency. 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 and 2004 included in the 2006 submission. The transfer of energy data to a new database at SEI has identified issues such as double counting of CHP energy use and inconsistent treatment of calorific values for solid fuels in some years, which have been taken into account in revised energy balances.

The methods used for routine energy balance compilation are being made more robust and more transparent and new sources of information are being pursued by SEI to supplement traditional approaches to energy accounting where the results are based on surveys of inadequate frequency or insufficient bottom-up detail. Arrangements are being 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 will be reconciled at an early stage with the corresponding top-down information returned to SEI. More extensive surveys are still needed to confirm the apportionment of agricultural fuel use between stationary and mobile sources and to give a more complete split of fuels used in construction from the total used in the industrial sector. New methods need to be developed to routinely quantify the amount of automotive fuels being purchased in Ireland by vehicle users from outside the State. In recognition of its key role within the national system, 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.

3.7 Recalculations in *Energy*

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

(a) Application of the expanded energy balance for 1990;

(b) Inclusion of estimates for the sub-category *1.A.1(c) Manufacture of Solid Fuel and Other Energy Industries*, a minor emission source in Ireland;

(c) Adjustment to correct for double counting of energy consumption related to CHP plants in 1990;

(d) Consistent treatment of calorific values for coal and peat (between 1990 and 2004) in the revised energy balance for 1990;

(e) A revised estimate of fugitive CH_4 emissions under *1.B.2.b(ii) Natural Gas Production and Processing* in 2003.

The updated and expanded energy balances were not available to the inventory agency in time to complete the various minor recalculations for all years in the time-series for reporting at this time. Consequently, the recalculations (except (e) above) only refer to 1990. The effect of the recalculations in the *Energy* sector is small but they nevertheless contribute to general improvement in regard to completeness and consistency of the inventories for 1990 and the latest year. The revision for 1990 indicates an increase of 608.66 Gg CO_2 on the sector total given in the 2005 submission. Most of this is due to the addition of a minor source using peat in *1.A.1(c) Manufacture of Solid Fuels and Other Energy Industries*, fuller accounting of CHP and inclusion of petroleum coke in *1.A.2 Manufacturing Industries and Construction* along with more precise treatment of bituminous coal, anthracite, lignite and petroleum coke in sub-category *1.A.4 (b) Residential* where they were formerly aggregated as smokeless solid fuel.

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 thus *2.A.3 Limestone and Dolomite Use* is a relevant activity in Ireland. The associated CO_2 emissions from this minor source are included in the annual inventories for the first time in the present 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 1990-2004 for the relevant sources in Ireland. They indicate contributions of 5.7 percent and 4.6 percent to total emissions in 1990 and 2004, 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. 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 2004, largely due to the influence of the air conditioning and refrigeration sub-categories while the emissions of PFC and SF_6 both reduced substantially in 2004. The estimates given in Table 4.2 for the period 1990-2003 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	CO2	CH4	N2O	HFC	PFC	SF6
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	NE	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	NO	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 *2.A Mineral Products*

The IPCC Level 3 emission source categories relevant under *2.A Mineral Products* in 2004 are limited to *2.A.1 Cement Production, 2.A.2 Lime Production* and *2.A.3 Limestone and Dolomite Use*. Total CO_2 emissions from these activities amounted to 2,504.09 Gg, of which cement production accounted for 91 percent.

4.2.1 2.A.1 Cement Production

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.

Table 4.2. Emissions from Industrial Processes 1990-2004

	Gas	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
INDUSTRIAL PROCESSES	All	kt CO_2 eq	3,166.46	2,866.26	2,781.45	2,746.11	3,117.66	3,062.75	3,204.72	3,656.26	3,494.73	3,560.04	4,186.65	4,294.30	3,734.39	3,050.92	3,169.72
2.A. Mineral Products																	
Cement Production	CO2	kt	884.0	782.0	753.0	729.0	859.0	879.0	983.0	1,145.0	1,059.0	1,166.0	1,700.9	1,851.2	1,859.8	2,128.0	2,290.0
Lime Production	CO2	kt	214.1	192.2	162.4	204.9	205.4	187.5	198.2	221.9	211.7	170.1	190.4	189.4	190.3	206.2	201.5
Limestone and Dolomite Use	CO2	kt	7.594	7.394	7.294	6.994	7.294	7.994	7.794	8.794	8.644	8.944	9.342	13.479	10.954	11.368	12.550
2.B. Chemical Industry																	
Ammonia Production*	CO2	kt	989.2	1030.6	1003.0	945.5	1055.8	973.0	922.5	1074.2	1058.1	943.1	883.3	1037.4	809.7	NO	NO
Nitric Acid Production*	N2O	kt CO_2 eq	1035.4	812.45	812.2	812.2	812.2	812.2	812.2	812.2	812.2	812.2	812.2	584.35	292.18	NO	NO
2.F. Consumption of Halocarbons and SF_6																	
Emissions of HFC	HFC	kt CO_2 eq	0.693	5.133	5.891	8.887	20.451	44.597	75.640	130.994	189.016	194.833	228.928	253.071	288.840	357.911	399.254
Emissions of PFC	PFC	kt CO_2 eq	0.093	0.093	0.093	0.093	75.382	75.382	103.085	130.823	61.870	195.933	305.406	295.984	212.403	228.795	196.370
Emissions of SF6	SF6	kt CO_2 eq	35.405	36.381	37.357	38.334	81.852	82.827	102.062	132.100	94.245	68.956	55.907	69.429	70.224	118.590	70.007
Implied Emission Factor for CO_2 in Cement Production		t CO2/t clinker	0.549	0.549	0.549	0.549	0.549	0.549	0.549	0.549	0.549	0.549	0.547	0.547	0.545	0.536	0.535
Implied Emission Factor for CO_2 in Lime Production		t CO2/t lime	0.839	0.830	0.753	0.843	0.832	0.839	0.826	0.877	0.826	0.823	0.767	0.778	0.785	0.861	0.819

* Ammonia and nitric acid plants ceased production in 2002

The first estimates of greenhouse gas emissions in Ireland (McGettigan, 1993) used a CORINAIR default emission factor of 0.5 tonne CO_2 per tonne of cement clinker produced to estimate the process emissions from cement production. This value was substantiated by information received by direct correspondence with the single company manufacturing cement in the country at that time and is very close to the original IPCC Tier 1 default value (0.4985 t CO_2/t cement). The emission factor of 0.5 tonne CO_2 per tonne of cement clinker was retained to estimate CO_2 from cement production for all years up to 2002 using the Tier 1 method. Information on CO_2 emissions from cement production 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 provided a basis for re-examination of both the historical activity data and the emission factor used to estimate CO_2 from cement production for the years 1990-2002. The new information was obtained from a number of additional cement producers who had entered the Irish market in 2000, in addition to the larger original manufacturer.

As the emission estimates from individual cement plants are subject to verification under Directive 2003/87/EC, their validity is being 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 in respect of the four cement plants in operation in 2003, allowing for more accurate accounting of combustion emissions and process emissions separately. The process CO_2 emissions from these plants were 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. The emission factors in 2003 ranged from 0.525 t CO_2/ t clinker to 0.542 t CO2/ t clinker with a weighted average of 0.536 for all clinker production. The procedure was repeated for 2004, giving process emissions of 2,290 kt CO_2 and an implied emission factor of 0.535 t CO_2/ t clinker.

The 2005 NIR stated that the approach used for 2003 would be applied for systematic updating of the reported estimates for source category *2.A.1 Cement Production* for all years with a view to submitting more robust estimates for the entire time-series in 2006. This objective has been achieved and Table 4.2 summarises the annual process CO_2 emissions estimates for cement production, which have been calculated using the appropriate emission factors corresponding to the plants in operation over the years 1990-2002, consistent with the 2003 data.

4.2.2 2.A.2 Lime Production

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).

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 enabling the inventory agency to review and revise the previously submitted estimates for another important source of CO_2 emissions in *Industrial Processes*. The CO_2 estimates have been obtained for all years up to 2004, 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 2.A.3 Limestone and Dolomite Use

Ireland has not previously reported emissions arising from this activity. Information has recently become available to allow for the inclusion of CO_2 emissions associated with the use of carbonates in the manufacture of building bricks and ceramics and from limestone use for the absorption of SO_2 emitted in one new peat-burning power station. The emissions from these sources are rather small, amounting to 5 percent of the total for *Industrial Processes* in 2004 but nevertheless their inclusion adds further to the level of inventory completeness.

Information on the raw materials used in brick manufacture (clay, carbonates and shale) has been supplied for the years 1990-2003 by three companies who are participants in the EU emissions trading scheme. Estimates of the CO_2 emissions produced from conversion of the carbonate fractions in the raw materials were produced for the years 2001-2003 using the BCC/CERAM methodology for ceramics developed for use in the pilot phase of the EU scheme. The average emission factors indicated by the outcome for these years were used to estimate emissions for this activity for all years from 1990 to 2000, using the reported data on raw materials.

Limestone has 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 the manufacture of bricks and ceramics only up to the year 2000 and thereafter also include the emissions from limestone use in the new peat-fired power plant.

4.3 Emissions of HFC, PFC and SF_6 from *Industrial Processes*

4.3.1 Special Studies

The compilation of emissions estimates for fluorinated gases presents major new 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. 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 bottom-up approach took full account of the available IPCC methodologies and IPCC good practice guidance in developing the 1998 emissions estimates for HFC, PFC and SF_6. Tier 2 methods were used for estimating the emissions from the majority of sources that have non-zero emissions. The actual and potential emissions in 1998 were compiled in the CRF tables, with table modifications where necessary to facilitate transparent reporting of the country-specific data.

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.

4.3.2 HFC, PFC and SF_6 Time-Series 1990-2004

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 has allowed, emission estimates have been calculated following the sectoral guidance provided by the Intergovernmental Panel on Climate Change (IPCC) publications. Where changes in methodology have occurred in any sector, or where new or corrected information for previous years has become available, emissions have been recalculated for the entire time-series 1995-2001.

Emissions from the consumption of HFC, PFC and SF_6 i.e. through the production, use and disposal of equipment containing these fluids (e.g. refrigerators, electrical switchgear etc) remain the only relevant emissions in Ireland. The following paragraphs describe the overall approach and assumptions made to achieve the estimates of both actual and potential emissions with reference to the relevant source categories, as identified by the earlier 2002 studies. Reference should be made to the special study report for further clarification on those sources actually covered and those that have non-zero emissions.

In the consumption of HFC, PFC and SF_6, a distinction can be made between uses as aerosols and fire-fighting equipment that release fluid at the near-instantaneous time it is used and applications such as mobile air conditioning and foams where the release happens slowly over its lifetime and on disposal. The IPCC guidance recommends that, where information is available, the whole product life cycle be considered when estimating emissions, including imported and exported goods. For example, production-related emissions are typically estimated from the amount of fluid charged into the equipment during manufacture multiplied by a percentage loss rate. In this study, where this data is available, the production levels and loss factors are generally based on the information received from manufacturers, and IPCC default values are used in other cases.

For many applications, the major form of emissions is gradual loss from a bank of fluid contained in a large number of similar products. This may occur through leakage or through equipment failure. The applications subject to loss in this way include refrigeration and air conditioning equipment, closed-cell foams, fire extinguisher systems and electrical switch-gear. The annual emissions from these types of equipment can be calculated as the sum of the manufacturing, usage and disposal emissions for all the different types of equipment within a specific sector.

The IPCC Good Practice Guidance (IPCC, 2000) proposes a Tier 3b ‘top down’ approach and a Tier 3a ‘bottom up’ approach. It is clear however, as is the case for many other countries including the U.K., that data availability in Ireland means that it is not possible to use Tier 3b for all sources. In order to apply Tier 3b it is necessary to obtain complete, accurate and precisely defined data. This is most likely to be possible when there are a small number of operators with well-established data collection systems in a given sector (e.g. in electrical switchgear use), but in contrast for sectors such as the refrigeration and air conditioning sector, there are large numbers of small and medium-sized service companies in addition to the main distributors and equipment manufacturers. Hence, the likely accuracy and completeness of the data are not sufficient to apply Tier 3b to all relevant sectors in Ireland. Instead a pragmatic approach has been used in sectors where lack of data precludes the use of a full Tier 3b methodology. Instead, the use of an alternative Tier 1 methodology for estimating emissions as described in the Good Practice Guidance is used in several sectors.

In the 2005 contract study (Adams et al, 2005), emissions of HFC, PFC and SF_6 have been estimated from the consumption of halocarbons and SF_6 for the following activities:

- 2.F.1 Stationary Refrigeration and Air Conditioning;
- 2.F.2 Foams;
- 2.F.3 Fire-extinguishers;
- 2.F.4 Aerosols and Metered Dose Inhalers;
- 2.F.7 Semiconductor manufacture;
- 2.F.8 Electrical equipment;
- 2.F.9 Other, which includes emissions from window sound-proofing, medical applications, sporting goods and as a gas-air tracer in research and leak detection.

The category *2.F.9 Other* includes estimates for SF_6 emissions from its use in medical applications and sporting goods. These two sources were noted as potential emission sources in the 2002 inventory study but the actual emissions were not quantified. The inclusion of emission estimates for these uses, although both relatively minor in terms of the level of their respective emissions, therefore helps to improve the completeness of Ireland's inventory.

The results of the inventory update for F-gases are shown in Table 4.3. They clearly indicate that for most sectors emissions of HFC, PFC and SF_6 have generally increased year on year. This trend reflects the increasing use of these fluorinated species 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. One exception to this trend is in the manufacture of semiconductors, where the reported emissions received from manufacturing companies in Ireland show annual fluctuations reflecting changing manufacturing activity in response to the global trends in this market. For the years 1999-2003, this sector produced much higher 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. In contrast, in 2004 the reported emissions from this sector decreased substantially, reflecting a lower usage of PFC in particular.

4.4 Uncertainty Analysis for HFC, PFC and SF_6 Emissions

An uncertainty analysis has been performed for the aggregated F-gas emissions derived from a specific consideration of the individual sector uncertainty estimates using an iterative Monte Carlo simulation procedure by @RISK uncertainty analysis software (Palisade Corp. 2004). Uncertainties were calculated as two standard deviations from the mean, corresponding to a 95 percent confidence interval. Uncertainty estimates for each sector (as plus or minus x percent), were based on expert judgement taking into account the overall confidence in the data, general assumptions for the individual source categories and the results of a similar uncertainty analysis performed for the UK F-gas inventory (AEAT, 2004). We assume this range corresponds to the 95 percent confidence interval for a normally distributed population. The use of Monte Carlo simulation complies with the IPCC good practice Tier 2 approach to uncertainty estimation, and is currently used by a number of other Annex I Parties in the calculation of uncertainties for national GHG inventories.

Table 4.3. Emissions of HFC, PFC and SF_6 from Industrial Processes 1990-2004 (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
2.F.1 Refrigeration and Air-Conditioning	NO	3.322	3.512	3.690	3.984	4.481	7.145	20.056	40.616	47.660	51.213	47.508	62.901	110.612	133.074
2.F.1 Mobile Air Conditioning	NO	NO	NO	1.222	5.068	10.141	16.357	25.077	38.229	54.119	70.461	83.364	96.376	110.148	124.290
2.F.2 Foams	NO	0.000	0.016	0.063	0.303	0.644	1.107	1.779	3.619	5.222	6.275	9.211	11.499	13.705	15.812
2.F.3 Fire-extinguishers	0.219	0.700	1.179	1.677	2.235	2.839	3.496	4.210	4.988	5.834	6.755	7.806	9.026	10.385	11.915
2.F.4 Aerosols	0.006	0.643	0.715	1.767	7.036	24.668	38.499	68.539	90.186	64.279	72.045	87.955	90.163	92.205	94.257
2.F.4 Metered Dose Inhalers	0.000	0.000	0.000	0.000	0.000	0.000	6.100	6.700	7.500	8.300	9.800	14.126	16.992	18.211	18.409
2.F.7 Semiconductor manufacture	0.468	0.468	0.468	0.468	1.825	1.825	2.937	4.633	3.877	9.418	12.379	3.101	1.884	2.644	1.498
TOTAL HFC	**0.693**	**5.133**	**5.891**	**8.887**	**20.451**	**44.597**	**75.640**	**130.994**	**189.016**	**194.833**	**228.928**	**253.071**	**288.840**	**357.911**	**399.254**
2.F.7 Semiconductor manufacture	0.093	0.093	0.093	0.093	75.382	75.382	103.085	130.823	61.870	195.933	305.406	295.984	212.403	228.795	196.370
TOTAL PFC	**0.093**	**0.093**	**0.093**	**0.093**	**75.382**	**75.382**	**103.085**	**130.823**	**61.870**	**195.933**	**305.406**	**295.984**	**212.403**	**228.795**	**196.370**
2.F.7 Semiconductor manufacture	0.478	0.478	0.478	0.478	43.020	43.020	62.140	81.260	52.580	16.730	31.070	20.435	28.584	59.917	35.635
2.F.8 Electrical equipment	21.510	22.466	23.422	24.378	25.334	26.290	26.386	37.284	25.238	34.990	7.787	32.050	22.786	38.446	21.553
2.F.9 Other - window soundproofing	0.431	0.451	0.472	0.492	0.512	0.532	0.551	0.570	0.590	0.465	0.333	0.195	0.193	0.191	0.189
2.F.9 Other - medical applications	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
2.F.9 Other - sporting goods	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.851	3.786	3.731	3.765	5.675	7.051	5.740
2.F.9 Other - gas-air tracers	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	6.095
TOTAL SF_6	**35.405**	**36.381**	**37.357**	**38.334**	**81.852**	**82.827**	**102.062**	**132.100**	**94.245**	**68.956**	**55.907**	**69.429**	**70.224**	**118.590**	**70.007**
TOTAL HFC, PFC and SF_6	**36.191**	**41.608**	**43.342**	**47.314**	**177.685**	**202.806**	**280.787**	**393.917**	**345.131**	**459.722**	**590.241**	**618.485**	**571.467**	**705.295**	**665.631**

Table 4.4. Recalculated Emission Estimates for Industrial Processes 1990-2003 (Gg CO_2 eq)

IPCC Source Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Previously Reported Values															
2.A.1 Cement Production	CO2	750.0	750.0	800.0	750.0	900.0	900.0	900.0	1,000.0	1,000.0	1,125.0	1,575.0	1,650.0	2,021.5	2,157.4
2.A.2 Lime Production	CO2	191.4	173.6	161.8	182.3	185.2	167.6	180.1	189.8	192.1	154.9	186.2	182.6	181.9	184.7
2.A.3 Limestone and Dolomite Use	CO2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.F.1 Refrigeration and Air-Conditioning	HFC	NE	NE	NE	NE	NE	4.458	34.272	43.034	53.929	71.597	73.625	81.873	92.503	106.160
2.F.1 Mobile Air Conditioning	HFC	NE	NE	NE	NE	NE	3.629	8.507	16.933	29.434	50.676	80.589	99.283	115.063	129.783
2.F.2 Foams	HFC	NE	NE	NE	NE	NE	0.432	0.772	1.285	2.736	4.189	5.321	7.894	10.727	12.255
2.F.3 Fire-extinguishers	HFC	NE	NE	NE	NE	NE	4.861	5.446	6.080	6.670	7.516	8.357	9.289	10.357	11.559
2.F.4 Aerosols	HFC	NE	NE	NE	NE	NE	5.500	6.090	6.598	7.410	8.198	9.139	19.414	19.414	22.693
2.F.4 Metered Dose Inhalers	HFC	NE	NE	NE	NE	NE	NO	0.019	0.059	0.081	0.105	0.674	1.565	2.315	2.315
2.F.7 Semiconductor manufacture	HFC	NE	NE	NE	NE	NE	1.825	2.937	4.633	3.877	9.418	12.379	11.583	2.539	3.625
2.F.7 Semiconductor manufacture	PFC	NE	NE	NE	NE	NE	75.382	103.085	130.823	61.870	195.933	305.406	296.502	327.947	223.627
2.F.7 Semiconductor manufacture	SF6	NE	NE	NE	NE	NE	44.047	61.901	82.049	52.580	15.668	31.285	21.845	30.902	61.782
2.F.8 Electrical equipment	SF6	NE	NE	NE	NE	NE	26.290	26.386	37.284	25.238	34.989	7.791	32.050	27.461	25.501
2.F.9 Other - window soundproofing	SF6	NE	NE	NE	NE	NE	0.526	0.551	0.570	0.586	0.608	0.627	0.664	0.695	0.724
2.F.9 Other - medical applications	SF6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.F.9 Other - sporting goods	SF6	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2.F.9 Other - gas-air tracers	SF6	NE	NE	NE	NE	NE	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189
Recalculated Values															
2.A.1 Cement Production	CO2	884.0	782.0	753.0	729.0	859.0	879.0	983.0	1,145.0	1,059.0	1,166.0	1,700.9	1,851.2	1,859.8	2,128.0
2.A.2 Lime Production	CO2	214.1	192.2	162.4	204.9	205.4	187.5	198.2	221.9	211.7	170.1	190.4	189.4	190.3	206.2
2.A.3 Limestone and Dolomite Use	CO2	7.594	7.394	7.294	6.994	7.294	7.994	7.794	8.794	8.644	8.944	9.342	13.479	10.954	11.368
2.F.1 Refrigeration and Air-Conditioning	HFC	NO	3.322	3.512	3.690	3.984	4.481	7.145	20.056	40.616	47.660	51.213	47.508	62.901	110.612
2.F.1 Mobile Air Conditioning	HFC	NO	NO	NO	1.222	5.068	10.141	16.357	25.077	38.229	54.119	70.461	83.364	96.376	110.148
2.F.2 Foams	HFC	NO	0.000	0.016	0.063	0.303	0.644	1.107	1.779	3.619	5.222	6.275	9.211	11.499	13.705
2.F.3 Fire-extinguishers	HFC	0.219	0.700	1.179	1.677	2.235	2.839	3.496	4.210	4.988	5.834	6.755	7.806	9.026	10.385
2.F.4 Aerosols	HFC	0.006	0.643	0.715	1.767	7.036	24.668	38.499	68.539	90.186	64.279	72.045	87.955	90.163	92.205
2.F.4 Metered Dose Inhalers	HFC	NO	NO	NO	NO	NO	NO	6.100	6.700	7.500	8.300	9.800	14.126	16.992	18.211
2.F.7 Semiconductor manufacture	HFC	0.468	0.468	0.468	0.468	1.825	1.825	2.937	4.633	3.877	9.418	12.379	3.101	1.884	2.644
2.F.7 Semiconductor manufacture	PFC	0.093	0.093	0.093	0.093	75.382	75.382	103.085	130.823	61.870	195.933	305.406	295.984	212.403	228.795
2.F.7 Semiconductor manufacture	SF6	0.478	0.478	0.478	0.478	43.020	43.020	62.140	81.260	52.580	16.730	31.070	20.435	28.584	59.917
2.F.8 Electrical equipment	SF6	21.510	22.466	23.422	24.378	25.334	26.290	26.386	37.284	25.238	34.990	7.787	32.050	22.786	38.446
2.F.9 Other - window soundproofing	SF6	0.431	0.451	0.472	0.492	0.512	0.532	0.551	0.570	0.590	0.465	0.333	0.195	0.193	0.191
2.F.9 Other - medical applications	SF6	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797	0.797
2.F.9 Other - sporting goods	SF6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.851	3.786	3.731	3.765	5.675	7.051
2.F.9 Other - gas-air tracers	SF6	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189	12.189

4.5 Recalculations for *Industrial Processes*

Following from the description above, the main recalculations for *Industrial Processes* being submitted in 2006 may be summarised as set out below. Most of the changes relate to the methods and data used for the individual source categories of HFC, PFC and SF_6, which are well documented in the 2005 study (Adams et al, 2005).

(i) Use of plant-specific data to revise process CO_2 emissions from *2.A.1 Cement Production* for the years 1990-2003;

(ii) Use of plant-specific data to revise process CO_2 emissions from *2.A.2 Lime Production* for the years 1990-2003;

(iii) Inclusion of estimates of CO_2 emissions for *2.A.3 Limestone and Dolomite Use;*

(iv) Application of information from the three special F-gas studies to produce and report estimates for HFC, PFC and SF_6 for the years 1990-2004;

(v) It become clear during the 2005 F-gas study that the industry estimate of 550 tonnes of HFC used in Ireland in 1998 (O'Leary et al, 2003) which served as the starting point to scale emissions from *2.F.1 Stationary Refrigeration and Air Conditioning* was a significant overestimate. Revised emission estimates are based on actual data reported by industry, extrapolated for years where data is not available;

(vi) The methodology for *2.F.1 Mobile Air Conditioning* was revised from Tier 2 to Tier 3b and the estimates are now in respect of HFC-134a only, based on recent information from the industry, whereas HFC-125 and HFC-143a were also included previously;

(vii) Updated global sales data for HFC-134a sales for foams on the AFEAS website were applied with Irish GDP data to revise activity data for 2.F.2 Foams for the years 1995-2003;

(viii) The activity data for *2.F.3 Fire Extinguishers* is split as 97.5 percent HFC-227ea and 2.5 percent HFC-23 and annual growth rates are slightly modified for some years. The emission factors incorporate product manufacturing losses of 0.5 percent and a disposal loss factor of 1 percent in addition to the lifetime emission rate of 1 percent previously used;

(ix) Irish HFC emissions from aerosols are derived from the BAMA estimate for the UK, using population as the scaling factor;

(x) Confidential data on use and loss of HFC-134a was obtained from the single producer of MDI in Ireland for the years 2001-2004. The mix of HFC in imported MDI was revised from total HFC-134a and taken as 80 percent HFC-134a and 20 percent HFC 227ea;

(xi) Minor changes in the reported company estimate of F-gas emissions are taken into account for the years 2001-2003;

(xii) A revised time-series of SF_6 use and losses was obtained from the ESB, which is used to update the SF_6 emissions from *2.F.8 Electrical Equipment*;

(xiii) Estimates of SF_6 emissions are included for the first time in respect of medical applications and sporting goods under *2.F.9 Other*.

Table 4.4 lists the previously reported estimates and recalculated values of emissions for Industrial Processes. While a lot of work has been undertaken, especially in relation to F-gases, the changes for the sector are small and the emissions from industrial processes remain small in Ireland compared to those from other sectors.

4.6 Improvements in *Industrial Processes*

The inventory agency will continue to use verified CO_2 emissions estimates for cement and lime production that become available through the EU emissions trading scheme as the most reliable data for these two sources. 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 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 agency have not worked on in detail in the past, as shown by the complete time-series of HFC, PFC and SF_6 emissions included in the 2006 submission.

Chapter Five

Solvent and Other Product Use

5.1 Overview of *Solvent and Other Product Use* Sector

This IPCC source category 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 category 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). 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). This time-series was extended to 2003 for submission in 2005. The CO_2 emissions were 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. 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 and the Solvents Directive. In these circumstances, the inventories of VOC emissions from solvent use over recent years have been 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.* As a result, the previous values for earlier years also warranted recompilation to maintain consistency across the full time series. This was achieved at a less detailed level than for the target years.

A list of the emission sources identified in the 1998 inventory and activity data used was summarised in a spreadsheet and compared with the UK inventory. This spreadsheet provided a means of checking the completeness of the source list. The Irish and UK emissions were normalized by population and compared to assess the completeness and comparability of source data. Uncertainty bounds were attached to the UK data based on comparisons of information from a number of industrial and non-UK information sources. Areas of mismatch (i.e. those areas where the Irish data was outside the UK uncertainty bound) were then examined to see if the differences could be explained. This exercise provided a means of ranking the Irish data in confidence terms and allowed for the identification of significant sources and those sectors needing further investigation.

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. Inspectors reports for the installation, compiled as part of the licence application process, were consulted in the case of recently licensed sites that have not yet submitted annual reports. Direct contact was also made with a large number of IPC sites to determine if solvents were in use and what was the level of consumption. 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 revised estimates of CO_2 emissions from are presented in Table 5.1 together with the results of the recompiled NMVOC estimates for the four sub-categories of solvent use. The largest contributor to overall emissions is domestic solvent use. It is also to be noted that emissions from this sector have increased while those from the majority of sectors 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 sectors 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 sector 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 (2004/42/EC) 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 for 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 2004. 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, from the data gathered and analysed it can be seen that there are specific instances of IPC licensed sites reducing VOC emissions through prevention at source or through abatement.

Table 5.1 Estimates of NMVOC and CO_2 Emissions from Solvent and Other Product Use 1990-2004

	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	6,878	2,304	3,534	13,253	25,969	80.94
1991	7,036	2,304	3,534	13,699	26,573	82.82
1992	7,231	2,304	3,534	13,576	26,645	83.04
1993	7,485	2,304	3,534	13,470	26,792	83.50
1994	7,782	2,291	3,534	13,472	27,079	84.40
1995	8,082	2,496	3,534	13,543	27,655	86.19
1996	8,406	2,423	3,534	13,511	27,874	86.87
1997	8,687	2,311	3,534	13,474	28,005	87.28
1998	9,060	2,158	3,534	13,588	28,340	88.33
1999	8,767	2,043	3,433	13,032	27,275	85.01
2000	8,079	1,883	3,332	12,476	25,770	80.32
2001	8,375	1,660	3,132	12,355	25,523	79.55
2002	8,649	1,067	2,932	12,121	24,770	77.20
2003	8,625	1,141	2,732	11,794	24,293	75.71
2004	8,700	1,155	2,532	11,508	23,895	74.47

5.3 Recalculations for *Solvents and Other Product Use*

As the underlying estimates of NMVOC have been revised, the CO_2 emissions listed in Table 5.1 for the years 1990-2003 are recalculated values. The estimates from this category are reduced with the decreases ranging from 11.6 percent in 1990 to 31.6 percent in 2003. This pattern of reduction reflects the general overestimation of NMVOC emissions for *Solvents and Other Product Use* as reported in previous NIRs.

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 1990-2004 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 could be 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. The major changes in the inventories for *Agriculture* in the 2006 submission are the adoption of Tier 2 methods for CH_4 emissions from enteric fermentation in cattle and robust improvement for estimates of emissions from manure management based on the results of major research and extensive farm facility surveys conducted in recent years. This research, together with other relevant work related to the development of an elaborate new NH_3 inventory for agriculture and guidelines on 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. In preparing the inventory time-series for the years 1990-2004, particular attention was given to detailed application of new methods and data for 1990 and 2004. The recalculations for the intervening years were undertaken at a more aggregated level in most cases although appropriate steps were taken to ensure overall consistency between years over the full period. This chapter describes the methods and data used with reference to 2004 emissions. Recalculations in *Agriculture* for the years 1990-2003 are described in section 6.7 below.

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. This is the official source of the basic data for inventory purposes, except for synthetic fertilizer use, for which annual data are obtained from the Department of Agriculture and Food. The practice of using a three-year averaging period that ends in the inventory year for all agricultural statistics has been discontinued because annual-specific activity data are considered more appropriate to the methods used for the most important emission sources of greenhouse gases and NH_3, which are closely linked. 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 and sheep, 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. The manner in which the populations are applied is explained in the documentation boxes of the CRF tables.

Table 6.1. Level 3 Source Category Coverage for Agriculture

Agriculture	CO2	CH4	N2O
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	All	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	NO	NO
4. Goats	NA	NO	NO
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	NO	NO	NO
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
** CO2 emissions from Liming of Agricultural Lands included in category 5.B of LULUCF (Chapter Seven)*

6.2 CH_4 Emissions from Enteric Fermentation

6.2.1 Overall Approach

Ireland has used Tier 1 methods to estimate CH_4 emissions from enteric fermentation for all previous inventory submissions. 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. In 1990, enteric fermentation in non-dairy cattle was the single largest individual source of emissions in Ireland, accounting for 9.6 percent of the national total. Implementation of the IPCC good practice guidance for GHG inventories requires that Parties use Tier 2 (detailed country-specific) methods for key sources of greenhouse gases, as in the case of CH_4 from enteric fermentation from cattle in Ireland. The recommendation to use Tier 2 methods has also been made in several reports on the review of Irelands inventory submissions to UNFCCC. This recommendation has now been implemented.

The Irish cattle herd is now characterised by 11 principal animal categories as given in Table 6.1 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 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. Dairy cows were covered by 12 systems and 18 were analysed for suckler cows, while up to 30 systems were used for both male and female beef cattle. The exercise to develop Tier 2 emission factors for the 11 animal categories was initially carried out for the 2003 herd and then repeated for 1990 and 1994. The following paragraphs outline the approach and a detailed description of the comprehensive study and analysis underlying the new emission factors is available (O'Mara, 2006).

Table 6.2 Animal Classification for Cattle Population

Cattle Type	Classification		
Dairy cattle	Dairy cows	Suckler 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 Dairy Cattle

For both dairy cows and suckler cows, the country was divided into three regions: (1) south and east, (2) west and midlands, and (3) north west, coinciding with regions used for implementing the Nitrates Directive based on slurry storage requirements of local planning authorities. This facilitated in-depth analysis for separate regions with different lengths of winter housing and took account of different animal feeding practices. The number of cows in each category given by CSO statistics was allocated to the regions using CMMS reports published by the Department of Agriculture and Food (DAF, 2005). The cattle production system in each region was defined in terms of calving date, dates of winter housing and spring turn-out to grass, milk yield and composition, forage and concentrate feeding level, cow liveweight and liveweight change and lactation period.

The daily energy requirement of cows in each region was calculated by month 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 are 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 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 was applied when the diet consisted of grazed grass and 3 kg or less of concentrate supplement per day. This was 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). The daily CH_4 emissions were summed to give annual emissions for cows in each region, and a weighted national average was then calculated.

6.2.3 Enteric Fermentation in Beef Cattle

Emission factors for the beef cattle categories given in Table 6.1 were 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 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.

The analysis was undertaken for a total of 11 separate production systems covering the three groups of male and female beef cattle given in Table 6.1 after the proportion of the herd in each category was calculated. Important parameters such as housing dates (expert opinion), turnout dates (expert opinion) and liveweight gains (expert opinion reconciled with actual national carcass weights) during winter housing periods and grazing seasons were defined for each system. The most important parameter is liveweight gain as it directly affects the energy requirement and thus 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 were applied to the various life stages of each animal category, such that when all categories were combined, that data were consistent with the national statistics for carcass weight (+/- 10 kg difference).

Given these data for liveweight and liveweight gain, energy requirements of animals were estimated during the winter housing periods and grazing seasons of the animals lifetime using the INRAtion computer programme, version 3.0. This programme is 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*) and 1 UFV is equal to 7.61 MJ NE_{mg}.

The composition of the diet in each system was described by grazing season and winter housing period 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. 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. The daily emissions were aggregated to give annual emissions per system and a weighted national average was then calculated.

6.2.4 Enteric Fermentation in Other Cattle

Bulls for breeding and in-calf heifers account for approximately 6 percent of the national cattle herd. Separate production systems are not defined for these categories because of lack of published data on their feed intake and the small number of animals involved. 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 value of 66.5 kg/year for animals in this category is determined by an applicable period of 310 days in their second year, which is adjusted to 81.5 kg/year using the full period of 365 days for breeding bulls.

In-calf heifers were assigned the same emission factors as female beef cattle (50.16 and 53.58 kg/year for dairy and beef animals, respectively) 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. Female beef cattle in the category 1-2 years old are assumed to be slaughtered on 3rd February of their third year. Adjustment for the slightly longer period was 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 2004, 2003 and 1990 are summarised in Table 6.3 for the 11 principal categories chosen to characterise the Irish cattle herd. 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, which Ireland has used to date. The corresponding value for 2003 indicates an increase of about 8 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 2003, 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, 2003 and 2004

	Enteric Fermentation (kg/head/year)			Manure Management (kg/head/year)		
	2004	2003	1990	2004	2003	1990
Dairy cows	108.50	108.8	101.38	20.53	20.53	21.57
Suckler cows	74.41	74.20	74.03	13.90	13.90	14.02
Male cattle < 1 year	29.70	29.53	30.46	8.50	8.50	9.73
Male cattle 1 - 2 years	59.26	60.37	62.22	13.75	14.25	16.68
Male cattle > 2 years	35.23	34.27	55.08	1.60	1.48	4.57
Female cattle < 1 year	27.89	27.86	27.05	8.30	8.28	8.79
Female cattle 1 - 2 years	44.50	44.60	53.54	9.11	9.34	14.74
Female cattle > 2 years	22.46	22.46	21.65	0.34	0.34	0.33
Bulls for breeding	81.21	81.55	86.38	18.58	18.95	23.79
Dairy in-calf heifers	50.03	50.16	51.82	10.74	10.93	13.40
Beef in-calf heifers	53.44	53.58	55.42	12.66	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, 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 those for Western Europe given in Table 4.3 of the IPCC Guidelines.

6.3 CH_4 Emissions from Manure Management

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 farm facilities surveys that were undertaken as part of the research underlying an elaborate new NH_3 inventory for Ireland and the work on emission factors for enteric fermentation in cattle described above is the basis for revised CH_4 emission factors for manure management. The results of the farm facilities surveys 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. Previous NIRs have stated that sheep remain outdoors all year round and that there is no management of sheep manures in Ireland. The farm facilities surveys show that lowland sheep are housed for some time during the year thus allowing for the inclusion of sheep manures in the estimation of emissions from manure management. The manures from horse, mules and asses are also included on the assumption that they are distributed equally between solid storage and pasture systems.

The analysis of the feeding regime for cattle included a full evaluation of the organic matter content of the feeds applicable to the 11 categories that characterise the national herd, which facilitated the estimation of their respective levels of organic matter excretion. The emission factors for manure management were 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. They are higher than those previously used mainly because a much higher proportion of waste is allocated to liquid systems for which the applicable updated MCF value is 0.39.

The calculation methane 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 emission factors for swine are substantially higher than previously used, as all wastes are allocated to liquid systems, which have a relatively high MCF of 0.39. The application of the manure management emission factors for sheep, horses and poultry means that all CH_4 emissions from livestock are now included in the latest estimates. The CH_4 emissions from manure management in 2004 amounted to 23.4 percent of those from enteric fermentation.

6.4 N_2O Emissions from Manure Management

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. 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 now used by the inventory agency, along with the information on the allocation of animal manures to each applicable animal waste management system, to produce a more robust CRF Table 4.B(b) for all years in order to derive improved estimates of N_2O emissions from manure management according to the IPCC methodology.

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. The bulk of animal wastes in housing are managed in liquid storage systems (93 percent and 70 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 2004 amounted to 1,331 tonnes.

6.5 N_2O Emissions from Agricultural Soils

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.

6.5.1 4.D.1 Direct Soil Emissions

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 sludges 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 1990-2004 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 south-east 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 2004)
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
$Frac_{GASM1}$ = fraction of animal manure nitrogen that volatilizes as NH_3 during housing, manure storage and landspreading (0.491 in 2004)
$N_2O\text{-}N_{hs}$ = amount of animal manure nitrogen emitted as N_2O in housing and storage (kg N2O-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 new 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 2004 values of $Frac_{GASM1}$ and $Frac_{GASM2}$ are 0.491 and 0.038, respectively indicating an overall volatilisation rate of 0.194 for animal manure nitrogen, which is close to the value used previously.

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 0.491, respectively in 2004 from the NH_3 inventory. Published estimates of sludge production (Smith et al, 2003) and the proportion applied on agricultural lands are used to estimate F_S on the basis of 3 percent nitrogen content in sewage sludges 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 2004.

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 2004 for category *4.D.1 Direct Soil Emissions* amounted to 9,630 tonnes, of which synthetic fertilizers accounted for 7,010 tonnes, 2,150 tonnes was due to land spreading of animal manures and crops produced 470 tonnes.

6.5.2 4.D.2 Pasture Range and Paddock Manure

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 Animal Production*. The amount of organic nitrogen input concerned (N_{ex} * $Frac_{GRAZ}$) from the equations above, is large in Ireland 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 fraction $Frac_{GASM2,}$ estimated at 0.038 for 2004, is used to adjust nitrogen inputs from grazing animals due to NH_3 volatilisation. The direct N_2O emission factor (EF_3) for this unmanaged nitrogen input is 0.02 kg N_2O-N/kg N and the estimate of emissions in 2004 was 9,080 tonnes.

6.5.3 4.D.3 Indirect Emissions

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

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

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

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 (0.038 in 2004)
$Frac_{LEACH}$ = fraction of synthetic fertilizer nitrogen and animal manure nitrogen that leaches from agricultural soils (0.1 in 2004)
EF_4 = N_2O emission factor for nitrogen inputs from atmospheric deposition
EF_5 = N_2O emission factor for nitrogen leaching

The expressions for $N_2O_{indirect\text{-}dep}$ and $N_2O_{indirect\text{-}leach}$ are slightly modified to be consistent with those for estimating direct emissions above 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 2004, 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 2004 amounted to 4,422 tonnes N_2O, or approximately 46 percent of direct emissions from soils (sub-category 4.D.1).

6.6 QA/QC in Agriculture

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 has been developed to calculate these emissions in a more efficient and transparent manner, which takes into account the strong links to Ireland's new 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 outputs directly compatible with the CRF Reporter as well as internal checks on the calculations. The entire compilation for 2004 and all previous years was reviewed internally by a research fellow not directly involved with the inventory for *Agriculture* and reviewed externally by a technical person from the Department of Agriculture and Food.

The intensive collaboration between inventory experts and researchers involved in developing the improved inventory methodologies for both CH_4 and NH_3 together with assessment and endorsement of the outcomes by other experts in TEAGASC and the DEHLG adds significantly to the quality and reliability of the emissions estimates produced in this system according to the IPCC good practice guidance. It may be concluded that the uncertainty associated with a key component of Irish greenhouse gas emissions has therefore been reduced.

6.7 Recalculations in *Agriculture*

The major methodological change in the sector is the application of a robust Tier 2 approach for the estimation of CH_4 emissions from both enteric fermentation and manure management in cattle. Other changes are largely due to the treatment of source categories *4.A Enteric Fermentation* and *4.B Manure Management* at a more disaggregated level and the application of official annual statistics (without three-year averaging) in a manner that best represents the activity data required for the individual sources in general. The nitrogen excretion rates for all animals in Ireland officially adopted by the Department of Agriculture for implementation of the Nitrates Directive are now consistently applied in the inventories. Reliable data on animal waste management systems and other farm-level practices underlying Ireland's elaborate NH_3 inventory for *Agriculture* are fully utilised where appropriate in relation to *4.B Manure Management* and *4.D Agricultural Soils* and minor modifications to some of the IPCC emission equations have been introduced in the latter category to adequately account for country-specific circumstances.

The quantitative effects of recalculations for the main sub-categories of CH_4 and N_2O emissions in *Agriculture* are presented in Table 6.4 for the years 1990-2003. Revised estimates of total emissions for the sector are 4.56 percent higher in 1990 and 2.04 percent higher in 2003, while there were modest reductions in the three years 2000-2002. This overall change is determined by an increase for CH_4 and a decrease for N_2O.

The Tier 2 approach for enteric fermentation in cattle fully captures the evolution in CH_4 emissions from this important source since 1990 due to changes in population, dairy cattle productivity, beef cattle production systems and other factors. The emission factor for dairy cattle increased by about 8 percent from 1990 to 2003 (Table 6.3) but the effect of this temporal change is reduced by a population decrease of about 16 percent in the same period. The emission factor for other cattle decreased marginally between 1990 and 2003 (Table 6.3) while the population increased by 11 percent with the result that the impact of recalculation is not large for this major component of emissions from the sector. The largest recalculation changes are those given for manure management. The CH_4 emission factors in manure management are increased for all animal categories due the higher allocation of wastes to liquid systems for which the MCF of 0.39 is now used compared with 0.1 previously (NIR 2005, Table F.2 of Appendix F). The increase in CH_4 emissions varies from 43 percent in 1990 to 38 percent in 2003. The greater allocation of animal wastes to liquid systems reduces N_2O emissions for manure management as the emission factor for liquid systems is 0.001 kg N_2O-/kg N while that for solid systems is 0.02 kg N_2O-/kg N. Although this is not a major component of emissions from Agriculture the decrease in N_2O emissions varies from 55 percent in 1990 to 60 percent in 2003.

6.8 Improvements in *Agriculture*

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 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. The agency has also been intensively engaged with researchers working on the DNDC model (Li, 1994) that 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. The results of both field and lysimeter studies conducted in Ireland in recent years 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 DNDC model has been applied at both regional and national scale and the outcomes were assessed at a workshop in September 2005 attended by the developer of the model and by other eminent agricultural experts in Ireland and the UK. Soil properties, particularly bulk density and organic carbon content, were found to be the key model variables controlling N_2O and it was concluded that a lack of reliable data on these two parameters precludes routine application of the DNDC model at this stage for the purposes of annual emissions reporting. Nevertheless, the model is a very useful supplementary method for assessing emissions, especially in the analysis of the relative importance of all input variables and their effects on total N_2O emissions. Field studies on N_2O fluxes are ongoing and the use of DNDC is under review.

Table 6.4 Percentage Change in Emissions from Agriculture due to Recalculations

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
2005 Submission - Total CH_4 (Gg CO2)	497.193	509.614	516.498	519.700	521.714	523.894	529.848	540.276	551.865	551.965	540.483	527.264	519.245	506.867
2005 Submission - Total N_2O (Gg CO2)	25.552	26.219	26.401	26.503	26.963	27.433	27.951	28.122	28.521	28.725	28.597	27.592	26.675	26.139
2006 Submission - Total CH_4 (Gg CO2)	550.668	558.194	560.647	564.587	563.208	564.393	580.958	594.528	602.020	581.495	554.109	552.672	546.506	541.712
2006 Submission - Total N_2O (Gg CO2)	24.762	24.851	24.797	25.266	25.901	26.551	26.630	26.119	27.629	27.665	26.054	24.806	24.459	25.037
Enteric Fermentation - CH_4	1.69	0.56	-0.20	-0.14	-0.64	-0.81	0.92	1.23	0.45	-2.79	-5.50	-3.22	-2.86	-0.98
Manure Management - CH_4	43.36	42.85	41.94	41.87	41.02	40.64	41.64	41.88	41.08	38.20	36.04	37.45	37.77	37.83
Manure Management - N_2O	-54.56	-52.26	-52.93	-51.60	-55.36	-52.03	-53.27	-54.42	-54.66	-52.59	-57.37	-59.31	-61.60	-59.44
Animal Production N_2O	1.96	0.71	0.77	0.02	-1.03	-0.65	1.05	1.48	0.72	-1.95	-4.44	-2.75	-2.34	0.13
Agricultural Soils - Direct N_2O	-1.16	-5.17	-7.18	-3.26	-0.26	0.67	-4.31	-10.50	-0.42	0.42	-8.81	-12.88	-8.50	-1.08
Agricultural Soils - Indirect N_2O	-3.15	-4.99	-6.05	-4.34	-3.57	-3.28	-4.13	-6.40	-2.04	-2.42	-7.91	-10.22	-8.11	-4.65
TOTAL CH_4	9.71	8.70	7.87	7.95	7.37	7.18	8.80	9.13	8.33	5.08	2.46	4.60	4.99	6.43
TOTAL N_2O	-3.19	-5.51	-6.47	-4.90	-4.10	-3.32	-4.96	-7.67	-3.23	-3.83	-9.76	-11.23	-9.06	-4.40
Total % Change in Emiss. from Agricult.	4.56	3.07	2.21	2.84	2.73	2.87	3.25	2.52	3.66	1.40	-2.55	-1.71	-0.60	2.04

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 and adoption of the IPCC good practice guidance on LULUCF, 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 guidance 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 land drainage 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

7.2.1 Sector Coverage

The 2006 inventory submission includes the results of Ireland's first attempts to comply with the reporting requirements of Decision 13/CP.9 for the LULUCF sector. Complete coverage of the relevant gases has been achieved for the years 1990-2004 in all IPCC land categories, as indicated by Table 7.1, whereas in previous submissions Ireland reported CO_2 estimates only in respect of carbon stock change in forests and CO_2 emissions from the liming of agricultural soils. These categories correspond to above-ground biomass under *5.A Forest Land* and liming reported in CRF Table 5(IV), respectively in the revised source classification. The reporting of estimates for all land-use categories in LULUCF in the present submission represents a major improvement in terms of inventory completeness for Ireland. The availability of an overall quantitative assessment of emissions and removals for the sector in 1990 also fulfils an important criterion related to the determination of assigned amount for the Kyoto Protocol (Chapter Ten). The estimates of emissions and removals from LULUCF over the period 1990-2004 are presented in Table 7.2 for all land-use categories. The only non-CO_2 emissions accounted for explicitly in this compilation are the emissions of N_2O from disturbance associated with land-use conversion to cropland, which are reported in CRF Table 5(III). Other potential emissions of N_2O and CH_4 are not reported by Ireland according to the following rationale

- The amount of nitrogen fertilizer used for forests is negligible compared to that in agriculture and therefore all N_2O emissions from fertilization are reported under in the *Agriculture* sector and the notation IE is used in CRF Table 5(I);
- The N_2O emissions from drainage of forest lands and wetlands is an optional reporting category for which Ireland has elected not to include at this time and hence the notation NA appears in CRF Table 5(II);
- No information is available on biomass burning and this activity is assumed not to occur and therefore the notation NO applies in respect of CH_4 and N_2O emissions from biomass burning in CRF Table 5(V).

The data in Table 7.2 show that the LULUCF sector was a small net source of emissions in the years 1990-1997 and was a net sink of carbon in the other six years. This outcome is determined essentially by the balance between the categories *5.A Forest Land*, which is a major carbon sink, and *5.C Grassland*, which is a large emission source. 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. The increase in carbon stocks in living biomass in the categories *5.A.1 Forest Land remaining Forest Land* and *5.A.2 Land Converted to 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 towards the end of the time series.

Table 7.1. Level 3 Category Coverage for Land Use, Land-Use Change and Forestry

5 Land Use Land-Use Change and Forestry	Carbon Stock Changes Emissions of CO_2			CH_4	N_2O
	Biomass	DOM	Soils		
A. Forest Land					
1. Forest Land remaining Forest Land	All	All	NO*	NA	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	NE
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	NE
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*

Table 7.2. Emissions[a] and Removals[a] from Land Use Land-Use Change and Forestry 1990-2004 (Gg CO_2 eq)

IPCC Source Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
A. Forest Land	-478.98	-393.12	-202.34	-277.34	-209.03	-246.60	-218.63	-351.12	-506.73	-593.20	-475.40	-626.24	-739.87	-1061.36	-671.29
1. Forest Land remaining Forest Land	-1078.90	-1163.38	-884.40	-876.45	-587.48	-437.51	-358.95	-238.61	-521.46	-579.24	-116.18	-37.62	-358.01	-1258.08	-724.25
2. Land converted to Forest Land	599.91	770.26	682.06	599.11	378.45	190.91	140.32	-112.51	14.72	-13.97	-359.22	-588.62	-381.86	196.71	52.95
B. Cropland	10.52	16.28	12.44	-57.72	-14.62	-51.24	-13.00	39.16	51.58	-7.20	36.25	29.36	120.74	103.42	171.93
1. Cropland remaining Cropland	8.30	13.22	8.07	-67.94	-86.57	-84.86	-48.72	-39.70	-46.13	-77.96	-35.78	-44.86	-40.68	-54.58	-30.05
2. Land converted to Cropland	2.22	3.05	4.36	10.22	71.95	33.62	35.72	78.86	97.71	70.76	72.03	74.23	161.42	158.00	201.98
C. Grassland	520.76	624.10	496.27	411.86	228.42	463.26	502.70	396.66	191.07	300.57	388.60	376.04	404.09	540.28	430.50
1. Grassland remaining Grassland	295.97	293.04	293.04	290.73	274.04	267.12	267.01	262.68	262.68	262.68	262.68	262.68	262.68	262.68	262.68
2. Land converted to Grassland	-130.25	15.92	-52.36	-236.17	-315.26	-298.46	-248.34	-289.51	-377.19	-345.34	-240.47	-271.93	-132.50	-109.16	-72.97
Agricultural Lime Application[b]	355.04	315.15	255.60	357.30	269.64	494.60	484.03	423.49	305.58	383.23	366.38	385.28	273.90	386.76	240.80
D. Wetlands	44.68	44.56	44.43	44.31	42.37	31.87	31.43	31.00	30.56	30.13	23.36	22.92	22.49	22.05	21.62
1. Wetlands remaining Wetlands	44.68	44.56	44.43	44.31	42.37	31.87	31.43	31.00	30.56	30.13	23.36	22.92	22.49	22.05	21.62
2. Land converted to Wetlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
E. Settlements	11.20	10.39	10.92	12.48	14.36	14.35	17.85	20.29	23.69	24.42	25.22	37.61	31.73	40.37	38.97
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
2. Land converted to Settlements	11.20	10.39	10.92	12.48	14.36	14.35	17.85	20.29	23.69	24.42	25.22	37.61	31.73	40.37	38.97
F. Other Land	NE, NO	NE, NO	-11.92	-11.92	-13.31	-6.42	-27.34	NE, NO	-5.10	NE, NO	NE, NO	-13.57	-30.30	-27.54	-63.32
1. Other Land remaining Other Land	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Land converted to Other Land	NO	NO	-11.92	-11.92	-13.31	-6.42	-27.34	NO	-5.10	NO	NO	-13.57	-30.30	-27.54	-63.32
G. Other	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
TOTAL LULUCF	**108.17**	**302.20**	**349.80**	**121.67**	**48.20**	**205.22**	**293.01**	**135.99**	**-214.94**	**-245.29**	**-1.98**	**-173.88**	**-191.12**	**-382.78**	**-71.60**

a positive values indicate emissions and negative values indicate removals

b the emissions from lime application to grassland are reported in CRF Table 5(IV) rather than under Grassland in CRF Table 5.C

Table 7.3. Land Use Categories

Land Use Category	Definition and Coverage	Area 1990 (ha)	Area 2004 (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	370,160	587,494	FIPS (Forest Inventory 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 recorded by the Central Statistics Office (CSO)	394,800	423,900	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	4,040,600	3,880,280	CSO, CORINE Land Cover LPIS (Land Parcels information System) CORINE Land Cover General Soil Map		Other Land
Wetlands	Natural unexploited wetlands	1,228,660	1,171,137	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	73,980	57,550	Bord na Mona (BNM) area statistics; Expert opinion		
Settlements	Urban areas, roads, airports and the footprint of industrial, commercial/institutional and residential buildings	98,105	107,853	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	905,480	883,570	Natural grasslands not in use for agricultural purposes, water bodies, bare rock	Grassland	
Total Land	National territorial area	7,111,785	7,111,785	CORINE Land Cover		

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 have been used for estimating the respective areas remaining in the category and areas converted to the category and their associated greenhouse gas emissions and removals. The IPCC Wetlands category has been split into natural unexploited wetlands, and peatlands, which are wetlands drained for the purpose of commercial and domestic harvesting of peat for combustion or horticultural use.

Table 7.5 records the land-use changes among the various categories over the period 1990-2004 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 for Irish circumstances 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 LULUCF 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 57 percent of total area in 1990. The *Other Land* category was the next largest at almost 11 percent, followed by *Forest Land* which was 7 percent of the total. The major land-use change since 1990 has been the conversion of grassland and peatland to forest land. The area of forests increased by 44 percent from 1990 to 2004, but the proportion of *Forest Land* to total land in the country is still only 10 percent, which is low compared to many Annex I Parties.

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. Mineral soils as identified from the general soil map were allocated to the HAC (high activity clay), LAC (low activity clay), sandy and humic soil classes used by IPCC while peats were allocated to the IPCC wetlands class as shown on Table 7.4, based on detailed national assessment of soil carbon stocks in Ireland (Tomlinson, 2003). The values of SOC_{ref} appropriate to each soil association may then be assigned using the correspondence to IPCC classes given in Table 7.4. 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 7.4. 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	

Table 7.5 Land Use Matrices 1990-1997 (ha)

	Forest Land	Cropland	Grassland	Peatland	Wetland	Settlements	Other Land	Total
1990	**370,160**	**394,800**	**4,040,599**	**73,980**	**1,228,661**	**98,105**	**905,481**	**7,111,785**
Forest Land	370,132					28		370,160
Cropland	394	392,000	2,384			22		394,800
Grassland	11,888		4,028,473			239		4,040,599
Peatland	320		61	73,380	219			73,980
Wetland	6,573				1,222,088			1,228,661
Settlements						98,105		98,105
Other Land			19,181			16	886,284	905,481
1991	**389,307**	**392,000**	**4,050,099**	**73,380**	**1,222,307**	**98,409**	**886,284**	**7,111,785**
Forest Land	389,278					29		389,307
Cropland	325	391,652				23		392,000
Grassland	10,291	1,248	4,020,238			251	18,071	4,050,099
Peatland	320		61	72,780	219			73,380
Wetland	5,792				1,216,515			1,222,307
Settlements						98,409		98,409
Other Land						16	886,267	886,284
1992	**406,006**	**392,900**	**4,020,299**	**72,780**	**1,216,734**	**98,728**	**904,338**	**7,111,785**
Forest Land	405,973					33		406,006
Cropland	322	392,552				26		392,900
Grassland	9,904	11,248	3,998,860			287		4,020,299
Peatland	320		61	72,181	219			72,780
Wetland	5,485				1,211,249			1,216,734
Settlements						98,728		98,728
Other Land			1,478			19	902,842	904,338
1993	**422,004**	**403,800**	**4,000,399**	**72,181**	**1,211,468**	**99,092**	**902,842**	**7,111,785**
Forest Land	421,965					38		422,004
Cropland	435	400,400	2,935			30		403,800
Grassland	12,227		3,987,302			330	539	4,000,399
Peatland	320		61	71,581	219			72,181
Wetland	6,515				1,204,953			1,211,468
Settlements						99,092		99,092
Other Land						22	902,820	902,842
1994	**441,462**	**400,400**	**3,990,298**	**71,581**	**1,205,172**	**99,512**	**903,359**	**7,111,785**
Forest Land	441,424					38		441,462
Cropland	574	399,401	396			30		400,400
Grassland	15,080		3,974,887			331		3,990,298
Peatland	140		30	70,721	690			71,581
Wetland	7,954				1,197,218			1,205,172
Settlements						99,512		99,512
Other Land			13,885			22	889,452	903,359
1995	**465,172**	**399,401**	**3,989,198**	**70,721**	**1,197,908**	**99,934**	**889,452**	**7,111,785**
Forest Land	465,124					48		465,172
Cropland	539	398,824				37		399,401
Grassland	13,473	7,677	3,934,968			415	32,665	3,989,198
Peatland	140		30	69,861	690			70,721
Wetland	6,877				1,191,031			1,197,908
Settlements						99,934		99,934
Other Land						27	889,425	889,452
1996	**486,153**	**406,501**	**3,934,998**	**69,861**	**1,191,721**	**100,461**	**922,090**	**7,111,785**
Forest Land	486,098					55		486,153
Cropland	334	406,125				43		406,501
Grassland	7,509	7,977	3,919,037			475		3,934,998
Peatland	140		30	69,001	690			69,861
Wetland	3,506				1,188,215			1,191,721
Settlements						100,461		100,461
Other Land			98,131			31	823,928	922,090
1997	**497,587**	**414,102**	**4,017,198**	**69,001**	**1,188,905**	**101,065**	**823,928**	**7,111,785**

Table 7.5 (continued) Land Use Matrices 1997-2004 (ha)

	Forest Land	Cropland	Grassland	Peatland	Wetland	Settlements	Other Land	Total
1997	**497,587**	**414,102**	**4,017,198**	**69,001**	**1,188,905**	**101,065**	**823,928**	**7,111,785**
Forest Land	497,522					65		497,587
Cropland	327	408,001	5,723			50		414,102
Grassland	8,281		4,001,045			559	7,313	4,017,198
Peatland	140		30	68,141	690			69,001
Wetland	4,245				1,184,660			1,188,905
Settlements						101,065		101,065
Other Land						36	823,892	823,928
1998	**510,515**	**408,001**	**4,006,798**	**68,141**	**1,185,350**	**101,775**	**831,205**	**7,111,785**
Forest Land	510,447					67		510,515
Cropland	371	400,902	6,676			52		408,001
Grassland	8,325		3,997,894			579		4,006,798
Peatland	140		30	67,281	690			68,141
Wetland	3,898				1,181,452			1,185,350
Settlements						101,775		101,775
Other Land			12,798			38	818,369	831,205
1999	**523,183**	**400,902**	**4,017,398**	**67,281**	**1,182,142**	**102,511**	**818,369**	**7,111,785**
Forest Land	523,113					70		523,183
Cropland	451	400,396				54		400,902
Grassland	10,276	605	4,005,916			601		4,017,398
Peatland	327		75	65,335	1,544			67,281
Wetland	4,711				1,177,431			1,182,142
Settlements						102,511		102,511
Other Land			35,907			39	782,423	818,369
2000	**538,878**	**401,001**	**4,041,898**	**65,335**	**1,178,975**	**103,275**	**782,423**	**7,111,785**
Forest Land	538,773					105		538,878
Grassland	10,245	15,154	3,994,424			902	21,173	4,041,898
Cropland	473	400,447				81		401,001
Peatland	327		75	63,389	1,544			65,335
Wetland	4,523				1,174,452			1,178,975
Settlements						103,275		103,275
Other Land						59	782,364	782,423
2001	**554,341**	**415,601**	**3,994,499**	**63,389**	**1,175,996**	**104,422**	**803,537**	**7,111,785**
Forest Land	554,252					89		554,341
Grassland	9,973	8,829	3,948,524			768	26,405	3,994,499
Cropland	460	415,072				69		415,601
Peatland	327		75	61,443	1,544			63,389
Wetland	4,383				1,171,613			1,175,996
Settlements						104,422		104,422
Other Land						50	803,487	803,537
2002	**569,395**	**423,901**	**3,948,599**	**61,443**	**1,173,157**	**105,398**	**829,892**	**7,111,785**
Forest Land	569,281					114		569,395
Cropland	280	423,533				88		423,901
Grassland	6,033	12,968	3,928,616			982		3,948,599
Peatland	327		75	59,497	1,544			61,443
Wetland	2,571				1,170,586			1,173,157
Settlements						105,398		105,398
Other Land			5,209			64	824,619	829,892
2003	**578,492**	**436,501**	**3,933,900**	**59,497**	**1,172,130**	**106,647**	**824,619**	**7,111,785**
Forest Land	578,382					110		578,492
Cropland	277	423,901	12,238			85		436,501
Grassland	5,969		3,867,968			949	59,014	3,933,900
Peatland	327		75	57,551	1,544			59,497
Wetland	2,537				1,169,593			1,172,130
Settlements						106,647		106,647
Other Land						62	824,557	824,619
2004	**587,492**	**423,901**	**3,880,281**	**57,551**	**1,171,137**	**107,853**	**883,570**	**7,111,785**

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

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

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

where

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

The factors F_{LU}, F_{MG} and F_I account for changes in SOC due to management practices that impact on soil carbon. Table 7.6 shows the adjustment factors derived from the product of F_{LU}, F_{MG} and F_I taken from GPG Table 3.3.4 for the land uses defined for Ireland in Table 7.3. Equation 7.1 is the basic Tier I method 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 reasonable first 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 7.4 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.

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 factor 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 below.

Table 7.6. Adjustment Factors for SOC

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

7.3 5.A Forest Land

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) and how it has been applied for the period 1990-2004 is available (Gallagher et al, 2004). 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. 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 FIPS.

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 1990-2004.

Forest Area and Species
A time series of forest strata by area and age was constructed for the years 1990-2004 using information from the Forest Inventory and Planning System (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 2004 were obtained by growing the forest estate forward in time, using annual data on planting and clearfelling 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 and Forest and Wildlife 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.

1990-2004 Time Series Data

The carbon stock change estimates for living biomass in forests are slightly revised on those given in the 2005 submission due to the effect of some updated information for felling in State forests, provided by Coillte, and an increase in private felling and afforestation from 200 to 250 ha/year after 1999. These changes in felling can have an immediate effect on the stock calculation because felling causes an immediate reduction in carbon stock, whereas the reforestation of the same area will not contribute to carbon stock increase for 7 years after reforestation. The uneven pattern of stock increment over the time-series can be explained by the fluctuations which occur in afforestation, reforestation and felling normally taking effect at different times and which may coincide periodically.

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 (GPG Section 3.2.1.2). In the case of litter, the default net litter accumulation values for wet temperate forests are adopted, as outlined in GPG Table 3.2.1 and the stock change is estimated with reference to young and mature forests separately. The values from GPG 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 than20 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 forest inventory 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 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 tC/ha/year for older stands, based on litter inputs of 1 to 4 tC/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 defaults but the default values are adopted for now because we do not have sufficient country specific data.

7.3.3 Net Carbon Stock Change in Soils

5.A.1 Forest land Remaining Forest Land
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.

5.A.2. Land Converted to Forest Land
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 other agricultural practices. In more recent years, and especially with the increase in private afforestation, land of higher quality has been converted, 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 activity areas 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. The GIS analysis provided the means by which to allocate the land areas in the conversion categories 5.A.2.1 through 5.A.2.5 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 conversions 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.

Afforestation occurs on mineral and organic soils at a ratio of approximately 60:40. 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 of Non-CO_2 Gases

Ireland does not report emissions of non-CO_2 greenhouse gases 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 application are reported under agriculture. The notation IE is therefore used in CRF Table 5(I). No estimates have been made of N_2O emissions associated with the drainage of forest soils, an optional reporting category in the LULUCF sector, and the notation NA is used in CRF Table 5(II). Biomass burning does not occur in Ireland with the result that the notation key NO is used in CRF Table 5(V) for the gases concerned.

7.4 5.B Croplands

7.4.1 *Cropland* Areas

Cropland areas are based on CSO annual statistics for tillage crops. 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. The CSO data include set-aside areas within the Other Crops class. 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*. 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 the 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 tC/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

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

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

7.4.3 Carbon Stock Change in Soils

The spatial distribution of cropland areas over IPCC soil class is derived from GIS analysis of LPIS 2004 data, superimposed on the general soil association map. The GIS analysis shows that a very high proportion (98 percent) of croplands are 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 duration of 20 years. Organic soils continue to lose carbon until such time as they are no longer organic. It is assumed that none of the soils classified as organic managed to change this status during the inventory period. Therefore all croplands that were on organic soils in 1990 continue to be assigned to organic soils.

7.4.4 N_2O Emissions in Cropland

Soil disturbance associated with land-use conversions to cropland result in minor emissions of N_2O. Such emissions are estimated 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 5.C Grassland

7.5.1 *Grassland* Areas

Grassland is the dominant land-use category in Ireland. Areas are based principally on CSO annual statistics on improved grassland (pastures and areas harvested for silage and hay) and unimproved grassland, which refers to rough grazing. 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 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 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 areas on mountains. 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 flux of 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 figures, which record only the area given over to each activity 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 I default methods are applied. There is little data on conversion of forest land to grassland. For the purposes of the 2006 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.

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 I 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 at Tier I in the same was 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 the default values[1].

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. 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 is 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.

[1] There appears to be some inconsistency between default biomass carbon stocks given in GPG Table 3.4.9 and those derived from GPG Tables 3.4.2 and 3.4.3. The inventory agency believes that the value of 13.6 tonnes DM/ha for the cold wet temperate climate zone should be 12 tonnes DM/ha.

7.5.3 Agricultural Lime Application

Much of the total emission of carbon for grassland 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 and as the bulk of lime is applied to grassland, the split between cropland and grassland is not made for reporting purposes. The CO_2 emissions are calculated using the default emission factor of 120 kg C/tonne lime. The estimates are reported in CRF Table 5(IV) rather than in CRF Table 5.C, the carbon stock change table for grassland.

7.6 5.D Wetlands

7.6.1 *Wetland* Areas

The national wetland area was split into two types (Table 7.3). 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. This split was necessary to account for the conversion of wetlands to peatland, which would be 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 the 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 wetlands 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. The company 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 the new extraction areas, and therefore they are an estimate of the area from which biomass has been removed. Until recently, BnM held a small area of undrained wetlands in reserved. However, these lands have been transferred to the National Parks and Wildlife for conservation.

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	

Bord na Mona supplied the area estimates for the company's commercial activities and for private industrial and domestic harvesting of peat. The data for BnM commercial peat extraction areas were 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 BnM. As similar harvesting methods are used, the areas have been extrapolated from the BnM values for individual years. Domestic harvesting of peat bogs by private land-owners 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.

7.6.2 Carbon Stock Changes in *Wetland*

Biomass

Carbon stock changes in biomass are determined by the balance between carbon loss due the removal of vegetation on preparation for peat harvesting and gain on areas of peatland restoration. 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. The area from which vegetation is removed is given by the amount of reserve that enters production annually and the restoration area is taken as the annual increase in cutaway wetland from 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 BnM bog 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.

7.7 5.E Settlements

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.

The identification of the land use from which settlement areas are converted is based 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 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 roads 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 year of completion of road projects. The biomass loss from grassland and cropland is as per guidelines Tier I. The loss of biomass from forest 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 when one considers the active policy of encouraging urban tree planting along new roads and in new housing developments, but no data are available.

7.8 5.F Other Land

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 for categories 5.A through 5.E and the total land area. A large part of *5.F Other Land* is not relevant in terms of 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" 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 soils. The soil classes are identified for *5.F.2.3 Grassland Converted to Other Land* in the same way as for other land-use categories. For mineral soils, SOC_{ref} is assigned according to Table 7.4 while Table 7.5 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 I 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 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 then 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 results contained in the 2006 submission for the years 1990-2004 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 previous submissions. As such, they constitute a new set of estimates derived for a different set of emission and removals categories and they are not regarded as recalculations in the same way as estimates have been revised for other sectors as described in this report.

7.11 Improvements in ***LULUCF***

The coverage of sources of emissions and removals by Ireland in LULUCF is now complete for the years 1990-2004. 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 given a new understanding of the contribution of this sector and it has identified a number of important CO_2 emission sources. The inventory agency is continuing to collaborate with the bodies from which the key land-use and forestry datasets are obtained and is establishing more formal arrangements for the provision of the data in a manner that is compatible with the needs of the inventory. 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.

Various research projects are ongoing in relation to the carbon sequestration potential of forests and grasslands, the two most important land uses in the context of the LULUCF inventory in Ireland. The results of research on forests, which is being extended to include a new focus on the soil carbon pool, will facilitate the further development of the CARBWARE model for carbon accounting in forests to make available an integrated system that will meet the reporting needs of the Convention and the Kyoto Protocol. Carbon flux studies in grasslands will provide a means for assessment of exchanges with the atmosphere in Irish conditions as well as country-specific information on biomass and soil carbon stocks that may be used in the future.

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. All wastewater treatment in Ireland is aerobic and no CH_4 emissions are produced. However, estimates of CH_4 emissions from sludge treatment are included for the first time in this submission as part of the work to achieve full inventory completeness. 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 hospital 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 will become an additional source of emissions for inclusion in annual inventories in the coming years following the grant of IPC licences for two incinerators by the EPA recently.

Table 8.1. Level 3 Category and Gas Coverage for Waste

Waste	CO2	CH4	N2O
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 (SWD)

The anaerobic decomposition of organic matter in solid waste disposal sites (SWDS) is a major source of methane in developed countries. The methane production potential of solid waste disposal sites in a particular year depends on the cumulative solid waste disposal over many previous years, the composition of the wastes 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 methane 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 methane usually being realised within a period of approximately 20 years.

8.2.1 Methodology for CH_4 Emissions from Solid Waste

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 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 revised methodology were included as an important component of the recalculations reported in the 2002 submission. More in-depth analysis of the historical time series of solid waste disposal was undertaken in estimating the 2001 emissions from this source, necessitating further revision of the previous estimates for the years 1990 to 2000. The revised estimates were submitted in 2003. The same basic 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.

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. 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. The 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 2004, 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 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 practice 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 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, 1994b) have also been used to some extent in compiling the MSW time-series.

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

The National Waste Database reports for 1995 (Carey *et al*, 1996), 1998 (Crowe *et al*, 2000) and 2001 (Meaney *et al*, 2003) were used to establish the MSW time-series up to 2004 and the corresponding annual CH_4 emission estimates. The time-series estimates given in the present submission are updated to account for the inclusion of sewage sludge and are fully consistent over the period 1990-2004. The historical time series of wastes placed in solid waste disposal sites up to 2004, 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 all years;
- similarly, the proportion of MSW that is placed in landfills in 1995, 1998 and 2001 is used to assign the corresponding value in other years;
- 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 amount of street cleansings is estimated from the ratio of street cleansings to MSW given by the 1995, 1998 and 2001data;
- the waste constituents of MSW that contribute to DOC are organics, paper, textiles and the category other (fine elements, unclassified materials and wood wastes), as identified in the available breakdown for 1995, 1998 and 2001;
- 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 achieved in 2004 is 0.67 for managed sites and 0.33 for unmanaged sites.

8.2.3 CH_4 Emissions from Solid Waste in 2004

The final estimates of CH_4 emissions from the IPCC source-category *6.1 Solid Waste Disposal on Land* are derived for the years 1990-2004 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. 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 1997. The amount of CH_4 captured 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 in the national energy balance, assuming 35 percent conversion efficiency. As part of the implementation of Directive 1999/31/EC (CEU, 1999b) and reporting to the European Pollution Emissions Register (EPER), the EPA has 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 are considered to be all the landfills that were producing CH_4 in any appreciable quantities in that year and the exercise is a repeat of that undertaken for 2001. The estimates were developed from information obtained from local authorities on the solid wastes placed in the individual landfills and selection of appropriate values of other parameters for use in the emission models. The EPER results indicate 34,659 tonnes utilised and 23,554 tonnes of CH_4 flared in 2004 and actual CH_4 emissions, derived as the difference between the model estimate of CH_4 generation and flaring/utilisation, of 44,456 tonnes from the 65 landfills covered by the bottom-up analysis. The amount of gas utilisation is more than twice the estimate of 16,800 tonnes obtained from the reports on renewable energy that is reflected in the national energy balance. The latter source is retained for the purposes of the top-down inventory but the amount of CH_4 flared is an additional data item that is accounted for in estimating actual CH_4 release from landfills in 2004. The EPER report data for 2001 gives 13,198 tonnes for CH_4 flaring. Estimates of CH_4 flaring in 2002 and 2003 have been obtained by interpolation of the 2001 and 2004 values and the flaring amounts are taken into account in revised estimates of CH_4 emissions from managed landfills in the years 2001-2003.

Figure 8.2 shows the trend in emissions from solid waste disposal over the period 1990-2004 achieved from the analysis described above and using the EPER results for flaring and utilisation for the years 2001 to 2004. The revised estimates indicate CH_4 emissions of 63,430 tonnes in 1990 from an annual average of 0.94 million tonnes of contributing municipal waste over the preceding period of 20 years. In 2004, emissions had increased to 79,900 tonnes after recovery and flaring and the average contributing wastes were approximately 1.4 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 tCH_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 IEF approximately 30 percent higher than those based on MSW for the year concerned, e.g. range 0.066-0.076 compared to 0.1-0.11 over the period 1990-2004. Ireland has no waste incineration and a high proportion of waste consequently goes to landfill.

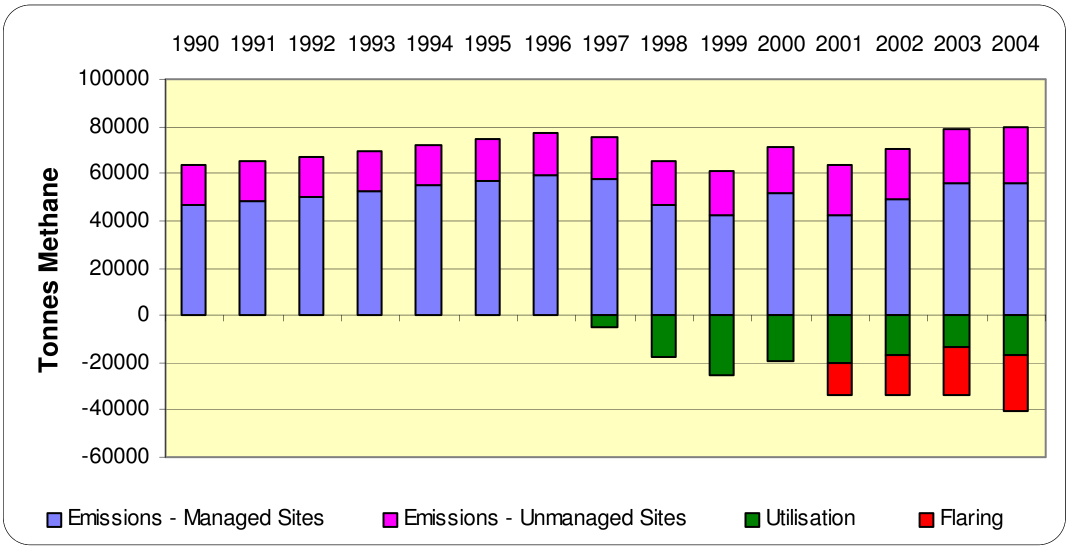


Figure 8.2. Methane Emissions from Solid Waste Disposal Sites 1990-2004

8.3 Emissions from Wastewater Handling

8.3.1. CH_4 Emissions from Wastewater and Sludge

It is assumed that in Ireland all wastewaters sent to municipal wastewater treatment plants are treated aerobically and that all wastewater treatment plants on-site of industries also operate aerobically. A third of the population, mostly found in rural areas, treat their wastewater using septic tanks (Smith *et al*, 2003). The temperature experienced in a septic tank is not optimum for methane-producing bacteria, therefore there is negligible methane production. The wastewater treated by the septic tank is released to a percolation area or to surface waters. The commercial wastewater that does not go to municipal wastewater treatment plants is assumed to be treated aerobically on site before discharge to percolation areas or surface waters and again there are no methane emissions. Consequently, there are no CH_4 emissions produced from wastewater handling and the notation key NO is used under sub-categories 6.B.1(a) and 6.B.2(a) of CRF Table 6.B.

National studies (O'Leary and Carty, 1998) indicate that 3 percent of sludge produced in both industrial wastewater and domestic and commercial wastewater handling, including septic tanks, is treated anaerobically. A portion of this sludge is spread on agricultural lands (12 percent in 1990 and 34 percent in 2004) where it contributes to the N_2O emissions from soils, as described in section 6.5.1. Some of the sludge is also sent to landfill (42 percent in 1990 and 30 percent in 2004) and is accounted for in the estimate of degradable organic carbon that generates CH_4 in landfills as outlined in section 8.2.1 of this chapter. The estimates of CH_4 emissions from wastewater and sludge are derived using the national statistics, country specific values and default values from the IPCC Guidelines listed in Table 8.2.

8.3.2 N_2O Emissions from Human Sewage

Emissions of N_2O from human sewage discharges reported under source category *6.B Wastewater Handling* have been made following the IPCC methodology. This source of emissions was first included as part of the recalculation exercise undertaken for the 2002 submission and continues to be part of the inventory. 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 2003 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 of the 2005 submission. The emissions in 2004 are estimated in the same way. 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.

Table 8.2 Parameters for Estimation of CH_4 Emissions from Wastewater and Sludge 2004

Parameter	Source	Value
Population Equivalent	National Statistic (Incl. Dom/Commercial and Some Industry)	7,324.41
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)	160.4
Total amount of sludge (Tonnes of DS)	National Statistic for some years	42,988
Total Wet Sludge (Gg Dc/yr)(20% solids)	Tonnes of DS * 100/20	214,940
Fraction of Sludge (wet weight) comes off Wastewater	Total Wet Sludge (M^3) /Total Wastewater (M^3)	0.005
Bo Maximum Methane Producing Potential CH4kg/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/m3)	0.4 of Ave.BOD of Treated Ind. WW- 150kg/m3	60
Methane Conversion Factor for Wastewater	All Aerobic treatment	0
Emission Factor for Wastewater (100% Aerobic)	0*0.6	0.00
Fraction of BOD in sludge degrades anaerobically (FTA)	Country Specific	3%
Emission Factor for Sludge (3% Anaerobic)	0.03*0.6	0.018

8.4 Recalculations in *Waste*

Recalculated estimates of emissions in the Waste sector are due to the following inventory revisions carried out in the 2006 reporting cycle for the years 1990-2003

(a) accounting for the contribution of sewage sludge to the DOC available in solid waste in landfills;

(b) application of estimates of landfill gas flaring at individual managed landfills for the years 2001-2003, as compiled for EPER reporting;

(c) inclusion of CH_4 emissions from wastewater handling and sludge treatment;

(d) application of updated population statistics published by the CSO for the time series to maintain consistency with populations used in other sectors.

Accounting for the additional DOC from sewage sludge in landfill solid waste increases emissions by the order of 6 percent to 10 percent in both managed and unmanaged landfills (Table 8.3) but the introduction of the flaring data in the years 2001 to 2003 gives a substantial opposing effect for managed landfills with the result that the revised estimates are reduced by a proportion ranging from 16.8 percent in 2001 to 24.5 percent in 2003. The effects of items (c) and (d) above are insignificant and the change for the sector largely reflects that for category *6.A Solid Waste Disposal on Land*, although the reduction in the total for the years 2001 to 2003, which ranges from 8.2 percent to 15 percent, is less pronounced than for category 6.A.

Table 8.3. Recalculations for Waste 1990-2003

IPCC Source Category		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Emissions 2005 Submission (Gg CO2eq)															
6.A.1 Managed Waste Disposal on Land	CH4	908.08	942.35	983.52	1029.82	1076.30	1123.70	1174.91	1126.67	906.17	806.48	1000.62	1077.79	1273.68	1480.54
6.A.2 Unmanaged Waste Disposal Sites	CH4	325.91	324.76	325.01	327.02	330.84	337.04	345.09	353.07	361.90	373.35	388.55	405.90	426.79	449.99
6.B Wastewater Handling	CH4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
6.B.2 Domestic & Commercial Wastewater	N2O	114.56	116.35	120.51	117.31	114.58	111.22	112.44	115.68	117.62	121.02	125.38	125.74	126.61	129.27
Total		1348.55	1383.46	1429.05	1474.14	1521.73	1571.96	1632.44	1595.42	1385.70	1300.85	1514.54	1609.43	1827.08	2059.81
Emissions 2006 Submission (Gg CO2eq)															
6.A.1 Managed Waste Disposal on Land	CH4	980.17	1015.35	1056.52	1103.41	1151.95	1201.60	1254.38	1207.59	988.00	889.68	1088.82	896.77	1000.92	1117.76
6.A.2 Unmanaged Waste Disposal Sites	CH4	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	479.40
6.B Wastewater Handling	CH4	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
6.B.2 Domestic & Commercial Wastewater	N2O	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
Total		1460.748	1495.765	1541.044	1586.649	1636.264	1688.554	1750.395	1718.327	1512.228	1429.553	1650.917	1477.358	1606.134	1750.283
% Change from Recalculation															
6.A.1 Managed Waste Disposal on Land	CH4	7.94	7.75	7.42	7.15	7.03	6.93	6.76	7.18	9.03	10.32	8.81	-16.80	-21.42	-24.50
6.A.2 Unmanaged Waste Disposal Sites	CH4	7.97	7.80	7.52	7.28	7.16	7.05	6.88	6.72	6.52	6.34	6.34	6.45	6.49	6.54
6.B Wastewater Handling	CH4														
6.B.2 Domestic & Commercial Wastewater	N2O	-0.49	-0.68	-0.29	0.11	0.16	0.04	0.00	0.12	0.49	0.45	1.05	-0.07	0.52	0.00
Total		8.32	8.12	7.84	7.63	7.53	7.42	7.23	7.70	9.13	9.89	9.00	-8.21	-12.09	-15.03

8.5 Improvements in *Waste*

Radical changes in waste management are taking 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, 1999b).

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. 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 split between managed and unmanaged sites in this methodology is a key factor that has a major bearing on the estimate of CH_4 produced in landfills. A gradual increase has been applied to the proportion of solid waste placed in managed landfills up to 2004, when two-thirds of the wastes are assumed to go to fully managed sites. It may be argued that this split does not reflect the level of change in waste management that has occurred in Irish landfills, as all solid waste may be currently disposed of in conditions that would equate to the IPCC definition of managed sites that underlies the basic methodology for CH_4 estimation. The inventory agency is aware of the need to review this aspect of its methodological approach. Further assessment of landfill gas production is also needed on an individual site basis to compare results from top-down and bottom-up approaches currently being used. The quantities of landfill gas that are reported to be flared in the estimates compiled for EPER purposes, which are high in comparison to the top-down estimate for total CH_4 production, need further investigation and validation as such reporting develops. To this end, the inventory experts will continue to collaborate with colleagues in the EPA using available models to estimate landfill gas emissions for individual sites as part of bottom-up emissions reporting related to Directive 1999/31/EC and EPER.

Chapter Nine

Recalculations and Improvements

9.1 Recalculation Issues

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.

The primary reason for undertaking recalculations for the 2006 submission was the need to provide the best possible estimates of GHG emissions in the base year, in the knowledge that such estimates become fixed from 2006 for the purposes of establishing the assigned amount under the Kyoto Protocol. The main focus of the work was therefore the revisions to the estimates of CO_2, CH_4 and N_2O for 1990, which involved a move from Tier 1 to Tier 2 methods in a number of key categories, and updating of the estimates of HFC, PFC and SF_6 for 1995. These revisions were made in parallel with the inventory compilation for the year 2004, which involved a range of additional improvements in methodologies and data across most sectors, along with the inclusion of some minor additional sources. Another key element of the work on recalculations was the completion of the inventory for the LULUCF sector in accordance with the requirements of Decision 13/CP.9 for all years, which Ireland was unable to achieve in time for the 2005 submission. The recalculation exercise needed to achieve a consistent set of inventories for the intervening years 1991-2003 was a secondary objective. For many of the sectors or source categories concerned, the revised estimates for these years were obtained using consistent methods and data but at a more aggregated level in many cases.

9.2 Recalculations in the 1990-2003 Time Series

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 2006 submission. The information given here corresponds to that in Table 8 of the CRF for each year. The principal changes that result in recalculated estimates for the years 1990-2003 are

(i) An expansion and updating of the 1990 energy balance, which facilitated more detailed treatment of *1.A.2 Manufacturing Industries and Construction* and the inclusion of a minor source under

1.A.1(c) Manufacture of Solid Fuels and Other Energy Industries;

(ii) The application of information obtained through the EU emissions trading scheme to update the estimates of process CO_2 emissions from cement and lime production;

(iii) The inclusion of estimates of CO_2 emissions for *2.A.3 Limestone and Dolomite Use*;

(iv) Re-evaluation of the emissions of HFC, PFC and SF_6 under *2.F Consumption of Halocarbons and* SF_6 for the years 1995-2003, including revisions to methods and data in several of the sub-categories and the addition of two minor sources not previously included;

(v) The inclusion of estimates of HFC, PFC and SF_6 under *2.F Consumption of Halocarbons and* SF_6 for the years 1990-1994 consistent with the updated time-series 1995-2003;

(vi) Discontinuation of three-year averaging for activity data in *Agriculture* with more precise use of livestock statistics, which is dictated to some extent by Ireland's NH_3 inventory;

(vii) Application of Tier 2 method for CH_4 emissions from enteric fermentation in cattle;

(viii) Revision of Tier 2 method for CH_4 and N_2O emissions from manure management for cattle, sheep and pigs;

(ix) More detailed treatment (accounting for sewage sludge disposal on land, links to improved NH_3 inventory) of the N_2O estimates from agricultural soils;

(x) Modifications such as the accounting for sludge disposal in landfills and emissions from wastewater treatment in all years

(xi) The inclusion of estimates for landfill gas flaring for the years 2001-2003;

(xii) Provision of estimates for the LULUCF sector in accordance with the requirements of Decision 13/CP.9 for all years 1990-2004;

The original and revised numerical values of the emissions estimates for the years 1990-2003, 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 trend in emissions over this period is discussed in Chapter Two.

9.3 Effect of Recalculations in the 1990-2003 Time Series

Tables 9.1 and 9.2 present the changes due to recalculations according to greenhouse gas and IPCC sector. The overall effect is a very minor increase in total emissions in most years. More significant changes are evident for some individual gases and sectors, although the largest proportional changes occur in the case of either sectors or gases that contribute a relatively small percentage of total emissions. The major change for gases in Table 9.1 is the increase in CH_4 emission estimates, which ranges from 10.4 percent in 1990 to 2.8 percent in 2002. This increase reflects that for manure management (Table 6.4) due to the use of revised emission factors and the higher estimates of emissions from solid waste resulting largely from the inclusion of DOC contributed by sewage sludge. The accounting of a relatively high level of CH_4 flaring at managed landfills in the years 2001-2003, described in the previous chapter, offsets these increases for CH_4 estimates to a substantial degree towards the end of the time-series. The lower estimates of N_2O emissions in all years result from the recalculations in *Agriculture* where they reflect the substantially revised N_2O emissions from manure management and marginally reduced estimates of N_2O from agricultural soils (Table 6.4).

The largest sectoral change occurs in the case of *Solvents and Other Product Use* where the revised and improved inventories of NMVOC result in estimated CO_2 contributions for this sector that are of the order of 10 to 30 percent lower than those given in the 2005 submission. The revised estimates for *Waste* are higher by 7 to 10 percent over the years 1990-2000 due to the additional CH_4 contribution from sewage sludge in landfills but the inclusion of estimates for landfill gas flaring in the years 2001-2003 results in substantially reduced estimates for the sector in these years. The balance between increased CH_4 and decreased N_2O estimates resulting from the extensive recalculations in *Agriculture* result in a marginal increase for the sector in most years. The estimates for

Industrial Processes are slightly increased in all years except 2002 and they are considered to be much more robust than those provided in previous submissions.

9.4 Recalculation of Base Year Emission Estimates

The base year emissions for Ireland are determined by the emissions of CO_2, CH_4 and N_2O in 1990 together with the emissions of HFC, PFC and SF_6 in 1995. The estimate according to the 2005 submission was 53,974.33 Gg CO_2 equivalent, made up from 53,795.19 Gg CO_2 equivalent from the three principal gases and 179.14 Gg CO_2 equivalent from the F-gases. The revised inventories for 1990 and 1995 put the total base year emissions at 55,780.24 Gg CO_2 equivalent, with 55,577.43 Gg CO_2 equivalent from CO_2, CH_4 and N_2O in 1990 and 202.81 Gg CO_2 equivalent due to HFC, PFC and SF_6 in 1995. The absolute increase of 1,782.24 in respect of the combined emissions of CO_2, CH_4 and N_2O reflects CO_2 increases of 608.66 Gg and 164.25 Gg in *Energy* and *Industrial Processes*, respectively, together with CH_4 increases of 1,123 Gg CO_2 equivalent in *Agriculture* and 112.75 Gg CO_2 equivalent in *Waste*. The only significant decrease given by the revised estimates is that for N_2O emissions from manure management, where the value is 221.28 Gg CO_2 equivalent lower than that in the 2005 submission.

9.5 Inventory Improvements to Date

Consistent greenhouse gas inventories in Ireland are available for the years 1990 and 2004. The annual inventories are substantially 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 now taken into account in the current approach to estimating their emissions. In the past, the full implementation of sector-specific good practice guidance was constrained by a lack of resources and the scarcity of activity data and country-specific emission factors, which precluded the use of the recommended high-tier methodologies in several instances. The inventory agency has recently acquired additional staff resources and has been able to apply the results of several important outsourced projects that were targeted at producing the necessary information to apply more appropriate methods and emission factors in these areas during the 2006 reporting cycle. As a consequence, a large amount of work has been undertaken to recalculate previously reported inventories for the years 1990-2003, with particular focus on the estimates that constitute emissions in the base year. A number of time-series data gaps have been filled and several additional minor sources have been covered to improve completeness. Some work remains to be done to elaborate various minor improvements for the *Energy* sector when the updated and expanded energy balances become available for the years 1991-2003. This will make the inventories for this sector fully consistent with those for 1990 and 2004.

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 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 2003 submission (UNFCCC, 2003b) was an important development in this regard. The majority of the recommendations in the 2003 review report have now been implemented, following the extensive improvements and recalculations conducted for the 2006 submission. As these improvements cover issues such as the development of an expanded national inventory report in line with the structure specified in the UNFCCC reporting guidelines, the complete coverage of the LULUCF sector according to the requirements of Decision 13/CP.9 and detailed work to ensure full consistency between the NIR information and the CRF tables, they also address the main findings of the more recent centralised reviews in 2004 and 2005. It may be stated therefore that the inventory material being submitted in 2006 broadly meets the principles of transparency, completeness, consistency, comparability and accuracy laid down in the UNFCCC reporting guidelines.

9.6 Inventory Improvements Going Forward

Reporting by Ireland as a Member State of the EU under Decision 280/2004/EC and as a Party to the UNFCCC will undergo a transitional phase over the period 2007-2010. Further general improvements to greenhouse gas inventories during this period will take place through consolidation and implementation of the national system, which is currently being established, and through application of formal QA/QC procedures that are being put into operation as an integral part of the system. The consultant's Scoping Report (Thistlethwaite *et al*, 2005) concluded that many of the essential aspects of a national system are in place in Ireland and that the principal requirements are to clarify the roles and responsibilities between EPA and DEHLG, formalise arrangements with the key data providers and officially designate the Single National Entity responsible for the greenhouse gas inventory compilation and delivery on the basis of new legislation where appropriate. An updated national climate change strategy will be published in 2006 providing a framework in which internal review of annual inventories will take place among all stakeholders to monitor progress on the strategy and fulfil another important requirement of national system implementation. The Scoping Report proposes that a series of Memoranda of Understanding define the relationships between the inventory agency and key data providers and outline the responsibilities that are conferred to the data providers under the NIS including their involvement in the annual inventory review process.

Formal QA/QC activities have been lacking in Ireland's work on emission inventories to date. Routine implementation of comprehensive QA/QC procedures from now on according to the plan supporting the national inventory system therefore represents an important step towards the general improvement in quality of Irish greenhouse gas inventories. The document identifies the specific data quality objectives required for Ireland's national inventory and provides specific guidance and documentation forms and templates for the QA/QC system for Ireland's emissions inventory for greenhouse gases and air pollutants. 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, selection of appropriate source data and calculation methodologies, 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 intends to avail of this provision in the coming years.

Table 9.1 Recalculations by Gas 1990-2003

(a) Emissions by Gas 1990 –2003 in 2005 Submission (Gg CO2eq)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Net CO_2 emissions/removals	31,390.20	32,063.57	32,740.99	32,223.11	33,675.35	34,327.75	35,567.71	37,860.29	39,628.85	41,757.47	43,564.89	45,721.29	44,833.99	43,468.69
CO_2 emissions (without LULUCF)	31,797.22	32,534.98	33,113.32	32,680.30	34,113.95	34,758.68	35,953.95	38,312.45	40,249.82	42,133.27	44,159.74	46,460.47	45,808.14	44,449.95
CH_4	11,975.67	12,263.37	12,428.85	12,528.18	12,598.32	12,691.35	12,869.64	13,056.54	13,079.64	12,982.83	12,954.06	12,770.31	12,795.04	12,753.26
N_2O	10,022.30	10,054.94	10,152.13	10,183.00	10,412.78	10,552.03	10,770.24	10,940.89	11,181.51	11,361.62	11,307.06	10,916.84	10,249.89	9,739.04
HFCs	NE	NE	NE	NE	NE	20.71	58.04	78.62	104.14	151.70	190.08	230.90	252.92	288.39
PFCs	NE	NE	NE	NE	NE	75.38	103.09	130.82	61.87	195.93	305.41	296.50	207.26	223.63
SF_6	NE	NE	NE	NE	NE	83.05	101.03	132.09	90.59	63.46	51.89	66.75	71.25	100.20
Total (without CO2 from LULUCF)	**53,795.19**	**54,853.29**	**55,694.30**	**55,391.48**	**57,125.05**	**58,181.20**	**59,855.98**	**62,651.42**	**64,767.57**	**66,888.81**	**68,968.25**	**70,741.77**	**69,384.50**	**67,554.47**

(b) Recalculated Emissions by Gas 1990 –2003 in 2006 Submission (Gg CO2eq)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Net CO_2 emissions/removals	32,667.65	32,858.83	33,437.87	32,823.02	34,163.99	34,987.89	36,374.48	38,639.74	40,090.59	41,890.74	44,238.96	46,530.37	45,509.39	44,136.60
CO_2 emissions (without LULUCF)	32,559.48	32,556.64	33,088.07	32,701.35	34,115.79	34,782.67	36,081.48	38,503.75	40,305.53	42,136.03	44,240.93	46,704.25	45,700.51	44,519.38
CH_4	13,215.96	13,396.72	13,468.58	13,584.48	13,584.24	13,658.67	14,061.52	14,319.02	14,259.35	13,732.07	13,376.07	13,172.85	13,146.94	13,735.97
N_2O	9,801.99	9,632.70	9,654.21	9,779.97	10,086.57	10,279.24	10,361.68	10,320.58	10,905.14	11,034.23	10,521.43	10,054.19	9,565.64	9,399.85
HFCs	0.69	5.13	5.89	8.89	20.45	44.60	75.64	130.99	189.02	194.83	228.93	253.07	288.84	357.91
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
SF_6	35.40	36.38	37.36	38.33	81.85	82.83	102.06	132.10	94.24	68.96	55.91	69.43	70.22	118.59
Total (without CO2 from LULUCF)	**55,613.62**	**55,627.66**	**56,254.20**	**56,113.11**	**57,964.28**	**58,923.38**	**60,785.47**	**63,537.27**	**65,815.15**	**67,362.05**	**68,728.67**	**70,549.78**	**68,984.55**	**68,360.50**

(c) Percentage Change in Emissions by Gas 1990-2003

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Net CO_2 emissions/removals	4.07	2.48	2.13	1.86	1.45	1.92	2.27	2.06	1.17	0.32	1.55	1.77	1.51	1.54
CO_2 emissions (without LULUCF)	2.40	0.07	-0.08	0.06	0.01	0.07	0.35	0.50	0.14	0.01	0.18	0.52	-0.23	0.16
CH_4	10.36	9.24	8.37	8.43	7.83	7.62	9.26	9.67	9.02	5.77	3.26	3.15	2.75	7.71
N_2O	-2.20	-4.20	-4.90	-3.96	-3.13	-2.59	-3.79	-5.67	-2.47	-2.88	-6.95	-7.90	-6.68	-3.48
HFCs						115.39	30.32	66.61	81.51	28.43	20.43	9.60	14.20	24.11
PFCs						0.00	0.00	0.00	0.00	0.00	0.00	-0.17	2.48	2.31
SF_6						-0.27	1.03	0.01	4.03	8.67	7.74	4.02	-1.44	18.36
Total (without CO2 from LULUCF)	3.38	1.41	1.01	1.30	1.47	1.28	1.55	1.41	1.62	0.71	-0.35	-0.27	-0.58	1.19

Table 9.2 Recalculations by IPCC Sector 1990-2003

(a) Emissions by IPCC Sector 1990 –2003 in 2005 Submission (Gg CO2eq)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Energy	31,027.47	31,780.99	32,361.24	32,004.09	33,240.05	33,973.75	35,255.36	37,472.72	39,527.22	41,537.64	43,124.17	45,348.14	44,438.27	43,664.59
Industrial Processes	2,965.99	2,766.39	2,776.94	2,689.92	2,953.25	3,031.96	3,076.91	3,417.72	3,318.97	3,445.70	4,004.10	4,050.08	3,836.64	2,971.88
Solvent and Other Product Use	91.58	92.21	93.48	94.66	96.45	98.30	100.15	102.76	105.32	106.79	109.17	108.59	109.20	110.80
Agriculture	18,361.49	18,830.22	19,033.60	19,128.70	19,313.51	19,505.20	19,791.14	20,062.87	20,430.47	20,497.88	20,216.29	19,625.57	19,173.21	18,747.41
LULUCF	-407.02	-471.41	-372.33	-457.19	-438.60	-430.93	-386.24	-452.16	-620.97	-375.80	-594.85	-739.18	-974.15	-981.26
Waste	1,348.66	1,383.48	1,429.04	1,474.11	1,521.79	1,571.99	1,632.42	1,595.35	1,385.59	1,300.80	1,514.51	1,609.39	1,827.18	2,059.80
Total (without CO_2 from LULUCF)	**53,795.19**	**54,853.29**	**55,694.30**	**55,391.48**	**57,125.05**	**58,181.20**	**59,855.98**	**62,651.42**	**64,767.57**	**66,888.81**	**68,968.25**	**70,741.77**	**69,384.50**	**67,554.47**

(b) Recalculated Emissions by IPCC Sector 1990 –2003 in 2006 Submission (Gg CO2eq)

Energy	31,665.36	31,757.08	32,387.91	32,008.14	33,269.36	34,002.81	35,287.99	37,493.27	39,512.58	41,500.00	43,097.80	45,402.54	44,507.99	44,346.10
Industrial Processes	3,166.43	2,866.26	2,781.45	2,746.11	3,117.66	3,062.75	3,204.72	3,656.26	3,494.73	3,560.03	4,186.65	4,294.30	3,734.39	3,050.92
Solvent and Other Product Use	80.94	82.82	83.04	83.50	84.40	86.19	86.87	87.28	88.33	85.01	80.32	79.55	77.20	75.71
Agriculture	19,240.15	19,425.74	19,460.76	19,688.71	19,856.60	20,083.07	20,455.48	20,582.13	21,207.28	20,787.46	19,712.98	19,296.04	19,058.84	19,137.49
LULUCF	108.17	302.20	349.80	121.67	48.20	205.22	293.01	135.99	-214.94	-245.29	-1.98	-173.88	-191.12	-382.78
Waste	1,460.75	1,495.77	1,541.04	1,586.65	1,636.26	1,688.55	1,750.39	1,718.33	1,512.23	1,429.55	1,650.92	1,477.36	1,606.13	1,750.28
Total (without CO_2 from LULUCF)	**55,613.62**	**55,627.66**	**56,254.20**	**56,113.11**	**57,964.28**	**58,923.38**	**60,785.47**	**63,537.27**	**65,815.15**	**67,362.05**	**68,728.67**	**70,549.78**	**68,984.55**	**68,360.50**

(c) Percentage Change in Emissions by Sector 1990-2003

Energy	2.06	-0.08	0.08	0.01	0.09	0.09	0.09	0.05	-0.04	-0.09	-0.06	0.12	0.16	1.56
Industrial Processes	6.76	3.61	0.16	2.09	5.57	1.02	4.15	6.98	5.30	3.32	4.56	6.03	-2.67	2.66
Solvent and Other Product Use	-11.62	-10.18	-11.16	-11.79	-12.50	-12.32	-13.26	-15.06	-16.13	-20.40	-26.43	-26.75	-29.30	-31.66
Agriculture	4.79	3.16	2.24	2.93	2.81	2.96	3.36	2.59	3.80	1.41	-2.49	-1.68	-0.60	2.08
LULUCF														
Waste	8.31	8.12	7.84	7.63	7.52	7.42	7.23	7.71	9.14	9.90	9.01	-8.20	-12.10	-15.03
Total (without CO2 from LUCF)	3.38	1.41	1.01	1.30	1.47	1.28	1.55	1.41	1.62	0.71	-0.35	-0.27	-0.58	1.19

Chapter Ten

Calculation of Assigned Amount

10.1 Definition and Modalities

The emission targets for Annex I Parties under the Kyoto Protocol must be achieved by the end of the first commitment period, which covers the five years 2008 through 2012. A five-year commitment period was adopted rather than a single target year in order to smooth out annual fluctuations in emissions due to influences such as the weather and economic cycles. Generally, Parties must reduce or limit their emissions from their 1990 base year levels, although any Party may choose either 1990 or 1995 as the base year in respect of the emissions of HFCs, PFCs and SF_6. The total quantity of greenhouse gas emissions that a Party may emit over the commitment period and still meet its emissions target is known as its assigned amount (AA).

This assigned amounts for Annex I Parties together with the annual inventories for the years 2008 through 2012 will form the basis of the compilation and accounting database held with the UNFCCC secretariat to facilitate the accounting of emissions and assigned amount for the compliance assessment of their respective commitments under the Kyoto Protocol. As the assigned amount is established on the basis of the inventories submitted in 2006, which is the subject matter of the present NIR, the value of assigned amount for Ireland indicated by the improved base year emissions estimates included in this time-series is presented in this additional chapter for information purposes.

Article 3.7 of the Kyoto Protocol states that *the assigned amount for each Annex I Party shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in the base year multiplied by five.* The net greenhouse gas emissions (i.e. emissions minus removals) from Land-Use Land-Use Change and Forestry (LULUCF) source and sink categories (refer to Annex A of this report) are excluded from the aggregate anthropogenic carbon dioxide equivalent emissions used to calculate the assigned amount, except in the case of those Parties for whom such source and sink categories constituted a net source of emissions in the base year. It is for this reason that the compilation of definitive base year emissions, taking full account of the IPCC Good Practice Guidance and the various inventory improvements adopted over recent years, along with the confirmation whether the LUCF sector constituted a net source of emissions in the base year, are key outcomes of the reporting cycle to which this NIR refers.

10.2 Determination of Assigned Amount for Ireland

Prior to the start of the 2008-2012 commitment period each Annex I Party must submit a report providing the necessary emissions data for its 1990 baseline and other relevant information in order to formally establish its assigned amount. The report, referred to as the initial report, should contain *inter alia*, complete greenhouse gas inventories for the years 1990-2004, choices relating to election and accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol and descriptions of the national inventory system and the national registry. For Ireland and other EU Member States, this submission takes place in January 2006 under Decision 280/2004/EC, concerning a mechanism for monitoring greenhouse gas emissions and for implementing the Kyoto Protocol in the European Community (EP and CEU, 2004), which establishes the legal and procedural framework for implementing the UNFCCC and the Kyoto Protocol in Member States.

The January 2006 submission is the first step in the process that will culminate in the delivery of Member State and Community reports determining their respective and definitive assigned amounts to the UNFCCC by 31 December 2006. The report from each Member State in January 2006 must contain its proposed emission level in terms of tonnes of carbon dioxide equivalent in accordance with the quantified emission limitation or reduction commitments set out in Annex II of Decision 2002/358/EC (the so-called EU burden-sharing agreement) and Articles 3.7 and 3.8 of the Kyoto Protocol following the establishment of their definitive base year emissions estimates.

The quantified emission limitation or reduction commitment for the EU is 92 percent and accordingly this value is also specified for all 15 Member States in Annex B to the Kyoto Protocol. However, in accordance with Annex II of Decision 2002/358/EC, the appropriate quantified emission limitation for Ireland is 113 percent. As Ireland has chosen 1995 as the base year for HFC, PFC and SF_6 emissions and LULUCF did not constitute a net source of emissions in 1990, Ireland's assigned amount (AA) is calculated as follows

$$AA = [\, E(CO_2, CH_4, N_2O)_{1990} + E(HFC, PFC, SF_6\,)_{1995} \,] * 1.13 * 5$$

where $E(CO_2, CH_4, N_2O)_{1990}$ is the definitive estimate of emissions of CO_2, CH_4 and N_2O in 1990 in tonnes CO_2 equivalent and similarly $E(HFC, PFC, SF_6\,)_{1995}$ is the definitive estimate of HFC, PFC and SF_6 emissions in 1995 in tonnes CO_2 equivalent. Using the relevant emissions estimates for the years 1990 and 1995 presented in Chapter Two above, the proposed assigned amount is

$$AA = (\, 55.577 + 0.203 \,) * 1.13 * 5 \text{ million tonnes } CO_2 \text{ eq}$$

$$= 315.16 \text{ million tonnes } CO_2 \text{ eq}$$

10.3 Application of Assigned Amount

Expert review teams will conduct an in-depth assessment of the information contained in the initial report submission before the start of the commitment period, with particular emphasis on the inventories used to establish the assigned amount. Assuming no questions of implementation are raised and that there are no problems relating to the underlying emissions inventories, the 315.16 million tonnes of CO_2 equivalent will be recorded in the database for the accounting of emissions and assigned amount for Ireland's compliance assessment. In addition, an equivalent number of assigned amount units (AAUs) will be issued into Ireland's national registry to facilitate transactions relating to these and other units that may be added to or subtracted from assigned amount in the accounting for the purpose of the compliance assessment.

The database will also record the annual emissions for each year of the commitment period as well as Ireland's annual transactions in AAUs, certified emissions reductions (CERs) obtained from projects under the Clean Development Mechanism, emissions reductions units (ERUs) relating to emissions trading and removal units (RMUs) generated by activities under Article 3.3 and Article 3.4 of the Kyoto Protocol. This information will be published annually by the UNFCCC secretariat in a compilation and accounting report for all Parties. The final report published at the end of the commitment period will form the basis for assessing Parties' compliance with their respective commitments under the Protocol. This will be done by comparing emissions during the five years of the commitment period with holdings of AAUs, CERs, ERUs and RMUs in the national registry.

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.

Ahlvik, P. *et al*, 1997. COPERT II (Computer Programme to Calculate Emissions from Road Transport). Methodology and Emission Factors. European Environment Agency, Copenhagen.

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), 1993. Council Decision 93/389/EEC for a monitoring mechanism of Community CO_2 and other greenhouse gas emissions. O.J. L.375 31 December 1991.

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), 1999a. Council Decision 99/296/EC (amending Council Decision 93/389/EEC) for a monitoring mechanism of Community CO_2 and other greenhouse gas emissions. O.J. L117, May 1999.

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

CEU (Council of the European Union), 2001. Council Directive 2001/80/EC of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants. O.J. L309*,* 27 November 2001.

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.

CSO (Central Statistics Office), 2003. Livestock Survey. Central Statistics Office, Ireland. http://www.cso.ie/

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), 2005. CMMS Statistics Report 2004. Department of Agriculture and Food, Dublin. www.agriculture.gov.ie.

DEHLG (Department of the Environment Heritage and Local Government), 2003. Irish Bulletin of Vehicle and Driver Statistics.

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.

DELG (Department of the Environment and Local Government), 2000. National Climate Change Strategy Ireland, The Stationery Office, Dublin. http://www.environ.ie/

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), 1993. IRELAND : Climate Change. CO_2 Abatement Strategy. Department of the Environment, Custom House, Dublin.

DOE (Department of the Environment), 1994a. IRELAND : Communication under the UN Framework Convention on Climate Change. Department of the Environment, Custom House, Dublin.

DOE (Department of the Environment), 1994b. 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.

ISEO (Institute for the Study of Earth, Oceans and Space), 2002. Users Guide for the DNDC Model, DNDC 7.7. Institute for the Study of Earth, Oceans and Space, University of New Hampshire, Durham, USA.

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), 2004. 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.

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

ERM (Environmental Resources Management), 1998. Limitation and Reduction of CO_2 and Other Greenhouse Gas Emissions in Ireland. Stationery Office, 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.

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.

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

Hynds, P., 1994. A nutrient balance model for typical Irish farming systems. M.Sc. Thesis, National Council for Education Awards.

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

IPCC (Intergovernmental Panel on Climate Change), 1995. IPCC Guidelines for National Greenhouse Gas Inventories. OECD, 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), 1993. United Nations Framework Convention on Climate Change. UNEP, Geneva.

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

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.

McCulloch, A., 2002. Comparison between the results of RTDI Projects L.S.-5.1.3(a) and L.S.-5.1.3(b): Emission Inventories of HFC, PFC and SF_6 from Ireland. Note to the Environmental Protection Agency.

McGettigan, M., 1989. Realisation of the Second Stage of the CORINAIR Working Programme for Ireland. Environmental Research Unit, Dublin.

McGettigan, M., 1993. CORINAIR 1990 Emissions Inventory for Ireland. Contract B92/B4-3200-11/3208. Environmental Research Unit, Dublin.

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

Mulligan, F. and O'Mara, F., 2002. The Excretion of Nitrogen by Dairy Cows and Beef Cattle. A Review Presented to the Environmental Protection Agency. July 2002.

Myers, A., 1994. Energy in Ireland 1980-1993. A Statistical Bulletin. Department of Transport, Energy and Communications, Dublin.

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

O'Doherty, S. and McCulloch, A. 2002. Emission Inventories of HFC, PFC and SF_6. RTDI Project L.S.-5.1.3(a) Final Report. Environmental Protection Agency, Johnstown Castle, Wexford.

O'Leary, E., Finn, J. and Cunningham, D., 2002. Emission Inventories for HFCs, PFCs and SF_6 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 SF_6 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 Enteric Fermentation from the Irish Cattle Herd. LS 5.1.1 Final Report. Environmental Protection Agency, Johnstown Castle, Wexford, Ireland.

Pulles, P. *et al*, 1999. CollectER : Installation and User Guide. European Environment Agency, Copenhagen.

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

Ryall, D. B. and Maryon, R. H., 1998. Validation of the UK Met Office's NAME model against the ETEX dataset; Atmospheric Environment, 32, 4265-4276.

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.

SEI (Sustainable Energy Ireland), 2004. Energy Balance Sheets for Ireland 2003. Energy Policy Statistical Support Unit, Sustainable Energy Ireland, Cork.

Smith, D., O'Neill, N., Clinton, F. and Crowe, M., 2003. Urban Waste Water Discharges in Ireland. A Report for the Years 2000/2001. 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.

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). 2003b. Ireland : Report on the Individual Review of the Greenhouse Gas Inventory Submitted in 2003. FCCC/WEB/IRI(2)/2003/IRL (http://unfccc.int/program/mis/ghg/indrev2003.html). UNFCCC Secretariat, Bonn.

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 2004

Table B.1 Expanded Energy Balance Sheet 2004

2004 Units = ktoe	COAL	Bituminous Coal	Anthracite + Manuf Ovoids	Coke	Lignite	PEAT	Milled Peat	Sod Peat	Briquettes	OIL	Crude	Refinery Gas	Gasoline	Kerosene	JET Kerosene	Fueloil	LPG	Gasoil / Diesel /DERV
Ind. Production	**0.00**	**0.00**				**889.35**	712.19	177.16		**0.00**								
Imports	**1,724.74**	**1,663.44**	**41.90**		19.41	**0.00**				**9,668.07**	2,959.40		1,267.35	404.29	1,016.43	1,298.10	126.15	2,596.34
Exports	**5.35**	**0.00**	**5.35**		0.00	**10.19**			10.19	**1,222.22**			129.93	13.72	0.00	927.78	22.53	128.27
Mar. Bunkers	**0.00**					**0.00**				**152.73**						48.26		104.47
Stock Change	**-48.30**	**-47.21**	2.69		-3.79	**-305.42**	-313.97	-0.31	8.86	**148.73**	32.72		85.20	-2.11	71.62	-53.18	0.00	14.48
Total Primary Energy Requirement	**1,671.09**	**1,616.23**	**39.24**	**0.00**	**15.62**	**573.74**	**398.23**	**176.85**	**-1.33**	**8,441.85**	**2,992.13**	**0.00**	**1,222.62**	**388.46**	**1,088.06**	**268.88**	**103.62**	**2,378.09**
Transformation Input	**1,404.57**	**1,386.61**	**17.96**	**0.00**	**0.00**	**386.88**	**386.88**	**0.00**	**0.00**	**3,793.45**	**2,992.13**	**8.05**	**0.00**	**0.00**	**0.00**	**745.57**	**0.12**	**47.58**
Public Thermal Power Plants	**1,383.52**	1,383.52				**289.23**	289.23	0.00		**784.88**						745.57		39.31
Combined Heat and Power Plants	**3.10**	3.10				**6.70**	6.70			**8.17**		8.05				0.00	0.12	0.00
Pumped Storage Consumption																		
Patent Fuel and Briquetting Plants	**17.96**		17.96			**90.95**	90.95			**0.00**								
Oil Refineries & other energy sector	**0.00**					**0.00**				**3,000.40**	2,992.13							8.28
Transformation Output	**42.04**	**0.00**	**42.04**	**0.00**	**0.00**	**91.26**	**0.00**	**0.00**	**91.26**	**2,960.15**	**0.00**	**97.99**	**587.88**	**266.01**	**0.00**	**951.41**	**59.69**	**997.16**
Public Thermal Power Plants	**0.00**					**0.00**				**0.00**								
Combined Heat and Power Plants - Electricity	**0.00**					**0.00**				**0.00**								
Combined Heat and Power Plants - Heat																		
Pumped Storage Generation																		
Patent Fuel and Briquetting Plants	**42.04**		42.04			**91.26**			91.26	**0.00**								
Oil Refineries	**0.00**					**0.00**				**2,960.15**		97.99	587.88	266.01		951.41	59.69	997.16
Exchanges and transfers	**0.00**	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**-3.70**	0.00	0.00	8.52	254.40	-254.90	6.89	0.00	-18.62
Electricity																		
Heat																		
Other										**-3.70**			8.52	254.40	-254.90	6.89		-18.62
Own Use and Distribution Losses	**0.00**					**23.99**	23.99			**122.70**		89.94				17.73	6.76	8.28
Available Final Energy Consumption	**308.55**	**229.62**	**63.32**	**0.00**	**15.62**	**254.13**	**-12.65**	**176.85**	**89.93**	**7,482.15**	**0.00**	**0.00**	**1,819.02**	**908.87**	**833.16**	**463.89**	**156.44**	**3,300.77**
Non-Energy Consumption	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Final non-Energy Consumption (Feedstocks)	0.00					0.00				0.00								
Total Final Energy Consumption	**293.42**	**218.78**	**59.50**	**0.00**	**15.15**	**266.77**	**0.00**	**176.85**	**89.93**	**7,460.54**	**0.00**	**0.00**	**1,731.69**	**895.15**	**742.58**	**513.13**	**152.05**	**3,425.93**
Industry*	**36.57**	**36.57**				**0.44**	**0.00**	**0.00**	**0.44**	**736.97**	**0.00**	**0.00**	**0.00**	**120.34**	**0.00**	**367.37**	**63.07**	**186.19**
Non-Energy Mining	**0.00**	0.00				**0.00**				**60.23**				3.47		10.58	0.74	45.43
Food, beverages and tobacco	**5.40**	5.40				**0.00**				**200.30**				37.05		113.11	12.90	37.23
Textiles and textile products	**2.35**	2.35				**0.00**				**35.21**				3.00		9.16	16.73	6.33
Wood and wood products	**0.00**	0.00				**0.00**				**7.05**				1.67		5.10	0.00	0.28
Pulp, paper, publishing and printing	**0.00**	0.00				**0.00**				**8.48**				0.65		1.99	0.00	5.83
Chemicals & man-made fibres	**0.00**	0.00				**0.00**				**65.32**				12.22		37.30	3.05	12.75
Rubber and plastic products	**0.00**	0.00				**0.00**				**9.80**				0.25		0.76	2.46	6.33
Other non-metallic mineral products	**26.77**	26.77				**0.00**				**50.16**				6.17		18.84	3.33	21.82
Basic metals and fabricated metal products	**0.00**	0.00				**0.00**				**228.29**				52.31		159.69	12.83	3.45
Machinery and equipment n.e.c.	**0.00**	0.00				**0.00**				**15.28**				1.01		3.10	8.00	3.16
Electrical and optical equipment	**2.05**	2.05				**0.00**				**48.93**				1.46		4.47	1.56	41.44
Transport equipment manufacture	**0.00**	0.00				**0.00**				**3.80**				0.32		0.98	1.08	1.41
Other manufacturing	**0.00**	0.00				**0.44**			0.44	**4.13**				0.75		2.28	0.39	0.71
Transport	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**4,685.29**	**0.00**	**0.00**	**1,731.69**	**0.00**	**742.58**	**17.73**	**4.51**	**2,188.79**
Road	**0.00**					**0.00**				**3,883.58**			1,730.63				4.51	2,148.45
Rail	**0.00**					**0.00**				**39.31**								39.31
Inland Navigation	**0.00**					**0.00**				**18.76**						17.73		1.03
Marine Transport	**0.00**					**0.00**				**0.00**								0.00
Domestic Aviation	**0.00**					**0.00**				**37.93**			1.07		36.87			
International Aviation	**0.00**					**0.00**				**705.71**					705.71			
Residential	**231.01**	**157.61**	58.73		**14.67**	**266.33**		**176.85**	**89.49**	**1,086.97**			**0.00**	**774.81**		**0.00**	**73.21**	**238.95**
Commercial/Public Services	**25.84**	**24.60**	**0.76**	**0.00**	**0.47**	**0.00**	**0.00**	**0.00**	**0.00**	**689.61**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**128.04**	**11.26**	**550.30**
Commercial Services	**25.84**	24.60	0.76		0.47	**0.00**				**384.42**				0.00		12.49	8.38	363.54
Public Services	**0.00**					**0.00**		0.00	0.00	**305.19**						115.55	2.88	186.76
Agricultural	**0.00**	**0.00**				**0.00**				**261.70**			**0.00**	**0.00**			**0.00**	**261.70**
Statistical Difference	**15.14**	**10.84**	**3.82**	**0.00**	**0.47**	**-12.65**	**-12.65**	**0.00**	**0.00**	**21.61**	**0.00**	**0.00**	**87.33**	**13.72**	**90.58**	**-49.25**	**4.39**	**-125.16**

Table B.1 (continued) Expanded Energy Balance Sheet 2004

2004 Units = ktoe	Naphta	Pet Coke	Bitumen	White Spirit	Lubricants	NATURAL GAS	RENEWABLES	HYDRO	Wind	Biomass	Landfill Gas	Biogas	Wastes	Solar	Geothermal	ELECTRICITY	Heat	TOTAL
Ind. Production						**690.07**	**324.67**	54.18	56.33	183.97	19.94	9.91		0.29	0.05			
Imports	0.00	293.18	166.57	149.24	34.34	**2,965.35**	**0.00**									135.36		
Exports	27.33	0.00	0.00	74.62	6.06	**0.00**	**0.00**									0.00		
Mar. Bunkers							**0.00**											
Stock Change	6.31	0.00	0.00	0.00	0.00	**-2.42**	**0.00**											
Total Primary Energy Requirement	**-21.02**	**293.18**	**166.57**	**74.62**	**28.28**	**3,653.00**	**324.67**	**54.18**	**56.33**	**183.97**	**19.94**	**9.91**	**0.00**	**0.29**	**0.05**	**135.36**	**0.00**	**15,341.34**
Transformation Input	**0.00**	**12.49**	**0.00**	**0.00**	**0.00**	**2,251.14**	**22.35**	**0.00**	**0.00**	**0.00**	**19.94**	**2.41**	**0.00**	**0.00**	**0.00**	**63.81**	**0.00**	**7,934.69**
Public Thermal Power Plants						**2,156.97**	**19.94**				19.94							
Combined Heat and Power Plants						**94.17**	**2.41**					2.41						
Pumped Storage Consumption																47.47		
Patent Fuel and Briquetting Plants		12.49					**0.00**											
Oil Refineries & other energy sector							**0.00**									16.34		
Transformation Output	**22.07**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**7.31**	**0.00**	**0.00**	**0.00**	**7.31**	**0.00**	**0.00**	**0.00**	**0.00**	**2,081.11**	**0.00**	**5,203.94**
Public Thermal Power Plants							**7.31**				7.31					1,993.22		
Combined Heat and Power Plants - Electricity							**0.00**									57.45		
Combined Heat and Power Plants - Heat							**0.00**											
Pumped Storage Generation																30.44		
Patent Fuel and Briquetting Plants							**0.00**											
Oil Refineries	22.07						**0.00**											
Exchanges and transfers	0.00	0.00	0.00	0.00	0.00	**0.00**	**-117.82**	-54.18	-56.33	0.00	-7.31	0.00	0.00	0.00	0.00	**117.82**	**-7.41**	0.00
Electricity							**-117.82**	-54.18	-56.33		-7.31					**117.82**		
Heat																		
Other							**0.00**										**-7.41**	
Own Use and Distribution Losses						**60.38**	**0.00**									**273.65**		
Available Final Energy Consumption	**1.05**	**280.69**	**166.57**	**74.62**	**28.28**	**1,341.48**	**191.80**	**0.00**	**0.00**	**183.97**	**0.00**	**7.50**	**0.00**	**0.29**	**0.05**	**1,996.83**	**-7.41**	**12,118.75**
Non-Energy Consumption		**0.00**	**166.57**	**74.62**	**28.28**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Final non-Energy Consumption (Feedstocks)			166.57	74.62	28.28	0.00	0.00											
Total Final Energy Consumption	**1.05**	**264.03**	**0.00**	**0.00**	**0.00**	**1,327.52**	**191.42**	**0.00**	**0.00**	**183.95**	**0.00**	**7.47**	**0.00**	**0.29**	**0.29**	**1,982.90**	**0.00**	**11,787.65**
Industry*	**1.05**	**234.04**	**0.00**	**0.00**	**0.00**	**434.31**	**145.62**	**0.00**	**0.00**	**140.56**		**5.06**	**0.00**	**0.00**	**0.00**	**592.11**	**0.00**	**2,181.12**
Non-Energy Mining		60.46				32.72	**0.00**			0.00						35.25		
Food, beverages and tobacco		97.58				143.55	**5.06**			0.00		5.06				143.16		
Textiles and textile products		0.00				1.86	**0.00**			0.00						13.90		
Wood and wood products		0.00				0.43	**140.56**			140.56						25.91		
Pulp, paper, publishing and printing		0.00				29.00	**0.00**			0.00						24.38		
Chemicals & man-made fibres		0.00				105.35	**0.00**			0.00						105.23		
Rubber and plastic products		0.00				4.72	**0.00**			0.00						26.97		
Other non-metallic mineral products		0.00				45.95	**0.00**			0.00						44.08		
Basic metals and fabricated metal products		0.00				4.81	**0.00**			0.00						34.80		
Machinery and equipment n.e.c.		76.00				13.57	**0.00**			0.00						14.99		
Electrical and optical equipment		0.00				32.17	**0.00**			0.00						94.04		
Transport equipment manufacture		0.00				10.96	**0.00**			0.00						9.04		
Other manufacturing	1.05	0.00				9.24	**0.00**			0.00						20.37		
Transport	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**12.99**	**0.00**	**4,698.28**
Road							**0.00**											
Rail							**0.00**									12.99		
Inland Navigation							**0.00**											
Marine Transport							**0.00**											
Domestic Aviation							**0.00**											
International Aviation							**0.00**											
Residential		**29.98**				**592.97**	**43.39**			**43.39**				**0.29**	**0.29**	**631.76**		**2,882.40**
Commercial/Public Services	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**300.24**	**2.41**	**0.00**	**0.00**	**0.00**	**0.00**	**2.41**	**0.00**	**0.00**	**0.00**	**693.76**	**0.00**	**1,711.87**
Commercial Services						**131.59**	**2.41**					2.41				497.38		
Public Services						**168.69**	**0.00**									196.41		
Agricultural						**0.00**	**0.00**									**52.29**		**313.99**
Statistical Difference	**0.00**	**16.66**	**0.00**	**0.00**	**0.00**	**13.96**	**0.38**	**0.00**	**0.00**	**0.02**	**0.00**	**0.02**	**0.00**	**0.00**	**-0.24**	**13.93**	**-7.41**	**61.62**

Annex C

Calculation Sheets for Energy 2004

Table C.1 Calculation Sheet for Emissions from Fuel Combustion 2004 *(continued on following pages)*

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			**Emission Factors**				**Emissions**		
				CO_2	**CH_4**	**N_2O**	***Unit***	**CO_2**	**CH_4**	**N_2O**
	Sector/Fuel	kTOE	TJ					Gg	Mg	Mg
1	Public Power Plants Peat	289.22	12109.063	140236	0	12	*kg/TJ*	1698.124	0	145.31
2	Public Power Plants Coal	1383.52	57925.215	92881	0	14	*kg/TJ*	5380.152	0	810.95
3	Public Power Plants Fuel Oil	745.57	31215.525	77287	0	14	*kg/TJ*	2539.757	0	437.02
4	Public Power Plants Gasoil	39.31	1645.831	0	0	14	*kg/TJ*		0	23.04
5	Public Power Plants Natural Gas	2156.97	90308.020	56681	0	3	*kg/TJ*	5118.789	0	270.92
6	Electricity Landfill Gas	19.94	834.848	54940	30	4	*kg/TJ*	45.867	25.05	3.34
	Public Electricity Total	**4614.59**	**193203.654**					**14736.822**	**25.05**	**1690.5**
7	**Manufact. Of Briquettes**	**24**	**1004.832**	115000	50	5	*kg/TJ*	**115.556**	**50.24**	**5.02**
8	Refinery Gas	97.99	4102.645	65000	0	3	*kg/TJ*	266.672	0	12.31
9	Refinery Fueloil	17.73	742.320	76000	0	10	*kg/TJ*	56.416	0	7.42
10	Refinery Gasoil	8.28	346.667	73300	2	10	*kg/TJ*	25.411	0.69	3.47
11	Refinery LPG	6.76	283.028	63700	2	3	*kg/TJ*	18.029	0.57	0.85
	Refinery Total	**130.76**	**5474.66**					**366.528**	**1.26**	**24.05**
12	Residential Peat	176.85	7404.356	104000	50	5	*kg/TJ*	770.053	370.22	37.02
13	Residential Peat Briquettes	89.49	3746.767	98860	50	5	*kg/TJ*	370.405	187.34	18.73
14	Residential Coal	157.61	6598.815	94600	100	12	*kg/TJ*	624.248	659.88	79.19
15	Residential Anthracite	58.73	2458.908	98260	100	12	*kg/TJ*	241.612	245.89	29.51
16	Residential Lignite	14.67	614.204	101200	50	12	*kg/TJ*	62.157	30.71	7.37
17	Residential Petroleum Coke	29.98	1255.203	100800	50	12	*kg/TJ*	126.524	62.76	15.06
18	Residential Gasoil	238.95	10004.359	73300	5	10	*kg/TJ*	733.319	50.02	100.04
19	Residential Kerosene	774.81	32439.745	71400	5	10	*kg/TJ*	2316.198	162.20	324.40
20	Residential Natural Gas	592.97	24826.468	56772	5	2	*kg/TJ*	1409.448	124.13	49.65
21	Residential LPG	73.21	3065.156	63700	0	2	*kg/TJ*	195.250	0	6.13
22	Residential Biomass	43.39	1816.653	110000	30	4	*kg/TJ*	199.832	54.50	7.27
	Residential Total	**2250.66**	**94230.633**					**6849.216**	**1947.6**	**674.37**
23	Commercial Peat Briquettes	0.00	0.00	98860	50	5	*kg/TJ*	0.00	0.00	0.00
24	Commercial Coal	24.60	1029.953	94600	100	12	*kg/TJ*	97.434	103.00	12.36
25	Commercial Lignite	0.47	19.678	101200	50	12	*kg/TJ*	1.991	0.98	0.24
26	Commercial Anthracite	0.76	31.820	98260	100	12	*kg/TJ*	3.127	3.18	0.38
27	Commercial Pet Coke	0	0.00	100800	50	12	*kg/TJ*	0.000	0.00	0.00
28	Commercial Gasoil	550.30	23039.96	73300	5	10	*kg/TJ*	1688.829	115.20	230.40
29	Commercial Kerosene	0.00	0.00	71400	5	10	*kg/TJ*	0.00	0.00	0.00

	Sectoral Disaggregation of Fuel Combustion from National Energy Balance			Emission Factors				Emissions		
				CO_2	CH_4	N_2O	*Unit*	CO_2	CH_4	N_2O
	Sector/Fuel	kTOE	TJ					Gg	Mg	Mg
30	Commercial Fueloil	128.04	5360.779	76000	0	10	*kg/TJ*	407.419	0.00	53.61
31	Commercial Natural Gas	300.24	12570.448	56772	5	2	*kg/TJ*	713.649	62.85	25.14
32	Commercial LPG	11.26	471.434	63700	0	2	*kg/TJ*	30.030	0.00	0.94
33	Commercial Biomass	2.41	100.902	110000	30	4	*kg/TJ*	11.099	3.03	0.40
	Commercial Total	**1018.08**	**42624.973**					**2942.480**	**288.24**	**323.47**
34	Industry Briquettes	0.44	18.422	98860	50	5	*kg/TJ*	1.821	0.92	0.09
35	Industry Pet Coke	234.04	9798.787	100800	5	10	*kg/TJ*	987.718	48.99	97.99
36	Industry Coal	36.57	1531.113	94600	100	3	*kg/TJ*	144.843	153.11	4.59
37	Industry Gasoil	186.19	7795.403	73300	2	10	*kg/TJ*	571.403	15.59	77.95
38	Industry Kerosene	120.34	5038.395	71400	2	10	*kg/TJ*	359.741	10.08	50.38
39	Industry Fueloil	367.37	15380.957	76000	0	10	*kg/TJ*	1168.953	0.00	153.81
40	Industry Natural Gas	434.31	18183.691	56772	2	3	*kg/TJ*	1032.325	36.37	54.55
41	Industry LPG	63.07	2640.615	63700	2	3	*kg/TJ*	168.207	5.28	7.92
42	Industry Biomass	140.56	5884.966	110000	30	4	*kg/TJ*	647.346	176.55	23.54
43	Industry Biomass(Biogas)	5.06	211.852	110000	30	4	*kg/TJ*	23.304	6.36	0.85
44	CHP Coal	3.10	129.791	92881	15	12	*kg/TJ*	12.055	1.95	1.56
45	CHP Peat	6.70	280.516	140236	0	12	*kg/TJ*	39.338	0.00	3.37
46	CHP Natural Gas	94.17	3942.710	56772	2	3	*kg/TJ*	223.836	7.89	11.83
	Industry Total	**1691.92**	**70837.217**					**4710.240**	**463.08**	**488.43**
47	Road Transport Petrol	1730.63	72.458.017	69960	27.7	11.3	*kg/TJ*	5069.163	2009	817
48	Road Transport Diesel	2148.45	89951.305	73300	2.4	5.7	*kg/TJ*	6593.431	218	516
49	Road Transport LPG	4.51	188.825	63700	5.3	0.0	*kg/TJ*	12.028	1	0
	Road Transport Total	**3883.59**	**162598.1461**					**11674.622**	**2228**	**1333**
50	Railways Diesel	39.31	1645.831	73300	5	30	*kg/TJ*	120.639	8.23	49.37
51	Agriculture Machinery Gasoil	235.53	9861.17	73300	5	30	*kg/TJ*	722.824	49.31	295.84
52	Navigation Fuel Oil	16.74	700.87	76000	5	30	*kg/TJ*	53.266	3.5	21.03
53	Navigation Gasoil	1.03	43.124	73300	5	30	*kg/TJ*	3.161	0.22	1.29
54	Gas Distribution-Use	57.18	2394.012	54940	5	3	*kg/TJ*	135.913	11.97	7.18
55	Domestic Aviation-LTO		597.053	71400	2.74	2.74	*kg/TJ*	42.630	1.64	1.64
56	Domestic Aviation-Cruise		874.204	71400	0.00	2.25	*kg/TJ*	62.418	0.00	1.97
	Other Transport Total		**16238.882**					**418.09**	**26**	**82**
57	Agriculture Stationary Gasoil	26.17	1095.686	73300	5	10	*kg/TJ*	80.314	5.48	10.96
58	Agriculture Biomass	0.00	0.00	110000	30	4	*kg/TJ*	0.00	0.00	.00
	Agriculture Total	**261.70**	**10956.856**					**803.138**	**54.78**	**306.79**
	Total Energy							**42616.621**	**5084**	**4929**

Table C.2 Emissions from Fuel Combustion Allocated by IPCC Source Category

	Allocation by IPCC Source Category			Implied Emission Factors				Emissions		
	Source Category/Fuel	kTOE	TJ	CO_2	CH_4	N_2O	*Unit*	CO_2 (Gg)	CH_4 (Mg)	N_2O (Mg)
A	**1.A.1 Energy Industries**	**4789.29**	**200517.99**					**15,218.905**	**77**	**1720**
B	(a) Solid Fuels	1696.74	71039.11	101266	0.71	13.53	*kg/TJ*	7,193.832	50.242	961.286
C	(b) Liquid Fuels	915.64	38336.02	75811	0.03	12.63	*kg/TJ*	2,906.285	1.26	484.11
D	(c) Gaseous Fuels	2156.97	90308.02	56681	0.28	3.04	*kg/TJ*	5,118.789	0.00	270.92
E	(d) Biomass	19.94	834.85	54940	30.00	4.00	*kg/TJ*	45.867	25.05	3.34
F	**1.A.2 Manufacturing Industries & Construction**	**1686.42**	**70606.94**					**4,740.241**	**463.35**	**488.99**
G	(a) Solid Fuels	46.37	1941.42	101079	79.87	4.90	*kg/TJ*	198.058	155.98	10.00
H	(b) Liquid Fuels	971.01	40654.16	80091	1.97	9.55	*kg/TJ*	3,256.022	80	388.16
I	(c) Gaseous Fuels	528.48	22126.40	56772	2.00	3.00	*kg/TJ*	1,256.160	44.25	66.38
J	(d) Biomass	140.56	5884.97	110000	30.00	4.00	*kg/TJ*	670.650	182.90	24.38
K	**1.A.3 Transport**	**4032.99**	**168853.24**					**12,092.649**	**2,253.56**	**1,415.48**
L	(a) Solid Fuels	0.00					*kg/TJ*	0.000	0.00	0.00
M	(b) Liquid Fuels	3975.81	166459.23	71830	13.47	8.46	*kg/TJ*	11,956.736	2,241.59	1,408.30
N	(c) Gaseous Fuels	57.18	2394.01	56772	5.00	3.00	*kg/TJ*	135.913	11.97	7.18
O	(d) Biomass	0.00					*kg/TJ*	0.000	0.00	0.00
P	**1.A.4 Other Sectors**	**3455.81**	**144687.85**					**10,594.833**	**2290.68**	**1304.64**
Q	(a) Solid Fuels	448.55	18779.89	99156	70.31	7.84	*kg/TJ*	2171.028	1601.2	184.8
R	(b) Liquid Fuels	2068.25	86593.49	72762	5.14	11.98	*kg/TJ*	6,300.708	444.96	1,037.38
S	(c) Gaseous Fuels	893.21	37396.92	56772	5.00	2.00	*kg/TJ*	2,123.098	186.98	74.79
T	(d) Biomass	45.80	1917.55	110000	30.00	4.00	*kg/TJ*	210.931	57.53	7.67
U	**1.A.5 Other**			**NA**	**NA**	**NA**	***kg/TJ***			
V	**1.A Fuel Combustion**	**13964.51**	**584666.03**					**42,616.621**	**5084.11**	**4928.76**
	Memo Items									
W	Air Bunkers		29663.69	71398	1.12	2.36	*kg/TJ*	2117.923	32	70
X	Marine Bunkers		6394.50	74153			*kg/TJ*	474.172	NE	NE
Y	CO_2 from Biomass		8637.37	107376				927.448	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 + 7
C	(b) Liquid Fuels	3 + 4 + 9 + 10
D	(c) Gaseous Fuels	5 + 8 + 11
E	(d) Biomass	6
F	**1.A.2 Manufacturing Industries (F = G+H+I+J)**	
G	(a) Solid Fuels	34 + 36 + 44 + 45
H	(b) Liquid Fuels	35 + 37 + 38 + 39
I	(c) Gaseous Fuels	40 + 41 + 46
J	(d) Biomass	42 + 43
K	**1.A.3 Transport (K = L+M+N+O)**	
L	(a) Solid Fuels	NO
M	(b) Liquid Fuels	47 + 48 + 49 + 50 + 51 + 52 + 53 + 55 + 56 + 57
N	(c) Gaseous Fuels	54
O	(d) Biomass	58
P	**1.A.4 Other Sectors (P = Q+R+S+T)**	
Q	(a) Solid Fuels	12 + 13 + 14 + 15 + 16 + 23 + 24 + 25 + 26
R	(b) Liquid Fuels	17 + 18 + 19 + 27 + 28 + 29
S	(c) Gaseous Fuels	20 + 21 + 30 + 31 + 32
T	(d) Biomass	22 + 33
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 2004 [CRF 2004 Table 1.A(b); Biomass excluded]

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)
Liquid Fossil	Primary Fuels	Crude Oil	kt	NA	2,894.00			-32.00	2,925.99	42.81	NCV	125,273.42	20.00	2,505.47	NA
		Orimulsion		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
		Natural Gas Liquids	ktoe	97.99	NA	NA		NA	97.99	41.87	NCV	4,102.65	17.73	72.73	NA
	Secondary Fuels	Gasoline	kt		1,190.00	122.00	1.01	-80.00	1,147.00	44.59	NCV	51,143.36	19.08	975.82	NA
		Jet Kerosene	kt		965.00		671.64	-68.00	361.35	44.10	NCV	15,935.54	19.47	310.31	NA
		Other Kerosene	kt		383.00	13.00	NA	2.00	368.00	44.20	NCV	16,264.08	19.47	316.69	NA
		Shale Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
		Gas / Diesel Oil	kt		2,510.00	124.00	101.00	-14.00	2,298.99	43.31	NCV	99,564.83	19.99	1,990.40	NA
		Residual Fuel Oil	kt		1,318.00	942.00	49.00	54.00	273.00	41.24	NCV	11,257.55	20.73	233.34	NE
		Liquefied Petroleum Gas (I	kt		112.00	20.00			92.00	47.16	NCV	4,338.35	17.37	75.37	NA
		Ethane			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA
		Naphtha	ktoe		NE	27.33		-6.31	-21.02	41.87	NCV	-880.07	20.00	-17.60	NE
		Bitumen	ktoe		166.57	NO		NO	166.57	41.87	NCV	6,973.95	22.00	153.43	153.43
		Lubricants	ktoe		34.34	6.06			28.28	41.87	NCV	1,184.03	20.00	23.68	11.84
		Petroleum Coke	ktoe		293.18				293.18	41.87	NCV	12,274.86	27.49	337.45	NO
		Refinery Feedstocks			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
		Other Oil			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
Other Liquid Fossil												NO		NO	NO
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO
Liquid Fossil Totals												347,432.56		6,977.08	165.27
Solid Fossil	Primary Fuels	Anthracite [2]	ktoe	NO	41.90	5.35		-2.69	39.24	41.87	NCV	1,642.90	26.80	44.03	NO
		Coking Coal		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NA
		Other Bituminous Coal	ktoe	NE	1,663.44			47.21	1,616.23	41.87	NCV	67,668.32	25.80	1,745.84	NA
		Sub-bituminous Coal		NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO
		Lignite	ktoe	NO	19.41			3.79	15.62	41.87	NCV	653.98	27.60	18.05	NO
		Oil Shale		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
		Peat		889.35				314.28	575.07	41.87	NCV	24,077.03	33.26	800.71	NA
	Secondary Fuels	BKB [3] and Patent Fuel			NA	10.19		-8.86	-1.33	41.87	NCV	-55.68	26.96	-1.50	NA
		Coke Oven/Gas Coke			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
Other Solid Fossil												NO		NO	NO
Other non-specified				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO
Solid Fossil Totals												93,986.54		2,607.13	NA,NO
Gaseous Fossil		Natural Gas (Dry)	ktoe	690.07	2,965.35			2.42	3,653.00	41.87	NCV	152,943.80	15.48	2,368.03	NE
Other Gaseous Fossil												NO		NO	NO
	Other non-specified			NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO
Gaseous Fossil Totals												152,943.80		2,368.03	NE,NO
Total												594,362.90		11,952.23	165.27
Biomass total												8,851.31		253.00	NO
		Solid Biomass	ktoe	183.97					183.97	41.87	NCV	7,702.46	30.00	231.07	NO
		Liquid Biomass		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO
		Gas Biomass	ktoe	27.44					27.44	41.87	NCV	1,148.86	19.09	21.93	NO

Table C.5 Comparison of Results from Sectoral Approach and Reference Approach for 2004 [CRF 2004 Table 1.A(c)]

FUEL TYPES	REFERENCE APPROACH			SECTORAL APPROACH [1]		DIFFERENCE [2]	
	Apparent energy consumption [3]	Apparent energy consumption (excluding non-energy use and feedstocks) [4]	CO_2 emissions	Energy consumption	CO_2 emissions	Energy consumption	CO_2 emissions
	(PJ)	(PJ)	(Gg)	(PJ)	(Gg)	(%)	(%)
Liquid Fuels (excluding international bunkers)	347.43	NE	24,976.64	332.04	24,419.74	4.63	2.28
Solid Fuels (excluding international bunkers) [5]	93.99	NE	9,559.46	94.90	9,562.92	-0.97	-0.04
Gaseous Fuels	152.94	NE	8,682.77	152.23	8,633.96	0.47	0.57
Other [5]	NO	NE	NO	NA,NO	NA,NO		
Total [5]	*594.36*	*NE*	*43,218.88*	*588.02*	*42,616.62*	*2.62*	*1.41*

Annex D

Activity Data for Agriculture

Year 1990-2004

Table D.1(a) Activity Data for Agriculture

Housing Storage(1000's)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total Cattle	5969	6100	6147	6236	6264	6344	6451	6661	6882	6952	6558	6330	6408	6333	6224
Dairy Cows	1342	1322	1288	1246	1248	1233	1221	1216	1201	1199	1174	1153	1148	1129	1136
All Other Cattle(exclud.Dairy Cows)	4628	4778	4859	4990	5016	5111	5230	5445	5680	5753	5384	5177	5260	5204	5088
Other Cows	659	729	784	917	937	969	1005	1083	1164	1196	1167	1155	1160	1151	1144
Dairy Heifers	172	185	182	199	194	209	235	244	244	224	210	203	206	216	226
Other Heifers	100	91	92	117	121	107	129	139	154	129	125	140	148	142	141
Cattle <1 yrs	1436	1477	1491	1472	1565	1557	1631	1735	1829	1790	1649	1690	1879	1806	1751
Cattle 1-2 yrs	1312	1348	1399	1379	1361	1404	1380	1425	1482	1549	1446	1269	1329	1364	1320
Cattle >2yrs	923	920	882	874	803	829	811	778	763	819	739	670	485	471	450
Bulls	26	28	30	32	35	36	39	42	45	47	48	50	53	55	57
Total Sheep	7783	8371	8605	9057	8618	8438	8348	7921	8457	8608	8030	7690	6941	6766	7043
Ewes Lowland	2904	3142	3234	3353	3255	3157	3031	2981	3017	2989	2871	2754	2668	2612	2574
Ewes Upland	1245	1346	1386	1437	1395	1353	1299	1278	1293	1281	1231	1180	1144	1119	1103
Rams	123	128	129	130	129	124	122	116	119	117	115	112	108	104	102
Other Sheep>1	263	192	175	149	163	178	180	171	182	201	191	181	152	163	180
Lambs	3248	3564	3681	3989	3677	3626	3716	3375	3845	4021	3622	3464	2869	2768	3084
Pigs	1221	1326	1406	1504	1513	1546	1643	1708	1810	1775	1732	1756	1776	1713	1702
Gilts in Pig	21	22	26	23	21	24	25	27	26	25	23	24	20	20	21
Gilts not yet Served	12	14	15	15	15	17	17	18	19	16	17	18	20	18	19
Sows in Pig	83	91	96	101	99	100	103	108	109	109	110	108	110	104	102
Other Sows for Breeding	30	31	34	32	30	31	36	37	38	38	35	39	33	23	30
Boars	6	7	7	6	6	5	5	5	5	4	4	4	3	3	3
Pigs 20 Kg +	749	803	837	905	918	952	1016	1064	1144	1094	1038	1034	1049	1029	1019
Pigs Under 20 Kg	319	358	392	422	425	417	442	450	469	489	504	530	541	516	507
Poultry	11446	12372	12947	12746	13709	14113	15050	15221	15349	15143	15338	15673	15193	15796	16589
Layer	1868	1800	2231	1832	1730	1371	1701	1580	1559	1537	1572	1676	1613	1907	1906
Broiler	8035	8905	9067	9522	10393	11092	11730	12096	12287	12200	12426	12629	12322	12672	13213
Turkey	1543	1667	1649	1392	1586	1650	1619	1545	1504	1406	1340	1368	1258	1218	1470
Horses	54	63	65	66	67	68	70	72	73	76	70	71	73	70	73
Mules	7	7	8	9	8	7	8	7	8	7	5	5	5	6	6
Goats	17	17	18	18	16	16	15	15	15	14	8	8	8	8	8
Fertiliser (1000's kg/N)	379311	370121	358302	377985	404811	428826	416918	380350	431999	442916	407598	368667	363513	388080	362525

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
total Cattle	6816	6912	6951	6982	6997	7034	7314	7533	7640	7387	7037	7050	6992	6967	7016
Dairy Cows	1360	1331	1278	1264	1261	1256	1266	1252	1234	1201	1178	1183	1164	1156	1156
All Other Cattle(exclud.Dairy Cows)	5456	5581	5674	5718	5736	5778	6047	6281	6406	6186	5860	5867	5828	5811	5860
Other Cows	731	817	889	980	1011	1039	1113	1202	1248	1217	1187	1197	1154	1187	1207
Dairy Heifers	159	130	175	188	204	224	231	244	229	214	207	198	231	216	230
Other Heifers	69	50	95	112	102	117	129	144	127	117	125	133	143	137	140
Cattle <1 yrs	1716	1765	1695	1738	1736	1746	1852	1938	1965	1821	1752	1824	1799	1729	1771
Cattle 1-2 yrs	1663	1692	1638	1587	1586	1586	1639	1717	1783	1706	1517	1515	1593	1577	1535
Cattle >2yrs	1093	1099	1152	1078	1058	1023	1036	986	1002	1058	1016	941	845	902	911
Bulls	26	29	32	37	40	42	47	51	53	55	56	59	63	64	67
Total Sheep	8021	8484	8736	8977	8559	8364	8329	8051	8572	8547	7957	7616	6925	6722	6903
Lowland Ewes	3050	3236	3337	3279	3196	3089	3015	3042	3056	2936	2814	2704	2637	2552	2464
Upland Ewes	1307	1387	1430	1405	1370	1324	1292	1304	1310	1258	1206	1159	1130	1094	1056
Rams	117	123	126	125	122	120	113	116	116	113	111	107	105	102	100
Other Sheep>1	298	175	161	179	195	205	192	215	245	218	205	182	184	206	199
Lambs	3248	3564	3681	3989	3677	3626	3716	3375	3845	4021	3622	3464	2869	2768	3084
Pigs	1221	1326	1406	1504	1513	1546	1643	1708	1810	1775	1732	1756	1776	1713	1702
Gilts in Pig	21	22	26	23	21	24	25	27	26	25	23	24	20	20	21
Gilts not yet Served	12	14	15	15	15	17	17	18	19	16	17	18	20	18	19
Sows in Pig	83	91	96	101	99	100	103	108	109	109	110	108	110	104	102
Other Sows for Breeding	30	31	34	32	30	31	36	37	38	38	35	39	33	23	30
Boars	6	7	7	6	6	5	5	5	5	4	4	4	3	3	3
Pigs 20 Kg +	749	803	837	905	918	952	1016	1064	1144	1094	1038	1034	1049	1029	1019
Pigs Under 20 Kg	319	358	392	422	425	417	442	450	469	489	504	530	541	516	507
Poultry	11446	12372	12947	12746	13709	14113	15050	15221	15349	15143	15338	15673	15193	15796	16589
Layer	1868	1800	2231	1832	1730	1371	1701	1580	1559	1537	1572	1676	1613	1907	1906
Broiler	8035	8905	9067	9522	10393	11092	11730	12096	12287	12200	12426	12629	12322	12672	13213
Turkey	1543	1667	1649	1392	1586	1650	1619	1545	1504	1406	1340	1368	1258	1218	1470
Horses	54	63	65	66	67	68	70	72	73	76	70	71	73	70	73
Mules	7	7	8	9	8	7	8	7	8	7	5	5	5	6	6
Goats	17	17	18	18	16	16	15	15	15	14	8	8	8	8	8
Fertiliser(kgs N)	379311	370121	358302	377985	404811	428826	416918	380350	431999	442916	407598	368667	363513	388080	362525

Annex E

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

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	Cabon Stock in Young Forests	Cabon Stock in Mature Forests	Cabon 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	$1000m^3$	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C	Gg C
1990	15817	3882	4203	111528	370160	481688	1676	508.83	273.03	1937.06	13948.18	15885.24	215.831	271.155	-55.323	-5.532	-16.597	-31.534	-1.660
1991	19147	4203	4063	127246	373728	500974	1769	537.07	330.51	1853.03	14259.29	16112.32	227.089	311.119	-84.029	-8.403	-25.209	-47.897	-2.521
1992	16699	4063	4621	140883	376237	517120	2083	632.42	288.25	1801.56	14496.45	16298.01	185.684	237.158	-51.474	-5.147	-15.442	-29.340	-1.544
1993	15998	4621	4816	151985	380940	534918	2100	637.60	276.15	1776.17	14730.81	16506.97	208.965	234.357	-25.392	-2.539	-7.618	-14.473	-0.762
1994	19459	4816	5447	165792	386598	552390	2287	694.30	335.89	1818.06	14888.74	16706.80	199.826	157.932	41.894	4.189	12.568	23.880	1.257
1995	23710	5447	6203	180777	395331	576108	2382	723.28	409.27	1920.35	15005.91	16926.26	219.460	117.168	102.292	10.229	30.688	58.307	3.069
1996	20981	6203	7090	190089	407000	597089	2465	748.35	362.17	2044.93	15100.13	17145.05	218.794	94.217	124.577	12.458	37.373	71.009	3.737
1997	11434	7090	7185	189009	419514	608523	2322	705.11	197.37	2231.13	15164.68	17395.81	250.753	64.552	186.201	18.620	55.860	106.134	5.586
1998	12928	7185	7924	186511	434940	621451	2638	800.90	223.16	2376.63	15301.01	17677.64	281.829	136.331	145.498	14.550	43.649	82.934	4.365
1999	12668	7924	7747	186164	447955	634119	2777	843.12	218.67	2517.10	15455.78	17972.88	295.248	154.774	140.475	14.047	42.142	80.071	4.214
2000	15695	9238	8677	189917	459897	649814	3008	913.36	270.92	2746.15	15491.77	18237.92	265.034	35.990	229.044	22.904	68.713	130.555	6.871
2001	15465	8755	9132	190239	475501	665740	2836	861.01	266.95	3045.39	15504.83	18550.22	312.300	13.054	299.247	29.925	89.774	170.571	8.977
2002	15054	9258	10286	186422	494926	681348	2911	883.69	259.86	3295.12	15597.80	18892.92	342.699	92.976	249.723	24.972	74.917	142.342	7.492
2003	9097	10313	9289	177624	513338	690962	3000	910.80	157.03	3388.48	15928.79	19317.27	424.353	330.985	93.368	9.337	28.010	53.220	2.801
2004	9000	9289	9828	178667	522436	701103	3000	910.80	155.35	3513.85	16125.37	19639.23	321.955	196.584	125.371	12.537	37.611	71.461	3.761

K The value 3,513.85 Gg is the afforestation carbon stock for the years 1985 to 1998 inclusive; similarly 3,388.48 Gg is the afforestation carbon stock for the years 1984 to 1997 inclusive, etc

N Carbon stock change after harvest (corresponding in 2004 to difference between carbon stocks of 19,639.23 Gg in 2004 and 19,317.27 Gg in 2003)

P Carbon stock change for youg forests (corresponding in 2004 to difference between carbon stocks of 3,513.85 Gg in 2004 and 3,388.48 Gg in 2003)

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.

YOUNG CROPS

General rule for years before 1995:
Current year = (Current year+1) ha. - (afforestation [current year + 1 - minimum age for young trees] + reforestation [current year + 1 - minimum age for young trees])*(Category % related to planting) + (Current year+ 1)*Accretion Rate

Example: 1993 ha. = 1994 ha. - (afforestation 1987 + reforestation 1987)*species % + 1994 ha.*0.05
Example: 1994 ha. = 1995 ha. - (afforestation 1988 + reforestation 1988)*species % + 1995 ha.*0.05

1995 ha. = FIPS ha. For 1995 for a given category

General rule for years after 1995:
Current year = (Current year -1) ha. + (afforestation [current year - minimum age for young trees] + reforestation [current year - minimum age for young trees])*(Category % related to planting) - (Current year - 1)*Accretion Rate

Example: 1996 ha. = 1995 ha. + (afforestation 1989 + reforestation 1989)*species % - 1995 ha.*0.05
Example: 1997 ha. = 1996 ha. + (afforestation 1990 + reforestation 1990)*species % - 1996 ha.*0.05

MATURE CROPS

General Rule for years before 1995:
Current Year = (Current Year + 1)ha - ([Current Year + 1] Young Trees)ha*(Accretion Rate)+ ([Current Year + 1 Felling]ha * [Category % in Felling])

Example: 1993 ha. = 1994 ha. - 1994 'young' ha * 0.5 + 1994 Felling ha * Category % in Felling
Example: 1994 ha. = 1995 ha. - 1995 'young' ha. * 0.5 + 1995 Felling ha * Category % in Felling

1995 ha. = FIPS ha. For 1995 for a given category

General Rule for years after 1995:
Current Year = (Current Year - 1)ha + ([Current Year - 1] Young Trees)ha*(Accretion Rate) - ([Current Year Felling]ha * [Category % in Felling])
Example: 1996 ha. = 1995 ha. + 1995 'young' ha. * 0.5 - 1996 Felling ha * Category % in Felling
Example: 1997 ha. = 1996 ha. + 1996 'young' ha. * 0.5 - 1997 Felling ha * Category % in Felling

CLEARED/UNCLASSIFIED AREAS

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

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

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

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

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

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

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

<u>Annex F</u>

Activity Data for 6.A Solid Waste Disposal on Land

Years 1968 – 2004

Table F.1 Time Series of Solid Waste Disposal and Composition 1968-2004

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	13,564	183,503
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	13,624	184,322
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	13,739	185,879
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	13,871	187,662
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	14,086	190,573
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	14,312	193,635
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	14,549	196,843
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	14,798	200,201
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	15,033	203,390
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	15,239	206,168
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	15,435	208,821
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	15,687	212,237
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	15,840	214,303
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	16,038	216,975
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	16,208	219,281
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	16,320	220,794
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	16,436	221,645
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	16,487	228,841
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	16,490	231,532
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	16,518	236,060
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	16,444	239,614
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	16,345	248,585
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	16,328	260,644
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	16,421	268,901
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	16,555	285,734
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	16,646	295,778
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	16,701	310,283
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	16,727	312,623
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	16,750	336,995
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	20,873	357,048
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	23,745	394,392
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	26,766	431,342
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	30,083	483,192
2001	3,847,200	1.87	2,625,566	0.87	1,992,050	78,469	0.29	0.37	0.03	0.20	578,317	738,384	65,526	389,665	29,513	515,891
2002	3,917,200	1.86	2,658,166	0.79	1,901,864	65,573	0.30	0.36	0.03	0.20	561,437	677,322	64,114	379,881	21,147	475,312
2003	3,978,900	2.02	2,929,237	0.72	1,832,625	71,779	0.29	0.36	0.03	0.20	539,491	657,417	61,572	364,754	21,480	462,657
2004	4,043,800	1.98	2,929,237	0.72	1,832,625	71,779	0.29	0.36	0.03	0.20	539,491	657,417	61,572	364,754	21,830	463,007

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 1968-2004

Year	DOC in MSW tonnes	DOC Managed SWDS %	DOC Unmanaged SWDS %	Fraction DOC Dissimilated	Fraction CH4 in Landfill	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	183503	0.40	0.60	0.60	0.50	1.00	0.40	29360	17616	46977
1969	184322	0.40	0.60	0.60	0.50	1.00	0.40	29492	17695	47187
1970	185879	0.40	0.60	0.60	0.50	1.00	0.40	29741	17844	47585
1971	187662	0.41	0.59	0.60	0.50	1.00	0.40	30777	17715	48492
1972	190573	0.42	0.58	0.60	0.50	1.00	0.40	32016	17685	49701
1973	193635	0.43	0.57	0.60	0.50	1.00	0.40	33305	17660	50965
1974	196843	0.44	0.56	0.60	0.50	1.00	0.40	34644	17637	52281
1975	200201	0.45	0.55	0.60	0.50	1.00	0.40	36036	17618	53654
1976	203390	0.46	0.54	0.60	0.50	1.00	0.40	37424	17573	54997
1977	206168	0.47	0.53	0.60	0.50	1.00	0.40	38760	17483	56243
1978	208821	0.48	0.52	0.60	0.50	1.00	0.40	40094	17374	57468
1979	212237	0.49	0.51	0.60	0.50	1.00	0.40	41598	17318	58917
1980	214303	0.50	0.50	0.60	0.50	1.00	0.40	42861	17144	60005
1981	216975	0.51	0.49	0.60	0.50	1.00	0.40	44263	17011	61274
1982	219281	0.52	0.48	0.60	0.50	1.00	0.40	45610	16841	62451
1983	220794	0.53	0.47	0.60	0.50	1.00	0.40	46808	16604	63412
1984	221645	0.54	0.46	0.60	0.50	1.00	0.40	47875	16313	64188
1985	228841	0.55	0.45	0.60	0.50	1.00	0.40	50345	16477	66822
1986	231532	0.56	0.44	0.60	0.50	1.00	0.40	51863	16300	68163
1987	236060	0.57	0.43	0.60	0.50	1.00	0.40	53822	16241	70063
1988	239614	0.58	0.42	0.60	0.50	1.00	0.40	55590	16102	71693
1989	248585	0.59	0.41	0.60	0.50	1.00	0.40	58666	16307	74973
1990	260644	0.60	0.40	0.60	0.50	1.00	0.40	62555	16681	79236
1991	268901	0.60	0.40	0.60	0.50	1.00	0.40	64536	17210	81746
1992	285734	0.60	0.40	0.60	0.50	1.00	0.40	68576	18287	86863
1993	295778	0.60	0.40	0.60	0.50	1.00	0.40	70987	18930	89917
1994	310283	0.60	0.40	0.60	0.50	1.00	0.40	74468	19858	94326
1995	312623	0.60	0.40	0.60	0.50	1.00	0.40	75030	20008	95037
1996	336995	0.60	0.40	0.60	0.50	1.00	0.40	80879	21568	102447
1997	357048	0.60	0.40	0.60	0.50	1.00	0.40	85692	22851	108543
1998	394392	0.61	0.39	0.60	0.50	1.00	0.40	96232	24610	120842
1999	431342	0.62	0.38	0.60	0.50	1.00	0.40	106973	26226	133198
2000	483192	0.63	0.37	0.60	0.50	1.00	0.40	121764	28605	150369
2001	515891	0.64	0.36	0.60	0.50	1.00	0.40	132068	29715	161784
2002	475312	0.65	0.35	0.60	0.50	1.00	0.40	123581	26617	150199
2003	462657	0.66	0.34	0.60	0.50	1.00	0.40	122141	25169	147310
2004	463007	0.67	0.33	0.60	0.50	1.00	0.40	124086	24447	148533

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