IRELAND

NATIONAL INVENTORY REPORT 2005

GREENHOUSE GAS EMISSIONS 1990 - 2003 REPORTED TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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EXECUTIVE SUMMARY

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. 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 first NIR submitted by Ireland pursuant to the requirements of the UNFCCC reporting guidelines set out the status of Irish inventories with respect to the inventory data time-series for the years 1990 to 2000, submitted to the UNFCCC secretariat in 2002. The present report constitutes Irelands NIR for 2005. It is an update of the 2003 and 2004 reports, extending the time series of inventory data to 2003 and it retains the structure adopted for previous NIR. As such, it includes sections describing emission trends, key sources, recalculations and ongoing improvements, in addition to the detailed description of methods, activity data and emission factors used for each of the IPCC source categories. Calculation sheets are included wherever practicable for the latest year in the time-series or for all years, as appropriate, to support the description of methods and in order to achieve full transparency, as envisaged by the UNFCCC Reporting Guidelines. The NIR also provides an assessment of the extent to which the inventory agency has implemented the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.

In addition to complying with the UNFCCC reporting Guidelines, the report is intended to inform Government departments and other national agencies in Ireland of the state of the art of Irish greenhouse gas inventories as they face the challenge to curb the sustained and rapid growth in emissions. The in-depth analysis of key sources and the up-to-date trend data will provide useful support for the implementation of the Government's strategy to limit the increase in emissions. 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 serve as a means of identifying areas where improvements in input data may be possible.

The EPA has compiled a consistent time-series of greenhouse gas inventories for the years 1990 through 2003 for submission to the UNFCCC secretariat in April 2005. The results are available as a complete set of Common Reporting Format files, the electronic reporting format 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. However, emission estimates for HFC, PFC and SF_6 are available only for the years 1995 through 2003. Some lack of completeness remains in regard to potentially important sources and sinks under *Land-Use Change and Forestry*, where CO_2 is by far the most important gas. Ireland has deferred the inclusion of estimates for the source categories concerned until the results of a number of major national research projects relevant to the sources become available. Some minor recalculations have been undertaken for the purposes of the 2005 submission and the inventories for the years 1990-2002 reflect these revisions.

Total emissions of greenhouse gases in Ireland increased from 53.9 million tonnes CO_2 equivalent in 1990 to 70.5 million tonnes CO_2 equivalent in 2001. Following this period of sustained increase, the emissions decreased to 67.5 million tonnes CO_2 equivalent in 2003, a reduction of 4 percent on their highest level in 2001. The decrease is due a number of factors, including the closure of Irelands only nitric acid plant and its associated ammonia production facility, CO_2 reduction in electricity generation through the greater use of cleaner fuels and continued decreases in CH_4 and N_2O emissions in agriculture, in line with the decline in both cattle populations and fertilizer use.

In 2003, total emissions were 25.3 percent higher than the emissions in 1990. The *Energy* sector accounted for 64.6 percent of total emissions, *Agriculture* contributed 27.8 percent while a further 4.4 percent emanated from *Industrial Processes* and 3 percent was due to *Waste*. Emissions of CO_2 accounted for 65.8 percent of the total of 67.5 million tonnes CO_2 equivalent in 2003, with CH_4 and N_2O contributing 18.9 percent and 14.4 percent, respectively. The combined emissions of HFC, PFC and SF_6 accounted for less than 1 percent of total emissions in 2003.

The application of uncertainty analysis for Irish greenhouse gas inventories indicates an overall uncertainty of 12.2 percent in the 2003 inventory and a trend uncertainty of 7.7 percent for the period 1990 to 2002. This outcome is determined largely by the high uncertainty in the estimate of N_2O emissions from agricultural soils. Two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have an uncertainty of less than 2 percent. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2003 is negligible because they account for less than 1 percent of total emissions.

Tier 1 level assessment of sources (ranking by contribution to total emissions) at the level of emissions calculation identified 38 key emission sources in 2003. There were 25 key sources of CO_2, accounting for 64.3 percent of total emissions. There were six key source categories of CH_4 and five key source categories of N_2O in level assessment, which accounted for 18.2 percent and 12 percent, respectively, of total emissions. The results of the Tier 1 key source analysis clearly show the impact of CO_2 emissions from energy consumption on total emissions in Ireland. These emissions account for 24 out of 38 key source categories identified by level assessment in 2003 and for 61.2 percent of total emissions.

Ireland's 2003 submission was the subject of an in-country review as part of the rigorous review process now underway under the Convention. The review report recorded no major problems or shortcomings in the Irish inventories but nevertheless made recommendations that the inventory agency could pursue to increase transparency and achieve better compliance with UNFCCC reporting requirements in general. It has not been possible to fully implement the recommendations for the current reporting cycle but the present NIR mentions some changes and improvements now planned in response to the in-country review report. Some minor recalculations have been performed for the 2005 submission. Some major recalculations are still pending and they will be undertaken during 2005 for submission in 2006.

The range of important sources of greenhouse gas emissions in Ireland is not as extensive as in many other Annex I Parties. The resources available for the annual reporting cycle and related issues remain quite limited and relatively simple calculation methods continue to be used to produce the estimates of emissions. Against this background and the improvements that are being pursued, the present report continues to improve the basis for technical assessment and expert review of Irish greenhouse gas inventories.

Chapter One

Introduction

1.1 Background

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 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 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 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 ongoing review of submissions from Annex I Parties.

The present report constitutes Ireland's NIR for 2005 and sets out the status of Irish inventories with respect to the emissions time-series submitted for the years 1990 through 2003, which is an integral part of the report. It is structured broadly in accordance with the format adopted for previous NIR (SBSTA, 2002) and thereby addresses the full range of reporting requirements related to annual inventories set down in the UNFCCC 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, necessary 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/CRF2005/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 Appendix 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. 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 now, 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.

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 128 sub-categories at Level 3. Table A.2 of Appendix A lists the Level 1 and Level 2 source/sink categories. The Level 3 sources are detailed in the description of inventory methods and data in Chapter Five. The computation of emissions is usually undertaken at Level 3 or below, using further appropriate disaggregation (for example, by using fuel type in the case of all 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 Emission Inventories in Ireland

Air pollutant emission inventories in Ireland were first produced in the early 1980s as simple estimates of the main pollutants (particulate matter, SO_2, NO_X, CO and hydrocarbons) emanating from the combustion of fuels in a small number of broad source sectors. The necessary input statistics were quite limited and there was a poor understanding of emission rates in some important sectors, such as road traffic. Irish participation in the European Commission's CORINAIR programme on emissions inventories from 1987 provided the opportunity to develop more complete inventories at the national level based on an accepted methodology. This was necessary to meet the emerging data needs of national Government departments and for reporting to international organizations.

Following the Irish submissions of detailed inventories for 1985 (McGettigan, 1989) and 1990 (McGettigan, 1993) to the European Commission, the CORINAIR/EMEP system was adopted as the emissions inventory database for Ireland. Its flexibility and ongoing development under the workplan of the European Environment Agency allows for additional pollutants to be added as necessary and for the application of specially designed calculation methods in key emission sectors. The CORINAIR database methodology, currently containing many additional features and known as CollectER (Pulles *et al*, 1999), is now used in Ireland to produce and store annual emission inventories of a range of compounds.

The first comprehensive Irish emission inventories of the three main greenhouse gases, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were produced in 1992 as part of the CORINAIR 1990 database. The 1990 base year emissions for reporting under the Framework Convention on Climate Change were extracted from the 1990 CORINAIR results by conversion to the required IPCC source categories. These data were also used to meet reporting obligations under Decision 93/389/EEC (CEC, 1993) concerning a monitoring mechanism on CO_2 and other greenhouse gases.

The inventories for subsequent years were compiled using a simple national system that was based largely on the CORINAIR methodology but which also attempted to take into account relevant guidance and reporting procedures of the IPCC guidelines which were undergoing rapid development in the early and mid 1990s (IPCC, 1995). The inventories for CO_2, CH_4 and N_2O produced in this way for the years 1990 through 1997, as well as projections for 2000, were included in two Irish national communications under the Convention (DOE, 1994a and DOE, 1997). The emissions data produced for CO_2 were of reasonably good quality but the estimates for CH_4 and N_2O were considered to be highly uncertain. The first attempts to compile emissions of the three additional greenhouse gases (HFC, PFC and SF_6) were made in 1998. These focussed on 1995 but the results were recognised as tentative and incomplete.

1.4 Institutional and Procedural Arrangements

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 99/296/EEC (CEU, 1999a). The latter has been superceded by Decision 280/2004/EC (EP and CEU, 2004), which now becomes the basis for reporting under the Convention and the Kyoto Protocol. The EPA also acts as the Irish national reference centre for the European Environment Agency's

Topic Centre on Air and Climate Change.

Figure 1.1 gives an 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's own 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. The estimates of carbon emissions and removals associated with forest biomass are made by COFORD, the National Council for Forest Research and Development in Ireland

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 contain 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 and from the operators of landfill gas capture programmes is used as the primary input 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 25 million tonnes annually, equal to approximately 35 percent of total greenhouse gas emissions. Guidance provided by the 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.

Various preparatory calculations and conversions are generally required for both the already computed emissions estimates and the activity data acquired from the different sources before they become part of the actual inventory, at the lowest possible level of aggregation and computation. Suitable emission factors are combined with the activity data to calculate emissions and the results are combined with those already available from some data suppliers for appropriate aggregation according to the IPCC reporting format. The greenhouse gas emission estimates for key source categories, such as *Energy* and *Agriculture*, are reproduced in three different computational systems in parallel – simple spreadsheets and the IPCC and CollectER software applications – to facilitate reporting to the various international bodies. All inventory data, including background information and supporting calculation spreadsheets, are stored on servers at the EPA offices in Dublin.

1.5 Overview of Completeness

Table 1.1 gives an overview of the level of completeness of the 1990-2003 inventories with respect to the six greenhouse gases covered by the UNFCCC guidelines and the IPCC Level 2 source-category split. The extent of source/gas coverage in 2003 is the same as that in 2002. Further detail on source/gas coverage at IPCC Level 3 is provided in Chapter Five, describing the inventory methods and data for each Level 1 source-category.

There is full coverage of both combustion and fugitive emission sources of CO_2, CH_4 and N_2O under *Energy*, which accounts for the bulk of CO_2 emissions. The production of cement, lime, ammonia and nitric acid are the only activities under *Industrial Processes* that are relevant to the emissions of CO_2, CH_4 or N_2O in Ireland and estimates are included for the gases concerned in each case. Emissions of HFC, PFC and SF_6 only occur for source category *2.F Consumption of Halocarbons and SF_6* and the various sources are considered to be well covered for the years 1995 to 2003. The potential CO_2 arising from emissions of volatile organic compounds from *Solvent and Other Product Use* is accounted for by assuming that 85 percent of the mass emission of VOC is converted in the atmosphere to CO_2. The annual VOC emission for this category, as well as the totals for NO_X, VOC and CO, are taken from the inventory data reported by Ireland to the UNECE Secretariat under the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

Agriculture is a very import source of CH_4 and N_2O in Ireland and the principal sources are usually given high priority in the inventory process. These are *4.A Enteric Fermentation, 4.B Manure Management* and *4.D Agricultural Soils*. The inventories are now fully complete in the case of *4.D Agricultural Soils* following the inclusion from submission 2003 of estimates for the N_2O emissions associated with nitrogen-fixing crops and crop residues. The CO_2 emissions arising from the liming of agricultural lands are not included under *Agriculture* but they are accounted for under *5.D CO_2 Emissions and Removals from Soils* under the Level 1 source category *Land Use Change and Forestry*. This IPCC Guidelines make allowance for the alternative source allocation in the case of this activity.

The inventory time-series for 1990-2003 extends the updated and improved estimates of the carbon emissions and removals under *5.A Changes in Forest and Other Woody Biomass Stocks*. No other estimates of emissions or removals are reported under *Land-Use Change and Forestry*, except the CO_2 emissions arising from the liming of agricultural lands, as mentioned above. Major research has been undertaken in Ireland to develop the necessary input data and country-specific factors that will allow for a full application of the available IPCC methods in relation to *5.B Forest and Grassland Conversion, 5.C Abandonment of Managed Lands* and *5.D CO_2 Emissions and Removals from Soils*. A national review of reporting needs and category coverage is underway to prepare for reporting in accordance with the CRF tables adopted for *Land Use Land-Use Change and Forestry* at COP9.

Ireland makes an estimate of the CH_4 emissions emanating from solid waste disposal under *Waste*. The inclusion of an estimate of the N_2O emissions arising from *6.B Wastewater Handling* is one element of the recalculations completed for the 2003 submission and is now covered in all years. The emissions of CH_4 from this source and the emissions of greenhouse gases associated with *6.C Waste Incineration* are considered to be negligible in Ireland. All relevant emissions under the Memo Items are reported separately from national totals in the up-to-date CRF time-series, as required by the UNFCCC guidelines.

1.6 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 emission estimates. In practice, very few measured data are available for greenhouse gases and, consequently, the emissions from most source 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 factor 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 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 1.2 and Table 1.3 present an overview of the methodologies and emission factors used by Ireland to estimate emissions for the years 1990-2003. 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 co-dependent 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.

1.7 Quality Assurance and Quality Control

Ireland has not yet developed formal quality assurance and quality control (QA/QC) systems on the scale recommended by the IPCC good practice guidance (IPCC, 2000). In particular, a system for review of annual inventories that could be regarded as the basis for quality assurance has not been set up. Such a system would require the timely and co-ordinated participation of several competent institutions on a routine basis following inventory preparation. A worthwhile review would shorten the already limited time available for annual inventory compilation and reporting and it would demand significant operational and management resource. At the end of 2004, Ireland commissioned a project to establish formal QA/QC procedures in emission inventories meeting the needs of the UNFCCC reporting requirements.

The inventory preparation process employed in Ireland does incorporate a number of activities that may be regarded as fundamental elements of quality control. The emission estimates for the most important source sectors (*Energy* and *Agriculture*) are produced in three computational systems simultaneously. Firstly, simple spreadsheets are used to undertake a considerable amount of preparatory calculations and to subsequently derive the emissions estimates by combining activity data and emission factors at the most appropriate level of disaggregation. Conversion to IPCC source categories is part of this process. Secondly, the greenhouse gas emission estimates are derived by the CollectER software, as part of a much wider range of emission inventories stored in the database. Thirdly, the IPCC software is used to produce emissions in the major source categories because the results may be directly imported into the CRF file, providing a convenient starting point in the preparation of the annual CRF. This duplication provides rigorous internal checking of the 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 *Energy*, 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.

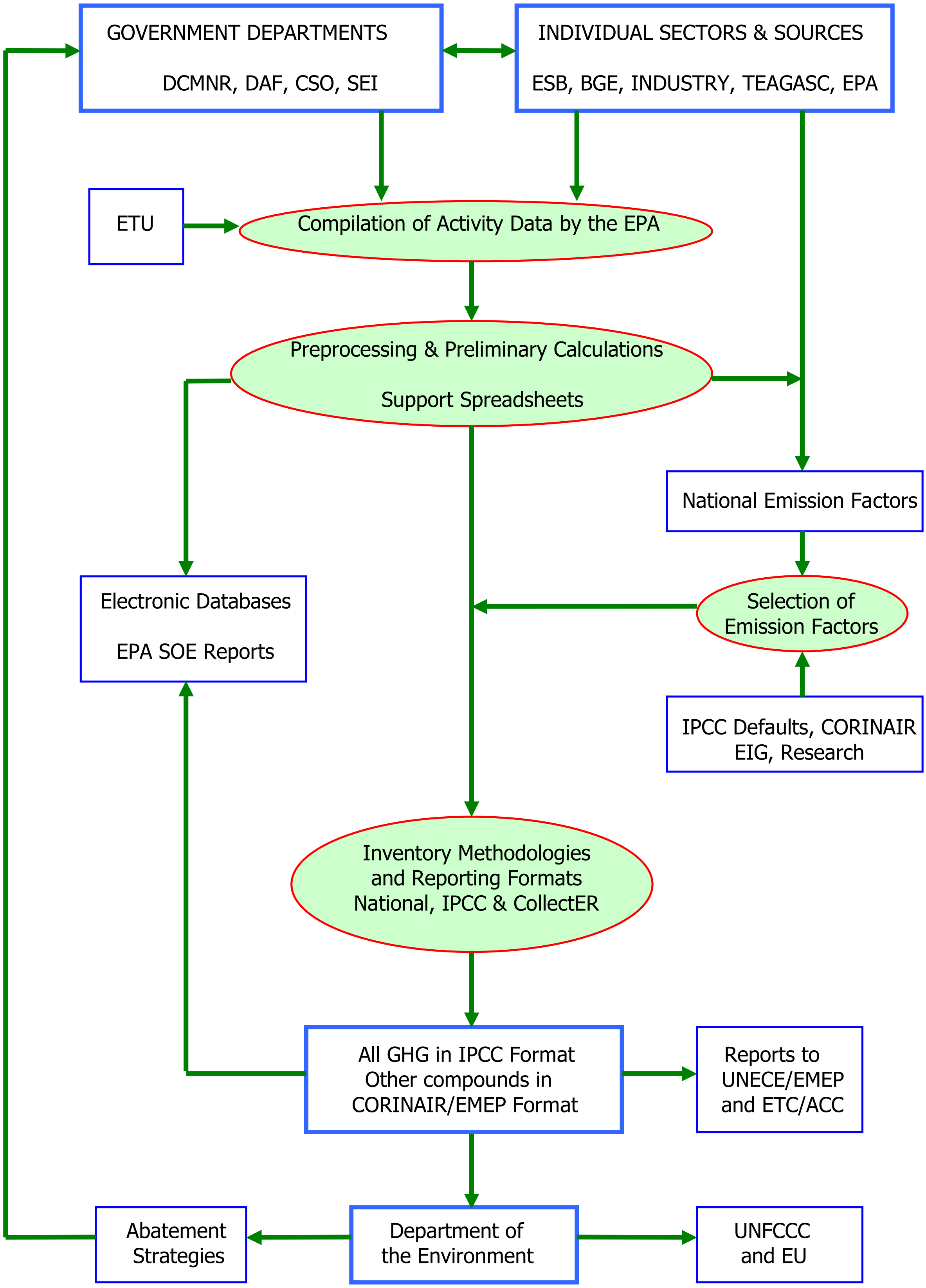
1.8 Uncertainty Assessment

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 2003. 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 2003 is presented in Table 1.3, 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 1.3 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, is currently engaged in a process to develop and improve Irish energy balances, which provides an opportunity to gain further insight into uncertainty in the statistical data compiled from annual fuel-use questionnaires. The inventory experts have therefore consulted SEI again to ascertain their views 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 original uncertainty estimates used for these sources have been modified by assigning uncertainties to the various component parts 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 1.3 show how some of these revised uncertainty inputs were obtained.

The Tier 1 uncertainty analysis for 2003 gives an overall uncertainty of 12.2 percent in total emissions and a trend uncertainty of 7.7 percent for the period 1990 to 2003. This 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. The revisions to the input values of uncertainty described above have very little bearing on the result. Two-thirds of total Irish emissions, i.e. the proportion contributed by CO_2, are estimated to have an uncertainty of less than two percent. When CH_4 is included, bringing the proportion of total emissions up to 85 percent, the total uncertainty remains less than four percent, even though there are large uncertainties assigned to the CH_4 emission factors in most 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 2003 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 2003 is negligible because these gases account for less than 1 percent of total emissions in Ireland.



DCMNR : Department of Communications, Marine & Natural Resources
ETU : Emissions Trading Unit
DAF : Department of Agriculture and Food
CSO : Central Statistics Office
ETC/ACC : European Topic Centre Air & Climate Change
SEI : Sustainable Energy Ireland

ESB : Electricity Supply Board
EPA : Environmental Protection Agency
BGE : Bord Gais Eireann
EIG : Emissions Inventory Guidebook
SOE : State of the Environment

Figure 1.1. Inventory Institutional and Procedural Arrangements

Table 1.1. 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	All	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	All	All	All	NA	NA	NA
B. Chemical Industry	All	All	All	NO	NO	NO
C. Metal Production	NO	NO	NO	NO	NO	NO
D. Other Production	NO	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	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	**All**	**NA**	**NO**	**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	All	All	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 Change and Forestry						
A. Changes in Forest and Other Woody Biomass Stocks	All	NA	NA	NA	NA	NA
B. Forest and Grassland Conversion	NE	NE	NE	NA	NA	NA
C. Abandonment of Managed Lands	NE	NE	NE	NA	NA	NA
D. CO_2 Emissions and Removals from Soil	Part	Part	Part	NA	NA	NA
E. 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	NO	NO	NO	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

Table 1.2. 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	Tier 1	Tier 1	NA	NA	NA
2. Manufacturing Industries and Construction	Tier 1	Tier 1	Tier 1	NA	NA	NA
3. Transport	Tier 1	Tier 3	Tier 3	NA	NA	NA
4. Other Sectors	Tier 1	Tier 1	Tier 1	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	CS	CS	NO	NA	NA	NA
2. Industrial Processes						
A. Mineral Products	D	NO	NO	NA	NA	NA
B. Chemical Industry	D	NO	D	NO	NO	NO
C. Metal Production	NO	NO	NO	NO	NO	NO
D. Other Production	NO	NO	NO	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	Tier 2	Tier 2	Tier 2
G. Other	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CS, C	NO	NO	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	Tier 1	NA	NA	NA	NA
B. Manure Management	NA	Tier 1	Tier 1	NA	NA	NA
C. Rice Cultivation	NO	NO	NO	NA	NA	NA
D. Agricultural Soils	Tier 1	NO	Tier 1	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 Change and Forestry						
A. Changes in Forest and Other Woody Biomass Stocks	CS	NA	NA	NA	NA	NA
B. Forest and Grassland Conversion	NE	NE	NE	NA	NA	NA
C. Abandonment of Managed Lands	NE	NE	NE	NA	NA	NA
D. CO_2 Emissions and Removals from Soil	D	NE	NE	NA	NA	NA
E. Other	NO	NO	NO	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NO	Tier 2	NA	NA	NA	NA
B. Wastewater Handling	NA	NE	D	NA	NA	NA
C. Waste Incineration	NO	NO	NO	NA	NA	NA
D. Other	NO	NO	NO	NA	NA	NA
7. Other	NO	NO	NO	NA	NA	NA
International Bunkers						
Aviation	D	D	D	NA	NA	NA
Marine	D	D	D	NA	NA	NA
Multilateral Operations	NO	NO	NO	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 1.3. 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	C	NA	NA	NA
2. Manufacturing Industries and Construction	PS, CS	C	C	NA	NA	NA
3. Transport	CS	M	M	NA	NA	NA
4. Other Sectors	CS	C	C	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	D	NO	NO	NA	NA	NA
B. Chemical Industry	D	NO	CS	NO	NO	NO
C. Metal Production	NO	NA	NA	NO	NO	NO
D. Other Production	NO	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	D, CS	D, CS	D, CS
G. Other	NA	NA	NA	NA	NA	NA
3. Solvent and Other Product Use	CS, C	NA	NO	NA	NA	NA
4. Agriculture						
A. Enteric Fermentation	NA	CS, D	NA	NA	NA	NA
B. Manure Management	NA	CS, D	CS, D	NA	NA	NA
C. Rice Cultivation	NA	NA	NA	NA	NA	NA
D. Agricultural Soils	NA	NA	D	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 Change and Forestry						
A. Changes in Forest and Other Woody Biomass Stocks	CS	NA	NA	NA	NA	NA
B. Forest and Grassland Conversion	NE	NE	NE	NA	NA	NA
C. Abandonment of Managed Lands	NE	NE	NE	NA	NA	NA
D. CO_2 Emissions and Removals from Soil	D	NA	NA	NA	NA	NA
E. Other	NO	NO	NO	NA	NA	NA
6. Waste						
A. Solid Waste Disposal on Land	NO	CS, D	NA	NA	NA	NA
B. Wastewater Handling	NA	NA	D	NA	NA	NA
C. Waste Incineration	NO	NO	NO	NA	NA	NA
D. Other	NO	NO	NO	NA	NA	NA
7. Other	NO	NO	NO	NA	NA	NA
International Bunkers						
Aviation	CS	D	D	NA	NA	NA
Marine	CS	D	D	NA	NA	NA
Multilateral Operations	NO	NO	NO	NA	NA	NA
CO_2 Emissions from Biomass	D	D	D	NA	NA	NA

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

Table 1.4. Tier 1 Uncertainty Estimates 2003

	IPCC Source Category	Gas	Emissions in 1990	Emissions in 2003	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Total Emissions in 2003	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-Coal	CO2	4844.66	5294.14	1	5	5.10	0.40	0.16	-0.01	0.10	0.14	-0.07	0.16	0.02
	Energy-Peat	CO2	3064.65	2437.37	1	5	5.10	0.18	0.03	-0.03	0.04	0.06	-0.13	0.14	0.02
	Energy-Gas	CO2	1880.66	5384.46	1	2.5	2.69	0.21	0.05	0.06	0.10	0.14	0.14	0.20	0.04
	Energy-Other	CO2	1267.50	2364.33	1	2.5	2.69	0.09	0.01	0.01	0.04	0.06	0.04	0.07	0.01
1A2	Industry-Coal	CO2	970.37	508.46	2	5	5.39	0.04	0.00	-0.01	0.01	0.03	-0.07	0.07	0.00
	Industry-Pet Coke	CO2	0.00	848.74	5	10	11.18	0.14	0.02	0.02	0.02	0.11	0.16	0.19	0.04
	Industry-Gas	CO2	855.68	1119.75	2.5	2.5	3.54	0.06	0.00	0.00	0.02	0.07	0.00	0.07	0.01
	Industry-Oil	CO2	2007.12	2287.37	10	2.5	10.31	0.35	0.12	0.00	0.04	0.60	-0.01	0.60	0.36
	Industry-Peat	CO2	0.00	20.39	1.5	5	5.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3	Transport-Oil	CO2	4971.32	11281.09	1	2.5	2.69	0.45	0.20	0.09	0.21	0.29	0.23	0.38	0.14
1A3	Transport-Gas	CO2	48.30	111.56	1	2.5	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4	Other-Coal and PC	CO2	2327.15	1048.64	5	10	11.18	0.17	0.03	-0.03	0.02	0.14	-0.34	0.37	0.14
	Other-Peat	CO2	3259.38	1160.62	10	20	22.36	0.38	0.15	-0.05	0.02	0.30	-1.08	1.12	1.25
	Other-Gas	CO2	469.25	1937.48	2.5	2.5	3.54	0.10	0.01	0.02	0.04	0.13	0.06	0.14	0.02
	Other-Oil	CO2	3670.18	6116.21	10	5	11.18	1.01	1.02	0.03	0.11	1.60	0.14	1.60	2.57
1B	Fugitive Emissions	CO2	138.90	58.88	2.5	10	10.31	0.01	0.00	0.00	0.00	0.00	-0.02	0.02	0.00
2A1	Cement Production	CO2	750.00	2157.42	7.5	5	9.01	0.29	0.08	0.02	0.04	0.42	0.11	0.44	0.19
2A2	Lime Production	CO2	191.42	202.25	5	5	7.07	0.02	0.00	0.00	0.00	0.03	0.00	0.03	0.00
2B	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
5D	Liming of Ag Lands	CO2	384.45	348.65	5	20	20.62	0.11	0.01	0.00	0.01	0.05	-0.05	0.07	0.00
	Total CO2		*32090.16*	*44687.81*				*1.38*	*1.89*					*2.19*	*4.82*
1A	Fuel Comb-All Fuels	CH4	149.94	99.98	2	50	50.04	0.07	0.01	0.00	0.00	0.01	-0.08	0.08	0.01
1B	Fugitive Emissions	CH4	150.78	78.55	2.5	10	10.31	0.01	0.00	0.00	0.00	0.01	-0.02	0.02	0.00
4A	Dairy Cattle	CH4	2847.60	2420.10	1	20	20.02	0.71	0.51	-0.02	0.04	0.06	-0.42	0.43	0.18
4A	Other Cattle	CH4	5172.30	5785.25	1	30	30.02	2.56	6.56	-0.01	0.11	0.15	-0.38	0.41	0.17
4A	Other Livestock	CH4	1160.46	1088.47	1	50	50.01	0.80	0.64	-0.01	0.02	0.03	-0.34	0.34	0.11
4B	Manure Management	CH4	1260.84	1350.38	32	50	59.36	1.18	1.40	0.00	0.02	1.13	-0.21	1.15	1.32
6A	Solid Waste	CH4	1158.15	1930.53	41	47	62.37	1.78	3.15	0.01	0.04	2.07	0.42	2.11	4.44
	Total CH4		*11900.07*	*12753.27*				*3.50*	*12.28*					*2.49*	*6.22*
	Cumulative CO2 and CH4		*43990.23*	*57441.08*				*3.76*	*14.17*					*3.32*	*11.04*

Table 1.4. Tier 1 Uncertainty Estimates 2003 (continued)

1A3	Fuel Comb-Road Traffic	N2O	56.11	382.85	1	25	25.02	0.14	0.02	0.01	0.01	0.01	0.14	0.14	0.02
1A	Fuel Comb-Other Sectors	N2O	895.20	1123.72	2	50	50.04	0.83	0.69	0.00	0.02	0.06	0.00	0.06	0.00
2B	Nitric Acid	N2O	1035.40	0.00	1	10	10.05	0.00	0.00	-0.02	0.00	0.00	-0.24	0.24	0.06
4B	Manure Management	N2O	626.82	659.96	32	100	105.00	1.02	1.04	0.00	0.01	0.55	-0.23	0.60	0.36
4D	Agricultural Soils	N2O	7294.30	7443.25	32	100	105.00	11.52	132.89	-0.03	0.14	6.22	-3.10	6.95	48.24
6B	Wastewater	N2O	114.55	129.27	10	10	14.14	0.03	0.00	0.00	0.00	0.03	0.00	0.03	0.00
	Total N2O		*10022.38*	*9739.05*				*11.60*	*134.65*					*6.98*	*48.68*
	Cumulative CO2, CH4, N2O		*54012.61*	*67180.13*				*12.20*	*148.81*					*7.73*	*59.72*
2F	Halocarbons & SF6	HFC	20.71	288.39	20	25	32.02	0.14	0.02	0.00	0.00	0.12	0.12	0.17	0.03
2F	Halocarbons & SF6	PFC	75.38	223.63	20	25	32.02	0.11	0.01	0.00	0.00	0.09	0.06	0.11	0.01
2F	Halocarbons & SF6	SF6	83.05	100.20	20	25	32.02	0.05	0.00	0.00	0.00	0.04	0.00	0.04	0.00
	Total HFC, PFC & SF6		*179.14*	*612.22*				*0.18*	*0.03*					*0.21*	*0.04*
	Total all gases		*54191.75*	*67792.34*					*148.85*						*59.76*
					Level Uncertainty in emissions			***12.20***				***Trend Uncertainty***		***7.73***	

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%, 20% 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

Chapter Two

Emission Trends

2.1 Trends in Total Emissions

Table 2.1 and Figure 2.1 show the trends in total greenhouse gas emissions in Ireland over the period 1990-2003. These time-series data are extracted from the trend tables of the 2003 CRF and they reflect some minor recalculations conducted for the 2005 submission, which are described in Chapter Four. The trends by sector and gas are shown on Figure 2.1(a) and Figure 2.1(b), respectively. Figure 2.1(c) shows CO_2 emissions from fuel combustion, the major source of greenhouse gases in Ireland. Emissions from Agriculture, the other principal source sector, are shown on Figure 2.1(d). Total emissions (excluding net CO_2 from *Land Use Change and Forestry*) increased steadily from 53.9 million tonnes CO_2 equivalent in the base year[1] to 70.5 million tonnes CO_2 equivalent in 2001 and then decreased slightly to 67.5 million tonnes CO_2 equivalent in 2003. Total emissions in 2003 were 25 percent higher than in the base year and 4 percent lower than the peak level of 2001.

The overall increase of 31 percent in the period 1990-2001 was driven by the growth in CO_2 emissions from energy use, which is well shown by the similarities between emissions from energy on Figure 2.1a and the CO_2 trend on Figure 2.1b. The increase in CO_2 amounted to 44 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 3 percent annually. The rate of economic growth slowed down considerably from 2000 to 2003, which together with the closure of some major industrial plants and continued decline in cattle populations and fertilizer use, resulted in the change in emission trends given by Table 2.1 and Figure 2.1.

In 2003, the *Energy* sector accounted for 64.6 percent of total emissions, *Agriculture* contributed 27.8 percent while a further 4.4 percent emanated from *Industrial Processes* and 3 percent was due to *Waste*. Emissions of CO_2 accounted for 65.8 percent of the total of 67.5 million tonnes CO_2 equivalent in 2003, with CH_4 and N_2O contributing 18.9 percent and 14.4 percent, respectively. The emissions of HFC, PFC and SF_6 accounted for less than 1 percent of total emissions in 2003.

2.2 Trends by Sector and Gas

Fuel combustion in energy industries (1.A.1) and in transport (1.A.3) accounted for 26.9 million tonnes CO_2 in 2003 or approximately 40 percent of total greenhouse gas emissions. The largest increases in CO_2 emissions have taken place in energy industries and in the transport sector (Figure 2.1c). 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

[1] The base year emissions are the sum of CO_2, CH_4 and N_2O emissions in 1990 along with the combined emissions of HFC, PFC and SF_6 in 1995, expressed in CO_2 equivalents.

associated CO_2 emissions from energy industries increased by 55 percent from 11 million tonnes in 1990 to 17 million tonnes in 2001. There were some gains from energy efficiency and fuel switching as some new electricity suppliers entered the market in 2002 and 2003 with the result that CO_2 emissions from electricity generation reduced to 15 million tonnes in 2003, which is 36 percent higher than in 1990.

The CO_2 emissions from transport sources, which are largely accounted for by road traffic in Ireland, increased by 126 percent between 1990 and 2003, due to sustained growth in vehicle fleets and road travel. 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 6 percent for petrol in 2003 but it may have been as high as 19 percent in the case of diesel. It is worth noting that in 1990 there was significant cross-border movement of automotive fuels into Ireland. 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 25 percent between 1990 and 2003. The contribution from industrial process decreased significantly in 2003 following the closure of Ireland's ammonia and nitric acid plants in June 2002.

Residential fuel combustion (1.A.4(b)) accounts for the bulk of emissions from other energy-use sectors and this source category is a larger contributor to CO_2 emissions in Ireland than combustion in industry (Figure 2.1c). Although residential energy consumption increased by about 22 percent from 1990 to 2003 (Figure 2.2), the CO_2 emissions in this sector show a decrease of 4 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 72 percent between 1990 and 2003 while those from oil and natural gas trebled over this period.

The main drivers of emissions in *Agriculture* are shown in Figure 2.3(c) and the component CH_4 and N_2O emission trends are shown on Figure 2.3(d). Large livestock populations produce about 0.52 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 24,000 tonnes N_2O. These emissions from *Agriculture,* equal to approximately 18.5 million tonnes CO_2 equivalent annually, account for a comparatively larger share of total national emissions than in most other Annex I Parties. However, this share decreased from 34 percent in 1990 to approximately 28 percent in 2003 due to the sustained CO_2 increase 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.

2.3 Emissions of Indirect Greenhouse Gases

The total emissions of SO2, NO_X, NMVOC and CO for the years 1990 to 2003 are summarised on Table 2.4. 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 2003 were similar to that in 1990.

Total SO_2 emissions decreased by approximately 60 percent, from 185,700 tonnes in 1990 to 76,360 tonnes in 2003. Power stations remain the principal source of SO_2 emissions, contributing approximately 58 per cent of the total in 2003. Combustion sources in the industrial and residential/commercial sectors largely account for the remainder of emissions, with contributions of 23 per cent and 14 per cent, respectively in 2003. In 1990, coal combustion accounted for 51 per cent of SO_2 emissions and fuel oil contributed 31 per cent. By 2003, the share of SO_2 emissions from coal had decreased to 40 per cent and that from fuel oil had remained at 31 per cent. This also reflects increased dependence on natural gas for electricity generation.

Table 2.2. Emissions of SO_2, NO_X, VOC and CO 1990-2003 (Gg)

	SO_2	NO_X	NMVOC	CO
1990	185.70	118.10	111.11	400.90
1991	180.20	119.50	111.06	394.40
1992	171.50	130.40	114.33	394.60
1993	160.80	119.10	108.55	350.30
1994	175.00	115.30	107.45	329.20
1995	161.20	115.30	105.35	304.40
1996	147.40	119.90	111.85	306.80
1997	166.00	118.50	115.70	312.10
1998	176.00	121.80	117.64	317.70
1999	157.40	118.50	98.41	285.10
2000	131.49	125.13	90.27	279.57
2001	125.80	131.60	86.70	269.70
2002	96.25	125.26	81.42	254.12
2003	76.37	119.75	77.85	238.80

Unlike SO_2, total NO_X emissions have not decreased below 1990 levels; but the 2003 estimate is about 5 percent lower than that for the previous year. Road transport is the principal source of NO_X emissions, contributing approximately 37 per cent of the total in 2003. The power generation sector is the other main source of NO_X emissions, accounting for 28 per cent of emissions in 2003. The benefits given by catalytic converters in cars and heavy-duty vehicles, which were expected to bring about substantial reductions in NO_X emissions from road transport from the mid-1990s, have been offset by the large increases in the use of petrol and diesel that began around the same time. This trend 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.

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 large decrease in CO emissions reflects the 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). Directive 2001/80/EC (CEC, 2001) and with obligations under other EU legislation and the Gothenburg Protocol (UNECE, 1999). Benefits will also accrue in terms of reduced CO and CO_2 emissions.

Table 2.1. Greenhouse Gas Emission Trends in Ireland 1990-2003

(a) Emissions by Gas (CO2 equivalent)

GREENHOUSE GAS EMISSIONS	**Base year[1]**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Net CO_2 emissions/removals	31,390.20	31,390	32,064	32,741	32,223	33,675	34,328	35,568	37,860	39,629	41,757	43,565	45,721	44,834	43,468.69
CO_2 emissions (exc LUCF)	31,797.22	31,797	32,535	33,113	32,680	34,114	34,759	35,954	38,312	40,250	42,133	44,160	46,460	45,808	44,449.95
CH_4	11,899.86	11,900	12,183	12,344	12,441	12,506	12,595	12,769	12,955	12,970	12,885	12,785	12,563	12,795	12,753.26
N_2O	10,022.30	10,022	10,055	10,152	10,183	10,413	10,552	10,770	10,941	11,182	11,362	11,307	10,917	10,250	9,739.04
HFCs	20.71	0	0	0	0	0	21	58	79	104	152	190	231	253	288.39
PFCs	75.38	0	0	0	0	0	75	103	131	62	196	305	297	207	223.63
SF_6	83.05	0	0	0	0	0	83	101	132	91	63	52	67	71	100.20
Total (with net CO_2 emissions/removals)	**53,491.50**	**53,312**	**54,302**	**55,237**	**54,847**	**56,594**	**57,654**	**59,369**	**62,097**	**64,037**	**66,415**	**68,204**	**69,795**	**68,410**	**66,573.21**
Total (without CO_2 from LUCF) [6]	**53,898.52**	**53,719**	**54,773**	**55,610**	**55,305**	**57,032**	**58,085**	**59,755**	**62,550**	**64,658**	**66,791**	**68,799**	**70,534**	**69,385**	**67,554.47**

(b) Emissions by Source Category (CO2 equivalent)

SOURCE AND SINK CATEGORIES	**Base year[1]**	**1,990**	**1,991**	**1,992**	**1,993**	**1,994**	**1,995**	**1,996**	**1,997**	**1,998**	**1,999**	**2,000**	**2,001**	**2,002**	**2003**
1. Energy	31,027.47	31,027	31,781	32,361	32,004	33,240	33,974	35,255	37,473	39,527	41,538	43,124	45,348	44,438	43,664.59
2. Industrial Processes	3,145.13	2,966	2,766	2,777	2,690	2,953	3,032	3,077	3,418	3,319	3,446	4,004	4,050	3,837	2,971.88
3. Solvent and Other Product Use	91.58	92	92	93	95	96	98	100	103	105	107	109	109	109	110.80
4. Agriculture	18,361.49	18,361	18,830	19,034	19,129	19,314	19,505	19,791	20,063	20,430	20,498	20,216	19,626	19,173	18,747.41
5. Land-Use Change and Forestry [7]	-407.02	-407	-471	-372	-457	-439	-431	-386	-452	-621	-376	-595	-739	-974	-981.26
6. Waste	1,272.85	1,273	1,303	1,344	1,387	1,429	1,476	1,532	1,494	1,276	1,203	1,345	1,402	1,827	2,059.80
7. Other	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Total (including net CO_2 from LUCF)	**53,491.50**	**53,312**	**54,302**	**55,237**	**54,847**	**56,594**	**57,654**	**59,369**	**62,097**	**64,037**	**66,415**	**68,204**	**69,795**	**68,410**	**66,573.21**

(1) The base year is 1990 for CO2, CH4 and N2O and 1995 for HFC, PFC and SF6

(2) The values for Land-Use Change and Forestry are net emissions/removals (positive values indicate emissions and negative values indicate removals)

(a) Total Emissions by Source Category (Gg CO2)

(b) Total Emissions by Gas (Gg CO2)

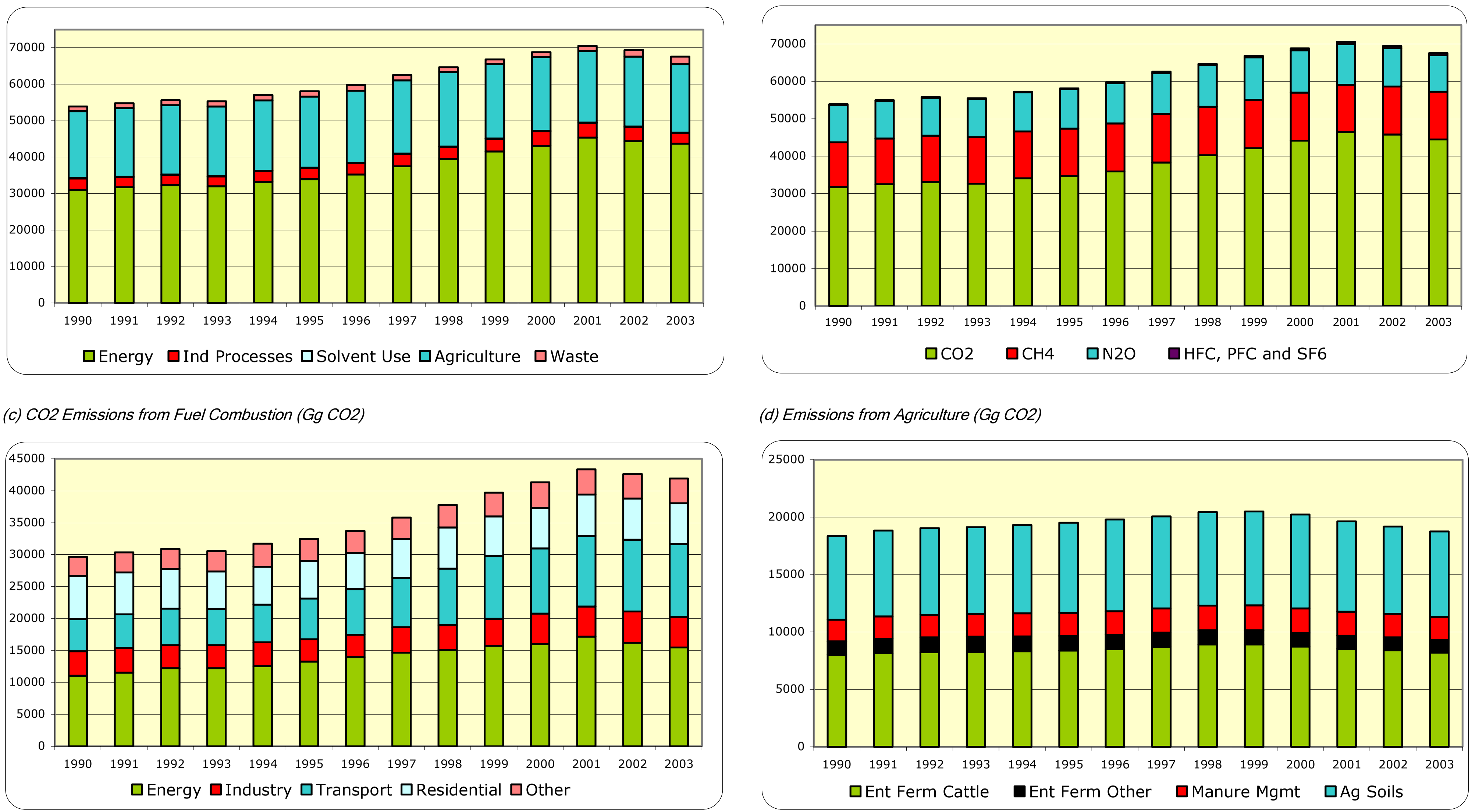
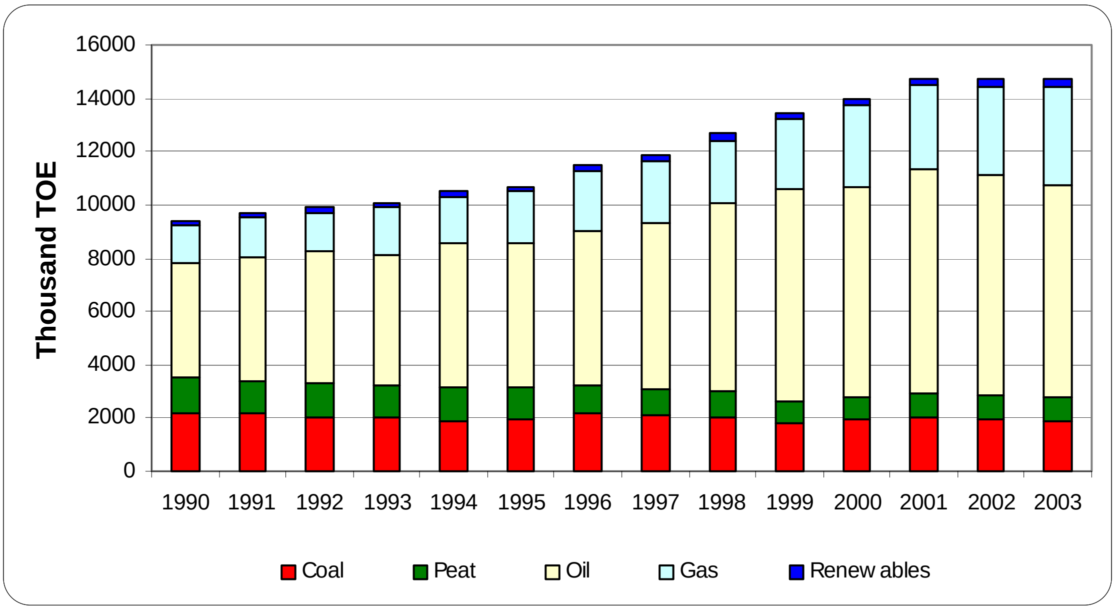
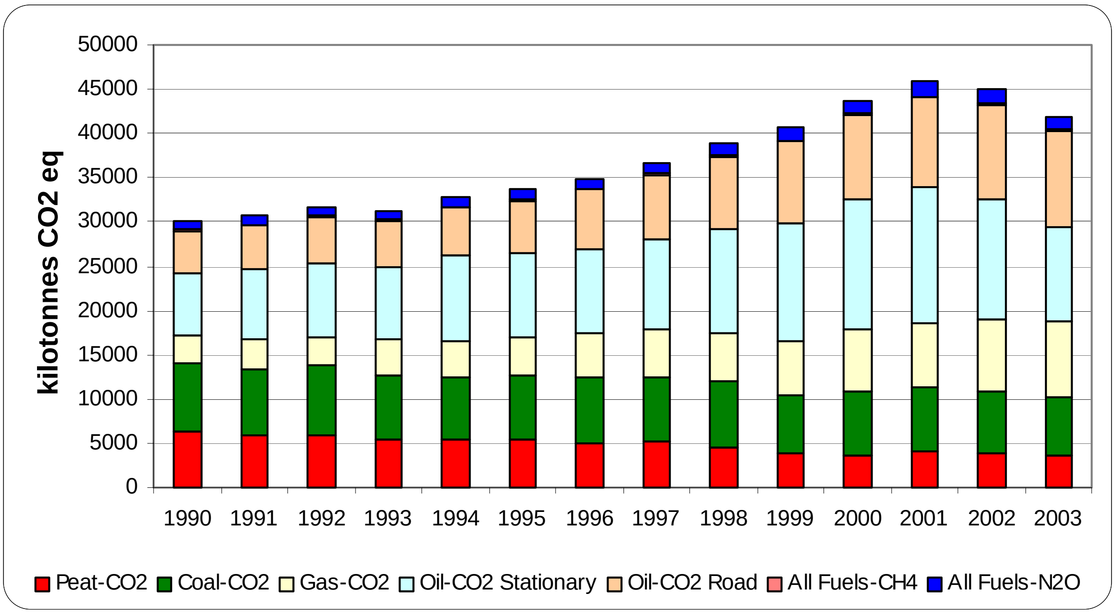


Figure 2.1. Greenhouse Gas Emission Trends 1990-2003

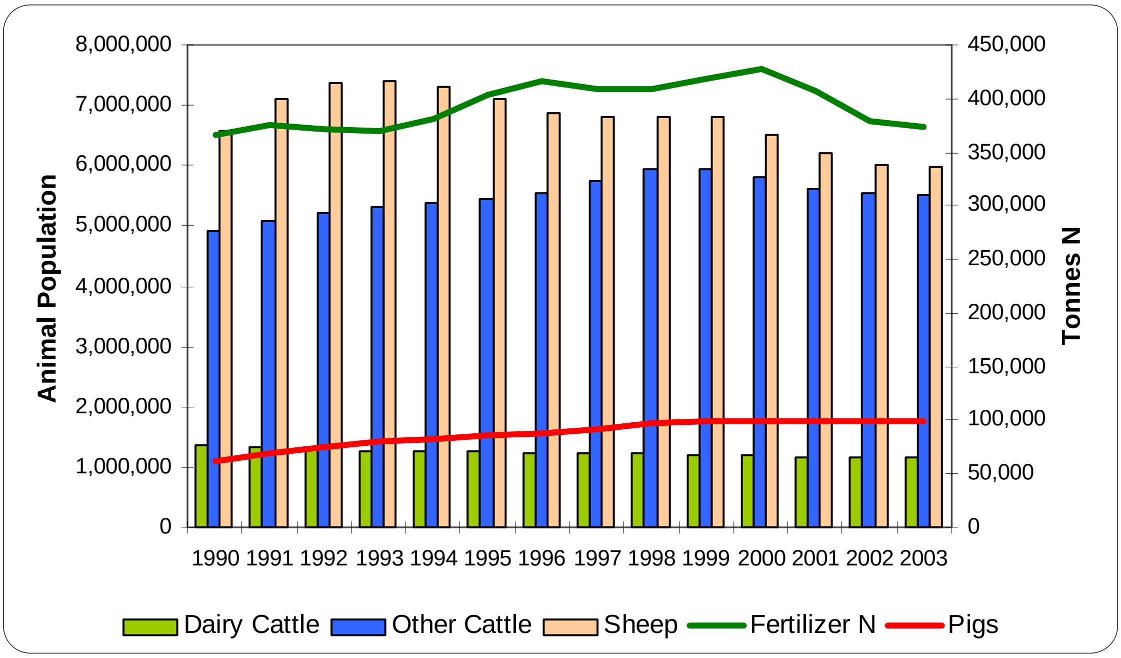


(a) Total Primary Energy Requirement

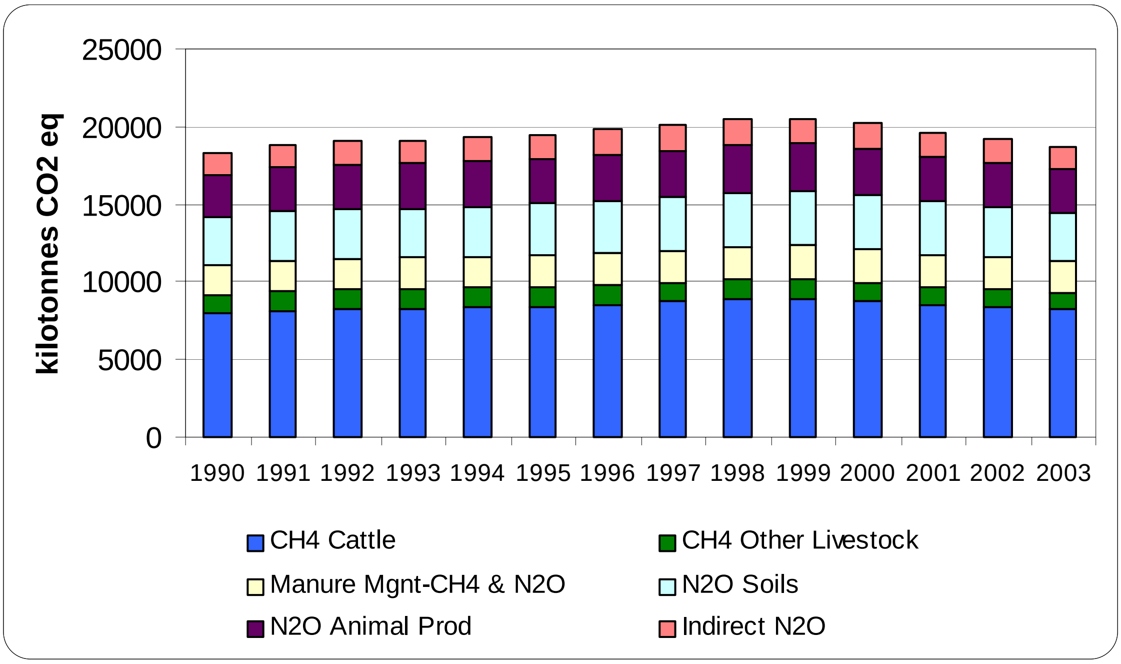


(b) Component Emissions from Energy Use

Figure 2.2. Energy Consumption and Component Emissions from Energy Combustion 1990-2003



(a) Principal Drivers



(b) Component CH4 and N2O Emissions

Figure 2.3. Principal Drivers and Component Emissions from Agriculture 1990-2003

Chapter Three

Key Source Analysis

3.1 Introduction

The IPCC good practice guidance defines a key source 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 sources 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 sources 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 sources 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 2003 to further highlight which sources of emissions are the most important in Ireland.

3.2 Key Source Identification

3.2.1 Key Source 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 source categories is therefore provided by considering the emissions aggregated at the IPCC Level 2 source 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 2003 are shown in Table 3.1. It can be seen that CO_2 emissions from the main fuel combustion source categories (energy industries, manufacturing industries, transport and other sectors), along with CH_4 emissions from enteric fermentation and N_2O emissions from agricultural soils, accounted for 86.8 percent of total emissions in 2003. The corresponding total contribution from these six source categories in 1990 was similar at 85.5 percent of total emissions. In the case of 2003 emissions, only four additional Level 2 source categories are needed to reach the cumulative 95 percent threshold that defines a key source. The increase in the contribution of CO_2 emissions from transport, from 9.4 percent in 1990 to 16.86 percent in 2003, is notable. This simple analysis of key sources has already proved useful in the formulation of abatement strategies and for prioritising work on inventories in Ireland.

Table 3.1. Key Source Categories at IPCC Level 2

IPCC Level 2 Source Category		GHG	Emissions in 1990 Gg CO_2	1990 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO_2	11057.48	20.70	20.70
1.A.4	Other Sectors	CO_2	9725.97	18.21	38.91
4.A	Enteric Fermentation	CH_4	9180.21	17.19	56.09
4.D	Agricultural Soils	N_2O	6870.08	12.86	68.95
1.A.3	Transport	CO_2	5019.62	9.40	78.35
1.A.2	Manufacturing Industries	CO_2	3833.08	7.18	85.53
4.B	Manure Management	CH_4	1260.83	2.36	87.89
6.A	Solid Waste Disposal	CH_4	1158.21	2.17	90.05
2.B	Chemical Industry	N_2O	1035.40	1.94	91.99
2.B	Chemical Industry	CO_2	989.17	1.85	93.84
2.A	Mineral Products	CO_2	941.42	1.76	95.61
IPCC Level 2 Source Category		GHG	Emissions in 2003 Gg CO_2	2003 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO_2	15480.30	22.92	22.92
1.A.3	Transport	CO_2	11392.65	16.86	39.78
1.A.4	Other Sectors	CO_2	10262.95	15.19	54.97
4.A	Enteric Fermentation	CH_4	9293.82	13.76	68.73
4.D	Agricultural Soils	N_2O	7443.25	11.02	79.75
1.A.2	Manufacturing Industries	CO_2	4784.71	7.08	86.83
2.A	Mineral Products	CO_2	2359.66	3.49	90.32
6.A	Solid Waste Disposal	CH_4	1930.53	2.86	93.18
4.B	Manure Management	CH_4	1350.38	2.00	95.18
4.B	Manure Management	N_2O	659.96	0.98	96.16
1.A.1	Energy Industries	N_2O	547.77	0.81	96.97

3.2.2 Key Sources at the Level of Emissions Calculation

Ireland has used the Tier 1 methods provided in the IPCC good practice guidance to extend the analysis above to identify individual key sources. This is carried out at the level of calculation normally used for greenhouse gas emissions. There is insufficient information available on uncertainties to allow for analysis using the Tier 2 methods. The results of the analysis for Tier 1 level assessment in relation to emissions in both 1990 and 2003 are presented in Table 3.2(a) and Table 3.2(b), respectively. Results for Tier 1 trend assessment for 2003 are shown in Table 3.3. The results for 2003 may be summarised as follows

(i) level assessment identifies 38 key source categories;

(ii) there are 25 key source categories of CO_2 in level assessment, accounting for 64.3 percent of total emissions;

(iii) there are six key source categories of CH_4 and five key source categories of N_2O in level assessment, which account for 18.2 percent and 12 percent, respectively, of total emissions;

(iv) trend assessment identifies 26 key source categories;

(v) there are 16 key source categories of CO_2 in trend assessment, accounting for 77.6 percent of the total trend;

(vi) there are five key source categories of CH_4 and four key source categories of N_2O in trend assessment, which account for 10.1 percent and 7.0 percent, respectively, of the total trend;

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

(viii) in level assessment, *Energy* accounts for 24 key source categories, *Industrial Processes* for four, *Agriculture* for eight while *Land-Use Change and Forestry* and *Waste* contribute one each and

(ix) in trend assessment, *Energy* accounts for 16 key source categories, *Industrial Processes* for two, *Agriculture* for seven and *Waste* contributes one.

The list of key sources given by level assessment in 1990 is very similar to that for 2003 but the higher ranking of the main CO_2 sources in *Energy* is notable in 2003. The top ten key sources contributed approximately 60 percent of total emissions in both years. The closure of Ireland's ammonia and nitric acid plants in 2002 means the loss of two key sources in 2003. The main findings of level assessment for 1990 emissions indicate that

(i) there was a total of 40 key source categories in that year, two more than in 2003;

(ii) there were 28 key source categories of CO_2, three more than in 2003, accounting for 58 percent of total emissions;

(iii) there were seven key source categories of CH_4 and five key source categories of N_2O, which accounted for 21.4 percent and 15.9 percent, respectively, of total emissions and

(iv) *Energy* accounted for 26 key source categories, *Industrial Processes* for four, *Agriculture* for eight while *Land-Use Change and Forestry* and *Waste* contributed one each.

3.3 Applicability 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 category determination for Ireland, based on Tier 1 level assessment. The results indicate that 23 out of 38 key source categories in 2003 each account for less than 2 percent of the total emissions and that only five key source categories contribute 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 source analysis clearly show the impact of CO_2 emissions from energy consumption on total emissions in Ireland. These emissions account for 24 out of 38 key source categories identified by level assessment in 2003 and for 61.2 percent of total emissions. In trend assessment, they account for 15 out of 26 key source categories and for 75.5 percent of total emissions. While key source 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 source categories is 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. This would also be the case for the larger CO_2 key sources under *Industrial Processes*, such as cement and lime production. For Ireland, the number of key source categories requiring special consideration in terms of reducing uncertainty is therefore rather small compared to the number identified by Tier 1 key source analysis. The source categories concerned are the principal CH_4 and N_2O sources in *Agriculture* and CH_4 production under *Waste*.

The IPCC good practice guidance recommends the use of good practice methods, specific to each source category, as well as detailed source-level quality control and quality assurance procedures for key source categories. The information on the number and type of key source categories in Ireland obtained from the above analysis is useful for the ongoing evaluation of methods employed for the sources concerned and for developing a QA/QC system.

Table 3.2 (a) Key Source Level Assessment 1990

Disaggregated[a] Emission Source	GHG	Emissions in 1990 Gg CO2	1990 Level Assessment[b] %	Cumulative Total of Level %
1 Enteric Fermentation - Other Cattle	CH4	5172.30	9.60	9.60
2 Energy Industries- Coal	CO2	4844.66	8.99	18.58
3 Residential Peat	CO2	3123.50	5.80	24.38
8 Direct Soil Emissions	N2O	3084.50	5.72	30.10
4 Energy Industries- Peat	CO2	3064.65	5.69	35.79
5 Enteric Fermentation - Dairy Cattle	CH4	2847.60	5.28	41.07
6 Animal Production	N2O	2780.70	5.16	46.23
7 Road Transport - Petrol	CO2	2760.03	5.12	51.35
9 Residential Coal	CO2	2023.92	3.76	55.11
10 Road Transport - Diesel	CO2	1901.14	3.53	58.63
11 Energy Industries- Natural Gas	CO2	1880.66	3.49	62.12
12 Commercial Gasoil	CO2	1482.29	2.75	64.87
13 Indirect Soil Emissions	N2O	1432.20	2.66	67.53
14 Solid Waste Disposal	CH4	1158.15	2.15	69.68
15 Enteric Fermentation - Sheep	CH4	1102.92	2.05	71.73
16 Energy Industries- Oil	CO2	1086.52	2.02	73.74
17 Nitric Acid	N2O	1035.40	1.92	75.66
18 Industrial Processes - Ammonia	CO2	989.17	1.84	77.50
19 Industry Natural Gas	CO2	855.68	1.59	79.09
20 Industrial Processes - Cement	CO2	750.00	1.39	80.48
21 Alumina Production - Fuel Oil	CO2	712.76	1.32	81.80
22 Manure Management - Other Cattle	CH4	662.13	1.23	83.03
23 Agriculture Gasoil	CO2	659.82	1.22	84.25
24 Industry Fuel Oil	CO2	623.67	1.16	85.41
25 Residential Gasoil	CO2	601.51	1.12	86.53
26 Cement Production - Coal	CO2	495.09	0.92	87.44
27 Industry - Coal	CO2	475.29	0.88	88.33
28 Commercial Fuel Oil	CO2	467.75	0.87	89.19
29 Industry Gasoil	CO2	466.48	0.87	90.06
30 Manure Management - Dairy Cattle	CH4	452.76	0.84	90.90
31 Liming of Agricultural Lands	CO2	384.45	0.71	91.61
32 Residential SSF	CO2	299.26	0.56	92.17
33 Residential Natural Gas	CO2	269.13	0.50	92.67
34 Residential Kerosene	CO2	248.12	0.46	93.13
35 Energy Industries- Coal	N2O	238.70	0.44	93.57
36 Commercial Natural Gas	CO2	200.12	0.37	93.94
37 Industrial Processes - Lime	CO2	191.42	0.36	94.30
38 Residential LPG	CO2	186.69	0.35	94.64
39 Industry LPG	CO2	165.35	0.31	94.95
40 Fugitive Emissions-Oil and Natural Gas	CH4	150.78	0.28	95.23
41 Railways	CO2	147.31	0.27	95.50
42 Fugitive Emissions-Oil and Natural Gas	*CO2*	*138.90*	*0.26*	*95.76*
43 Manure Management - Swine	*CH4*	*123.90*	*0.23*	*95.99*
44 Energy Industries Refinery Gas	*CO2*	*119.74*	*0.22*	*96.21*

a disaggregated to level of emission calculation
b percent of total emissions in 1990

Table 3.2 (b) Key Source Level Assessment 2003

Disaggregated[a] Emission Source	GHG	Emissions in 2003 Gg CO2	2003 Level Assessment[b] %	Cumulative Total of Level %
1 Road Transport - Diesel	CO2	6073.80	8.99	8.99
2 Enteric Fermentation - Other Cattle	CH4	5785.25	8.56	17.55
3 Energy Industries- Natural Gas	CO2	5384.46	7.97	25.53
4 Energy Industries- Coal	CO2	5294.14	7.84	33.36
5 Road Transport - Petrol	CO2	4906.60	7.26	40.63
6 Direct Soil Emissions	N2O	3159.21	4.68	45.30
7 Animal Production	N2O	2812.94	4.16	49.47
8 Energy Industries- Peat	CO2	2437.37	3.61	53.07
9 Enteric Fermentation - Dairy Cattle	CH4	2420.10	3.58	56.66
10 Industrial Processes - Cement	CO2	2157.42	3.19	59.85
11 Residential Kerosene	CO2	2126.64	3.15	63.00
12 Energy Industries- Oil	CO2	1992.62	2.95	65.95
13 Solid Waste Disposal	CH4	1930.53	2.86	68.81
14 Commercial Gasoil	CO2	1754.96	2.60	71.40
15 Indirect Soil Emissions	N2O	1470.95	2.18	73.58
16 Cement Production - Coal/Pet Coke	CO2	1342.98	1.99	75.57
17 Residential Natural Gas	CO2	1239.59	1.83	77.40
18 Residential Peat	CO2	1156.93	1.71	79.12
19 Industry Natural Gas	CO2	1119.75	1.66	80.77
20 Alumina Production - Fuel Oil	CO2	1050.11	1.55	82.33
21 Enteric Fermentation - Sheep	CH4	1004.49	1.49	83.82
22 Agriculture Gasoil	CO2	836.62	1.24	85.05
23 Residential Gasoil	CO2	762.69	1.13	86.18
24 Manure Management - Other Cattle	CH4	740.50	1.10	87.28
25 Commercial Natural Gas	CO2	679.89	1.01	88.29
26 Residential Coal	CO2	604.21	0.89	89.18
27 Industry Gasoil	CO2	591.47	0.88	90.06
28 Commercial Fuel Oil	CO2	418.17	0.62	90.67
29 Manure Management - Dairy Cattle	CH4	384.80	0.57	91.24
30 Road Transport	N2O	382.85	0.57	91.81
31 Liming of Agricultural Lands	CO2	348.65	0.52	92.33
32 Industry Kerosene	CO2	333.08	0.49	92.82
33 Residential SSF/Pet Coke	CO2	303.74	0.45	93.27
34 Consumption of Halocarbons	HFC	288.39	0.43	93.70
35 Energy Industries Refinery Gas	CO2	284.88	0.42	94.12
36 Energy Industries- Coal	N2O	262.26	0.39	94.51
37 Consumption of Halocarbons	PFC	223.63	0.33	94.84
38 Industrial Processes - Lime	CO2	202.25	0.30	95.14
39 Manure Management - Swine	*CH4*	*198.45*	*0.29*	*95.43*
40 Industry Fuel Oil	*CO2*	*144.68*	*0.21*	*95.64*

a disaggregated to level of emission calculation
b percent of total emissions in 2003

Table 3.3. Key Source Trend Assessment 2003

	Disaggregated Emission Source	GHG	Emissions in 1990 Gg CO2	Emissions in 2003 Gg CO2	Level Assessment in 2003 %	Trend Assessment in 2003	Contribution to Trend %	Cumulative Total Contribution %
1	Road Transport - Diesel	CO2	1901.14	6073.80	8.99	4.36	12.85	12.85
2	Energy Industries- Natural Gas	CO2	1880.66	5384.46	7.97	3.58	10.54	23.38
3	Residential Peat	CO2	3123.50	1156.93	1.71	3.26	9.60	32.98
4	Residential Coal	CO2	2023.92	604.21	0.89	2.28	6.72	39.70
5	Residential Kerosene	CO2	248.12	2126.64	3.15	2.14	6.32	46.02
6	Road Transport - Petrol	CO2	2760.03	4906.60	7.26	1.71	5.04	51.06
7	Energy Industries- Peat	CO2	3064.65	2437.37	3.61	1.66	4.88	55.94
8	Industrial Processes - Cement	CO2	750.00	2157.42	3.19	1.44	4.24	60.18
9	Enteric Fermentation - Dairy Cattle	CH4	2847.60	2420.10	3.58	1.36	4.00	64.18
10	Residential Natural Gas	CO2	269.13	1239.59	1.83	1.07	3.14	67.32
11	Energy Industries- Coal	CO2	4844.66	5294.14	7.84	0.92	2.71	70.02
12	Cement Production-Coal/Pet Coke	CO2	495.09	1342.98	1.99	0.85	2.51	72.54
13	Direct Soil Emissions	N2O	3084.50	3159.21	4.68	0.83	2.46	75.00
14	Enteric Fermentation - Other Cattle	CH4	5172.30	5785.25	8.56	0.82	2.43	77.42
15	Animal Production	N2O	2780.70	2812.94	4.16	0.79	2.34	79.76
16	Industry Fuel Oil	CO2	623.67	144.68	0.21	0.75	2.22	81.98
17	Energy Industries- Oil	CO2	1086.52	1992.62	2.95	0.75	2.20	84.17
18	Industry-Coal	CO2	475.29	14.22	0.02	0.69	2.02	86.20
19	Solid Waste Disposal	CH4	1158.15	1930.53	2.86	0.57	1.67	87.86
20	Commercial Natural Gas	CO2	200.12	679.89	1.01	0.51	1.49	89.36
21	Enteric Fermentation - Sheep	CH4	1102.92	1004.49	1.49	0.45	1.31	90.67
22	Indirect Soil Emissions	N2O	1432.20	1470.95	2.18	0.38	1.13	91.80
23	Road Transport	N2O	56.10	382.85	0.57	0.37	1.09	92.89
24	Industry Kerosene	CO2	38.86	333.08	0.49	0.34	0.99	93.88
25	Consumption of Halocarbons	HFC	20.71	288.39	0.43	0.31	0.91	94.97
26	Manure Management - Dairy Cattle	CH4	452.76	384.80	0.57	0.22	0.64	95.43
27	Commercial Fuel Oil	CO2	467.75	418.17	0.62	0.20	0.58	96.02
28	Alumina Production - Fuel Oil	CO2	712.76	1050.11	1.55	0.19	0.55	96.56
29	Energy Industries Refinery Gas	CO2	119.74	284.88	0.42	0.16	0.47	97.03
30	Liming of Agricultural Lands	CO2	384.45	348.65	0.52	0.16	0.46	97.50

Chapter Four

Recalculations

4.1 Need for Recalculations

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.

4.2 Recalculations in the 1990-2002 Time Series

Ireland undertook a substantial amount of recalculation as part of the preparations of the 1990-2000 CRF time-series that was submitted in 2002. Some further changes to methods and data were made in the compilation of the 2002 and 2003 inventories and, in order to maintain a consistent time-series, they were incorporated in the inventories for all previous years for submission in 2005 (no recalculations were submitted in 2004). The latest changes reflect a continued response to the results and recommendations of the various stages of the UNFCCC review process, error detection and the application of more robust methods and data in LUCF. The principal changes that result in recalculated estimates for the years 1990-2002 are

(i) Revision of the direct N_2O emissions from animal manures applied to soils in category 4.D.1 Direct Soil Emissions. This change follows the discovery that the IPCC software accompanying the 1996 IPCC guidelines (used by Ireland to estimate emissions in agriculture) calculates the nitrogen input to soils from animal manures in a manner that is not consistent with Equation 4.23 of the IPCC good practice guidance. The nitrogen input is underestimated and consequently the N_2O estimates are revised upwards in the recalculations;

(ii) In the COFORD analysis described in Appendix G, a conservative value of 1.3 was adopted for biomass expansion factor (BEF) to obtain whole-tree wood volume for growth and harvest. This value was revised to a weighted value of 1.64 for all tree species and a carbon content of 0.5 t C/t dry matter was also adopted for all tree species (previously in the range 0.4-0.45). These revised values were used in the calculations for 2002 and consequent updating of the time series estimates of carbon stock increment and annual harvest for the years 1990-2001 was completed by COFORD in early 2004. However, the new time-series for the years 1990-2001 was not available in time for inclusion in Ireland's inventory submission to the European Commission at the end of 2003 under Decision 99/296/EC and, in the interests of consistency, the recalculations were not included in the 2004 submission to UNFCCC. This means that the 2002 data in the 2004 submission for *5.A Changes in Forest and Other Woody Biomass Stocks* were not consistent with the data already submitted for the years 1990-2001. In the present submission, the recalculations obtained from COFORD in respect of the years 1990-2001 are included and the 2003 results are consisted with the updated time-series.

(iii) Ireland's estimates of N_2O emissions from human sewage in previous submissions were based on a protein intake of 60 g/capita/day, following a recommendation by the Food Safety Authority of Ireland. The in-country review of Ireland's 2003 submission identified that FAO statistics indicated an actual protein intake of about 114 g/capita/day annually for the population of Ireland. The FAO estimate of protein intake is used in the estimates for 2003 and the corresponding emissions in other years have been recalculated on this basis for the purpose of the present submission.

The original and revised numerical values of the emissions estimates for the years 1990-2002, 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.

4.3 Effect of Recalculations in the 2005 Submission

Recalculation in respect of the items listed above improve the inventory time-series by taking better account of the IPCC good practice guidance in agriculture and by using more appropriate national data for forest biomass and the protein consumption of the Irish population. The estimates of N_2O emissions in *4.D Agricultural Soils* and in *6.B Wastewater Handling* are increased by approximately 6 percent and 90 percent, respectively. The increases in CO_2 removals in *5.A Changes in Forest and Other Woody Biomass Stocks* resulting from the higher BEF and carbon content in forest biomass largely offset these increases in N_2O. The overall effect of recalculations is to increase total emissions excluding LUCF by approximately 1 percent in all years.

4.4 Planned Recalculations

Some important recalculations are still pending for Irish greenhouse gas inventories. Firstly, Chapter 1 of this report shows that the inventories currently available are still not fully complete with respect to the coverage of all IPCC source categories. Some of the sources concerned are expected to have relatively minor influence on total emissions but others could have a much greater effect. Secondly, it will be necessary to incorporate the findings of a number of major research projects that are being carried out to improve the inventory process in a number of areas. This research is designed to facilitate the application of high-tier methods and more complete country-specific data for some key source categories already covered, such as CH_4 emissions from enteric fermentation and N_2O from agricultural soils, where there remains heavy reliance on Tier 1 methods and default emission factors. It will also allow for the inclusion of potentially important sources of emissions and removals (Level 2 source categories *5.B Forest and Grassland Conversion, 5.C Abandonment of Managed Lands* and *5.D CO_2 Emissions and Removals from Soils*) where no estimates have yet been provided.

The major revisions that were planned to be carried out during 2004, primarily intended to reflect the outputs of extensive research carried out over the past three years have not been possible due to the late availability of the essential data. These recalculations will now be conducted as part of the substantial internal review and consolidation of inventory data to provide the information needed in the 2006 submissions to establish assigned amount for the Kyoto Protocol. During 2005, the inventory agency will be working to use the results of the various research projects to improve and further develop the inventories for *Agriculture* and *Land Use Change and Forestry*. In the case of the latter, considerable work is now also needed to start implementation of the new Good Practice Guidance on *Land Use Land Use Change and Forestry* and to use the revised CRF tables for this sector agreed at COP9 (UNFCCC, 2003a).

Chapter Five

Inventory Methods and Data

5.1 Introduction

This chapter presents the inventory agency's description of the data and methods used to achieve the current inventories of greenhouse gas emissions for the years 1990 through 2003, submitted to the UNFCCC secretariat in April 2005. Each of the six IPCC Level 1 source categories (Appendix A) is taken in turn and the methods, activity data, emission factors and other variables used in the calculations of emissions from the activities concerned in Ireland are described in detail. In addition, an assessment is given of the extent to which the current approach to emissions estimation in each source category takes account of those elements of the IPCC good practice guidance related specifically to the calculation of emissions and the development of a consistent time series. The tabular system used to record the extent of source category coverage at IPCC Level 3 and the status of implementation of sector-specific good practice guidance offers a convenient means of monitoring progress on these important issues in future NIR.

The description of methods applies only to the direct greenhouse gases listed in Table A.1 of Appendix A. Calculation sheets are included wherever practicable for the latest year in the time-series, or for all years, as appropriate, to support the description of methods and in order to achieve full transparency, as envisaged by the UNFCCC guidelines. These sheets also serve as a convenient means of linking this National Inventory Report and the Common Reporting Format for 2003 by presenting the pertinent information on activity data, actual emission factors and the resultant emissions. The appendices and references contain further detail on methods and data prepared by other contributors in respect of some particular elements of the inventory.

5.2 Energy

5.2.1 Overview of *Energy*

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 5.1 presents the 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 the completion of the CRF tables.

Tables B.1 and B.2 of Appendix B show the national energy and oil balance sheets for 2003, published by Sustainable Energy Ireland (DCMNR, 2004). These energy balances form the basis of all emission estimates related to the use of energy in Ireland.

The energy statistics are compiled by a combination of top-down and bottom-up methods. Tables B.1 and B.2 of Appendix B incorporate supplementary data compiled by Sustainable Energy Ireland related to combined heat and power (CHP) plants and the use of renewable energy in 2003.

Table 5.1. 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	NO	NO	NO
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	NE	NE	NE
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

Following the methods decision tree for combustion sources, Tables B.1 and B.2 of Appendix B allow for the full application of the two available Tier 1 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 entries below TPER (Total Primary Energy Requirement) in Table B.1(a) of Appendix B and by the corresponding further detail on oil products in Table B.2 of Appendix B.

The Reference Approach provides an estimate of aggregate CO_2 emissions only, based on the apparent consumption of fuels in the country. The apparent fuel consumption is determined from the energy balance items above TPER in Tables B.1(a) and from the further detail of Table B.2 of Appendix B. The application of these two Tier 1 methods are now described with reference to 2003 data and their results are then compared, as required by the UNFCCC guidelines.

5.2.2 Sectoral Approach for Emissions from Energy Use

5.2.2.1 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 2003 (Chapter Three). 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 national energy data are reasonably well disaggregated according to fuel and sector for the purposes of calculating emissions in the IPCC Level 3 source categories. However, there are a number of limitations associated with Irish energy balances, and other sources of information must be used to make the detail of the fuel-sector matrix more compatible with the inventory reporting format required for the Sectoral Approach. The final disaggregation is achieved as follows

- the emissions of CO_2 (as well as those of SO_2 and NO_X) for all power plants in *1.A.1 Energy Industries* operated by the Electricity Supply Board (ESB) are estimated on a plant-by-plant basis annually and reported directly by the company to the inventory agency. The 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 liberalisation of the electricity market has resulted in the construction of a number of new generating stations by other companies. Fuel use data and corresponding CO_2 emissions for these plants in 2003 were obtained from their Annual Environmental Reports (AER) submitted to the EPA in accordance with IPC licence conditions or by direct contact with the operators. The reported CO_2 emissions from the electricity companies have been aggregated on the basis of four main fuel types (peat, coal, oil and natural gas) and the national averaged emission factors have been computed for presentation in this report;
- information on fuel consumption for electricity generation from landfill gas and in combined heat and power plants is reported by Sustainable Energy Ireland as an integral part of the energy balance sheets;
- information on fuel consumption by a small number of energy intensive industries (e.g. alumina production and cement manufacture) is obtained from their respective AERs submitted to the EPA under their IPC licence conditions. These data sources supplement the oil balance sheet (Table B.2, Appendix B) when allocating fuels among the various sub-categories under *1.A.2 Manufacturing Industries and Construction*;
- fuel consumption data for Ireland's only oil refinery is also obtained in this manner and is useful for checking against that which appears in the energy balance sheet (Table B.1);
- the energy balance sheet (Table B.1) provides no indication on the end-use of gasoil in the agricultural sector and, consequently, a split based on information from agricultural experts (10 percent stationary sources and 90 percent mobile sources) is used 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;
- the use of natural gas in pipeline compressors by the gas company is taken to be the difference between the value given under own use/losses in the balance sheet (Table B.1) and the amount of gas estimated to be lost from the distribution network, as reported under fugitive emissions in *1.B.2 (b) Natural Gas*;
- the fuel consumption associated with domestic civil aviation is calculated from the number of domestic LTO cycles, the fuel consumption rates given by the IPCC good

practice guidance appropriate to the type of aircraft concerned and the length of the domestic flights;

- the amount of fuel consumption by military uses is not distinguishable in the annual energy balance sheet and no separate estimate of emissions is possible (normally reported under *1.A.5 Other* (Table 5.1).

The other essential input needed to compute emissions from combustion sources is the emission factors for the various fuels. All CO_2 emission factors, except those for petroleum coke and biomass, are country-specific values, determined directly from information on the carbon content of the fuels used in stationary and mobile sources. They 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).

The CH_4 and N_2O emission factors for road traffic are those used 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 the most 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 the emissions of a variety of gases on the basis of distance travelled using a detailed bottom-up approach (Tier 3) that accounts for such factors as fuel type, engine capacity, driving speed and the applicable technological emission control. The CH_4 and N_2O emission factors for road traffic are generated in this way annually. The 2003 results have been converted to national average values per fuel type for the purpose of the CRF and this report.

The simple calculation spreadsheet given in Table C.1 of Appendix C shows how the emissions from combustion sources are computed for the year 2003 using the activity data and emission factors described above. The complete allocation to IPCC Level 1 source categories is readily achieved from this compilation, as shown in Table C.2 of Appendix C. The correspondence between the national disaggregation of sources and IPCC combustion source categories is given in Table C.3 of Appendix C. The oil balance sheet and other information described above are used to give the required IPCC Level 2 disaggregation in the case of sub-categories (a) through (f) under *1.A.2 Manufacturing Industries and Construction* (Table 5.1).

5.2.2.2 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 industry and therefore fugitive emissions of greenhouse gases are limited to those associated with natural gas production and distribution.

In the inventories submitted in 2003, only the distribution losses of natural gas were included, as it had been difficult to obtain consistent information on other system losses for the full period. The distribution losses of natural gas were originally quantified simply as a percentage of annual sales. This validity of this approach, which showed emissions to be increasing, was questioned during the in-depth review of Ireland's second national communication in 1998. Subsequently, Bord Gais Eireann (BGE), Ireland's gas company, was requested to assess gas losses in the context of the needs of the annual inventory and emissions projections.

At that time, BGE was undertaking a long-term programme to replace cast-iron mains with polyethylene pipe in all urban areas served by gas and had generated some useful information regarding losses. The change to polyethylene pipe was 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, which was one-fifth of the original estimate. Projections were also provided by BGE for five-year intervals from 2000 that showed the losses reducing to zero by 2020 on completion of the pipe replacement programme. The BGE data were adopted as the best available for this particular fugitive emission source. The rate of loss implied by the 1998 value and the projections was 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 are now so small that they cannot 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 Marine and Natural Resources under the OSPAR Convention. Such reports have now been obtained for several years in the 1990-2003 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.

5.2.3 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 or 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 CRF) is reproduced as Table C.4 of Appendix 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 is 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. It may be noted that the energy balance sheet Table B.2 does not record the import of these products, although they would be expected to be used in the country. This shortcoming is under investigation by SEI as it attempts to improve Irish energy balance sheets. The Reference Approach also accounts for potential carbon storage in fuels used as a process feedstock. 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 2003.

5.2.4 Comparison of Results from the Sectoral Approach and Reference Approach

The national energy consumption and CO_2 emissions estimate obtained using the Sectoral Approach usually differ to some extent from the corresponding values resulting from the Reference Approach. According to the UNFCCC guidelines, differences greater than 2 percent should be explained and investigated to see whether they indicate systematic underestimation or overestimation of energy consumption by one or other of the methods. The comparison of results given by the two approaches for 2003 is presented in Table C.5 of Appendix C. Differences of less than 1 percent and 0.1 percent are indicated for total energy and CO_2

emissions, respectively. The largest differences are for solid fuels, where they amount to 2 percent for energy and 1.4 percent for CO_2 emissions, respectively. The small differences are largely explained by the highly aggregated manner in which emission factors are applied in the Reference Approach.

5.2.5 Memo Items

The memo items of the IPCC reporting format (Table 5.2) 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 the benefit of the international organisations with responsibility for the sources concerned. The emissions of CO_2 from biomass combustion are not included in national totals 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*.

Table 5.2. Level 3 Source Category and Gas Coverage for Memo Items

Memo Items	**CO2**	**CH4**	**N2O**
International Bunkers			
1. Aviation	All	NE	NE
2. Marine	All	NE	NE
Multilateral Operations	NO	NO	NO
CO2 Emissions from Biomass	All	All	All

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

The activity data for biomass appear under the heading other renewables in the Irish energy balance sheet (Table B.1 of Appendix 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 inclusion of emissions from domestic civil aviation was one of the changes introduced in the 2001 inventory that led to the recalculations described in Chapter Four of the 2004 NIR. The coverage of this source for 2003 is achieved using the same approach as that applied for 2002. The national energy and oil balance sheets include marine bunkers as a specific heading. Fuel use in aviation bunkers is not recorded explicitly on the energy balance sheet but kerosene use in air transport is included as a separate item in the oil balance sheet, although there is no indication as to how this fuel may be split between national and international consumption.

Fuel consumption in domestic civil aviation is determined from the number of domestic LTO cycles provided by Aer Rianta (the Irish airports authority), the estimated average length of the associated flights and the fuel consumption rates appropriate to the aircraft types operating on national routes, as given by the IPCC good practice guidance methodology (Table 2.10, GPG Appendix 2.5A.1). This fuel amount is used to calculate emissions from domestic aviation and is deducted from the value given in the energy balance sheet to obtain an estimate of international aviation bunker fuel. In 2003, the amount of fuel allocated to domestic aviation was approximately 6 percent of the total recorded under air transport in the energy balance.

5.2.6 Good Practice Guidance and Improvements in *Energy*

The foregoing description of emissions estimation for the *Energy* source category points to a relatively simple, but nevertheless substantially complete, treatment of emission sources in line with the IPCC Guidelines. Reasonable progress has been achieved within this approach on the implementation of the IPCC good practice guidance specific to this source category. Table 5.3 identifies those elements of good practice already applied in the preparation of emissions inventories for *Energy* and other elements remaining to be implemented at this stage.

Table 5.3. Sector-specific Good Practice Guidance for Energy

Source category or gas	Elements of GPG already implemented	Elements of GPG remaining to be addressed
1. Energy	Methods decision trees applied Results of key source analysis taken into consideration Comparison of national energy data with that of international bodies Consistent time-series produced by recalculation Tier 1 uncertainty assessment Adequate documentation and archiving QC computational and completeness checking	Assessment of time-series of statistical differences in energy balances Evaluation of QC for energy balance compilation QA and inventory review
CO_2	Carbon content and NCV values obtained from fuel suppliers resulting in mainly country-specific emission factors for CO_2	
CO_2 emissions from combustion sources	Comparison of Reference Approach and Sectoral Approach results and explanation of differences	
Emissions from road traffic	Tier 1 top-down method for CO_2 emissions and Tier 3 method for CH_4 and N_2O emissions	
CH_4 and N_2O		Review of emission factors for all stationary combustion sources

Given the importance of CO_2 emissions from energy use in Ireland, emissions from the *Energy* source category are given high priority in the inventory process. While the source category is well covered and the overall emissions are probably those with the least uncertainty, there are a number of specific areas where further improvements are possible. The methods used for energy balance compilation can be made even more robust and more transparent. Existing approaches to energy accounting rely on the results of surveys of inadequate frequency in some economic sectors and there are insufficient bottom-up fuel-use surveys. More detailed surveys are 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 quantify the amount of automotive fuels being purchased in Ireland by vehicle owners from outside the State. Sustainable Energy Ireland has begun to address these issues following its assessment and harmonisation of Irish energy statistics as reported to Eurostat. The inventory agency is continuing to collaborate with SEI to bring about the necessary improvements in energy balances for inventory purposes.

The emission factors for CH_4 and N_2O being used for stationary sources are those originally adopted for use in the CORINAIR 1990 inventory (McGettigan, 1993). These factors need to be reviewed as they are recognised to differ significantly from the IPCC default values. This review was not undertaken for the 2005 submission.

5.3 Industrial Processes

5.3.1 Overview of *Industrial Processes*

The list of activities under *Industrial Processes* in the IPCC reporting format is given in Table 5.4. Some of these activities are well known as major 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. Ireland does not have a proliferation of the heavy manufacturing industries that occurs in many other developed countries. Consequently, many of the production processes listed here are not relevant to the inventories of greenhouse gases. The four industrial sources that have been covered in the past 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. This leaves cement and lime production as the only important sources in 2003.

The *Industrial Processes* source category is the only IPCC Level 1 category for which emissions of HFC, PFC and SF_6 are reported. Both potential and actual emissions of the 21 individual substances concerned (Table A.1, Appendix A) are required by the UNFCCC guidelines 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 and all sub-categories are fully covered (Table 5.4), as described below.

5.3.2 Emissions of CO_2, CH_4 and N_2O from *Industrial Processes*

5.3.2.1 Cement and Lime Production

Ireland is largely self-sufficient in cement production, an important source of process CO_2 emissions (Chapter 3), and there has been a substantial increase in production in line with economic growth over recent years. Until 2000, only one manufacturer of cement operated in the country. Consequently, there have been some confidentiality issues associated with data on cement production needed for estimating process CO_2 emissions and it has usually been necessary to acquire production statistics indirectly or from unpublished sources. These sources may differ from year to year. In developing the consistent time-series of emissions inventories covered by the 2002 NIR, it was found that statistical data obtained for the full period concerned did not always match those obtained on an individual year basis at the time of the original annual inventory compilation. Minor revisions to activity data for this source were therefore part of the recalculations that were reported in the 2003 submission. There are currently two additional producers of cement but difficulties remain in regard to obtaining reliable data on annual production levels.

The first estimates of greenhouse gas emissions in Ireland (McGettigan, 1993) used a CORINAIR default process emission factor of 0.5 tonne CO_2 per tonne of cement clinker produced. This value was substantiated by information received through direct correspondence with the company at that time and is very close to the original IPCC Tier 1 default (0.4985 t CO_2/t cement). The original emission factor of 0.5 tonne CO_2 per tonne of cement clinker has been retained to give the latest estimates of CO_2 from cement production for all years up to 2002 using the Tier 1 method. Further assessment of the suitability of the default emission factor is now being made to take account of new entrants to this industry in Ireland in 2000 and better information on their individual plants being submitted to the EPA under their reporting arrangements related to IPC licensing and emissions trading. Even though the companies are reporting CO_2 emissions from their plants, the information on the quantities of cement produced is not being disclosed directly. Therefore, the inventory agency has derived the estimate of process CO_2 emissions from cement production as the difference between total emissions and the emissions from combustion, which can be obtained from the information available on the fuels used in the plants.

Table 5.4. 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	NE	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	NO	NO	NO	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*

The validity of the reported activity data for cement production in Ireland over the 1990-2001 time-series was questioned in the 2003 in-country review and the review report recommended that more reliable data be obtained for this important source of CO_2 emissions. Information on CO_2 emissions from cement production recently supplied to the EPA in connection with Directive 2003/87/EC (EP and CEU, 2003) on emissions trading provides a basis for re-examination of the activity data and the emission factor of 0.5 tonne CO_2 per tonne of cement clinker already used by the inventory agency in the inventories for the years 1990-2002. Table D.2 of Appendix D summarises the individual process CO_2 emissions estimates for all cement plants while the comparison between the resultant total annual CO_2 and that reported in the CRF files is shown in Figure D.1 of Appendix D. These process emissions have been calculated using a combination of Tier 1 and Tier 2 methods in accordance with the guidance on monitoring and reporting of greenhouse gas emissions provided by Decision 2004/156/EC (CEC, 2004), adopted pursuant to Directive 2003/87/EC. It can be seen that the difference between the inventory agency's estimates and the totals returned by the companies is less than 10 percent for most years. However, for the base year 1990, the value of process CO_2 emissions from cement production as reported in the 1990 CRF is 18 percent lower than the estimate provided by Irish Cement for that year while in the case of 2002 the CRF value exceeds the total for the three operating companies by 12 percent.

As the emission estimates from all individual cement plants undergo 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 provided by Decision 2004/156/EC. Such verification was achieved in respect of the four cement plants in operation in 2003, allowing for more precise accounting of combustion emissions and process emissions separately. In addition, the clinker production for each plant was made available, allowing the CO_2 emission factor to be calculated in each case. The emission factors ranged from 0.52 t CO2/ t clinker in the smallest plant to 0.55 t CO2/ t clinker in the largest plant with a weighted average of 0.544 for all clinker production in 2003. This type of information will allow for systematic updating of the reported CRF estimates for source category 2.A.1 for all years with a view to submitting more robust estimates for the entire time-series in 2006.

Statistical data on lime production in Ireland are obtained annually from the manufacturers (three companies up to 1998 and two companies since 1998). The CORINAIR default value for CO_2 emissions from lime production (0.75 t CO_2/t lime) has been used consistently to estimate process emissions from this source using the Tier 1 method. This default value is also given for high-calcium lime in the IPCC good practice guidance and it seems 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 must provide estimates of CO_2 emissions from lime manufacture under Directive 2003/87/EC, thus enabling the inventory to review and revise its estimates for another important source of CO_2 emissions in *Industrial Processes*.

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

5.3.3.1 Special Studies for 1998

The compilation of emissions estimates for fluorinated gases present 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 changing very rapidly in the marketplace. Issues of confidentiality are common and this also hinders the inventory process 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 the 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, designed to identify the important sources in Ireland and to quantify the emissions in 1998 on the basis of 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 provides a readily applicable approach that can 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 as appropriate to accommodate the country-specific data.

5.3.3.2 HFC, PFC and SF_6 Time Series 1995-2003

The methodological approach adopted in the special study for 1998 was subsequently used in early 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 for 1990 but data were difficult to obtain and it was clear that the use of many of the substances had not become established at that time. The focus 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 time series is now extended to include estimates up to 2003, based on the approach used for the 1995-2000 time-series. The following paragraphs describe the main steps taken and assumptions made to achieve the estimates of both actual and potential emissions with reference to the relevant source categories, as identified by the special study. Emission calculation sheets, or emissions estimates obtained directly from companies concerned, are provided in Appendix D for most of these source categories. Reference should be made to the special study report (O'Leary *et al*, 2002) for further clarification on those sources actually covered and those that have non-zero emissions.

A Stationary Refrigeration and Air Conditioning

HFCs are used in the refrigeration and air conditioning industry in commercial, industrial, and other installations. They are also used by one manufacturer of refrigerated transport equipment in Ireland, the bulk of which is destined for export. According to DuPont, commercial production of HFC-134a started in 1991. This information is supported by global production data, with negligible production of HFC-134a for refrigeration and air conditioning applications in 1990. Therefore, HFCs were not used in refrigeration or air conditioning systems in Ireland in 1990.

An estimate of sales data in 1998 was provided by one of the suppliers for the total Irish market. Sales data were also obtained for some of the years 1994 to 1998 from each of the major companies involved in the refrigerant supply market. Consequently, the usage of HFCs in refrigeration and air conditioning systems was estimated from the data obtained for the special study for 1998. This estimate is based on the total market for 1998, the known market share of one of the companies, and the sales of other companies in previous years. The estimates in those years for which data were unknown were interpolated from data known in other years. For the years 1999 through 2003, an estimate of sales in Ireland was generated by scaling up the 1998 Irish usage at the rate of increase indicated for the international usage of HFC-134a in stationary refrigeration and air conditioning systems. These data were obtained from the Alternative Fluorocarbon Environmental Assessment Study (AFEAS), which accounts for 98 percent of global HFC production. The available sales data were also used to estimate the share of each type of HFC in the total for each of the years in question. As per the 1998 special report, actual emissions were estimated as 5 percent of imported bulk chemicals. Table D.3 of Appendix D shows the usage and resulting emissions of HFCs in stationary refrigeration and air conditioning systems in Ireland for the years 1995 through 2003.

The bottom up approach was used in the case of the manufacture of transport refrigeration equipment since this applies to the manufacture of systems destined for export, rather than servicing existing systems in Ireland. Actual emissions are associated with assembly losses in the manufacture of transport refrigeration systems. Similar to stationary refrigeration above, and since HFC-134a was only commercially produced from 1991, usage is taken to be zero in 1990. The company stated that HFCs had been in use for the years since 1997 and supplied actual data for 1998 and 2000. The same split between HFC-125, HFC-134a and HFC-143a used for 1998 has been retained for all subsequent years. The 1999 data were estimated as the average of those for 1998 and 2000. An estimate of usage for 1997 was made using the 1998 values and the change in Irish GDP. Actual emissions were calculated as 0.05 percent of the HFC charged into the system. These results are also provided in Table D.3 of Appendix D.

B Mobile Air Conditioning

Three of the companies that install mobile air conditioning (MAC) were contacted in order to identify when HFCs were first used in MAC in Ireland and to obtain consumption data for each of the relevant years. Information was obtained on the usage rates of HFCs, the proportion of vehicles that would have air conditioning systems and the percentage of MAC systems that would be based on HFC. Emissions from mobile air conditioning are calculated as follows:

Annual Emissions of HFC = First-Fill Emissions + Operation Emissions + Disposal Emissions - Destruction

As for the 1998 inventory, actual emissions were calculated using a combination of the top-down and bottom-up approaches for the different elements of this expression. In the above equation, the term 'Destruction' has not been possible to calculate. This is discussed in the 1998 Final Report. The top-down approach was used to calculate the 'first-fill' emissions as follows:

First-Fill Emissions = (EF)*(Virgin HFC for first-fill of new MAC units for the year in question)

As per 1998 the IPCC emission factor of 0.5 percent for first-fill emissions was used. The MAC installation companies indicated that HFCs were first introduced into MACs in Ireland in 1993. Therefore, 'first-fill' emissions are not relevant to the 1990 inventory, but are relevant for the years 1995 to 2003. Two of the companies estimated that annual usage of HFCs would have been the same for each of the years 1995 to 2000. One of the companies also estimated that the total usage of HFCs in the years 1993 to 1995 during phase out of CFCs was about half of the 1992 annual usage. Therefore, the 1998 estimate for total virgin HFCs sold to the MACs industry was assumed to apply for each of the years 1995 to 2003. Similarly, 'first-fill' emissions was the same for each of the years1995 to 2003 (see the 1998 Final Report for the calculation). Since HFCs were first introduced into MACs in Ireland in 1993, operating emissions from the HFC stock in vehicles was relevant to each of the years 1995 to 2003. Operation emissions were calculated using a bottom-up approach as follows:

Operation Emissions = (number vehicles with MACs using HFCs) *(IPCC average charge per vehicle)*EF

Installers of MAC provided estimates of the proportion of new cars fitted with air conditioning systems in 1995, 1998 and 2000 as 20 percent, 60 percent and 70 percent, respectively. They estimated the percentage of these MAC systems that were HFC-based in 1995 and in 2000 as 30 percent and 90 percent, respectively. These figures were used to interpolate corresponding values for other years and it was assumed that the proportion of freight and commercial vehicles with MAC was the same as for cars. Information was also obtained on the total number of new and imported used vehicles in each of the years between 1993 and 2003 for all vehicles (DELG, 2003 and DEHLG, 2004). The stock of vehicles includes both private vehicles (private cars & small public service vehicles) and freight/commercial vehicles (goods vehicles & large public service vehicles). It is also assumed that the split in sales between HFC-14a and the blend R404a identified for 1998 is the same for all succeeding years. The IPCC average charge per vehicle is 0.8 kg for private vehicles and 1.2 kg for light trucks (IPCC, 2000).

An emission factor of 10 percent was chosen for the years 1999 through 2003, in accordance with section 3.7.5.1 of the IPCC good practice guidance (IPCC, 2000), since most Irish car air conditioning companies now recover the gas during servicing and there is little leakage. For the earlier years 1995 to 1997, a slightly higher emission factor was chosen (1 percent more per year) to take leakier MAC types and lower recovery rates into account. These estimates do not take retiring vehicles into account. Since the timeframe between the introduction of HFCs into MAC systems (1993) and the relevant years of the inventory (1995 to 2003) is between two and nine years this is not relevant to a significant degree, considering that the IPCC default vehicle lifetime for the calculation is 12 years.

The bottom-up approach is also used to estimate disposal emissions from MAC. As HFCs were only introduced to air conditioning in vehicles from 1993 and the average vehicle lifetime is 12 years, vehicles manufactured in the years 1983 to 1988 need to be considered in relation to disposal emissions for the years 1995 to 2003. Vehicles manufactured in the years 1983 to

1988 do not have HFC-based MACs, although some conversions took place. However, it is assumed that only very few of the vehicles disposed of in the years 1995 to 2003 were converted to HFCs, since they were about five to ten years old when HFCs were first introduced. Similarly for the top down approach, not very many of the vehicles being scrapped in the years 1995 to 2003 that had MAC systems in place were likely to be HFC based. Therefore, disposal emissions are estimated to be zero for each of the years 1995 to 2003. Table D.4 and Table D.5 of Appendix D give the estimated HFC usage and emissions from mobile air conditioning in Ireland using the method outlined above. The first fill emissions are negligible in comparison to operational emissions. Potential emissions from MACs in vehicles are included in the stationary refrigeration figure.

C Foam Blowing

None of the Irish foam manufacturing companies use HFCs as blowing agents. Instead, these companies use water, carbon dioxide, methylene chloride, air, pentane, and HCFC-141b as blowing agents. It would also appear that none of the companies have used HFCs during the years 1990 to 2003. Evidence of this is that one of the companies using HCFC-141b switched over to pentane in 2003, i.e. 'skipping' the use of HFCs in favour of hydrocarbons. Therefore, HFC emissions from open-cell foam manufacture in Ireland is zero for each of the years 1990 through 2003. The AFEAS data (which account for 98 percent of global HFC production), along with Irish and OECD GDP figures were used to estimate emissions associated with closed cell foam and foam products imported into Ireland. Global sales data for use in closed cell foam applications show that there were no sales for such applications in 1990, and only 1 tonne was used globally in 1991. Therefore, Irish emissions from closed cell foams were taken as zero in 1990. For the years 1995 – 2003, the calculation of actual emissions from closed cell foam use in Ireland is as follows:

Annual emissions = (cumulative HFC charge between 1991 and inventory year)*(annual loss EF)

Table D.6 of Appendix D shows the application of this simple approach for the years 1990 through 2003. The annual loss emission factor (IPCC default value) of 4.5 percent of the original HFC/PFC charged per year was used. Decommissioning losses for the years up to 2003 were negligible since product lifetime is estimated at 20 years. Similarly, no destruction of HFCs from such foam was carried out in Ireland up to 2003.

D Fire Protection

One Irish company provided a very approximate estimate of HFC usage in fire protection systems in Ireland as running at 40 tonnes/annum in 2002. The principal HFC used is HFC-227ea with very small amounts of some other gases, but they are not commonly used. The growth rate for 2000 to 2002 was of the order of 10 to 15 percent. The growth rate five years previously was 7 to 10 percent, with the market having initially taken off in 1993 or 1994. HFC-227ea was introduced into fire protection in Ireland in 1983/1984 with installations taking place slowly through until the major market growth in the early nineties. This information on market growth was used to generate an estimate of the annual usage and total quantity of HFC-227ea present in fire protection systems in each of the years 1990 through 2003. Annual emissions were calculated as 1 percent of the cumulative total HFC-227ea, as shown in Table D.7 of Appendix D. Potential emissions are taken as the annual usage of HFC-227ea.

E Metered Dose Inhalers (MDI)

Metered dose inhalers are used in the treatment of asthma and chronic obstructive pulmonary diseases such as emphysema and chronic bronchitis. Emissions are associated with the use of the products and also with fugitive emissions from one MDI manufacturing facility in Ireland. As a result of the exemption under the Montreal Protocol, conversion of MDIs from CFCs to HFCs has been later than for other applications.

Based on information obtained from the suppliers, MDIs utilising HFCs were only first put on the Irish market in 1996. Therefore, HFC emissions from MDI use in Ireland were zero in the years 1990 and 1995. In the years 1996 to 1999, only one company had HFC based MDIs on the Irish market. This company does not manufacture in Ireland. For the 1998 special investigation this company had provided 1997 and 1998 sales data. In 2003, this company provided further estimates on the number of inhalers sold in the years 1999 and 2000 and the typical charge of gas per unit. Sales in 1996 were assumed to be half of the sales in 1997. A second company brought HFC based MDIs onto the Irish market in 2000. The first company provided an estimate of the total Irish HFC based MDI market in 2000.

The first HFC-based MDI supplier also provided an estimate of the total market for MDIs in Ireland in 2001 and the fraction occupied by HFC/CFC-based inhalers. There are still only two companies supplying HFC-based MDIs in Ireland. Part of the market is dry powder inhalers and nebulisers, which do not contribute to HFC emissions. This share is growing and complete changeover is expected by 2005. For the purposes of the calculations, it is assumed that the use had stabilised from 2000. The Tier 2 bottom up approach, based on the number of aerosol products sold and the average charge per container, was used to estimate emissions from MDI use for the years 1996 to 2003 as follows:

Emissions of HFC = (HFC in MDI sold in the year)*(50%) + (HFC in MDI sold in previous year)*(50%)

There is one MDI manufacturing facility in Ireland, which exports about 98 percent of its products. This company first used HFC-134a in 2000 in set up trials only and the emissions may be taken as zero for inventory purposes for all years up to 2000. The amount of HFC-134a used in 2001 was reported as 66 tonnes by the company and it was indicated that losses were of the order of 1.65 percent. No further information was obtained from the company in respect of 2002 consumption, so it was assumed that the use of HFC-134a increased by 50 percent to 100 tonnes and the loss rate remained the same. The 1992 value was retained for 2003.

F Non-Medical Aerosols

The vast majority of aerosol products in Ireland do not contain HFCs. The few exceptions are pipe freezer aerosols, silly string aerosols, and klaxons, all of which use HFCs as a propellant. An estimate of HFC emissions associated with the use of these aerosol products was generated individually for 1998 based on average sales information from product suppliers or sales outlets, composition and weights of canisters, and number of sales outlets. This resulted in estimated actual emissions of 5.7 tonnes HFC-134a in 1998 from the use of pipe freezer aerosols, silly string aerosols, and klaxons in Ireland. Since such information came from disparate sources and was difficult to generate, emissions for other years were estimated using this 1998 sales figure and Irish GDP values as a driver for the relevant years. Global AFEAS sales of HFC-134a for 'other short term uses', which includes sterilants, non-medical aerosols, open cell foams plus fugitive emissions indicate that global usage in these applications only took off in 1993 and this trend is assumed to apply to HFC-134a usage in non-medical aerosols in Ireland. Emissions for the years 1995 to 2001 were estimated from the 1998 value of 5.7 tonnes and annual GDP growth. The estimate for 2002 is 17.456 tonnes and this has been retained for 2003 (AFEAS data not available).

G Solvent Use

There is minor usage of HFCs in cleaning applications in Ireland in various industries. Only one of the chemical suppliers contacted in generating the 1998 inventory sold HFC-134a for cleaning applications. This company did not have any such sales in Ireland for that year. No reliable information was obtained regarding the use of HFCs under this heading in the other years and emissions could not be estimated.

H Electrical Transmission and Distribution Equipment

Information was obtained from the Electricity Supply Board on actual SF_6 emissions from electrical transmission and distribution equipment for each of the years 1995 to 2003 (Table D.8(c) of Appendix D). There are no other emitters of SF_6 in this category in Ireland. According to the ESB, the 2001 stock of SF_6 in electrical equipment in Ireland was approximately 30 tonnes. This estimate is the result of an accurate inventory of high voltage equipment containing SF_6 (387 items), plus an estimate of SF_6 contained in lower voltage switchgear (estimated at 2.5 tonnes). The ESB reported 2001 emissions as 4.47 percent of stock, and the company expects that emissions will be reduced substantially on completion of a major leak reduction programme underway since 1997. These data are used to estimate the SF_6 bank present in electrical equipment for each of the years 1995 to 2003 for use in the CRF tables. The ESB did not provide an estimate of emissions for the year 2003 but had indicated in earlier correspondence that a five-year average loss rate would be a better indicator of emissions than year-on-year estimates and so this approach has been adopted to give an indicative emission of 1,067 kg for 2003.

I Semiconductor Manufacture
There are two major companies involved in semiconductor manufacture in Ireland that utilise PFC, HFC and SF_6 in their processes. Information on the use and losses of these compounds are reported by the individual companies in their Annual Environmental Reports to the EPA. Follow-up correspondence is initiated where necessary. Tables D.8(a) and D.8(b) of Appendix D show total usage and estimated emissions of PFC, HFC, and SF_6 for the two semiconductor manufacturing companies for the years 1995 through 2003. Emissions abatement is not taken into account for one of the two companies, even though there is some abatement present. Therefore the emissions are conservative estimates. This company estimates emissions as 72 percent of usage (10 percent of gas retained in heel in cylinders and approximately 20 percent of gas consumed in the process). This method of calculation was used for each of the years 1995 through 2003. The second company also provided emissions based on percentages of use and do take abatement into account for PFC-116, being 6 percent of PFC-116 use in 1990 to 1997, and 5 percent of use in 1998 to 2003. For all other gases the company takes emissions as 60 percent of usage.

J Gas Tracer Applications in Research and Leak Detection
One company using SF_6 for leak detection in the testing of seals on cans containing tennis balls provided information that the usage value of 764 kg given for 1998 can be taken as a standard usage value for each of the years 1995-2001 inclusive. The quantities of SF_6 used are directly related to production levels, which have remained constant. The company is changing the process to use helium instead of SF_6 with this conversion expected to be completed by the end of June 2002. Actual emissions for the years 1990-2002 were taken as two-thirds of SF_6 usage (51 kg tonnes SF_6 per year) and potential emissions were 764 kg SF_6 per year. This emission source did not exist in 2003.

K Window Soundproofing
Based on discussions with the glazing industry, the use of SF_6 in glazing commenced in the 1990s and the amount would have remained approximately constant over the years 1990-2000. It was assumed as a worst case that SF_6 has been used in glazing applications in Ireland since 1990, and that usage each year up to 1999 was taken as 52 kg. This was assumed to double by 2001. According to IPCC, approximately one-third of the total amount of SF_6 used is released during assembly (i.e. filling the double glazed unit). Therefore, assembly emissions are 17 kg SF_6. In the absence of any other data it was assumed that the quantity of imported glazing units up to 1999 is the same as that manufactured in Ireland and that the import increases by 50 percent in 2000 and 2001. The value of imported units in 2003 is taken to be the same as for 2002. According to the IPCC, average window lifetimes are 25 years (as per 1998 estimate). The application of SF_6 in windows began in Ireland in the early 1990s. Therefore, disposal had not yet occurred in any of the years up to 2003 and disposal emissions are assumed to be zero. The cumulative SF_6 stock can be calculated using the following equation:

SF6 stock at end of a given year before leakages = SF6 stock in previous year after leakages + (52 kg used in Irish manufacture per year – 17 kg assembly losses per year) + 52 kg imported

Using an annual leakage rate of 1 percent, the above equation has been used to calculate existing SF_6 stock in windows and total actual emissions from installed windows for each year as shown on Table D.9 of Appendix D. The annual potential emissions are 104 kg.

5.3.4 Verification Studies for Emissions of HFC, PFC and SF_6

Detailed studies that compare the results of HFC, PFC and SF_6 emissions obtained by the conventional bottom-up methods described above with those achieved through European-scale top-down methods and from inverse modelling have been completed for Ireland (O'Doherty and McCulloch, 2002). The top-down approach uses definitive European data on the sales of these substances within Europe and rigorously tested emission functions to calculate total European emissions in 1998. The emissions according to each Member State are achieved using information that they have supplied to the UNFCCC and national data on GDP and populations. The inverse modelling approach is based on statistical analysis of the atmospheric concentrations of a range of substances measured at the Mace Head atmospheric research station on the west coast of Ireland and back trajectories derived from the NAME model (Ryall, 1998).

The Irish emissions inventories of HFC, PFC and SF_6 determined from the top-down analysis at the European scale have been verified against those calculated using the NAME model. On average, there is very little difference between the results for the combined gases (of the order of 2 percent) but this masks substantial differences for individual compounds. Nevertheless, it is clear that the absolute values of these emissions are placed in similar categories of magnitude by both methods. In view of the wide differences in methodologies, this adds some confidence to the estimates.

Comparisons between the results obtained from the top-down and bottom-up methods suggest that emissions estimated using the bottom-up approach may be considerably underestimated for commonly used HFC, such as HFC-125, HFC-134a and HFC-143a. This finding reflects the difficulties in accounting for all the activities that give rise to emissions of these substances and the tendency for individual users to report losses that would occur under ideal conditions rather than for real situations in which economic and practical considerations prevail.

5.3.5 Good Practice Guidance and Improvements in *Industrial Processes*

Only a small number of industrial plants in Ireland produce emissions of CO_2 or N_2O and a very simple approach is used to quantify their emissions. The Tier 1 methods used for these sources give reasonable estimates of emissions when the total amounts of production are reliably known and the most crucial aspects of good practice guidance can be followed without difficulty. The inventory agency needs to enhance plant-specific data collection for these industries through its IPC licensing system and encourage the operators to make available the necessary production statistics in a consistent manner for inventory purposes. The monitoring, reporting and verification of greenhouse gas emissions through implementation of Directive 2003/87/EC provides an important new mechanism whereby a substantial proportion of the emissions from industrial installations can be examined in greater detail than heretofore and should lead to a reduction in uncertainty for the sector.

Table 5.5. Sector Specific Good Practice Guidance for Industrial Processes

Source category or gas	Elements of GPG already implemented	Elements of GPG remaining to be addressed
Industrial Processes	Methods decision trees applied Results of key source analysis taken into consideration Consistent use of methods Tier 1 uncertainty assessment Adequate documentation and archiving QC computational and completeness checking	Active involvement of key industrial players QC and review activities
CO2 (cement and lime)	Consistent time-series produced by recalculation	Tier 2 method for cement Completeness of data for lime production
HFC, PFC and SF6	Tier 2 methods used in general Verification studies undertaken Comparison of results from different methods	

The emissions of HFC, PFC and SF_6 in the years 1995 through 2003 are considered to be quite well covered using Tier 2 methods generally, based on in-depth investigations for 1998. Again, the substantial components of good practice guidance are applied. However, inventory experience in this particular area is limited and the inventory agency may have to retain the services of other institutions or consultants to continue the reporting cycle for fluorinated gases, especially if bottom-up methods are to be used. It is questionable whether such methods are indeed the most appropriate in some cases.

5.4 Solvent and Other Product Use

This IPCC source category is considered separately because of its importance in relation to the emissions of VOC (one of the indirect greenhouse gases) that 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 5.2.2), 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 VOC or CO. The Irish inventories include an estimate of CO_2 emissions in this way but no attempt has yet been made to quantify emissions associated with the direct use of N_2O.

The activity data used for generating CO_2 emissions in *Solvent and Other Product Use* are the mass emissions of VOC computed for the relevant source categories(*5.A Paint Application, 5.B Degreasing and Dry Cleaning, 5.C Chemical Products and 5.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 CLRTAP Convention. As part of the work on recalculations for the 2002 submission, Ireland produced a revised and consistent time-series of such VOC emissions estimates based on the results of detailed analysis and investigations for 1998 (Finn *et al*, 2001). This time-series is now extended to 2003. The CO_2 emissions are derived by assuming that 85 percent of the mass emissions of VOC in the four categories converts to CO_2. The calculation sheet for this component of the inventory is contained in Appendix E.

5.5 Agriculture

5.5.1 Overview of *Agriculture*

Table 5.6 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 1990-2000 submitted in 2002 did not account for the contribution of nitrogen-fixing crops or crop residues to the direct N_2O emissions from soils. This aspect was first covered in the 2001 inventory and the emissions from *Agriculture* in all previous years were revised for the 2003 submission to maintain consistency and comparability. The coverage of sources in 2003 remains the same as for 2002.

Source categories *4.C Rice Cultivation and 4.E Prescribed Burning of Savannas* are not relevant to Ireland. The notation key NO is used in relation to all emissions from source category *4.F Field Burning of Agricultural Residues* for all years. This notation signifies that, although this practice did exist on a small scale in the past, the emissions could be considered negligible, and it has now been discontinued.

The methods provided by the 1996 IPCC Guidelines 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. Ireland continues to rely heavily on the use of default emission factors in *Agriculture*, but country-specific values of several other important inputs and variables are used wherever possible. The practice of using a three-year averaging period that ends in the inventory year for all agricultural statistics is again adopted for activity data. The annual source data for agricultural statistics and the averaged values of the various activity data (livestock populations, fertilizer use, crop production etc) are given in Table F.1 of Appendix F.

Table 5.6. Level 3 Source Category and Gas Coverage for Agriculture

Agriculture	**CO2**	**CH4**	**N2O**
A. Enteric Fermentation	NA		NA
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	NE	NE
7. Mules and Asses	NA	NO	NO
8. Swine	NA	All	All
9. Poultry	NA	NE	NE
10. Anaerobic Lagoons	NA	All	All
11. Liquid Systems	NA	All	All
12. Solid Storage and Dry Lot	NA	All	All
13. Other	NA	NO	NO
C. Rice Cultivation			
1. Irrigated	NO	NO	NO
2. Rainfed	NO	NO	NO
3. Deep Water	NO	NO	NO
4. Other	NO	NO	NO
D. Agricultural Soils (1)			
1. Direct Soil Emissions	IE[1]	NE	All
2. Animal Production	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			
1. Cereals	NO	NO	NO
2. Pulse	NO	NO	NO
3. Tuber and Root	NO	NO	NO
4. Sugar Cane	NO	NO	NO
5. Other	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
1 : CO_2 emissions from liming of agricultural soils included under source-category 5.D

5.5.2 CH_4 Emissions from Enteric Fermentation

The Tier 1 method for CH_4 emissions from enteric fermentation is a simple combination of annual average ruminant livestock populations, allocated to a number of broadly homogeneous groups, and appropriate emission factors (kg CH_4/head/year) for the chosen animal groups. The IPCC Guidelines provide good default emission factor data for use by countries that do not have specific information for their particular livestock characterisation. The Tier 2 method requires enhanced ruminant characterisation and corresponding information on feed intake, feed energy accounting and conversion, milk production and other parameters that are used to derive the country-specific emission factors.

The emissions of CH_4 from enteric fermentation in cattle and sheep accounted for almost 14 percent of the total greenhouse gas emissions in 2003. Key source analysis (Table 3.1) ranks CH_4 emissions from enteric fermentation in non-dairy cattle as one of the single largest sources of CO_2 equivalent emissions in the country in 1990 and in 2003. According to the IPCC good practice guidance, the Tier 2 method should be used for key sources. However, to date, it has not been possible for the inventory agency to acquire and apply, in a systematic manner, the full range of input data necessary for the development of Tier 2 emission factors. Therefore, the inventory agency continues to use the Tier 1 approach for enteric fermentation. The agency has nevertheless managed to assess the suitability of the default emission factors for cattle and has made changes that are considered justifiable for Irish conditions.

Irish statistical publications on agriculture (CSO, 2003) provide sufficient detail for appropriate Tier 1 (and also Tier 2) characterisations of livestock populations for estimating emissions from enteric fermentation. For the cattle population, dairy cattle are taken as one group and all other categories of cattle reported by CSO are taken together in a second group. Account is taken of two census surveys per year and averaging over three years is also applied in the preparation of all representative livestock populations. As discussed in Chapter Four, the three-year period now ends in the inventory year, as all the necessary data are usually available for this approach to be used consistently. The IPCC default emission factor for highly productive dairy cattle in Western Europe is 100 kg CH_4/head/year. This value was subject to some appraisal before it was first used in Irish inventories in the early 1990s (McGettigan, 1993). The results of literature review and other investigations, as well as discussions with experts from the Department of Agriculture and TEAGASC indicated that this value was generally appropriate for dairy cattle in Ireland, where the feed is largely based on grass and silage. The same approach resulted in a value of 60 kg CH_4/head/year being adopted for other cattle at that time.

The emission factors for cattle were reviewed in 2000 during the preparation of Ireland's Climate Change Strategy. The inventory agency was advised by agricultural experts that they saw no reason to change the emission factor for dairy cattle. However, they were of the view that a value lower than 60 kg CH_4/head/year seemed more representative of other cattle, where the large population of cattle in this category is dominated by animals less than two years of age. Consequently, a weighted emission factor of 50 kg CH_4/head/year, determined by Irish agricultural experts largely in accordance with the Tier 2 approach (but not documented for the inventory agency), was adopted for this animal category. The enteric fermentation emission factors used for all livestock groups other than cattle are those given in Table 4.3 of the IPCC Guidelines. The calculation sheet for methane emissions from domestic livestock (Table F.2 of Appendix F) shows all values of activity data, emission factors and CH_4 emissions for enteric fermentation in 2003.

5.5.3 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. Information obtained from farm surveys that were undertaken in connection with the EU Rural Environment Protection Scheme (REPS) is the basis of the animal waste management data that underlie the CH_4 estimates for this source in Ireland. The characterisation of livestock used for enteric fermentation is again applied for manure management. However, manure management related only to cattle and pigs is relevant in this case. Sheep remain outdoors all year round and there is no management of sheep manures while no information is available on waste management practice for horses.

The 2003 in-country review report for Ireland pointed out that the IPCC Guidelines give non-zero default values for CH_4 emissions for manure management related to sheep, horse and mules, including management on pastures. The value for sheep, the most relevant of these livestock categories in Ireland, is 0.19 kg/head per year. Nevertheless, the assumption that CH_4 is not produced from sheep manures excreted on wet soils in Ireland's cool maritime climate seems reasonable and therefore no change has been made for 2003.

The calculation sheet for methane emissions from domestic livestock (Table F.2 of Appendix F) includes the derivation of the emission factors for manure management and the resultant CH_4 emissions in 2003. The values of B_O (the methane production potential of animal waste), V_S (the daily volatile solids production per animal) and MCF (the methane conversion factor for each waste management system) are taken from the IPCC Guidelines while accounting for the conditions that would be representative of Ireland. The CH_4 emissions from manure management in 2003 amounted to 14.5 percent of those from enteric fermentation.

5.5.4 N_2O Emissions from Manure Management

All nitrogen from animal wastes that are managed in storage or treatment systems has some potential to produce emissions of N_2O. The emission factors given by the IPCC good practice guidance indicate that 1 kg of nitrogen per tonne of nitrogen handled in anaerobic lagoons and 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. Animal wastes excreted at pasture are unmanaged and the associated emissions are accounted for under agricultural soils.

The nitrogen excretion rates for the selected animal categories, along with the proportions of manure nitrogen assigned to each applicable animal waste management system in Ireland available from the REPS survey data are used to estimate total nitrogen excretion for each management system as needed for the IPCC methodology. The nitrogen excretion rates of 92.5 and 50 kg/N for dairy cattle and other cattle, respectively, taken from the REPS survey data are close to the upper end of the range reported for typical Irish farming systems (Mulligan and O'Mara, 2002 and Hynds, 1994). These findings indicate that dairy cows producing 4,200, 5,600 and 7,000 kg of milk per year in Ireland excrete 82, 89 and 96 kg N, respectively while excretion rates for beef cattle are highly variable and range from 27 kg N to 69 kg N per year depending on performance level and age. The IPCC default nitrogen excretion rates of 8, 12 and 0.6 kg are used for sheep, swine and poultry, respectively in all years.

The values of nitrogen excretion and the proportions allocated to each AWMS given in the calculation sheets (Table F.3 of Appendix F) are the same for all years of the current time-series. More than 60 percent 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. A further 35 percent of excreted nitrogen is managed in solid or liquid storage systems for eventual spreading on agricultural lands and the remainder is treated in anaerobic lagoons. The N_2O emissions from manures managed in liquid systems, solid storage and anaerobic lagoons in 2003 amounted to 2129 tonnes (Table F.4 of Appendix F).

5.5.5 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 exercise for all inputs of nitrogen to agricultural soils and the subsequent application of default rates of nitrogen lost to the atmosphere as N_2O. The primary nitrogen inputs are subject to complex processes and partitioning between various nitrogen compounds within soils. 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 software accompanying the 1996 IPCC Guidelines to estimate N_2O emissions from agricultural soils and the procedure may be followed from the description below and the IPCC calculation sheets provided in Table F.6 through Table F.9 of Appendix F for 2003.

5.5.5.1 Direct Emissions of N_2O

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 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 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 inventories of direct N_2O emissions for the years 1990-2003 take into account the soil nitrogen inputs from all these sources, except those due to sludge spreading and the cultivation of organic soils. Sludge spreading does take place but the amount is not well quantified and therefore this component of direct emissions is not estimated. 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 reported in sub-category *4.D.1 Direct Soil Emissions* therefore becomes

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

where

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

$$F_{AM} = N_{ex}*(1-Frac_{GRAZ})*(1-Frac_{GASM})$$

and

N_{fert} = total amount of synthetic fertilizer nitrogen applied to soils
$Frac_{GASF}$ = fraction of synthetic fertilizer nitrogen that volatilizes as NH_3 and NO_X
N_{ex} = total amount of animal manure nitrogen excreted by livestock
$Frac_{GRAZ}$ = fraction of N_{ex} that is excreted by livestock during grazing
$Frac_{GASM}$ = fraction of animal manure nitrogen that volatilizes as NH_3 and NO_X

The annual statistics on nitrogen fertilizer use 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. A significant proportion of the nitrogen applied to soils in synthetic fertilizers and animal manures is normally volatilized as NH_3 or NO_X. These fractions, $Frac_{GASF}$ and $Frac_{GASM}$ respectively, 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 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 the NH_3 inventory for agriculture with the assumption that nitrogen lost as NO_X is negligible. Emission factors from CORINAIR (Richardson, 1999) are used to estimate NH_3 emissions from manure management, consistent with the quantitative information and management practices described above, and from the various types of synthetic fertilizers used annually, which are known from the DAF statistics. This approach results in volatilization rates annually of 4 percent and 17 percent for synthetic fertilizers and organic nitrogen applications, respectively (Table F.10 and Table F.11 of Appendix F).

The Tier 1b method given by the IPCC good practice guidance is used to estimate the nitrogen contributions from nitrogen-fixing crops and from crop residues returned to the soil (Table F.5 of Appendix F). Annual crop production statistics, averaged in the same way as for other activity data in *Agriculture* (Table F.1 of Appendix F) 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. The direct emissions of N_2O in 2003 amounted to 10,191 tonnes, of which synthetic fertilizers accounted for 7,056 tonnes, 2,755 tonnes was due to land spreading of animal manures and crops produced 380 tonnes.

The direct 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, deducted from N_{ex} using the fraction $Frac_{GRAZ}$ in the equation above, is large in Ireland due to the relatively short period that cattle remain in housing and to the contribution from large sheep populations, which are never housed. The N_2O emission factor for this unmanaged nitrogen input is 0.02 kg N_2O-N/kg N and the estimated emissions in 2003 were 9,074 tonnes.

5.5.5.2 Indirect Emissions of N_2O

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 nitrogen volatilized as NH_3 and NO_X, 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, as follows

$$N_2O_{indirect\text{-}dep} = (N_{fert}*Frac_{GASF} + N_{ex}*Frac_{GASM})*EF_4$$

$$N_2O_{indirect\text{-}leach} = (N_{fert} + N_{ex})*Frac_{LEACH}*EF_5$$

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
$Frac_{LEACH}$ = fraction of synthetic fertilizer nitrogen and animal manure nitrogen that leaches from agricultural soils
EF_4 = N_2O emission factor for emissions from atmospheric nitrogen deposition
EF_5 = N_2O emission factor for emissions from nitrogen leaching

As mentioned above, the NH_3 losses from organic nitrogen and synthetic fertilizer inputs are estimated at approximately 17 percent and 4 percent, respectively, as shown on Tables F.10 and F.11 of Appendix F, while NO_X emissions are assumed to be negligible. 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 is considered to be a more realistic estimate of $Frac_{LEACH}$ than the default value and it is used again for 2003, as it was for previous years.

The IPCC default values of the emission factors EF_4 and EF_5 are 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. The estimation of indirect emissions of N_2O is shown in Table F.7 and Table F.8 of Appendix F. Total indirect emissions in 2003 amounted to 4,745 tonnes, or approximately 46 percent of direct soil emissions (sub-category 4.D.1).

5.5.6 Good Practice Guidance and 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.

Table 5.7. Sector-Specific Good Practice Guidance for Agriculture

Source category or gas	Elements of GPG already implemented	Elements of GPG Remaining to be addressed
4.A, 4.B and 4.D	Methods decision trees applied Results of key source analysis taken into consideration Consistent livestock characterisation used across all relevant source categories Three-year averaging of activity data in accordance with IPCC guidelines Comparison of national activity data with those of international bodies Consistent time-series produced by recalculations Accounting for links with NH3 and NOX Tier 1 uncertainty assessment Adequate documentation and archiving All direct and indirect emissions of N2O addressed	Application of Tier 2 methods Assessment of time-series of statistical differences in livestock populations QA and inventory review
4.A and 4.B	Investigation of the suitability of the default emission factors	Assessment of the variation in emission factors over time
Indirect N2O Emissions		Investigation of the NOX contribution to N deposition

During 2005, it will be possible to achieve closer compliance with the Good Practice Guidance by the use of Tier 2 methods for CH_4 emissions from enteric fermentation and through the application of much more country-specific data in relation to N_2O emissions using suitable models. Major research projects on emissions of CH_4 from enteric fermentation and direct N_2O emissions from soils have been completed and a system is being developed for an efficient application of their findings, which includes re-assessment of the values adopted in the past for some of the most important input variables. This re-assessment responds to the inventory review process, which has identified large differences between the Irish values of some variables and IPCC default values or those of other Parties.

The results of an intensive measurement campaign using a SF_6 tracer technique will be combined with detailed characterisations of the cattle herd to develop a robust Tier 2 approach to calculate CH_4 emissions from cattle. Information from farm surveys will improve existing data on animal waste production and waste management practices at the national scale so that the methodology relating to CH_4 emissions from animal waste management can also be made more country-specific. More reliable estimates of nitrogen excretion rates for farm animals can now be adopted, which are crucial to the emissions inventories for *Agriculture*. Detailed studies on the direct N_2O emissions from soils provide the basis on which to systematically examine the influence of soil type, fertilizer type and application rates, temperature and rainfall on N_2O losses from Irish soils. The results of the Irish studies suggest N_2O emission rates that are substantially higher than the current IPCC default emission factors for N_2O from agricultural soils. Work is underway to apply the research findings in a model that accounts for these influences and that adequately reflects conditions during the year.

The indirect emissions of N_2O due to nitrogen deposition are based on country-specific values of $Frac_{GASFS}$ and $Frac_{GASM}$ that account only for the NH_3 component of volatilized nitrogen. The information gained with regard to nitrogen excretion and animal waste management practices is also being used to revise Irish inventories of NH_3 using a country-specific approach during 2004. This work should give more robust NH_3 estimates for the landspreading of animal wastes with consequent improvement in relation to the NH_3 component of the volatilized nitrogen giving rise to indirect N_2O emissions. The contribution of NO_X to $Frac_{GASF}$ and $Frac_{GASM}$ needs detailed assessment in the national context, as the assumption that it is negligible relative to NH_3 may not be justified.

5.6 Land-Use Change and Forestry

5.6.1 Overview of Land-Use Change and Forestry

The IPCC Level 3 source category classification for *Land-Use Change and Forestry* (LUCF) is listed in Table 5.8. The gas of most concern here is CO_2 and the most important activities in Table 5.8 may emit or sequester CO_2 by changing the way the land is used or by changing the amount of biomass in existing biomass stocks. The IPCC reporting format for *Land-Use Change and Forestry* is therefore different to that for other source categories in that it provides for the reporting of both the emissions and removals of CO_2. The CRF extends this further to include net CO_2 emissions or removals (the sum of emissions and removals). The exchange of CH_4 between land and atmosphere may also be an important process to consider in LUCF inventories while the emissions of CH_4 and N_2O are relevant for any activities that involve combustion.

The complex dynamic nature of the CO_2 sources and sinks to be considered in *Land-Use Change and Forestry,* along with the time scales that must be taken into account in some cases, present particular problems for estimating their corresponding emissions and removals on an annual basis. The CO_2 fluxes involved may be very large and any estimates of emissions or removals based on the current simplified IPCC methodologies and default input values for these source or sink categories could add significantly to the overall uncertainty in the inventory. For this reason, Ireland has deferred the inclusion of estimates for the majority of the LUCF activities that may be relevant in the country until the results of major national research in this area become available. The emission inventories submitted to date (1990-2002) include LUCF emissions and removals only in respect of temperate forests under category *5.A, Changes in Forest and Other Woody Biomass Stocks* and for the liming of agricultural lands under *5.D CO_2 Emissions and Removals from Soil*. There has been no change in the coverage of sources of emissions and removals in the 2003 inventory for *Land-Use Change and Forestry* .

Table 5.8. Level 3 Source/Sink Coverage for Land Use Change and Forestry

Land Use Change and Forestry	CO2 Emissions	CO2 Removals	CH4	N2O
A. Changes in Forest & Other Woody Biomass Stocks				
1. Tropical Forests	NO	NO	NO	NO
2. Temperate Forests	All	All	NE	NE
3. Boreal Forests	NO	NO	NO	NO
4. Grasslands/Tundra	NO	NO	NO	NO
5. Other	NO	NO	NO	NO
B. Forest and Grassland Conversion [(2)]				
1. Tropical Forests	NO	NO	NO	NO
2. Temperate Forests	NE	NE	NE	NE
3. Boreal Forests	NO	NO	NO	NO
4. Grasslands/Tundra	NO	NO	NO	NO
5. Other	NO	NO	NO	NO
C. Abandonment of Managed Lands				
1. Tropical Forests	NO	NO	NO	NO
2. Temperate Forests	NE	NE	NE	NE
3. Boreal Forests	NO	NO	NO	NO
4. Grasslands/Tundra	NO	NO	NO	NO
5. Other	NO	NO	NO	NO
D. CO_2 Emissions and Removals from Soil				
1. Cultivation of Mineral Soils	NE	NE	NA	NA
2. Cultivation of Organic Soils	NO	NO	NA	NA
3. Liming of Agricultural Soils	All	NO	NA	NA
4. Forest Soils	NE	NE	NA	NA
5. Other	NO	NO	NA	NA
E. Other	NO	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

5.6.2 Methodology for *5.A Changes in Forest and Other Woody Biomass Stocks*

A major change in the methodology used to estimate the annual increase in forest carbon stocks was one of the main reasons for carrying out the inventory recalculations described in Chapter Four of Ireland's 2002 NIR. Up to 2000, a simple Tier 1 methodology had been used to calculate carbon uptake by forestry. That methodology was based on mean annual growth increment, coniferous and deciduous forests were represented by one tree species in each case and wood harvesting was not taken into account. During 2001, forestry experts in COFORD produced substantially revised estimates of the level of carbon uptake in Irish forests for all years 1990 to 2000, using a range of new data and a much-improved Tier 2 methodology that is fully in line with the IPCC Guidelines. A summary of the revised approach is given here. A detailed account of the model used (CARBWARE) is given in Appendix G, along with the 1990-2000 estimates of carbon stock increment and annual harvest first obtained using the new approach. This method is again used for 2003, but some specific inputs to the CARBWARE model were revised to obtain the results given in Table 5.A of the CRF.

In the COFORD analysis described in Appendix G, a conservative value of 1.3 was initially adopted for biomass expansion factor to obtain whole-tree wood volume for growth and harvest. This value was reviewed by COFORD and was revised to a weighted value of 1.64 for all tree species in 2003 (corresponding 2.0 for the young tree category and 1.4 for the mature tree category). A carbon content of 0.5 t C/t dry matter was also adopted for all tree species (previously in the range 0.4-0.45). These revised values were used in the calculations for 2002 and consequent updating of the time series estimates of carbon stock increment and annual harvest for the years 1990-2001 was completed in early 2004. However, the new time-series for the years 1990-2001 was not available in time for inclusion in Ireland's inventory submission to the European Commission at the end of 2003 under Decision 99/296/EC and, in the interests of consistency, the recalculations were not included in the 2004 submission to UNFCCC. This means that the 2002 data in the 2004 submission for *5.A Changes in Forest and Other Woody Biomass Stocks* were not consistent with the data already submitted for the years 1990-2001. In the present submission, the recalculations obtained from COFORD in respect of the years 1990-2001 are included and the 2003 results are consisted with the updated time-series. The following summary of the methodological approach and the description given in Appendix G remain valid, notwithstanding the revisions for BEF and carbon content.

Forest Area and Species

A time series of forest strata by area and age was constructed for the years 1990-2003 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 comprises recorded and interpreted information on areas and species for identified state and private forests. Young (7 to 25 years) and mature (greater than 25 years) crop categories in FIPS were broken down by species to provide nine individual strata that could be regrouped and reported according to the strata adopted in Table 5.A of the CRF. 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 category includes cleared areas recorded in FIPS and the difference between total FIPS area and total Forest Service area.

Having established the basic area-species matrix for 1995, the corresponding data for the years 1996 to 2003 were obtained by growing the forest estate forward in time, using data on planting and clearfelling rates, 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 to obtain consistent time-series data for the years 1990 to 1994. Annex I to Appendix G of this report shows how the areas were determined.

Volume

The FIPS survey results do not contain wood volume and 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 volume is multiplied by a biomass expansion factor (BEF) and by dry density to obtain whole-tree wood volume (m^3/ha).

Carbon Uptake

The carbon uptake of each FIPS category is calculated by multiplying whole-tree volume by the corresponding carbon content and by area. The allocation of carbon uptake to the CRF categories is obtained using the correspondence given in Table G.1 of Appendix G and estimates of the uptake rate and volumes by CRF category are computed by area weighting.

Harvest
Coillte records (Coillte, 2001) represent the main source of data for wood harvesting. These 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) were converted to carbon using average carbon content of 0.5 (revised from an average of 0.4) and a biomass expansion factor of 1.64 (revised from 1.3). Harvest volumes include firewood, which is estimated to be in the region of 30,000 m^3/year.

Carbon Stock Increment
In the original version of the CRF, increment values are used to determine annual increments in carbon stocks and from these the harvest is subtracted to find the net changes in carbon stocks. In this instance, the table is modified and reduced actual standing volumes (less thinnings) on *a net areas basis* are used to estimate standing volume. Annual increment in a particular year is then calculated by subtracting from the carbon stock in that year the carbon stock in the previous year. This is the increment less the harvest as the thinning volumes have already been deducted in the data used (standing volumes less thinnings) and the areas are net of clearfelled volumes.

5.6.3 Liming of Agricultural Land

For all inventory years reported to date, Ireland has opted to include CO_2 emissions from the liming of agricultural soils under *5.D Emissions and Removals from Soil*. As an alternative, these emissions may be reported in category *4.D Agricultural Soils* (Table 5.6). Data on the annual amounts of lime applied to land (Table F.1, Appendix F) are currently obtained from the Irish Business and Employers Federation and three-year averaging is applied as for other activity data in *Agriculture*. The CO_2 emissions are calculated using the default emission factor of 120 kg CO_2/tonne lime.

5.6.4 Good Practice Guidance and Improvements in *LULUCF*

A comprehensive report on good practice guidance for *Land-Use Land-Use Change and Forestry* was published by the IPCC in 2003 (IPCC, 2003). It addresses all the issues relating to the estimation of emissions and removals in this complex source/sink category and their reporting for the purposes of the Convention and the Kyoto Protocol. Revised CRF tables for LULUCF that take account of this new good practice guidance were adopted at COP9 for reporting under the Convention and they have been recommended for use in the 2005 reporting cycle.

The coverage of sources of emissions and removals by Ireland in LULUCF is incomplete and, obviously, no assessment can be given in this NIR in regard to overall implementation of good practice guidance for *Land-Use Change and Forestry.* However, it may be stated that the model used to estimate carbon removals in Irish forests (Appendix G) is a robust carbon accounting technique that is in accordance with the IPCC guidelines and it may be readily extended to facilitate additional reporting under the Protocol.

The major improvement now needed in the LULUCF category is to achieve reporting completeness by including estimates of emissions and removals for all relevant sources and sinks. As already mentioned, major research has been completed to provide the basis for this task. Work is now underway to produce models, methods and data that can be applied to account for carbon stock changes in all relevant carbon pools and to report these changes according to the IPCC source/sink classification of Table 5.8 and the CRF tables agreed at COP9 (UNFCCC, 2004). The results of this research are being combined with further development of the CARBWARE model (Appendix G) for carbon accounting in forests to make available an integrated system that will meet the reporting needs of the Convention and the Kyoto Protocol.

5.7 Waste

5.7.1. Overview of *Waste*

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 5.9). The most important of these sources is solid waste disposal where CH_4 is the gas concerned. Landfills represent a key emission source in Ireland (Chapter Three) and the emission estimates are reasonably well quantified in current inventories. The treatment of wastewaters and sludge in anaerobic systems is also an important source of CH_4. However, the application of anaerobic treatment processes for either wastewaters or sludge remains very limited in Ireland. Consequently, the emissions of CH_4 are assumed to be negligible and no estimates have yet been made for this source (reported as NE). The N_2O emissions arising from the production of human sewage are now 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 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. Data on waste incineration are sparse and they are often confidential and, consequently, no estimates of emissions can be reported with any reliability. The quantities of both greenhouse gases and indirect gases concerned may be negligible. There is considerable public concern over the use of large-scale waste incinerators in Ireland and there is intense opposition to their introduction as part of waste management strategies. Waste incineration is therefore unlikely to be a major source of emissions for some years.

5.7.2 Solid Waste Disposal

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.

Table 5.9. Level 3 Source 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	NE	NE
2. Domestic and Commercial Wastewater	NA	NE	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

5.7.2.1 Methodology for CH_4 Emissions

For the years prior to 1998, Ireland used the Tier 1 default method to estimate CH_4 emissions from solid waste disposal. In this method, the emissions are determined on the basis of the amount of solid waste landfilled in the inventory year. The development of a national waste management strategy for Ireland (DELG, 1998) recognised the need for more 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 method was again used for the 2003 inventory.

The approach underlying the quantification of CH_4 from solid waste disposal uses the relationship given in Figure 5.1 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 potential CH_4 is assumed to be emitted. To estimate annual emissions for the years 1990 to 2001, 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 5.1 and their cumulative contributions for the 20 year period gives the total emissions for the end year in that period. This approach to estimating the emissions may be followed in the calculation sheets included in Appendix H.

5.7.2.2 CH_4 Production Potential of SWDS

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 and 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.

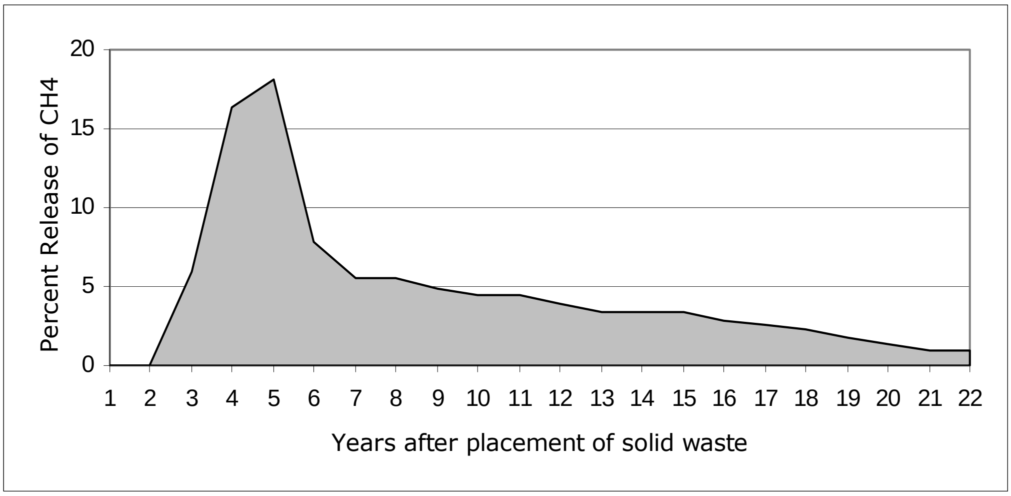


Figure 5.1. Typical CH_4 Production Pattern in Solid Waste Disposal Sites

The National Waste Database reports for 1995 (Carey *et al*, 1996) and 1998 (Crowe *et al*, 2000) available in 2003 were used as up to establish the MSW time-series up to and including 2001 and the corresponding annual CH_4 emission estimates. As such, the information for 2001 had to be extrapolated from that for previous years. The National Waste Database report for 2001 (Meaney *et al*, 2003) was used to revise the information for 2001, as reported in 2003, and to extend the time-series to 2002 for the purposes of the 2004 submission. The need to take account of the findings of the most recent report, particularly the sharp increase in the amount of municipal waste between 1998 and 2001, was identified in Ireland's 2003 in-country review report. The estimate of CH_4 emissions in 2001 from solid waste disposal was revised on this basis to maintain consistency with the 2002 result but this was not reported as a formal recalculation for 2001 at that time. While the calculation sheets presented in Appendix H give the CH_4 emissions for all years 1990-2002 (due to the type of methodology employed), they are primarily intended to show how the 2003 result is achieved for the purpose of this NIR. The time-series estimates given in the present submission are fully consistent.

The historical time series of wastes placed in SWDS up to 2003, along with their associated DOC contents, used as the basis of CH_4 emission estimates from this source are included in the calculation sheets for *Waste* (Appendix H). 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;
- 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 SWDS 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 SWDS are assumed to remain constant at 1 kg/cap/day and 75 percent, respectively prior to 1995;
- the amount of street cleansings is estimated on the basis of 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 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 all SWDS is dissimilated on an eqi-molar basis to CH_4 and CO_2;
- in 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 and the full CH_4 potential is ultimately realised;
- in 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 1995 and appropriate adjustment is made for the intervening years and for the years after 1995 with a gradual increase for managed landfills.

5.7.2.3 CH_4 Emissions from SWDS in 2003

The calculation sheets for *Waste* (Appendix H) show how the final estimates of CH_4 emissions from the IPCC source-category *6.1 Solid Waste Disposal on Land* are derived for the years 1990-2003 from the foregoing data on CH_4 potential using the time-dependent rate of release given in Figure 5.1. The emissions in a particular year are simply the cumulative contribution for that year arising from solid wastes placed in managed landfills (Table H.3 of Appendix H) and from solid wastes placed in unmanaged landfills (Table H.4 of Appendix H) 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 and these amounts are deducted from the CH_4 production in managed landfills to give the final estimate of emissions for this category of sites. 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. The foregoing analysis indicates CH_4 emissions of 58,760 tonnes in landfills in 1990 from an annual average of 0.94 million tonnes of contributing municipal waste over the preceding period of 20 years (Table H.5). In 2003, 91,930 tonnes of CH_4 was emitted with a further 13,776 tonnes recovered for energy purposes and the average contributing wastes amounted to approximately 1.35 million tonnes annually. It is evident from Figure 5.2 that emissions have increased significantly since 1999 as the amount of solid wastes increased sharply and methane recovery declined.

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 53 individual landfills in Ireland for 2002 using the LANDGEM Model developed by the USEPA. These are considered to be all the landfills that were producing CH_4 in any appreciable quantities in that year. The estimates were developed from information obtained from local authorities on the solid wastes placed in the landfills and selection of appropriate values of other parameters used in the LANDGEM model. The results are listed in Table H.6 of Appendix H and they include estimates of CH_4 utilised for energy or flared on site. These results indicate actual CH_4 emissions of 67,750 tonnes in 2002 from the 53 landfills covered by the bottom-up analysis with 19,450 tonnes utilised and 13,200 tonnes of CH_4 flared. If the quantity of CH_4 flared is deducted from the 80,975 tonnes emitted under the top-down approach, then the estimates of total emissions in 2002 for bottom-up and top-down methods are quite similar.

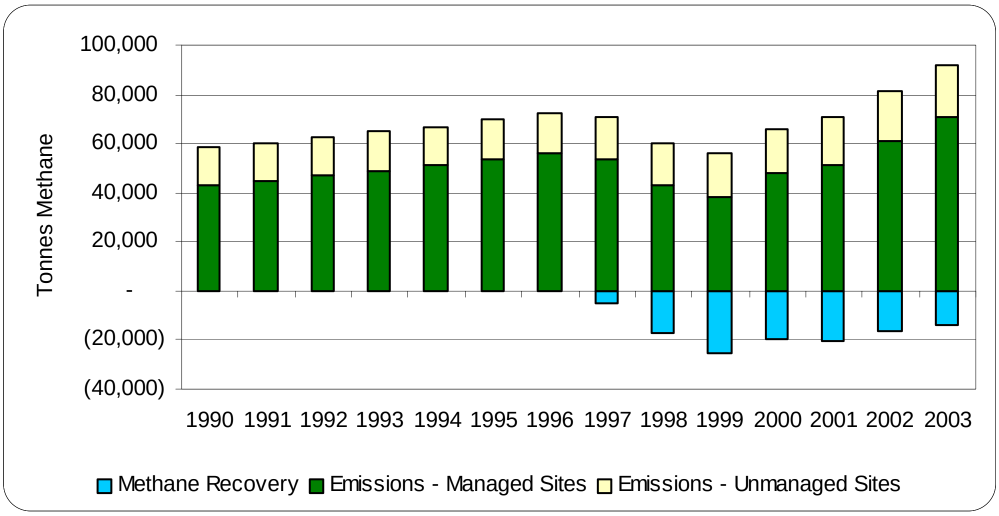


Figure 5.2. Methane Emissions from Solid Waste Disposal Sites1990-2003

5.7.3 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 has now adopted the FAO estimate of protein intake in the estimates for 2003 and the corresponding emissions in other years have been recalculated on this basis for the purpose of the present submission (Chapter Four). The calculation sheet for this activity is provided in Table H.7 of Appendix H. 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.

5.7.4 Good Practice Guidance and Improvements in *Waste*

Ireland's record on waste management is poor and the State is only now beginning to confront the challenges posed by ever increasing waste quantities and the recognition that alternatives to the landfill disposal option must be adopted without further delay. Although the introduction of new legislation and the development of the National Waste Database have contributed to some major advances in data collection, there remains considerable scope for improvements in the recording and tracking of waste quantities in general. There is an urgent need for better data on the quantities and composition of commercial and industrial wastes so that they are characterised to the same extent as domestic refuse. Radical changes are taking place through the EPA waste licensing system and other initiatives designed to implement waste management policies that favour prevention, minimisation and recycling options at the expense of waste disposal on land. Many landfills will be closed down and new landfills will 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 is currently 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 inevitable in 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 means that the emissions baseline relative to this new waste management regime is already highly uncertain. It may be 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. Further assessment of landfill gas production is therefore needed on an individual site basis to compare results from top-down and bottom-up approaches. To this end, the EPA will continue to use available models to estimate landfill gas emissions for all SWDS that are producing CH_4 as part of its reporting under Directive 1999/31/EC.

The quantities of sewage sludge produced in Ireland are increasing substantially as secondary treatment facilities are being put in place for a number of major population centres, such as Dublin, Cork, Limerick and Galway. The food industry is also a significant source of wastewater sludge. As the dumping of sludge at sea is now prohibited, landfills and land spreading will remain the mostly likely disposal options for some time. The possible contributions from sludges to CH_4 emissions in landfills and to indirect N_2O emissions from agricultural lands remain to be quantified. Waste incineration will soon be used as a solid waste management practice in Ireland, adding a new source of emissions under the *Waste* sector. These elements of emissions from waste disposal will be a matter for further investigation and improvement in inventories during 2005.

Table 5.10. Sector-specific Good Practice Guidance for Waste

Source category or gas	Elements of GPG already implemented	Elements of GPG Remaining to be addressed
6.A (CH_4 emissions)	Methods decision tree applied and Tier 2 method adopted Results of key source analysis taken into consideration Consistent time-series produced by recalculation Documentation and archiving Uncertainty assessment Comparison of top-down and bottom-up emissions estimates	QA and inventory review Completeness with respect to additional sources of organic waste including sludge and industrial wastes
6.B (CH_4 emissions)		Study and assessment of wastewater treatment systems needed to establish the extent of anaerobic systems

Chapter Six

Inventory Improvements

6.1 General Issues

A consistent time-series of greenhouse gas inventories in Ireland is available for the years 1990 through 2003. The annual inventories are substantially complete with respect to the coverage of the six greenhouse gases and the IPCC source categories although emission estimates for HFC, PFC and SF_6 are available only for the years 1995 through 2003.

Some lack of completeness remains in regard to potentially important sources and sinks under *Land-Use Change and Forestry*, where CO_2 is by far the most important gas. The complex dynamic nature of the sources and sinks to be considered in sub-categories *5.B Forest and Grassland Conversion, 5.C Abandonment of Managed Lands* and *5.D CO_2 Emissions and Removals from Soil*, along with the time scales that must be taken into account, present particular problems for estimating their emissions and removals on an annual basis. The CO_2 fluxes involved may be very large and any estimates based on the current simplified IPCC methodologies and default input values for these source categories could add significantly to the overall uncertainty in the inventory. For this reason, Ireland has deferred the inclusion of estimates for these source categories until the results of major national research in this area become available for inventory purposes. The research should establish the crucial items of background data, such as the national carbon stocks in soil and biomass and the factors affecting these stocks over time, to allow for a reasonably robust application of the IPCC methods under Irish circumstances.

An assessment of the extent to which the sector-specific good practice guidance is being implemented across the IPCC Level 1 source categories has been provided in Chapter Five. The range of really important greenhouse gas emission sources in Ireland is quite small and many of the important elements of good practice are already taken into account in the current approach to estimating the emissions. In general, the full implementation of sector-specific good practice guidance is constrained by a lack of resources and the scarcity of activity data and country-specific emission factors, which precludes the use of the recommended high-tier methodologies in several areas. Considerable enhancement of current data acquisition procedures and more in-depth examination of the scope for change in existing methodologies are needed for further progress.

This report also documents how some of the more general components of the IPCC good practice guidance, relating to routine documentation and reporting, overall inventory uncertainty, recalculations and the identification of key source categories, are now being addressed in a routine manner. The analysis of these issues has produced some interesting results, and it may now be readily applied as part of the annual cycle of inventory preparation and reporting. The combination of improved trend data, the detailed key source analysis and the information on uncertainty increases user confidence in the emissions data and can be used to prioritise specific areas for further improvement. The results are also valuable for the purpose of showing data suppliers in general that complete, consistent and reliable inputs on their part are crucial to the inventory improvement process.

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. Although only some of the report's recommendations have yet been implemented, a recalculation exercise to be undertaken in 2005 will take account of as many specific inventory issues as possible.

6.2 Research

Phase I of an environmental research programme under Ireland's National Development Plan. commenced in the first half of 2000. This programme is funding, *inter alia*, research on climate change topics designed to provide information that will assist the State in addressing national issues associated with climate change and contribute to ongoing international efforts to assess the phenomenon. The research has the following objectives

(i) to refine the current methodologies and generate the maximum amount of country-specific inputs used for estimating emissions from a number of key sources;

(ii) to develop the methods and data inputs for potentially important sources of emissions or removals not yet included in the Irish inventories;

(iii) to study likely impacts of climate change in Ireland and identify indicators of climate change in Ireland;

(iv) to investigate, in Ireland's background maritime conditions, the factors that influence the radiative forcing properties of the atmosphere and contribute further to ongoing international research in this field.

Objectives (i) and (ii) are directly relevant to the topic of this chapter. Enteric fermentation in large cattle populations and nitrogen inputs to soil are key emission sources of CH_4 and N_2O, respectively, in Ireland (Chapter Three). Major research projects have been undertaken to substantially improve on inventory methods and emission factors being used for these sources. The study on enteric fermentation used a tracer technique employing SF_6 to measure methane production by representative animals in all important cattle groups and relates CH_4 production to feed energy intake. The results will be combined with detailed characterisations of the cattle herd to develop a robust high-tier approach to calculate CH_4 emissions for the 2006 submission. The research includes comprehensive farm surveys to reliably quantify animal nitrogen excretion and waste management practices at the national scale so that the methodology relating to CH_4 emissions from animal waste management can also be made more country-specific.

Detailed studies on the N_2O losses from soils have been conducted in parallel with the research on CH_4 emissions from cattle. The results from these investigations are intended to provide a basis on which to adequately account for the influence of soil type, fertilizer type and application rates, temperature and rainfall on N_2O losses from soils. They should facilitate thorough appraisal of the default emission factors for direct N_2O emissions. The findings from the N_2O studies are being applied in the DNDC model (ISEO, 2002) to develop the model for use in Irish conditions with a view to producing alternative estimates of N_2O emissions from soils.

Another research project investigating soil and biomass carbon stocks as a basis for estimating emissions and removals of greenhouse gases for source categories not yet covered under *Land-Use Change and Forestry* has been completed. The results will assist in the estimation of carbon flux to or from the atmosphere for appropriate land-use categories on an annual basis. One element of this research targets peat soils, which present unique difficulties in quantifying the fluxes of greenhouse gases and which are particularly important in Ireland. Follow-up research activities are ongoing under Phase 2 of the environmental research programme to consolidate the findings of the projects described above and to extend their applicability. These activities involve detailed long-term measurements of greenhouse gas fluxes and other environmental variables for grassland, arable land and peatland sites. The field data will be used in the further development of models to represent the exchanges taking place under a variety of conditions and for up-scaling to determine annual balances of gas flux at the national level.

The National Climate Change Strategy has identified the forestry sector as crucial to securing compliance with Irish commitments under the Kyoto Protocol. In this context, the six-year research and development programme begun by COFORD in 2001 includes several projects that will provide better understanding of carbon sequestration in forests and other ecosystems and the scientific support for further development of methods for quantifying carbon removals. The CARBIFOR Project is designed specifically for the purpose of improving and validating the carbon accounting model (Appendix G) that is the basis for the estimates of carbon removals by forests as given in this report. The project is studying carbon cycling, carbon fluxes, biomass expansion, allometry and other parameters in a chronosequence of Sitka spruce sites to measure and model the rate of carbon sequestration and how it changes during forest stand development. The BOGFOR project aims to develop a forest resource on industrial cutaway peatland while the effects of forestry and forest management practices on biodiversity are being investigated by the BIOFOREST project.

6.3 Activity Data, Uncertainty and QA/QC

The Irish Government has established a cross-Departmental Climate Change Team to secure implementation of its climate change strategy, published in October 2000 (DELG, 2000). The team is assisted by a number of support groups with responsibility for particular aspects of the implementation process. The Inventory Data Users Group (IDUG) is responsible for strengthening existing data gathering capacity to facilitate ongoing inventory development and reporting of emissions at the most appropriate level of disaggregation. A comprehensive and efficient inventory process is seen as crucial in identifying the effects of emissions abatement measures and in the monitoring of overall progress on the strategy.

The institutions generating the principal statistical data used in greenhouse gas inventories, such as CSO, SEI, relevant Government Departments and the Irish Business and Employers Federation (IBEC), have representation in IDUG. The IDUG forum is being used to impress upon these data suppliers the importance of the timely delivery on their part of data that are closely compatible with the needs of the inventory. To this end, the EPA, as the inventory agency, is developing a number of data acquisition templates that are designed to facilitate submissions from the various institutions on an annual basis. All such templates will make explicit request for information on uncertainty associated with the various items of activity data. The templates are endorsed by the IDUG representatives and they are regarded as a useful step towards formalising primary data returns in the annual reporting cycle. They will allow for the documentation of uncertainties in the key national-level activity data by the individuals and institutions best placed to quantify them. The limitations of current Irish energy balances have already been mentioned in this report and this issue received considerable discussion in the 2003 in-country review. Following the work on the harmonisation of Irish energy statistics between SEI and Eurostat in 2003 and collaboration with the EPA, SEI has adopted a more detailed energy balance sheet that is better suited to the needs of emissions inventories and has begun to revise historical energy statistics for publication in this format.

The licensing system for integrated pollution control (IPC) operated in Ireland by the EPA provides a mechanism through which data acquisition for inventory purposes is being improved at the site-specific level. A wide range of industrial facilities are required to make an Annual Environmental Report (AER) under the terms of their IPC licences. The format of these reports is being updated to accommodate much more information relevant to greenhouse gas emissions inventories, including relevant uncertainty estimates, in much the same way as the templates developed under IDUG. Surveys of fuel use in the industrial sector will be conducted as part of AER submissions to supplement the compilation of national energy statistics and facilitate further disaggregation for the emissions estimation process. The implementation of Directive 2003/87/EC by the Emissions Trading Unit of the EPA is another means by which site-specific data gathering on CO_2 emissions can be expanded and improved. The provisions that the Directive makes for the monitoring and reporting of emissions and for their verification are a basis for developing robust estimates for the sources concerned along with the necessary support documentation that can contribute to the national inventory report in the future.

The Forest Climate Change Team (FCCT) is another technical unit that is making an important contribution to the implementation of the Climate Change Strategy and the work of the inventory agency. The FCCT is overseeing the development of the national methods and data needed in relation to *5.A Changes in Forest and Other Woody Biomass Stocks* and is preparing for the much more extensive reporting of information on land-use change and forestry under the Kyoto Protocol. The improved methodology underlying the recalculated estimates of carbon removals in Irish forests (Section 5.6.2) is an indication of the progress being achieved by this unit.

The enhancements in the acquisition of activity data and uncertainty estimates for key activity statistics outlined above will contribute to general inventory-level quality control and provide for better documentation on uncertainty. Good practice for quality assurance procedures requires an objective review of the inventory to assess its overall quality and to identify where improvements can be made. The first steps towards inventory review are also being planned under the aegis of IDUG. The inventory agency is attempting to establish a mechanism within this group whereby a review of the completed inventory can be conducted each year before its submission to the UNFCCC secretariat. This could be achieved by making the draft CRF and the latest NIR available to IDUG representatives and requesting them to conduct a general review of the inventory in relation to completeness, consistency and transparency and potential problems. In this way, the key data suppliers could contribute further to the inventory improvement process and they would gain valuable insight into the way their own data are used to produce the emissions estimates.

At the end of 2004 the EPA commissioned a project with UK consultants to produce a scoping report on the establishment of a national inventory system to meet the needs of the Kyoto Protocol and to develop a QA/QC system for Irish greenhouse gas inventories as part of that system. The project will determine the overall structure, content, and functionality of the national inventory system required to comply with the reporting needs of Decision 280/2004/EC (EP and CEU, 2004) and the Kyoto Protocol. The report will identify institute participation, resource requirements and the legal arrangements necessary to perform the functions prescribed by the guidelines for national systems and enable Ireland to meet the objectives set down in those guidelines. The scoping report will provide recommendations on how to achieve an acceptable standard of operational NIS under Irish circumstances, drawing on the practices and experience of other Member States. The project will also establish data quality objectives for greenhouse gas emission estimates and prescribe the full range of quality control and quality assurance procedures to be carried out during the annual reporting cycle. The expected outputs are an operational QA/QC programme, designed to become operational in the national inventory system for the 2006 reporting cycle, and a supporting QA/QC manual.

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Appendix A

Greenhouse Gases, GWP and IPCC Reporting Format

Table A.1. Greenhouse Gases and their 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-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. Changes in Forest and Other Woody Biomass Stocks						
B. Forest and Grassland Conversion						
C. Abandonment of Managed Lands						
D. CO_2 Emissions and Removals from Soil						
E. 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

Appendix B

Energy Balance Sheets for 2003

Table B.1 (a) Energy Balance Sheet 2003 - Main Sectors

ENERGY BALANCE 2003 (Thousand TOE)	Coal	Peat	Peat Briquettes	Oil	Natural Gas	Hydro	Other Renewables	Electricity	Total
Ind. Production	0.00	1062.47		0.00	544.80	50.91	209.37		1867.55
Imports	1978.00			9619.98	3139.90			101.14	14839.01
Exports	6.00		12.06	1513.77				0.86	1532.70
Mar. Bunkers	0.00			169.00					169.00
Stock Change	60.00	212.12		-57.00					215.12
TPER	1912.00	838.28		7994.00	3684.70	50.91	209.37	100.28	14789.55
Elec. Generation	1326.68	518.29		594.36	2356.10	51.00	57.56	2185.43	2718.56
Briquetting		155.21	123.60					4.30	31.61
Gasworks									
Own use/losses			17.18	132.83	48.50			281.64	480.14
TFC	585.42	176.85	94.36	7267.21	1279.70	0.00	151.55	1980.87	11535.95
Industry	262.42	0.00	0.00	743.00	437.40	0.00	105.71	625.67	2174.19
(Feedstock)	0.00				0.00				0.00
Transport	0.00	0.00	0.00	4507.00	0.00	0.00		2.00	4509.00
Residential	288.00	176.85	93.47	1030.67	538.90	0.00	43.40	599.33	2770.62
Commercial	35.00	0.00	0.89	713.93	303.40	0.00	2.44	701.87	1757.53
Agricultural	0.00	0.00	0.00	272.61	0.00	0.00		52.00	324.61

Table B.1 (b) Energy Balance Sheet 2003 - Sub-sectors (electricity excluded)

2003 (kTOE)	**Coal**	**Pet Coke**	**Sod Peat**	**Peat Briq**	**Petrol**	**Kerosene**	**Jet Kero**	**Fueloil**	**LPG**	**Gasoil**	**DERV**	**Natural Gas**	**Ren'bles**	**Total**
Final Consumption	**307.0**	**282.1**	**177.0**	**94.0**	**1676.9**	**822.8**		**524.8**	**147.3**	**1327.5**	**1979.1**	**1269.0**	**156.0**	**11530.4**
Industry	**39.0**	**227.0**				**111.4**		**296.8**	**61.1**	**192.7**		**399.00**	**109.0**	**2046.0**
Iron and Steel									4.8			3.6		9.5
Chemical						85.7		125.0	3.9	15.2		135.4		450.8
Nonferr. Metals								6.1						30.4
Nonmet. Minerals.	**23.4**	**227.0**						0.5	7.8	22.8		31.6		361.7
Transp. Equip.								0.1	3.9	3.8				14.1
Machinery						8.6		0.6	3.9	24.1				116.0
Mining								0.2		25.4		24.4		74.2
Food etc.	**15.6**					4.3		126.3	1.9	78.6		135.4		513.9
Paper etc.								0.2		3.8				16.6
Wood etc.								0.1		2.5			109.0	129.6
Construction														6.3
Textiles etc.						4.3		0.4	2.9	11.4				49.7
Non-Specified						8.6		37.4	32.0	5.1		68.6		273.3
(Feedstocks)												352.0		352.0
Transport					**1676.9**	**0**	**786.8**	**17.88**	**4.85**	**41.8**	**1979.1**			**4507.37**
Air					1.8	0	786.8							788.54
Road					1675.1				4.85		1979.1			3659.11
Rail										40.57				40.57
Inland Navigation.								17.88		1.3				19.15
Non-Specified														
Other Sectors	**268.0**	**55.1**	**177.0**	**94.0**	**0**	**711.4**		**227.5**	**81.4**	**1093.0**		**842.3**	**47.0**	**4992.3**
Agriculture										272.6			4.0	328.6
Comm. and Publn.	27.0	8.5		1.0				227.5	10.7	571.8		303.4		1894.4
Residential	241.0	46.6	177.0	93.0		711.4			70.8	248.5		539.00	43.0	2769.3
Non-Specified														

Table B.2. Oil Balance Sheet 2003

	Crude	Refinery	Gasoline	Kerosene	JET Kero	LSFueloil	HSFueloil	LPG	Gasoil	Derv	Naphta	Total
(kTOE)		**Gas**										
Production		104.68	680.41	333.04	0.00	989.63	0.00	66.67	458.79	579.05	32.30	3244.56
From Other Sources												
Import	3323.99		1145.40	412.17	1003.47	1077.42	74.27	115.29	929.25	1538.62		9619.88
Export			203.62	57.19	12.00	1064.68	0.00	23.78	43.46	81.82	27.24	1513.77
Marine Bunkers						12.19	48.30		108.49	0.00		168.98
Stock Changes	79.43	0.00	-54.72	-134.80	204.71	-101.27	10.20	5.00	-127.62	56.72	5.06	-57.28
DOMESTIC SUPPLY		**104.68**	**1676.91**	**822.82**	**786.76**	**1091.45**	**15.78**	**153.17**	**1363.70**	**1979.13**	**0.00**	**7994.40**
		92.94	1574.57	778.75	746.95	1108.19	16.02	135.99	1318.35	1913.31	0.00	**7685.06**
Returns to Supply												
Transfers												
Stat. Diff.												
TRANSF. SECTOR			0.00	0.00	0.00	564.68	0.00	0.00	29.68	0.00	0.00	594.36
Publ. Electr.						564.68			29.68			594.36
Autoproducers												0.00
CHP Plants												0.00
Distr. Heat												
Pat. Fuel Plants												
Coke Ovens												
Gas Works												
For Blast Fur.												
For BKB												
Refineries												
Liquefication												
Oth. Transform												
ENERGY SECTOR	0.00	104.68	0.00	0.00	0.00	17.77	0.00	3.90	6.48	0.00	0.00	132.83

Coal Mines												
Oil and Gas Extr												
Pat. Fuel Plants												
Coke Ovens												
Gas Works												
BKB												
Oil Refineries		104.68				17.77	0.00	3.90	6.48			132.83
Electrical Plants												
Pump Storage												
Nuclear Industry												
Non-Specified (E												
Distr. Losses												
FINAL CONSUMPTION	0.00		1676.91	822.82	786.76	509.01	15.78	149.26	1327.55	1979.13	0.00	7267.21
			1676.91	822.82	786.76	509.01	15.78	149.26	1327.55	1979.13	0.00	7267.21
INDUSTRY	**0.00**	**0.00**	**0.00**	**111.42**	**0.00**	**364.20**	**11.29**	**63.00**	**192.73**	**0.00**	**0.00**	**742.64**
Iron and Steel								4.85	0.00			4.85
Chemical				85.71		28.62	0.89	3.88	15.22			134.31
(Feedstocks)												
Nonferr. Met						196.84	6.10					202.94
Nonmet. Min.						14.74	0.46	7.75	22.82			45.78
Transp. Equip.						2.60	0.08	3.88	3.80			10.36
Machinery				8.57		20.81	0.65	3.88	24.09			58.00
Mining						5.20	0.16		25.36			30.72
Food etc.				4.29		67.64	2.10	1.94	78.61			154.57
Paper etc.						5.20	0.16		3.80			9.17
Wood etc.						1.73	0.05		2.54			4.32
Construction												
Textiles etc.				4.29		13.87	0.43	2.91	11.41			32.91
Non-Specified				8.57		6.94	0.22	31.98	5.07			52.78
Compensation for rounding												

TRANSPORT	**0.00**	**0.00**	**1676.91**	**0.00**	**786.76**	17.34	0.54	4.85	**41.84**	1979.13	**0.00**	**4507.37**
Air			1.78		786.76							788.54
Road			1675.13					4.85		1979.13		3659.11
Rail									40.57			40.57
Inland Navig.						17.34	0.54		1.27			19.15
Non-Specified												
OTHER SECTORS	**0.00**		**0.00**	**711.40**	**0.00**	127.47	3.95	81.42	**1092.97**	**0.00**	**0.00**	**2017.21**
Agriculture									272.61			272.61
Comm. and Publ.				0.00	0.00	127.47	3.95	10.66	571.85			713.93
Residential				711.40				70.75	248.52			1030.67
Non-Specified												

Appendix C

Calculation Sheets for Energy

Year 2003

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

	Sectoral Disaggregation of Fuel Consumption from National Energy Balance			Emission Factors				Emissions		
				CO2	**CH4**	**N2O**	***Unit***	**CO2**	**CH4**	**N2O**
	Sector/Fuel	kTOE	TJ					Gg	Mg	Mg
1	Public Power Plants Peat	513.99	21519.733	113262	0	12	*kg/TJ*	2437.374	0	256
2	Public Power Plants Coal	1323.30	55403.924	95555	0	14	*kg/TJ*	5294.143	0	846
3	Public Power Plants Fuel Oil	564.60	23638.673	80096	0	14	*kg/TJ*	1992.615	0	364
4	Public Power Plants Gasoil	29.60	1239.293	0	0	14	*kg/TJ*		0	0
5	Public Power Plants Natural Gas	2268.31	94969.603	56697	0	3	*kg/TJ*	5384.458	0	277
6	Electricity Landfill Gas	16.40	686.635	54940	0	0	*kg/TJ*	37.724	0	0
7	**Public Electricity Total**	**4699.80**	**197457.862**					**15108.590**	**0**	**1743**
8	Refinery Gas	104.68	4382.742	65000	0	3	*kg/TJ*	284.878	0	13
9	Refinery Fueloil	17.77	743.994	76000	0	10	*kg/TJ*	56.544	0	7
10	Refinery Gasoil	6.48	271.305	73300	2	10	*kg/TJ*	19.887	1	3
11	Refinery LPG	3.90	163.285	63700	2	3	*kg/TJ*	10.401	0	0
12	**Refinery Total**	**132.83**	**5561.33**					**371.710**	**1**	**24**
13	Residential Peat	176.85	7404.356	104000	50	5	*kg/TJ*	770.053	370	37
14	Residential Peat Briquettes	93.47	3913.402	98860	50	5	*kg/TJ*	386.879	196	20
15	Residential Coal	152.55	6386.963	94600	100	12	*kg/TJ*	604.207	639	77
16	Residential Petroleum Coke	71.97	3013.240	100800	50	12	*kg/TJ*	303.735	151	36
17	Residential Gasoil	248.52	10405.035	73300	5	10	*kg/TJ*	762.689	52	104
18	Residential Kerosene	711.40	29784.895	71400	5	10	*kg/TJ*	2126.642	149	298
19	Residential Natural Gas	538.90	22562.665	54940	5	2	*kg/TJ*	1239.593	113	45
20	Residential LPG	70.75	2962.161	63700	0	2	*kg/TJ*	188.690	0	6
21	Residential Biomass	43.40	1817.071	110000	30	4	*kg/TJ*	199.878	55	7
22	**Residential Total**	**2107.81**	**88249.789**					**6382.486**	**1724**	**630**
23	Commercial Peat	0.00	0.000	104000	50	5	*kg/TJ*	0.000	0	0
24	Commercial Peat Briquettes	0.89	37.263	98860	50	5	*kg/TJ*	3.684	2	0
25	Commercial Coal	27.00	1130.436	94600	100	12	*kg/TJ*	106.939	113	14
26	Commercial Pet Coke	8.00	334.944	100800	50	12	*kg/TJ*	33.762	17	4
27	Commercial Gasoil	571.85	23942.216	73300	5	10	*kg/TJ*	1754.964	120	239

28	Commercial Kerosene	0.00	0.000	71400	5	10	*kg/TJ*	0.000	0	0
29	Commercial Fueloil	131.42	5502.293	76000	0	10	*kg/TJ*	418.174	0	55
30	Commercial Natural Gas	303.40	12702.751	54940	5	2	*kg/TJ*	697.889	64	25
31	Commercial LPG	10.66	446.313	63700	0	2	*kg/TJ*	28.430	0	1
32	Commercial Biomass	2.44	102.158	110000	30	4	*kg/TJ*	11.237	3	0
33	**Commercial Total**	**1055.66**	**44198.373**					**3043.843**	**318**	**339**
34	Cement Gasoil	5.20	217.714	94600	2	10	*kg/TJ*	15.958	0	2
35	Cement Petroleum Coke	201.11	8420.073	100800	5	10	*kg/TJ*	848.743	42	84
36	Cement Coal	124.79	5224.510	94600	15	5	*kg/TJ*	494.239	78	26
37	Industry Gasoil	187.53	7851.506	73300	2	10	*kg/TJ*	575.515	16	79
38	Industry Kerosene	111.42	4664.933	71400	2	10	*kg/TJ*	333.076	9	47
39	Industry Fueloil	45.47	1903.738	76000	0	10	*kg/TJ*	144.684	0	19
40	Alumina Fuel Oil (Boilers)	221.11	9257.433	76000	0	10	*kg/TJ*	703.565	0	93
41	Alumina Fuel Oil (Calciners)	108.91	4559.844	76000	0	10	*kg/TJ*	346.548	0	46
42	Industry Natural Gas	399.00	16705.332	54940	2	3	*kg/TJ*	917.791	33	50
43	Industry LPG	63.00	2637.684	63700	2	3	*kg/TJ*	168.020	5	8
44	Industry Biomass	105.71	4425.866	110000	30	4	*kg/TJ*	486.845	133	18
45	CHP Coal	3.59	150.306	94600	15	12	*kg/TJ*	14.219	2	2
46	CHP Peat	4.30	180.032	113262	0	12	*kg/TJ*	20.391	0	2
47	CHP Natural Gas	87.80	3676.010	54940	0	3	*kg/TJ*	201.960	0	11
48	**Industry Total**	**1668.94**	**69874.982**					**4784.710**	**320**	**486**
49	Road Transport Petrol	1675.13	70134.343	69960	30.0	10.9	*kg/TJ*	4906.599	2104	767
50	Road Transport Diesel	1979.13	82862.215	73300	2.5	5.6	*kg/TJ*	6073.800	208	468
51	Road Transport LPG	4.85	203.060	63700	4.9	0.0	*kg/TJ*	12.935	1	0
52	**Road Transport Total**	**3659.11**	**153199.617**					**10993.334**	**2313**	**1235**
53	Railways Diesel	40.57	1698.585	73300	5	30	*kg/TJ*	124.506	8	51
54	Agriculture Machinery Gasoil	245.35	10272.314	73300	5	30	*kg/TJ*	752.961	51	308
55	Navigation Fuel Oil	17.88	748.600	76000	5	30	*kg/TJ*	56.894	4	22
56	Navigation Gasoil	1.27	53.172	73300	5	30	*kg/TJ*	3.898	0.3	2
57	Gas Distribution-Use	48.50	2030.598	54940	5	3	*kg/TJ*	111.561	10	6
58	Domestic Aviation-LTO	13.92	582.633	2600	0.10	0.10	*kg/LTO*	41.600	2	2
59	Domestic Aviation-Cruise	20.37	10963.522	3085.65	0.13	0.11	*kg/LTO*	60.903	0	2

60	International Aviation-LTO[a]	255.25	10686.764	3085.65	0.13	0.11	*kg/LTO*	782.795	33	28
61	International Aviation-Cruise[a]	488.83	20466.408	71400	0	2.25	*kg/TJ*	1461.302	0	46
62	**Other Transport Total**		**16238.882**					**1800.879**	**103**	**395**
63	Agriculture Stationary Gasoil	27.26	1141.322	73300	5	10	*kg/TJ*	83.659	6	11
64	Agriculture Biomass	2.10	87.923	110000	30	4	*kg/TJ*	9.672	3	0
65	**Agriculture Total**	**274.71**	**11501.558**					**836.619**	**60**	**320**
66	**Total Energy**							**44615.055**	**82159**	**5023**
67	Marine Bunkers Fuel Oil	60.49	2532.595	76000	0	0	*kg/TJ*	192.477	0	0
68	Marine Bunkers Gasoil	108.49	4542.259	73300	0	0	*kg/TJ*	332.948	0	0
69	Marine Bunkers Kerosene	0.00	0.000	71400	0	0	*kg/TJ*	0.000	0	0
70	CO2 from Biomass							**745.356**		

[a] LTO: (landing and take-off cycle) includes all activities near the airport that take place below 1,000m in altitude. This includes taxiing, take-off, climb-out and approach landing.
Cruise: defined as all activities above 1,000m in altitude. Cruise includes climb from end of climb-out in the LTO cycle to cruise altitude, cruise, and descent from cruise altitudes to the start of LTO operations of landing.

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	CO2	CH4	N2O	*Unit*	CO2 (Gg)	CH4 (Mg)	N2O (Mg)
A	**1.A.1 Energy Industries**	**4849.03**	**203019.19**					**15480.30**	**1**	**1767**
B	(a) Solid Fuels	1837.29	76923.66	100509	0.00	14.33	*kg/TJ*	7731.517	0	1102
C	(b) Liquid Fuels	727.03	30439.29	77673	0.03	12.74	*kg/TJ*	2364.325	1	388
D	(c) Gaseous Fuels	2268.31	94969.60	56697	0.00	2.90	*kg/TJ*	5384.46	0	277
E	(d) Biomass	16.40	686.64	54940	0.00	0.00	*kg/TJ*	37.72	0.00	0.00
F	**1.A.2 Manufacturing Industries**	**1668.94**	**69874.98**					**4784.710**	**320**	**486**
G	(a) Solid Fuels	132.68	5554.85	95205	14.51	5.42	*kg/TJ*	528.848	81	30
H	(b) Liquid Fuels	943.75	39512.93	79369	1.84	9.53	*kg/TJ*	3136.111	73	377
I	(c) Gaseous Fuels	486.80	20381.34	54940	1.64	3.00	*kg/TJ*	1119.751	33	61
J	(d) Biomass	105.71	4425.87	110000	30.00	4.00	*kg/TJ*	486.845	133	18
K	**1.A.3 Transport**	**3801.62**	**159166.19**					**11392.695**	**2337**	**1320**
L	(a) Solid Fuels	0.00	NO	NA	NA	NA	*kg/TJ*	0	0	0
M	(b) Liquid Fuels	3753.12	157135.59	71792	14.81	8.36	*kg/TJ*	11281.134	2327	1314
N	(c) Gaseous Fuels	48.50	2030.60	54940	5.00	3.00	*kg/TJ*	111.561	10	6
O	(d) Biomass	0.00	NO	NA	NA	NA	*kg/TJ*	0	0	0
P	**1.A.4 Other Sectors**	**3438.18**	**143949.72**					**10262.949**	**2101**	**1288**
Q	(a) Solid Fuels	450.76	18872.42	99180	69.92	7.79	*kg/TJ*	1871.762	1319	147
R	(b) Liquid Fuels	2097.18	87804.73	73501	6.21	12.11	*kg/TJ*	6453.705	545	1063
S	(c) Gaseous Fuels	842.30	35265.42	54940	5.00	2.00	*kg/TJ*	1937.482	176	71
T	(d) Biomass	47.94	2007.15	110000	30.00	4.00	*kg/TJ*	220.787	60	8
U	**1.A.5 Other**	**0**	**0.00**	**NA**	**NA**	**NA**	***kg/TJ***	**0.00**	**1**	**0**
V	**1.A Fuel Combustion**	**13757.76**	**576010.08**					**41920.654**	**4759**	**4860**
	Memo Items									
W	Air Bunkers		31429.93	71400	1.02	2.31	*kg/TJ*	2244.10	32	73
X	Marine Bunkers		7074.85	74267			*kg/TJ*	525.43	NE	NE
Y	CO2 from Biomass		7119.65	104690				745.35	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
C	(b) Liquid Fuels	3 + 4 + 8 + 9 + 10 + 11
D	(c) Gaseous Fuels	5
E	(d) Biomass	6
F	**1.A.2 Manufacturing Industries (F = G+H+I+J)**	
G	(a) Solid Fuels	36 + 45 + 46
H	(b) Liquid Fuels	34 + 35 + 37 + 38 + 39 + 40 + 41 + 43
I	(c) Gaseous Fuels	42 + 47
J	(d) Biomass	44
K	**1.A.3 Transport (K = L+M+N+O)**	
L	(a) Solid Fuels	NO
M	(b) Liquid Fuels	49 + 50 + 51 + 53 + 55 + 56 + 58 + 59
N	(c) Gaseous Fuels	57
O	(d) Biomass	NO
P	**1.A.4 Other Sectors (P = Q+R+S+T)**	
Q	(a) Solid Fuels	13 + 14 + 15 + 23 + 24 + 25
R	(b) Liquid Fuels	16 + 17 + 18 + 20 + 26 + 27 + 28 + 29 + 31+ 54 + 63
S	(c) Gaseous Fuels	19 + 30
T	(d) Biomass	21 + 32 + 64
U	**1.A.5 Other**	**NO**
V	**1.A Fuel Combustion (V = A+F+K+P+U)**	
	Memo Items	
W	Aviation Bunkers	60 + 61
X	Marine Bunkers	67 + 68 + 69
Y	CO2 from Biomass	70

Table C.4. Emissions of CO_2 from the Reference Approach in 2003 [CRF 2003 Table 1.A(b); Biomass excluded]

FUEL TYPES			**Unit**	**Prod'n**	**Imports**	**Exports**	**Int'l bunkers**	**Stock Change**	**Apparent Cons'n**	**Conv'n factor (TJ/Unit)**	**Apparent Cons'n (TJ)**	**Carbon EF (t C/TJ)**	**Carbon content (Gg C)**	**Carbon stored (Gg C)**	**Net carbon emissions (Gg C)**	**Fraction carbon oxidized**	**Actual CO_2 emissions (Gg CO_2)**
Liquid Fossil	Primary Fuels	Crude Oil	kt		3,250.53			77.67	3,172.86	42.81	135,842.83	20.00	2,716.86		2,716.86	1.00	9,961.81
		Orimulsion							0.00	41.87	0.00		0.00		0.00		0.00
		Natural Gas Liquids						0.00	0.00	41.87	0.00	17.73	0.00		0.00	1.00	0.00
	Secondary Fuels	Gasoline	kt		1,075.49	191.19	1.67	-51.38	934.01	44.59	41,646.57	19.08	794.62		794.62	1.00	2,913.59
		Jet Kerosene	kt		952.69	11.39	714.39	194.35	32.56	44.10	1,435.90	19.47	27.96		27.96	1.00	102.51
		Other Kerosene	kt		390.46	54.18		-127.70	463.98	44.20	20,506.06	19.47	399.29		399.29	1.00	1,464.08
		Shale Oil	kt						0.00	41.87	0.00		0.00		0.00		0.00
		Gas / Diesel Oil	kt		2,385.80	121.11	104.88	-68.54	2,228.35	43.31	96,505.38	19.99	1,929.24	0.00	1,929.24	1.00	7,073.88
		Residual Fuel Oil	kt		1,169.35	1,081.00	61.42	-92.47	119.40	41.24	4,923.58	20.73	102.05		102.05	1.00	374.19
		LPG	kt		102.36	21.11		4.44	76.81	47.16	3,622.05	17.37	62.93	0.00	62.93	1.00	230.73
		Ethane	kt						0.00	41.87	0.00		0.00	0.00	0.00		0.00
		Naphtha	kt			25.58		4.75	-30.33	44.59	-1,352.38	20.00	-27.05	0.00	-27.05	1.00	-99.17
		Bitumen							0.00		0.00		0.00	0.00	0.00		0.00
		Lubricants							0.00		0.00		0.00	0.00	0.00		0.00
		Petroleum Coke	ktoe		281.08	0.00		0.00	281.08	41.87	11,768.26	27.49	323.52		323.52	1.00	1,186.24
		Refinery Feedstocks							0.00		0.00		0.00		0.00		0.00
		Other Oil							0.00		0.00		0.00		0.00		0.00
Liquid Fossil Totals												314,898.24		6,329.41	0.00	6,329.41	
Solid Fossil	Primary Fuels	Anthracite [(2)]							0.00		0.00		0.00		0.00		0.00
		Coking Coal							0.00		0.00		0.00	0.00	0.00		0.00
		Other Bit. Coal	ktoe		1,696.92	6.00		60.00	1,630.92	41.87	68,283.36	25.80	1,761.71		1,761.71	1.00	6,459.61
		Sub-bit. Coal							0.00		0.00		0.00		0.00		0.00
		Lignite							0.00		0.00		0.00		0.00		0.00
		Oil Shale							0.00		0.00		0.00		0.00		0.00
		Peat	ktoe	1,062.4 7				212.12	850.35	41.87	35,602.45	29.57	1,052.76		1,052.76	1.00	3,860.14
	Secondary Fuels	BKB & Patent Fuel	ktoe			12.06			-12.06	41.87	-504.93	26.96	-13.61		-13.61	1.00	-49.91
		Coke Oven/Gas Coke							0.00		0.00		0.00		0.00		0.00
Solid Fuel Totals												103,380.88		2,800.86	0.00	2,800.86	
Gaseous Fossil		*Natural Gas (Dry)*	*ktoe*		544.80	3,139.90	0.00		0.00	3,684.70	41.87	154,271.02	14.98	2,311.60	0.00	2,311.60	1.00
Total											**572,550.15**		**11,441.87**	**0.00**	**11,441.87**		**41,953.53**
Biomass total												7,119.65		203.90	0.00	203.90	
		Solid Biomass	ktoe	151.55	0.00	0.00		0.00	151.55	41.87	6,345.10	30.00	190.35		190.35	1.00	697.96
		Liquid Biomass							0.00		0.00		0.00		0.00		0.00
		Gas Biomass	ktoe	18.50	0.00	0.00		0.00	18.50	41.87	774.56	17.49	13.55		13.55	1.00	49.68

Table C.5. Comparisons of Results from Sectoral Approach and Reference Approach for 2003 [CRF 2003 Table 1.A(c)]

	Reference Approach (RA)		Sectoral Approach (SA)		Difference (RA-NA/NA)*100	
	Energy Consumption PJ	CO2 Emissions Gg	Energy Consumption PJ	CO2 Emissions Gg	Energy Consumption %	CO2 Emissions %
Liquid Fuels (excluding international bunkers)	314.90	23,207.85	314.69	23,222.30	0.07	-0.06
Solid Fuels (excluding international bunkers)	103.38	10,269.83	101.35	10,132.13	2.00	1.36
Gaseous Fuels	154.27	8475.86	152.65	8,553.25	1.06	-0.90
Other			0.20	12.94	-100.00	-100.00
Total	**572.55**	**41,953.53**	**568.89**	**41,920.61**	**0.64**	**0.80**

Appendix D

Calculation Sheets for Industrial Processes

Years 1990-2003

1995-2003 for HFC, PFC and SF_6

Table D.1. Emissions from Production of Cement, Lime, Ammonia and Nitric Acid

	Cement Production			Lime Production			Ammonia Production				Nitric Acid Production		
	Clinker	CO2 EF	CO2 Emissions	Lime	CO2 EF	CO2 Emissions	Natural Gas Feedstock		CO2 EF	CO2 Emissions	Nitric Acid	N2O EF	N2O Emissions
	kt	kg/t	kt	kt	kg/t	kt	kTOE	TJ	kg/TJ	kt	kt	kg/t	kt
1990	1500	500	750	255.22	750	191.42	430	18003.240	54.94	989.10	338	9.88	3.34
1991	1500	500	750	231.47	750	173.60	448	18756.864	54.94	1030.50	260	10.07	2.62
1992	1600	500	800	215.70	750	161.78	436	18254.448	54.94	1002.90	260	10.07	2.62
1993	1500	500	750	243.01	750	182.26	411	17207.748	54.94	945.39	260	10.07	2.62
1994	1800	500	900	246.99	750	185.24	459	19217.412	54.94	1055.80	260	10.07	2.62
1995	1800	500	900	223.50	750	167.63	423	17710.164	54.94	973.00	260	10.07	2.62
1996	1800	500	900	240.14	750	180.11	401	16789.068	54.94	922.39	260	10.07	2.62
1997	2000	500	1000	253.00	750	189.75	467	19552.356	54.94	1074.21	260	10.07	2.62
1998	2000	500	1000	256.10	750	192.08	460	19259.280	54.94	1058.10	260	10.07	2.62
1999	2250	500	1125	206.59	750	154.94	410	17165.880	54.94	943.09	260	10.07	2.62
2000	3150	500	1575	248.30	750	186.23	384	16077.312	54.94	883.29	260	10.07	2.62
2001	3300[a]	500	1650[a]	243.50	750	182.63	451	18882.468	54.94	1037.40	260	7.27	1.89
2002	4043[a]	500	2021[a]	242.51	750	181.88	352	14737.536	54.94	809.68	130[b]	7.27	0.94[b]
2003	3967[a]	544	2157[a]	273.31	750	202.25	0	0		0	0	0	0

a indirect estimate; process emissions estimated as difference between total emissions and emissions from combustion

b plant closed in June 2002; values estimated as 50% of those for 2001

Table D.2. Process CO_2 Emissions from Cement Production 1990-2003

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Irish Cement 1	505.0	443.0	417.0	406.0	494.0	503.0	614.0	719.0	630.0	724.0	764.0	798.0	800.0	854.9
Irish Cement 2	379.0	339.0	336.0	323.0	365.0	376.0	369.0	426.0	429.0	442.0	502.0	506.0	486.0	501.0
Quinn Cement											434.9	547.2	560.4	604.4
Lagan Cement											0.0	0.0	0.0	197.2
Total Process CO_2 (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**	**1,846.4**	**2,157.4**

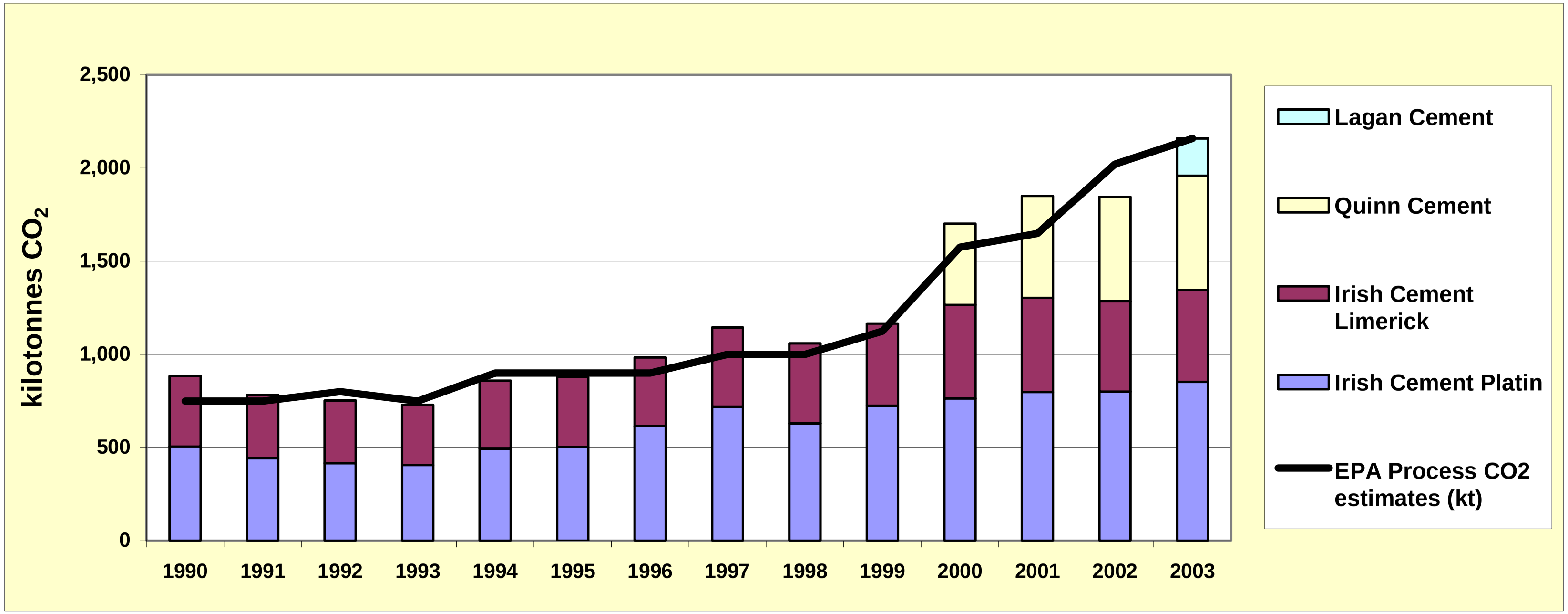

Figure D.2. Comparison of CRF and Company Estimates of Process CO_2 Emissions from Cement Production

Table D.3. HFC Emissions from Stationary Refrigeration and Air Conditioning

	Refrigeration and Air Conditioning					Manufacture of Transport Refrigeration			Totals				
	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-125	HFC-134a	HFC-143a	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a
	t	t	t	t	t	t	t	t	t	t	t	t	t
Consumption													
1995	0.060	1.031	6.150	37.595	5.831	0	0	0	0.060	1.031	6.150	37.595	5.831
1996	0.027	1.375	91.761	44.127	97.469	0	0	0	0.027	1.375	91.761	44.127	97.469
1997	0.030	13.900	108.459	130.806	98.939	27.127	5.711	32.059	0.030	13.900	135.586	136.517	130.998
1998	0.030	40.210	123.820	305.230	80.710	31.212	6.571	36.887	0.030	40.210	155.032	311.801	117.597
1999	1.478	57.547	206.447	239.880	127.828	28.250	5.948	33.390	1.478	57.547	234.697	245.828	161.218
2000	0.142	40.351	198.160	239.910	151.690	25.310	5.328	29.912	0.142	40.351	223.470	245.238	181.602
2001	0.158	44.870	220.354	266.780	168.679	28.145	5.925	33.262	0.158	44.870	248.499	272.705	201.941
2002	0.178	50.694	248.956	301.408	190.574	31.798	6.694	37.580	0.178	50.694	280.754	308.102	228.153
2003	0.204	58.177	285.702	345.896	218.703	36.491	7.682	43.126	0.204	58.177	322.193	353.578	261.829
Emissions	*Consumption*0.05*					*Consumption*0.0005*							
1995	0.0030	0.0516	0.3075	1.8798	0.2916	0.0000	0.0000	0.0000	0.0030	0.0516	0.3075	1.8798	0.2916
1996	0.0014	0.0688	4.5881	2.2064	4.8735	0.0000	0.0000	0.0000	0.0014	0.0688	4.5881	2.2064	4.8735
1997	0.0015	0.6950	5.4230	6.5403	4.9470	0.0136	0.0029	0.0160	0.0015	0.6950	5.4365	6.5432	4.9630
1998	0.0015	2.0105	6.1910	15.2615	4.0355	0.0156	0.0033	0.0184	0.0015	2.0105	6.2066	15.2648	4.0539
1999	0.0739	2.8774	10.3224	11.9940	6.3914	0.0141	0.0030	0.0167	0.0739	2.8774	10.3365	11.9970	6.4081
2000	0.0071	2.0176	9.9080	11.9955	7.5845	0.0127	0.0027	0.0150	0.0071	2.0176	9.9207	11.9982	7.5995
2001	0.0079	2.2435	11.0177	13.3390	8.4340	0.0141	0.0030	0.0166	0.0079	2.2435	11.0318	13.3420	8.4506
2002	0.0089	2.5347	12.4478	15.0704	9.5287	0.0159	0.0033	0.0188	0.0089	2.5347	12.4637	15.0737	9.5475
2003	0.0102	2.9088	14.2851	17.2948	10.9351	0.0182	0.0038	0.0216	0.0102	2.9088	14.3033	17.2986	10.9567

Table D.4. HFC Emissions from Mobile Air Conditioning

	First-Fill Emissions			Operating Emissions			Totals		
Consumption	HFC-125	HFC-134a	HFC-143a	HFC-125	HFC-134a	HFC-143a	HFC-125	HFC-134a	HFC-143a
	t	t	t	t	t	t	t	t	t
					From Table D.5				
2003	**0.45**	**1.19**	**0.53**	**120.966**	**320.822**	**142.587**	**121.416**	**322.012**	**143.117**
2002	0.45	1.19	0.53	107.243	284.427	126.412	107.693	285.617	126.942
2001	0.45	1.19	0.53	92.533	244.965	109.072	92.983	246.155	109.602
2000	0.45	1.19	0.53	75.081	198.765	88.501	75.531	199.955	89.031
1999	0.45	1.19	0.53	47.212	124.987	55.651	47.662	126.177	56.181
1998	0.45	1.19	0.53	27.423	72.598	32.325	27.873	73.788	32.855
1997	0.45	1.19	0.53	14.346	37.979	16.910	14.796	39.169	17.440
1996	0.45	1.19	0.53	6.544	17.325	7.714	6.994	18.515	8.244
1995	0.45	1.19	0.53	2.585	6.843	3.047	3.035	8.033	3.577
Emissions		*Consumption*0.95*0.005*			*From Table D.5*				
2003	**0.0021**	**0.0057**	**0.0025**	**12.0970**	**32.0820**	**14.2590**	**12.099**	**32.088**	**12.103**
2002	0.0021	0.0057	0.0025	10.7243	28.4427	12.6412	10.726	28.445	10.730
2001	0.0021	0.0057	0.0025	9.2533	24.4965	10.9072	9.255	24.499	9.259
2000	0.0021	0.0057	0.0025	7.5081	19.8765	8.8501	7.510	19.879	7.514
1999	0.0021	0.0057	0.0025	4.7212	12.4987	5.5651	4.723	12.501	4.727
1998	0.0021	0.0057	0.0025	2.7423	7.2598	3.2325	2.744	7.262	2.748
1997	0.0021	0.0057	0.0025	1.5781	4.1777	1.8601	1.580	4.180	1.584
1996	0.0021	0.0057	0.0025	0.7853	2.0790	0.9257	0.787	2.082	0.791
1995	0.0021	0.0057	0.0025	0.3360	0.8895	0.3961	0.338	0.892	0.342

Table D.5. HFC Emissions from Mobile Air Conditioning - Operating Emissions

					Cars					**All Vehicles : HFC Stock**			
	New vehicles	% MAC vehicles	% MAC vehicles with HFC	Annual MAC-HFC Vehicles	Cumulative MAC-HFC Vehicles	HFC Charge kg	HFC Stock t	HFC emi rate %	HFC emissions t	Total t	HFC-125 t	HFC-134a t	HFC-143a t
A	B	C	D	E	F	G	H	I	J	K	L	M	N
2003	**157063**	**77**	**90**	**108845**	**746279**	**0.8**	**451.848**	**10**	**45.185**	**584.3750**	**120.9661**	**320.8220**	**142.5870**
2002	163837	75	90	110590	637434	0.8	405.303	10	40.530	518.0820	107.2430	284.4270	126.4120
2001	176988	72	90	114688	526844	0.8	352.034	10	35.203	447.0171	92.5324	245.4124	109.0722
2000	250145	70	90	157591	412156	0.8	289.204	10	28.920	362.7100	75.0811	199.1280	88.5013
1999	208309	65	78	105613	254564	0.8	181.257	10	18.126	228.0788	47.2123	125.2152	55.6512
1998	179094	60	66	70921	148952	0.8	107.518	10	10.752	132.4779	27.4229	72.7304	32.3246
1997	168005	47	54	42640	78030	0.8	57.058	11	6.276	69.3042	14.3460	38.0480	16.9102
1996	154592	33	42	21426	35391	0.8	26.075	12	3.129	31.6156	6.5444	17.3570	7.7142
1995	125323	20	30	7519	13964	0.8	10.269	13	1.335	12.4864	2.5847	6.8550	3.0467
1994	117256	20	20	4690	6445	0.8	4.945	14	0.692	6.0162	1.2454	3.3029	1.4680
					Goods Vehicles					**All Vehicles : HFC Operating Emissions**			
										O	**P**	**Q**	**R**
2003	**37308**	**77**	**90**	**25854**	**141942**	**1.2**	132.527	10	13.253	58.4370	**12.0970**	**32.0820**	**14.2590**
2002	33697	75	90	22745	116087	1.2	112.779	10	11.278	51.8080	10.7240	28.4430	12.6410
2001	37072	72	90	24023	93342	1.2	94.982	10	9.498	44.7017	9.2532	24.5410	10.9072
2000	41490	70	90	26139	69319	1.2	73.506	10	7.351	36.2710	7.5081	19.9128	8.8501
1999	40037	65	78	20299	43180	1.2	46.822	10	4.682	22.8079	4.7212	12.5215	5.5651
1998	29588	60	66	11717	22882	1.2	24.960	10	2.496	13.2478	2.7423	7.2730	3.2325
1997	24201	47	54	6142	11165	1.2	12.247	11	1.347	7.6235	1.5781	4.1853	1.8601
1996	21713	33	42	3009	5023	1.2	5.541	12	0.665	3.7939	0.7853	2.0828	0.9257
1995	18013	20	30	1081	2013	1.2	2.218	13	0.288	1.6232	0.3360	0.8912	0.3961
1994	16632	20	20	665	932	1.2	1.071	14	0.150	0.8423	0.1744	0.4624	0.2055

E = B*C*D/10000
G from IPCC good practice guidance
I from IPCC good practice guidance

$H = (E*G/1000)_{year\ t} + (H-J)_{year\ t-1}$
$J = H*I$
$K = H_{cars} + H_{goods\ vehicles}$
$O = J_{cars} + J_{goods\ vehicles}$

L = K*0.207
M = K*0.548
N = K*0.244

P = O*0.207
Q = O*0.548
R = O*0.244

Table D.6. HFC Emissions from Closed Cell Foam

	Use of HFC t	Cumulative Charge t	Annual Losses t
A	B	C	D
		$= C_{t-1} - D_{t-1} + B_t$	$= C_t*0.045$
1990	0.0	0.000	0.000
1991	0.0	0.000	0.000
1992	0.2	0.200	0.009
1993	0.5	0.691	0.031
1994	2.7	3.360	0.151
1995	4.0	7.209	0.324
1996	6.0	12.884	0.580
1997	9.0	21.305	0.959
1998	25.0	45.346	2.041
1999	25.0	68.305	3.074
2000	19.0	84.232	3.790
2001	54.5	134.941	6.072
2002	54.5	183.369	8.252
2003	**54.5**	**229.617**	**10.333**

Table D.7. HFC Emissions from Fire Protection Equipment

	Growth Rate %	HFC-227ea Use t	Cumulative HFC-227ea t	HFC-227ea Emissions t
A	B	C	D	E
			$C_{year\ t}$ + $(D - E)_{year\ t-1}$	E=D*0.01
2003	**12.5**	**45.00**	398.56	3.986
2002	12.5	40.00	357.13	3.571
2001	12.5	35.56	320.33	3.203
2000	12.5	31.60	287.65	2.877
1999	8.8	28.09	258.63	2.586
1998	8.8	25.82	232.87	2.329
1997	8.8	23.73	209.14	2.091
1996	8.8	21.81	187.28	1.873
1995	8.8	20.05	167.14	1.671
1994	8.8	18.43	148.57	1.486
1993	8.8	16.94	131.46	1.315
1992	3.3	15.57	115.68	1.157
1991	1.9	15.07	101.13	1.011
1990	7.1	14.79	86.92	0.869
1989	6.2	13.81	72.87	0.729
1988	4.5	13.00	59.65	0.597
1987	4.4	12.44	47.12	0.471
1986	0.4	11.92	35.03	0.350
1985	2.4	11.87	23.35	0.233
1984	3.7	11.59	11.59	0.116

Table D.8. Company Estimates of HFC, PFC and SF_6 Emissions

(a) Use of HFC, PFC and SF6 in Semiconductor Manufacture (tonnes)

	HFC-23	HFC-32	HFC-125	HFC-134a	CF4	C2F6	C3F8	c-C4F8	SF6
1990	0.060	0.000	0.000	0.000	0.005	0.100			0.030
1995	0.200	0.000	0.000	0.000	2.700	10.600			2.600
1996	0.400	0.000	0.000	0.000	3.900	14.800			3.600
1997	0.600	0.000	0.000	0.300	5.100	19.000			4.800
1998	0.400	0.010	0.020	0.430	3.200	10.500			3.200
1999	1.100	0.010	0.020	0.480	5.700	29.100			1.000
2000	1.400	0.010	0.020	0.530	8.200	43.800			1.900
2001	1.026	0.000	0.000	0.000	8.718	43.000			1.257
2002	0.595	0.000	0.000	0.000	7.541	29.832	0.018	0.500	2.588
2003	**0.625**	**0.000**	**0.000**	**0.794**	**10.523**	**29.928**	**0.000**	**0.980**	**5.175**

(b) Emissions of HFC, PFC and SF6 in Semiconductor Manufacture (tonnes)

	HFC-23	HFC-32	HFC-125	HFC-134a	CF4	C2F6	C3F8	c-C4F8	SF6
1990	0.040	0.000	0.000	0.000	0.003	0.008			0.020
1995	0.200	0.000	0.000	0.000	1.900	6.800			1.800
1996	0.300	0.000	0.000	0.000	2.800	9.200			2.600
1997	0.400	0.000	0.000	0.180	3.600	11.700			3.400
1998	0.300	0.008	0.009	0.260	2.300	5.100			2.200
1999	0.800	0.008	0.009	0.290	4.100	18.400			0.700
2000	1.000	0.008	0.009	0.320	5.900	29.000			1.300
2001	0.990	0.000	0.000	0.000	7.280	27.085			0.914
2002	0.217	0.000	0.000	0.000	6.025	18.169	0.011	0.100	1.293
2003	**0.257**	**0.000**	**0.000**	**0.476**	**8.404**	**18.086**	**0.00**	**0.300**	**2.585**

(c) Emissions of SF6 from Electrical Equipment (tonnes)

	Stock	Emissions
1990	20	0.900
1995	24	1.100
1996	25	1.104
1997	26	1.560
1998	27	1.056
1999	28	1.464
2000	29	0.326
2001	30	1.341
2002	30	1.149[a]
2003	**30**	**1.067[b]**

a average over the previous five years
b average over the previous five years

Table D.9. Emissions of SF_6 from Soundproof Windows

	Units made in Ireland kg	Imported Units kg	Assembly Loss kg	Opening Stock kg	Closing Stock kg	Installed Leakage kg	Total Emissions t
A	B	C	D	E	F	G	H
1990	52	52	17.16	86.840	85.972	0.868	0.0180
1991	52	52	17.16	172.812	171.083	1.728	0.0189
1992	52	52	17.16	257.923	255.344	2.579	0.0197
1993	52	52	17.16	342.184	338.762	3.422	0.0206
1994	52	52	17.16	425.602	421.346	4.256	0.0214
1995	52	52	17.16	508.186	503.105	5.082	0.0222
1996	52	52	17.16	589.945	584.045	5.899	0.0231
1997	52	52	17.16	670.885	664.176	6.709	0.0239
1998	52	52	17.16	751.016	743.506	7.510	0.0247
1999	52	52	17.16	830.346	822.043	8.303	0.0255
2000	52	75	17.16	931.883	922.564	9.319	0.0265
2001	52	104	17.16	1061.404	1050.790	10.614	0.0278
2002	52	104	17.16	1189.630	1177.733	11.896	0.0291
2003	**52**	**104**	**17.16**	**1316.573**	**1303.408**	**13.165**	**0.0303**

D = B*0.33

$E = F_{year\ t-1} + (B + C - D)_{year\ t}$

G = E*0.01

H = (D + G)/1000

Appendix E

Calculation Sheets for Solvents

Years 1990 - 2003

Table E.1. Estimation of CO_2 Emissions from Solvents

	Painting	Degreasing & Dry Cleaning	Chemical Products	Other Uses of Solvents	Total VOC	CO_2 Gg
1990	8857	3981	3699	12812	29348	91.47
1991	9013	3988	3702	12848	29550	92.10
1992	9205	4010	3712	13029	29955	93.36
1993	9456	4032	3721	13126	30336	94.55
1994	9753	4054	3734	13367	30909	96.33
1995	10053	4076	3751	13623	31503	98.19
1996	10374	4099	3768	13855	32096	100.03
1997	10652	4136	3792	14354	32935	102.65
1998	11071	4181	3818	14687	33757	105.21
1999	10863	4237	3864	15134	34097	106.27
2000	10836	4348	3898	15763	34845	108.60
2001	10490	4385	3919	16047	34842	108.59
2002	10273	4422	3944	16398	35037	109.20
2003	**10454**	**4491**	**3968**	**16637**	**35550**	**110.80**

Total VOC (Mg) contribution to CO_2 (Gg) estimated as $CO_2 = 0.85*VOC*44/12000$

Appendix F

Activity Data and Calculation Sheets for Agriculture

Year 2003

Calculation Sheets Extracted from the IPCC Software Module for Agriculture

Table F.1. Activity Data for Agriculture

1. Published Annual Statistics **All figures Revised on 22/07/2004 using CSO EireStat Service**

	CSO Dairy Cattle June *capita*	*CSO* Dairy Cattle Dec *capita*	*CSO* Other Cattle June *capita*	*CSO* Other Cattle Dec *capita*	*CSO* Dairy Cattle average *capita*	*CSO* Other Cattle average *capita*	*CSO* Sheep June *capita*	*CSO* Sheep Dec *capita*	*CSO* Sheep average *capita*
1980	1,583,300	1,448,900	5,325,600	4,376,600	1,516,100	4,851,100	3,291,520	2,343,600	2,817,560
1985	1,579,100	1,495,200	5,240,300	4,317,800	1,537,150	4,779,050	4,486,600	3,304,000	3,895,300
1988	1,395,300	1,335,000	5,069,000	4,363,700	1,365,150	4,716,350	6,656,300	4,991,200	5,823,750
1989	1,381,900	1,341,600	5,260,400	4,627,500	1,361,750	4,943,950	7,624,600	5,713,900	6,669,250
1990	1,359,700	1,322,200	5,456,500	4,778,300	1,340,950	5,117,400	8,539,000	5,863,700	7,201,350
1991	1,330,800	1,288,000	5,581,200	4,859,400	1,309,400	5,220,300	8,888,200	5,982,600	7,435,400
1992	1,277,900	1,246,200	5,673,500	4,990,200	1,262,050	5,331,850	8,897,900	6,109,200	7,503,550
1993	1,263,500	1,248,300	5,718,300	5,015,600	1,255,900	5,366,950	8,626,700	5,966,500	7,296,600
1994	1,260,600	1,233,000	5,735,900	5,110,900	1,246,800	5,423,400	8,404,200	5,739,700	7,071,950
1995	1,256,200	1,220,800	5,777,800	5,229,800	1,238,500	5,503,800	8,331,500	5,543,400	6,937,450
1996	1,266,400	1,215,600	6,047,100	5,445,300	1,241,000	5,746,200	7,888,200	5,341,900	6,615,050
1997	1,251,700	1,201,400	6,281,000	5,680,200	1,226,550	5,980,600	8,131,500	5,577,200	6,854,350
1998	1,233,800	1,198,800	6,406,200	5,752,900	1,216,300	6,079,550	8,312,000	5,559,100	6,935,550
1999	1,200,600	1,173,800	6,186,400	5,384,100	1,187,200	5,785,250	7,925,500	5,318,600	6,622,050
2000	1,177,500	1,152,800	5,859,900	5,177,400	1,165,150	5,518,650	6,891,600	5,056,000	5,973,800
2001	1,182,500	1,148,000	5,867,200	5,260,100	1,165,250	5,563,650	7,330,300	4,807,000	6,068,650
2002	1,164,100	1,128,700	5,828,100	5,204,100	1,146,400	5,516,100	7,209,600	4,828,500	6,019,050
2003	1,155,600	1,135,700	5,811,200	5,087,800	1,145,650	5,449,500	6,848,900	4,850,100	5,849,500

Three-Year Averages Ending on the Year

	Dairy Cattle June	Dairy Cattle Dec	Other Cattle June	Other Cattle Dec	Dairy Cattle average	Other Cattle average	Sheep June	Sheep Dec	Sheep average
1980	1,583,300	1,448,900	5,325,600	4,376,600	1,516,100	4,851,100	3,291,520	2,343,600	2,817,560
1985	1,632,600	1,527,700	5,274,600	4,251,300	1,580,150	4,762,950	3,988,600	2,774,300	3,381,450
1990	1,378,967	1,332,933	5,261,967	4,589,833	1,355,950	4,925,900	7,606,633	5,522,933	6,564,783
1991	1,357,467	1,317,267	5,432,700	4,755,067	1,337,367	5,093,883	8,350,600	5,853,400	7,102,000
1992	1,322,800	1,285,467	5,570,400	4,875,967	1,304,133	5,223,183	8,775,033	5,985,167	7,380,100
1993	1,290,733	1,260,833	5,657,667	4,955,067	1,275,783	5,306,367	8,804,267	6,019,433	7,411,850
1994	1,267,333	1,242,500	5,709,233	5,038,900	1,254,917	5,374,067	8,642,933	5,938,467	7,290,700
1995	1,260,100	1,234,033	5,744,000	5,118,767	1,247,067	5,431,383	8,454,133	5,749,867	7,102,000
1996	1,261,067	1,223,133	5,853,600	5,262,000	1,242,100	5,557,800	8,207,967	5,541,667	6,874,817
1997	1,258,100	1,212,600	6,035,300	5,451,767	1,235,350	5,743,533	8,117,067	5,487,500	6,802,283
1998	1,250,633	1,205,267	6,244,767	5,626,133	1,227,950	5,935,450	8,110,567	5,492,733	6,801,650
1999	1,228,700	1,191,333	6,291,200	5,605,733	1,210,017	5,948,467	8,123,000	5,484,967	6,803,983
2000	1,203,967	1,175,133	6,150,833	5,438,133	1,189,550	5,794,483	7,709,700	5,311,233	6,510,467
2001	1,186,867	1,158,200	5,971,167	5,273,867	1,172,533	5,622,517	7,382,467	5,060,533	6,221,500
2002	1,174,700	1,143,167	5,851,733	5,213,867	1,158,933	5,532,800	7,143,833	4,897,167	6,020,500
2003	1,167,400	1,137,467	5,835,500	5,184,000	1,152,433	5,509,750	7,129,600	4,828,533	5,979,067

Table F.1 (continued). Activity Data for Agriculture

(c) Published Annual Statistics

	Pigs June capita	Pigs Dec capita	Pigs average capita	Poultry (June) capita	Horses capita	Mules capita	Goats capita	Chemical Fert Tonnes N	Limestone on Land Tonnes
1980	1,030,460	1,030,800	1,030,630	9,903,270	68,460	6,500	18,500	275,060	959,110
1985	1,004,000	994,100	999,050	9,582,000	57,700	6,900	18,000	322,750	878,410
1988	1,013,900	1,014,500	1,014,200	10,041,500				350,000	
1989	1,067,100	1,110,100	1,088,600	10,378,900	51,700	7,300	17,400	370,000	940,616
1990	1,194,400	1,249,100	1,221,750	11,335,400	53,500	7,300	17,400	379,311	806,900
1991	1,303,700	1,345,500	1,324,600	12,052,800	63,100	7,300	17,400	375,457	716,239
1992	1,385,800	1,422,700	1,404,250	12,039,200	65,100	8,000	17,800	358,302	580,911
1993	1,521,600	1,487,200	1,504,400	12,900,000	66,200	8,500	17,600	377,985	812,045
1994	1,530,400	1,498,300	1,514,350	14,615,800	67,000	7,800	16,100	404,811	612,821
1995	1,550,400	1,542,300	1,546,350	13,248,400	68,000	7,000	15,600	428,826	1,124,080
1996	1,620,800	1,664,500	1,642,650	13,170,500	69,900	7,600	14,900	416,918	1,100,076
1997	1,699,500	1,717,000	1,708,250	13,432,600	71,900	7,100	15,200	380,350	962,471
1998	1,818,600	1,800,900	1,809,750	13,146,900	72,800	7,500	15,100	431,999	750,000
1999	1,786,900	1,762,900	1,774,900	12,697,400	75,500	7,300	13,500	442,916	870,971
2000	1,722,100	1,731,500	1,726,800	13,960,800	69,900	5,000	8,100	407,598	832,689
2001	1,741,100	1,762,900	1,752,000	12,602,600	71,000	4,900	7,800	368,667	875,642
2002	1,769,500	1,781,500	1,775,500	12,708,600	72,600	4,700	7,700	363,513	622,499
2003	1,713,400	1,731,600	1,722,500	12,737,800	70,400	5,800	7,600	388,080	879,000

Three-Year Averages Ending on the Year

	Pigs June	Pigs Dec	Pigs average	Poultry	Horses	Mules	Goats	Chemical Fert	Limestone on Land
1980	1,030,460	1,030,800	1,030,630	9,903,270	68,460	6,500	18,500	275,060	959,110
1985	1,004,000	994,100	999,050	8,914,000	57,700	6,900	18,000	322,750	878,410
1990	1,091,800	1,124,567	1,108,183	10,585,267	52,600	7,300	17,400	366,437	873,758
1991	1,188,400	1,234,900	1,211,650	11,255,700	56,100	7,300	17,400	374,923	821,252
1992	1,294,633	1,339,100	1,316,867	11,809,133	60,567	7,533	17,533	371,023	701,350
1993	1,403,700	1,418,467	1,411,083	12,330,667	64,800	7,933	17,600	370,581	703,065
1994	1,479,267	1,469,400	1,474,333	13,185,000	66,100	8,100	17,167	380,366	668,592
1995	1,534,133	1,509,267	1,521,700	13,588,067	67,067	7,767	16,433	403,874	849,649
1996	1,567,200	1,568,367	1,567,783	13,678,233	68,300	7,467	15,533	416,852	945,659
1997	1,623,567	1,641,267	1,632,417	13,283,833	69,933	7,233	15,233	408,698	1,062,209
1998	1,712,967	1,727,467	1,720,217	13,250,000	71,533	7,400	15,067	409,756	937,516
1999	1,768,333	1,760,267	1,764,300	13,092,300	73,400	7,300	14,600	418,422	861,147
2000	1,775,867	1,765,100	1,770,483	13,268,367	72,733	6,600	12,233	427,504	817,887
2001	1,750,033	1,752,433	1,751,233	13,086,933	72,133	5,733	9,800	406,394	859,767
2002	1,744,233	1,758,633	1,751,433	13,090,667	71,167	4,867	7,867	379,926	776,943
2003	1,741,333	1,758,667	1,750,000	12,683,000	71,333	5,133	7,700	373,420	792,380

Table F.1 (continued). Activity Data for Agriculture

(e) Annual Crop Production 2003 (Tonnes)						
	Pulses	Potatoes	Sugarbeet	Barley	Oats	Wheat
1990	15000	605000	1480000	1223000	144000	598000
1991	13000	571000	1409000	1148000	143000	673000
1992	13000	642000	1397000	1168000	136000	713000
1993	26000	569000	1117000	958000	129300	539000
1994	25000	642000	1390000	910000	128000	572000
1995	19000	618000	1547000	1084000	129000	583000
1996	21000	733000	1395400	1225000	146000	771000
1997	19000	472000	1366300	1087000	132000	725000
1998	32000	482000	1375200	1073000	119000	673000
1999	18000	559000	1439900	1278000	136000	597000
2000	7200	455000	1410400	1309700	125600	737400
2001	9000	478000	1498000	1275600	120500	769000
2002	8000	519000	1313000	963000	134000	867000
2003	**14000**	**488000**	**1505000**	**1198000**	**155000**	**794000**

(f) Three-year Average Crop Production (Tonnes)						
	Pulses	Potatoes	Sugarbeet	Barley	Oats	Wheat
1990	15000	610000	1421667	1341000	141667	504000
1991	14333	576667	1446667	1232000	140333	576667
1992	13667	606000	1428667	1179667	141000	661333
1993	17333	594000	1307667	1091333	136100	641667
1994	21333	617667	1301333	1012000	131100	608000
1995	23333	609667	1351333	984000	128767	564667
1996	21667	664333	1444133	1073000	134333	642000
1997	19667	607667	1436233	1132000	135667	693000
1998	24000	562333	1378967	1128333	132333	723000
1999	23000	504333	1393800	1146000	129000	665000
2000	19067	498667	1408500	1220233	126867	669133
2001	11400	497333	1449433	1287767	127367	701133
2002	8067	484000	1407133	1182767	126700	791133
2003	**10333**	**495000**	**1438666**	**1145533**	**136500**	**810000**

Table F.2 CH_4 Emissions from Agriculture 2003

SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**					
WORKSHEET	**4-1**					
SHEET	**1 OF 2 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**					
		STEP 1	**STEP 2**			**STEP 3**
	A	B	C	D	E	F
Livestock Type	Population (1000s)	Emission Factor	Emissions from Enteric Fermentation	Emission Factor	Emissions from Manure Management	Total Annual Emissions from Domestic Livestock
		(kg/head/yr)	(t/yr)	(kg/head/yr)	(t/yr)	(Gg)
		Enteric Fermentation		Manure Management*		
			C = (A x B)		E = (A x D)	F =(C + E)/1000
Dairy Cattle	1,152.433	100	115,243.300	15.90	18,323.68	133.567
Non-dairy Cattle	5,509.750	50	275,487.500	6.40	35,262.40	310.750
Buffalo	0.000	0	0.000	0.00	0.00	0.000
Sheep	5,979.067	8	47,832.536	0.00	0.00	47.833
Goats	7.700	5	38.500	0.00	0.00	0.039
Camels	0.000	0	0.000	0.00	0.00	0.000
Horses	71.333	18	1,283.994	0.00	0.00	1.284
Mules & Asses	5.133	10	51.330	0.00	0.00	0.051
Swine	1,750.000	1.5	2,625.000	5.40	9,450.00	12.075
Poultry	12,683.000	0	0.000	0.10	1,268.30	1.268
Totals			442,562.160		64,304.38	506.867

**Manure management emission factors determined below*

	a	b	c	d	e	f
	Density	B_O	V_S	AWMS	MCF	EF
	kg/m^3	m^3/kg	kg/day	%		kg/year
						f=365*a*b*c*d*e
Lagoons	0.67	0.24	5.10	0.02	0.90	5.39
Liquid System	0.67	0.24	5.10	0.28	0.10	8.38
Storage/Drylot	0.67	0.24	5.10	0.12	0.01	0.36
Grazing	0.67	0.24	5.10	0.58	0.01	1.74
Dairy Cattle						**15.86**
Lagoons	0.67	0.24	2.70	0.02	0.90	2.85
Liquid System	0.67	0.24	2.70	0.15	0.10	2.38
Storage/Drylot	0.67	0.24	2.70	0.18	0.01	0.29
Grazing	0.67	0.24	2.70	0.65	0.01	1.03
Other Cattle						**6.54**
Lagoons	0.67	0.45	0.50	0.40	0.10	2.20
Liquid System	0.67	0.45	0.50	0.60	0.10	3.30
Storage/Drylot	0.67	0.45	0.50	0.00	0.01	0.00
Grazing	0.67	0.45	0.50	0.00	0.01	0.00
Pigs						**5.50**

a, b, c and e from IPCC Good Practice Guidance

d : estimated distribution of wastes for each management system

Table F.3 Animal Waste Management : Anaerobic Lagoons

MODULE	**AGRICULTURE**
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**
WORKSHEET	**4-1 (SUPPLEMENTAL)**
SPECIFY AWMS	**ANAEROBIC LAGOONS**
SHEET	**NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM**
COUNTRY	**Ireland**
YEAR	**2003**

Livestock Type	A Number of Animals (# of animals)	B Nitrogen Excretion Nex (kg//head/(yr)	C Fraction of Manure Nitrogen per AWMS (%/100) (fraction)	D Nitrogen Excretion per AWMS, Nex (kg/N/yr)
				D = (A x B x C)
Non-dairy Cattle	5,509,750	50	0.02	5,509,750.00
Dairy Cattle	1,152,433	92.5	0.02	2,132,001.05
Poultry	12,683,000	0.6	0.2	1,521,960.00
Sheep	5,979,067	8	0	0.00
Swine	1,750,000	12	0	0.00
Others				0.00
			TOTAL	9,163,711.05

Table F.3 (continued) Animal Waste Management : Liquid Systems

MODULE	**AGRICULTURE**
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**
WORKSHEET	**4-1 (SUPPLEMENTAL)**
SPECIFY AWMS	**LIQUID SYSTEMS**
SHEET	**NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM**
COUNTRY	**Ireland**
YEAR	**2003**

Livestock Type	A Number of Animals (1000s)	B Nitrogen Excretion Nex (kg//head/(yr)	C Fraction of Manure Nitrogen per AWMS (%/100) (fraction)	D Nitrogen Excretion per AWMS, Nex (kg/N/yr)
				D = (A x B x C)
Non-dairy Cattle	5,509,750	50	0.15	41,323,125.00
Dairy Cattle	1,152,433	92.5	0.28	29,848,014.70
Poultry	12,683,000	0.6	0.8	6,087,840.00
Sheep	5,979,067	8	0	0.00
Swine	1,750,000	12	1	21,000,000.00
Others	0	0	0	0.00
			TOTAL	98,258,979.70

Table F.3 (continued) Animal Waste Management : Solid Storage & Drylot

MODULE	**AGRICULTURE**
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**
WORKSHEET	**4-1 (SUPPLEMENTAL)**
SPECIFY AWMS	**SOLID STORAGE AND DRYLOT**
SHEET	**NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM**
COUNTRY	**Ireland**
YEAR	**2003**

Livestock Type	A Number of Animals (1000s)	B Nitrogen Excretion Nex (kg//head/(yr)	C Fraction of Manure Nitrogen per AWMS (%/100) (fraction)	D Nitrogen Excretion per AWMS, Nex (kg/N/yr)
				D = (A x B x C)
Non-dairy Cattle	5,509,750	50	0.18	49,587,750.00
Dairy Cattle	1,152,433	92.5	0.12	12,792,006.30
Poultry	12,683,000	0.6	0	0.00
Sheep	5,979,067	8	0	0.00
Swine	1,750,000	12	0	0.00
Others	0	0	0	0.00
			TOTAL	62,379,756.30

Table F.3 (continued) Animal Waste Management : Pasture, Range & Paddock

MODULE	**AGRICULTURE**
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**
WORKSHEET	**4-1 (SUPPLEMENTAL)**
SPECIFY AWMS	**PASTURE RANGE AND PADDOCK**
SHEET	**NITROGEN EXCRETION FOR ANIMAL WASTE MANAGEMENT SYSTEM**
COUNTRY	**Ireland**
YEAR	**2003**

Livestock Type	A Number of Animals (1000s)	B Nitrogen Excretion Nex (kg//head/(yr)	C Fraction of Manure Nitrogen per AWMS (%/100) (fraction)	D Nitrogen Excretion per AWMS, Nex (kg/N/yr)
				D = (A x B x C)
Non-dairy Cattle	5,509,750	50	0.65	179,066,875.00
Dairy Cattle	1,152,433	92.5	0.58	61,828,030.45
Poultry	12,683,000	0.6	0	0.00
Sheep	5,979,067	8	1	47,832,536.00
Swine	1,750,000	12	0	0.00
Others	0	0	0	0.00
			TOTAL	288,727,441.45

Table F.4 N_2O Emissions from Animal Production

MODULE	**AGRICULTURE**
SUBMODULE	**METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT**
WORKSHEET	**4-1**
SHEET	**2 OF 2 NITROUS OXIDE EMISSIONS FROM ANIMAL PRODUCTION EMISSIONS FROM ANIMAL WASTE MANAGEMENT SYSTEMS (AWMS)**
COUNTRY	**Ireland**
YEAR	**2003**

STEP 4			
Animal Waste Management System (AWMS)	A Nitrogen Excretion $Nex_{(AWMS)}$ (kg N/yr)	B Emission Factor For AWMS EF_3 (kg N_2O–N/kg N)	C Total Annual Emissions of N_2O (Gg)
			C=(AxB)[44/28] / 1 000 000
Anaerobic lagoons	9,163,711.05	0.001	0.0144
Liquid systems	98,258,979.70	0.001	0.1544
Daily spread	0.00		
Solid storage & drylot	62,379,756.30	0.02	1.9605
Pasture range and paddock[a]	288,727,441.45		
Other	0.00		0.0000
Total	458,529,888.50		2.1293

a : Emissions under pasture range and paddock calculated in Table F.7

Table F.5 N_2O Emissions from Crops in 2003

Crops *2003*	Production Mt	Residue/Prod Ratio	Fraction Dry Matter	Fraction Nitrogen	FBN kg N	Fcr kg N	EF_1 kg/kg	N_2O (Gg) N-fixing	N_2O (Gg) Residues
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Pulses	10,333	1.8	0.87	0.014	352,397	226,541	0.0125	0.007	0.004
Potatoes	495,000	0.4	0.85	0.011		1,851,300	0.0125		0.036
Sugarbeet	1,438,666	0.3	0.85	0.023		8,437,776	0.0125		0.166
Barley	1,145,533	1.2	0.85	0.004		4,673,775	0.0125		0.092
Oats	136,500	1.3	0.92	0.007		1,142,778	0.0125		0.022
Wheat	810,000	1.3	0.85	0.003		2,685,150	0.0125		0.053
					352,397	19,017,319		0.007	0.374

B	*Production data from CSO*	*H*	*GPG Table 4.17*
C, D, E	*GPG Table 4.16*	*I*	*F*H*44/28000000*
F	*GPG Equation 4.26*	*J*	*G*H*44/28000000*
G	*GPG Equation 4.29*		

Table F.6 Direct N_2O Emissions

MODULE	**AGRICULTURE**
SUBMODULE	**AGRICULTURAL SOILS**
WORKSHEET	**4-5**
SHEET	**1 OF 5 DIRECT NITROUS OXIDE EMISSIONS FROM AGRICULTURAL FIELDS, EXCLUDING CULTIVATION OF HISTOSOLS**
COUNTRY	**Ireland**
YEAR	**2003**

	STEP 1	STEP 2	
Type of N input to soil	A Amount of N Input (kg N/yr)	B Factor for Direct Emissions EF_1 (kg N_2O–N/kg N)	C Direct Soil Emissions (Gg N_2O-N/yr)
			C = (A x B)/1 000 000
Synthetic fertiliser (F_{SN})	359,230,040	0.0125	4.490
Animal waste (F_{AW})	140,256,821	0.0125	1.753
N-fixing crops (F_{BN})	352,396	0.0125	0.004
Crop residue (F_{CR})	19,017,318	0.0125	0.238
		Total	6.487

F_{SN} from Table F.8 [A less C]
F_{AW} from Supplemental Table below
F_{BN} and F_{cr} from Table F.5 above

MODULE	**AGRICULTURE**
SUBMODULE	**AGRICULTURAL SOILS**
WORKSHEET	**4-5A (SUPPLEMENTAL)**
SHEET	**1 OF 1 MANURE NITROGEN USED**
COUNTRY	**Ireland**
YEAR	**2003**

A Total Nitrogen Excretion (kg N/yr)	B Fraction of Nitrogen Burned for Fuel (fraction)	C Fraction of Nitrogen Excreted During Grazing FracGRAZ	D Fraction of Nitrogen Excreted Emitted as NOX and NH3 FracGASM	E Sum (fraction)	F Manure Nitrogen Used (corrected for NOX and NH3 emissions), FAW (kg N/yr)
				E = (1-C)*(1-D)	F = A x E
458,529,888.50	0.00	0.63	0.17	0.31	140,256,821.26

The value of 0.31 in column E obtained from (1-$Frac_{GRAZ}$)(1-$Frac_{GASM}$) corresponds to that in GPG Equation 4.23 (with $Frac_{FUEL}$ equal to 0) instead of the fraction as calculated according to the 1996 IPCC Guidelines*

Table F.7. N_2O Emissions from Grazing Animals

MODULE	**AGRICULTURE**		
SUBMODULE	**AGRICULTURAL SOILS**		
WORKSHEET	**4-5**		
SHEET	**3 OF 5 NITROUS OXIDE SOIL EMISSIONS FROM GRAZING ANIMALS - PASTURE RANGE AND PADDOCK**		
COUNTRY	**Ireland**		
YEAR	**2003**		
	STEP 5		
Animal Waste Management System (AWMS)	A Nitrogen Excretion $Nex_{(AWMS)}$ (kg N/yr)	B Emission Factor for AWMS EF_3 (kg N_2O–N/kg N)	C Emissions Of N_2O from Grazing Animals (Gg)
			C = (A x B)[44/28]/10^6
Pasture range & paddock	288,727,441.45	0.02	9.074

Table F.8 Indirect Emissions of N_2O from Atmospheric Deposition

MODULE	**AGRICULTURE**
SUBMODULE	**AGRICULTURAL SOILS**
WORKSHEET	**4-5**
SHEET	**4 OF 5 INDIRECT NITROUS OXIDE EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NH_3 AND NO_X**
COUNTRY	**Ireland**
YEAR	**2003**

	STEP 6							
Type of Deposition	A Synthetic Fertiliser N Applied to Soil, N_{FERT} (kg N/yr)	B Fraction of Synthetic Fertiliser N Applied that Volatilizes $Frac_{GASFS}$ (kg N/kg N)	C Amount of Synthetic N Applied to Soil that Volatilizes (kg N/kg N)	D Total N Excretion by Livestock N_{EX} (kg N/yr)	E Fraction of Total Manure N Excreted that Volatilizes $Frac_{GASM}$ (kg N/kg N)	F Total N Excretion by Livestock that Volatilizes (kg N/kg N)	G Emission Factor EF_4 (kg N_2O–N/kg N)	H Nitrous Oxide Emissions (Gg N_2O–N/yr)
			C = (A x B)			F = (D x E)		H = (C + F) x G /1 000 000
Total	373,420,000	0.038	14,189,960	458,529,889	0.174	79,784,201	0.01	0.940

$Frac_{GASFS}$ from Table F.11
$Frac_{GASM}$ from Table F.10

Table F.9 Indirect Emissions of N_2O from Nitrogen Leaching

MODULE	**AGRICULTURE**						
SUBMODULE	**AGRICULTURAL SOILS**						
WORKSHEET	**4-5**						
SHEET	**5 OF 5 INDIRECT NITROUS OXIDE EMISSIONS FROM LEACHING**						
COUNTRY	**Ireland**						
YEAR	**2003**						
	STEP 7					**STEP 8**	**STEP 9**
	I	J	K	L	M	N	O
	Synthetic Fertiliser Use N_{FERT}	Livestock N Excretion N_{EX}	Fraction of N that Leaches $Frac_{LEACH}$	Emission Factor EF_5	Nitrous Oxide Emissions From Leaching	Total Indirect Nitrous Oxide Emissions	Total Nitrous Oxide Emissions
	(kg N/yr)	(kg N/yr)	(kg N/kg N)		(Gg N_2O–N/yr)	(Gg N_2O/yr)	(Gg)
					M = (I + J) x K x L/1 000 000	N = (H + M)[44/28]	O = (G + C + N) (G from Worksheet 4 -5, sheet 2, Step 4; C from Worksheet 4-5, sheet 3, Step 5; N from Worksheet 4-5, sheet 5, Step 8).
Total	373,420,000.00	458,529,888.50	0.10	0.025	2.08	4.745	24.011

Table F.10. Emissions of NH_3 from Organic Nitrogen in 2003

b	CSO	*From above Worksheet 4-1(supplemental)*						*NH_3-N loss rates based on Atmospheric Emission Inventory Guidebook Vol 2, 1996*								
b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
	Pop 3-year average	N excretion kg/head	Aerobic Lagoons	kg N per AWMS Liquid	Solid Storage	Pasture	Total N kg e+f+g+h	N excreted in stable kg e+f+g	*NH_3-N in stable kg*	N to storage kg	*NH_3-N from storage kg*	Mineral N for spreading kg	*NH_3-N spreading kg*	*NH_3-N grazing kg*	*Total NH_3-N kg* k+m+o+p	NH3 Emissions tonnes q*17/14000
Dairy Cattle	1,152,433	92.5	2,132,001	29,848,015	12,792,006	61,828,030	106,600,053	44,772,022	*5,372,643*	39,399,379	*2,363,963*	18,517,708	*7,407,083*	*4,946,242*	*20,089,931*	**24,395**
Other Cattle	5,509,750	50	5,509,750	41,323,125	49,587,750	179,066,875	275,487,500	96,420,625	*11,570,475*	84,850,150	*5,091,009*	39,879,571	*15,951,828*	*14,325,350*	*46,938,662*	**56,997**
Pigs	1,750,000	12	8,400,000	12,600,000	0	0	21,000,000	21,000,000	*3,570,000*	17,430,000	*1,045,800*	8,192,100	*3,276,840*	*0*	*7,892,640*	**9,584**
Sheep	5,979,067	8	0	0	0	47,832,536	47,832,536	0	*0*	0	*0*	0	*0*	*1,913,301*	*1,913,301*	**2,323**
Poultry	12,683,000	0.6	1,521,960	6,087,840	0	0	7,609,800	7,609,800	*1,521,960*	6,087,840	*243,514*	2,337,731	*1,168,865*	*0*	*2,934,339*	**3,563**
			17,563,711	**89,858,980**	**62,379,756**	**288,727,441**	**458,529,889**	169,802,447	*22,035,078*	147,767,369	*8,744,285*	70,462,730	*27,804,617*	*21,184,894*	*79,768,874*	**96,862**
		% AWMS	*3.8*	*19.6*	*13.6*	*63.0*	**Percentage of total animal waste N lost as NH_3 [100*(total of q/total of I)]**								**17.40**	

Table F.11. Emissions of NH_3 from Chemical Fertilizers in 2003

Fertilizer Type	kg N applied	kg NH_3-N per kg N*	NH_3-N kg	NH_3 Tonnes
Ammonium Sulphate	571,000	0.08	45,680	55.5
Ammonium Nitrate		0.02	0	0.0
Calcium Ammonium Nitrate	137,384,000	0.02	2,747,680	3336.5
Anhydrous Ammonia		0.04	0	0.0
Urea	49,230,000	0.15	7,384,500	8966.9
Mono-ammonium Phosphate		0.02	0	0.0
Di-ammonium Phosphate		0.05	0	0.0
Other NPK Fertilizers	200,118,000	0.02	4,002,360	4860.0
Nitrogen Solution		0.08	0	0.0
ASN	777,000	0.05	38,850	47.2
Total	**388,080,000**		**14,219,070**	**17266.00**
Weighted Fertilizer NH_3 EF		**0.037**		

**based on Atmospheric Emission Inventory Guidebook Vol 2, (McInnes,1996)*

Appendix G

Preliminary Estimates of Carbon Stock Changes in Managed Forests In the Republic of Ireland 1990-2000

Gerhardt Gallagher, Eugene Hendrick and Kenneth Byrne

Introduction

In 2000, following a request from UNFCCC for additional information on net carbon uptake in forests in the Republic of Ireland during one year, COFORD commissioned a study to estimate carbon increment and carbon removed in harvesting in 1998 (Gallagher, 2000 and COFORD, 2001). This was followed by a request from the Forestry Climate Change Team to develop a full time series for carbon stocks and carbon stock changes over the period 1990 to 2000. This paper describes how these changes were estimated.

Data sources

Data were assembled from a number of sources. Forest inventories have been carried out in public forests since the 1950's (O'Flanagan, 1973). An inventory of private forests was last carried out in 1973 (Purcell, 1979). On the other hand Coillte's inventory is fully up-to-date, is very comprehensive and is continually updated. It has full information on thinning and felling harvests.

Private sector forests are, however, rapidly becoming a very significant part of the national estate, especially in the younger age categories. A full survey of all public and private forests was completed in 1996 under FIPS, the Forest Service's Forest Inventory and Planning System (Fogarty *et al*, 1999). It provides reasonably good information on areas by species category for all forests identified by remote sensing. The second phase of FIPS, covering volume and stock estimation, has yet to be begin (it is the intention to start this phase in 2001). Forest Service data on public and private planting can be tracked through recent reports and past Minister's reports on forestry (Forest Service, 2000 and Ministers reports, 1980-1988).

Forestry Commission yield models are a reliable source of production data for plantation species grown in Ireland. Irish models are relevant to species such as coastal lodgepole pine (Hamilton *et al*, 1971 and Forest and Wildlife Service, 1975). Irish models have recently been constructed for Sitka spruce but are not yet widely available and have not been used here. These show 10-15 percent higher wood volume production for a given crop.

Conversion factors relating wood volume to biomass and then to carbon have been developed by the Forestry Commission (Hamilton, 1975). These are in the range used by the IPCC (Houghton *et a*l, 1996) and in recent reports and studies on carbon storage in Ireland (Kilbride *et al.*,1999).

Methodology

Carbon in the national forest estate

The main problem was to accurately model the development of the national forest estate given the relative paucity of quantitative data. Two approaches were considered:

1. to base the time series mainly on Coillte inventory information and supplement this with largely speculative information for the private sector, or

2. to use FIPS data for the total forest estate which are area based but lack wood volume and increment data for the different strata.

The second approach was used, supplemented with yield data from Coillte forests and using Irish and UK yield models to determine wood production and thence carbon stocks and stock changes in Irish forests.

Another major task was to arrive at assumptions as to how the national estate developed between 1990 and 2000, considering that FIPS has data for just one year - 1995. There was also the problem that recent FIPS updates include non-surveyed planting-grant-data in the different strata, so the basis of 1995 data and those of later years was different. A time series of forest strata by age and area was constructed using the FIPS base year of 1995. It comprises recorded and interpreted information for identified forests. A considerable area of very young cleared or unclassified (uninterpreted) forest is included in the 1995 data, and estimated in the time series as a separate category for information purposes. The latter has little impact on the contribution to carbon storage or stock changes over the period.

The three broad categories identified by FIPS are:

1. cleared/unclassified (including young plantings),
2. young crops and
3. mature crops.

The latter two are further broken down into species categories to provide the individual strata (Table G.1). Over time there is a movement from cleared areas to young to mature crops and back to cleared, as stands are planted or reforested, grow to maturity and are felled. This is the pattern that was assumed in the model. How this movement takes place will be determined by the rates of afforestation, clearfelling and reforestation taking place prior to and during the series.

Assumptions made in relation to the FIPS categories

Age

Cleared areas assumed to include crops up to 7 years old. Young crops assumed to include from 7 to 25 years old. Mature crops assumed to include from 25 years old to final harvest

Species categories

FIPS categories (Table G.1) were regrouped into the common reporting format Table 5A categories, Quercus, Fagus, other broadleaves, Pinus, Picea, other conifers (Abies is not classified and is therefore included with other conifers).

Table G.1. FIPS Categories by Area for 1995 and their Relationship to CRF Strata

FIPS stratum	*FIPSCode*	*Area in 1995 ha*	*Common Reporting Format stratum*
Conifer spruce young	CYS	92,407	Picea
Conifer larch young	CYL	1,031	*Other coniferous*
Conifer pine young	CYP	29,083	*Pinus*
Conifer pine/spruce young	YPS	10,575	*Picea 50%, Pinus 50%*
Conifer other young	CYO	7,101	*Other coniferous*
Broadleaf oak young	BYK	218	*Quercus*
Broadleaf beech young	BYB	161	*Fagus*
Broadleaf other young	BYO	6,055	*Other broadleaf*
Mixed young	MXY	4,480	*Mixed broadleaf conifer forest*
Conifer spruce mature	CMS	93,004	*Picea*
Conifer larch mature	CML	3,502	*Other coniferous*
Conifer pine mature	CMP	32,608	*Pinus*
Conifer pine/spruce mature	MPS	27,369	*Picea 50%, Pinus 50%*
Conifer other mature	CMO	9,453	*Other coniferous*
Broadleaf oak mature	BMK	5,600	Quercus
Broadleaf beech mature	BMB	3,072	*Fagus*
Broadleaf other mature	BMO	43,233	*Other broadleaf*
Mixed mature	MXM	24,479	*Mixed broadleaf conifer forest*
Other	O	1,900	*Other forest*
TOTAL FIPS COVER		395,331	
Cleared/unclassified[2]	CUC	180,777	*Unclassified young forest plantations*
TOTAL FOREST SERVICE AREA		576,108	

[2] This includes the FIPS cleared category and the balance of area to make up the Forest Service total area for 1995.

Yield prediction
The Coillte average weighted yield class (wood production model) was applied to all public and private sector forests for each of the FIPS species categories Table G.2). Young broadleaves were given arbitrary yield class estimates.

Table G.2. Yield Classes for FIPS Strata

FIPS stratum	*Yield class* $m^3ha^{-1}yr^{-1}$
Spruce	16
Pine	10
Larch	8
Other conifers	14
Mature oak and beech	4
Other mature broadleaves	6
Young oak and beech	6
Other young broadleaves	8

Carbon removals through harvesting

Coillte records (Coillte, 2001) represent the main source of data for wood harvesting. These are compiled through the company's timber sales reporting system. Records go back to 1991. Detailed information is sparse or non-existent for the private sector. This series therefore relies mainly on Coillte data and works backwards from a forecast of production in the Republic of Ireland (Gallagher and O'Carroll, 2000) to estimate the harvest from private forests.

Area
The FIPS 1995 areas were accepted as the base line area for all strata except cleared. In the latter case accepting FIPS areas would have missed out on some very young grant-aided forests. It was decided therefore to use the Forest Service figure for the total forest area of that year *minus* the total of all the FIPS categories, *plus* the FIPS cleared category to create the category cleared/unclassified (see footnote 1). Using this approach for the years from 1995 to 2000 allowed the forest area to grow to the total forest area estimated by the Forest Service, from all sources, for the year 2000. These areas, estimated for 1995, were modelled forward and back as described in the following sections and in Annex I.

Crop volume production
Volume was determined from the Forestry Commission and Irish yield models (Hamilton *et al*, 1971, Forest and Wildlife Service, 2000). Main crop volume *after* thinning was used in conifers. The ages assumed for young and mature conifers were 15 years and 35 years respectively. Young broadleaved crops were allocated a nominal standing volume of 10 m^3ha^{-1}. 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.

Species volumes/ha and how they were derived are shown in the Table G.3. These were first allocated to the FIPS strata and were then redistributed by CRF species by area categories and converted to carbon equivalents. Standing volume was reduced by 15 percent to allow for roads and rides. Average standing volumes for the CRF categories changed each year as a result of area weighting when converting from the FIPS categories.

Change in forest areas over time

It was assumed that forests areas changed over time in the following manner.

1. Afforested areas and reforested areas, as determined from Forest Service planting records and Coillte clearfell data, currently described as cleared moved into the young category when they reached 7 years of age.

2. Five percent of young crops moved each year into the mature category. This assumes a turnover of all young crops over 20 years.

3. Clearfelled areas as recorded by Coillte statistics and an estimated 200 $ha^{-1}yr^{-1}$ for the private sector moved on each year from the mature to the cleared category. A delay of one year for reforestation to occur was assumed.

4. An exception was made for mature oak and beech where, because of increasing constraints on clearfelling of broadleaves no felling was assumed over the period 1990-2000.

5. Clearfelling was allocated to strata on the basis of their FIPS mature category distribution.

To estimate the rate of change prior to 1995 the process was worked in reverse (See examples in Annex I).

Table G.3. Standing Volume and Conversion Factors used for FIPS Strata

FIPS stratum	Standing volume m^3ha^{-1}	Reduced volume m^3ha^{-1}	Biomass expansion factor (BEF)	Dry density	Carbon content	Carbon tha^{-1}
(a)	(b)	(c= bx.85)	(d)	(e)	(f)	(g=cxdxexf)
CYS	57	48.5	1.3	0.35	0.40	8.721
CYL	46	39.1	1.3	0.44	0.40	8.993
CYP	40	34.0	1.3	0.40	0.40	7.140
YPS	53	45.1	1.3	0.38	0.40	9.010
CYO	52	44.2	1.3	0.40	0.40	9.282
BYK	10	8.5	1.3	0.55	0.45	2.720
BYB	10	8.5	1.3	0.55	0.45	2.720
BYO	10	8.5	1.3	0.55	0.45	2.720
MXY	30	25.5	1.3	0.48	0.45	6.630
CMS	256	217.6	1.3	0.35	0.40	39.168
CML	206	175.1	1.3	0.44	0.40	40.273
CMP	190	161.5	1.3	0.40	0.40	33.913
MPS	226	192.1	1.3	0.38	0.40	38.42
CMO	233	198.1	1.3	0.40	0.40	41.591
BMK	255	216.8	1.3	0.55	0.45	69.360
BMB	256	217.6	1.3	0.55	0.45	69.632
BMO	160	136.0	1.3	0.55	0.45	43.520
MXM	175	148.5	1.3	0.48	0.42	38.675
O	150	127.5	1.3	0.55	0.45	40.800
CUC	0	0	0	0	0	0

Determining carbon stocks and harvest

Basic density and carbon content for the different species (Hamilton, 1975) were multiplied and the product was multiplied in turn by the biomass expansion factor (BEF). These factors were used to convert the reduced timber volume to carbon (Table G.3). Carbon storage estimates in the FIPS categories were converted to the common reporting format categories (Table G.4 and Appendix H).

In the original version of the common reporting format, increment values are used to determine annual increments in carbon stocks and from these the harvest is subtracted to find the net changes in carbon stocks. (This is analogous to Article 3.4 of the Kyoto Protocol which can be paraphrased as: human induced net changes in carbon stocks). In this instance the table was modified to use reduced actual standing volumes (less thinning) on *a net areas basis* to estimate standing volume. Increment was then calculated by subtracting from the carbon stock in that year the carbon stock in the previous year. This is the increment less the harvest as the thinning volumes have already been removed in the data used (standing volumes less thinnings) and the areas are net of clearfelled volumes. For comparison purposes the annual wood harvest was converted to carbon. It includes firewood, which is estimated to be in the region of 30,000 m^3/yr. (Carbon dioxide emissions from the use of firewood are not counted under the Kyoto Protocol as the process is assumed to be carbon neutral).

Results

Carbon stocks in the national forest increased by an estimated 1.2 Mt C[3] (10.55 to 11.74 Mt C) over the period 1990 to 2000 (Table G.4). When carbon removed in harvest is added to the net annual increase in forests after thinning, the gross carbon stock change increased from 0.45 Mt C to 0.7 Mt C over the period. This was despite an annual harvest which increased from c. 0.4 to 0.6 Mt C over the same period (Figure G.1).

The average annual net increase in carbon stocks over the decade was 0.12 Mt C. The annual increase had reached 0.16 Mt C by 1998, but it fell off in the following two years as the harvest volumes increased. Overall the rise has been uneven, probably reflecting changing patterns in planting and increases in clearfelling. The impact of lower rates of new planting in the mid 1980s on the movement of cleared areas to young crops, and the movement of mature crops to cleared, resulted in a decrease in some forest categories for a time, although the total forest estate continues to increase as a result of the afforestation programme. The very high rates of planting in the mid 1990s did not make a significant impact on carbon stocks or increment by the year 2000. Overall, it is estimated (Table G.4) that 80 percent of the carbon stock increment was removed in harvesting over the decade.

The annual carbon storage as estimated by this model is somewhat less than the net storage for 1998 (0.194 compared with 0.156 Mt C) calculated from periodic annual volume increment of FIPS and previously forwarded to UNFCCC in 2001. The difference between the earlier submission to the UNFCCC and the present estimates referred to may be explained by the use of periodic annual increment in the latter calculation. It is of interest to note that the difference between Coillte figures for gross increment and cut for the year 2000 is 0.09 Mt C compared with 0.11 Mt C for the national estate for the same year.

Table G.4. Carbon Stocks, Harvest and Net Carbon Stock Changes 1990-2000.

Year	Standing carbon stock	Carbon stock change	Harvest	Net carbon stock change	Harvest as a percentage of annual increment
	Mt C				**%**
1990	10.552	0.445	0.322	0.123	72
1991	10.667	0.507	0.392	0.115	77
1992	10.754	0.487	0.401	0.087	82
1993	10.858	0.508	0.404	0.104	80
1994	10.969	0.551	0.440	0.111	80
1995	11.086	0.575	0.458	0.117	80
1996	11.200	0.589	0.474	0.115	80
1997	11.336	0.583	0.447	0.136	77
1998	11.493	0.664	0.508	0.156	77
1999	11.629	0.671	0.534	0.137	80
2000	11.740	0.690	0.579	0.111	84

[3] One MtC (Mega tonne carbon) is one million tonnes of carbon.

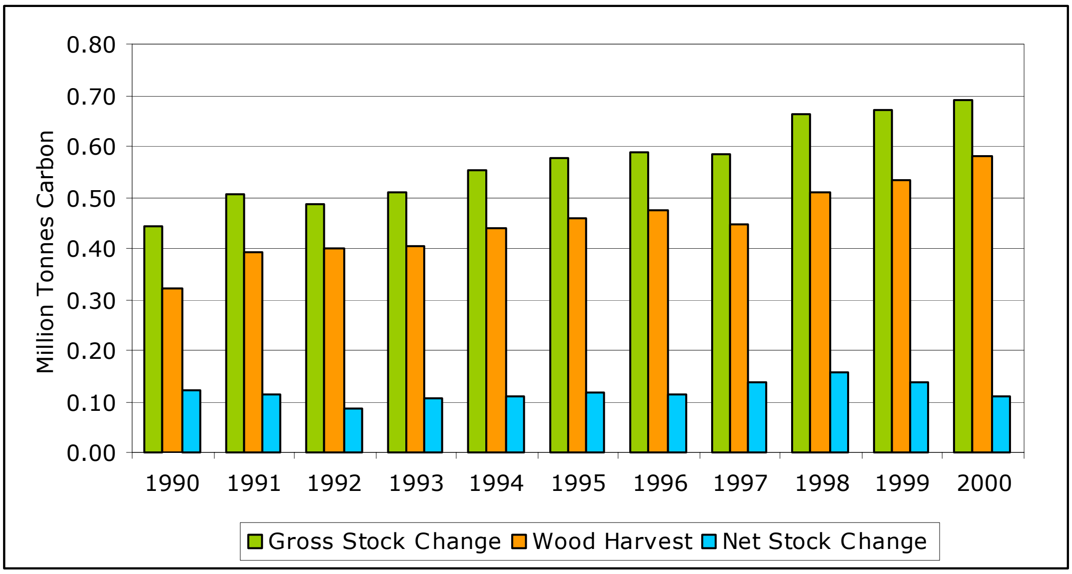

Figure G.1. Wood Harvest and Carbon Stock Change 1990-2000

The model indicates a higher total forest carbon store for the year 1999 (11.6 compared to 8.8 Mt C) than reported by Cruikshank *et al.* (2000), though this was for a smaller land base. When scrub is added their estimate comes to 10.7 Mt C. Some of this scrub, which was derived from the 1971 inventory of private woodlands (Purcell, 1979), will have disappeared through clearance and land reclamation. Some will have been recorded by FIPS as broadleaved forest. The average forest biomass carbon stock in the model for the year 1999 was 25.9 t C ha^{-1}, compared with 29.4 t C ha^{-1} for productive forest estimated by Cruikshank *et al.* (2000) and 24.7 t C ha^{-1} when scrub and discontinuous trees are included (taken from the Corine classification).

Discussion

The comparison between carbon storage estimates determined by us as compared with those of Cruikshank *et al.* (2000) suggests that the time series gives a realistic estimate carbon stocks and stock changes in the national estate for the decade under consideration. The high carbon stock estimate, compared with Cruikshank *et al.*, despite their having used a higher biomass expansion factor (1.5), may relate to the greater area used in our calculations and a more detailed breakdown of species.

The lower net annual carbon stock change for 2000 (0.111 Mt C) reflects a higher estimate for the clearfell area in that year than may be the case. In the absence of clearfelling data an area of 9,500 ha was assumed (based on extrapolating the trend that occurred over the decade). Were that figure closer to 8,500 ha the net change in carbon stocks would be about 0.16 Mt C.

Forest soils

Carbon stored in forest soils is estimated to be a very significant component of the forest ecosystem storage (Byrne, 2001). An estimate of the average carbon store in forest soils is 305 t C ha^{-1} (COFORD, 2001). On that basis carbon in the national estate may have increased from 112 Mt in 1990 to 137 Mt in 2000 (areas under forest cover only).

Improving the model

The model presented here represents an interim step in the development of forest carbon accounting. When the national forest inventory reports it will be updated by including up-to-date planting and felling data. The assumption that young crops in the FIPS categories reflect those of 7 years and over may not exactly reflect the conditions on the ground in 1995. If the crops were older than this the model would under-estimate carbon stocks. This would also be the case if crops under 7 years were vigorous enough to store measurable carbon as we have assumed there is no net carbon sequestration below this age. The results of the COFORD-funded CARBIFOR project will help to clarify the situation as far as those crops are concerned.

The pattern of movement assumed in the model - from cleared or recently planted categories to young, and then to mature categories - is crude. More precise distributions by age category over the time series would improve stock estimations. A large area of FIPS was classified as cleared. This includes actual clearfelled areas, newly planted areas or otherwise unidentified areas. The provision of afforestation and reforestation years through the Forest Service planting grant system (GPAS) across the species categories defined by FIPS would provide more complete information on very young crops and their progress over time to the other crop development categories. The work has also highlighted the need for more information on both thinnings and clearfelling by species in the private sector. This should be recorded through the Forest Service felling licence system.

As has been mentioned previously, basic density and carbon content are reasonably well defined for tree species but there is still some lack of knowledge about the most accurate biomass expansion factors for species and age class. In this case a conservative figure of 1.3 has been used for all tree species for both growing trees and harvested timber.

ACKNOWLEDGEMENTS

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ANNEX I

DETERMINATION OF TIME-SERIES FOREST AREAS USING 1995 BASE YEAR DATA

The assumptions use to assign areas to the three different categories were:

1. Afforested and reforested areas 7 years and over, defined as cleared/unclassified in FIPS move each year into the young crops category. Areas were derived from Coillte felling and Forest Service planting records.
2. Five percent of the young crop category moves each year into the mature category. This means that there is a full turn-over of these crops every 20 years.
3. Mature crops are clearfelled and these areas come back to the cleared/unclassified category.
4. For the purposes of the model clearfell is defined as Coillte felling plus an arbitrary 200 ha of private felling.
5. The reforestation is derived from the clearfell area of the previous year.
6. The process works forward or back from FIPS base year 1995.

YOUNG CROPS

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

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

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

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

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

MATURE CROPS

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

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

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

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

CLEARED/UNCLASSIFIED AREAS

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

General Rule for years before 1995:

Current Year= (Current Year + 1 ha) - Afforestation[Current Year +1] - Felling[Current Year + 1] + ([Current Year + 1 - minimum age for young trees]Afforestation) + ([Current Year + 1 - minimum age for young trees]Reforestation)

Example:

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

General Rule for years after 1995:

Current Year= (Current Year - 1 ha) + Afforestation[Current Year)+ Felling[Current Year) - ([Current Year - minimum age for young trees]Afforestation) - ([Current Year - minimum age for young trees]Reforestation)

Example:

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

The minimum age for young trees is7 in all examples:

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

Appendix H

Activity Data and Calculation Sheets for Waste

Years 1990 - 2003

Table H.1. Time Series of Solid Waste Disposal and Composition 1970-2003

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 MSW tonnes***
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	**P**
1970	2929502	1.00	1069268	0.750	801951	21385	0.36	0.28	0.03	0.19	288702	224546	24059	152371	**170949**
1971	2978248	1.00	1087061	0.750	815295	21741	0.36	0.28	0.03	0.19	293506	228283	24459	154906	**173794**
1972	3026994	1.00	1104853	0.750	828640	22097	0.36	0.28	0.03	0.19	298310	232019	24859	157442	**176638**
1973	3075740	1.00	1122645	0.750	841984	22453	0.36	0.28	0.03	0.19	303114	235755	25260	159977	**179483**
1974	3124486	1.00	1140437	0.750	855328	22809	0.36	0.28	0.03	0.19	307918	239492	25660	162512	**182327**
1975	3173232	1.00	1158230	0.750	868672	23165	0.36	0.28	0.03	0.19	312722	243228	26060	165048	**185172**
1976	3221978	1.00	1176022	0.750	882016	23520	0.36	0.28	0.03	0.19	317526	246965	26460	167583	**188017**
1977	3270724	1.00	1193814	0.750	895361	23876	0.36	0.28	0.03	0.19	322330	250701	26861	170119	**190861**
1978	3319470	1.00	1211607	0.750	908705	24232	0.36	0.28	0.03	0.19	327134	254437	27261	172654	**193706**
1979	3368217	1.00	1229399	0.750	922049	24588	0.36	0.28	0.03	0.19	331938	258174	27661	175189	**196550**
1980	3405811	1.00	1243121	0.750	932341	24862	0.36	0.28	0.03	0.19	335643	261055	27970	177145	**198744**
1981	3443405	1.00	1256843	0.750	942632	25137	0.36	0.28	0.03	0.19	339348	263937	28279	179100	**200938**
1982	3462852	1.00	1263941	0.750	947956	25279	0.36	0.28	0.03	0.19	341264	265428	28439	180112	**202073**
1983	3482299	1.00	1271039	0.750	953279	25421	0.36	0.28	0.03	0.19	343181	266918	28598	181123	**203207**
1984	3501746	1.00	1283556	0.750	962667	25671	0.36	0.28	0.03	0.19	346560	269547	28880	182907	**205209**
1985	3521193	1.02	1310940	0.750	983205	32774	0.36	0.28	0.03	0.19	353954	275297	29496	186809	**211225**
1986	3540643	1.04	1344028	0.750	1008021	33601	0.35	0.28	0.03	0.19	352807	282246	30241	191524	**215044**
1987	3537195	1.06	1368541	0.750	1026406	34214	0.35	0.28	0.03	0.19	359242	287394	30792	195017	**218967**
1988	3533747	1.09	1405901	0.750	1054426	35148	0.34	0.28	0.03	0.19	358505	295239	31633	200341	**223363**
1989	3530299	1.12	1443186	0.750	1082390	36080	0.34	0.29	0.03	0.19	368012	313893	32472	205654	**233616**
1990	3526851	1.15	1480396	0.770	1139905	37010	0.34	0.29	0.03	0.19	387568	330572	34197	216582	**245783**
1991	3523400	1.19	1530389	0.770	1178399	38260	0.33	0.29	0.03	0.19	388872	341736	35352	223896	**252315**
1992	3550000	1.24	1606730	0.780	1253249	40168	0.33	0.30	0.03	0.18	413572	375975	31331	225585	**268838**
1993	3565000	1.29	1680000	0.780	1310400	42000	0.32	0.30	0.03	0.18	419328	393120	32760	235872	**279132**
1994	3570000	1.33	1733057	0.800	1386445	43326	0.32	0.30	0.02	0.18	443662	415934	27729	249560	**292280**
1995	3580000	1.38	1801441	0.769	1385439	46791	0.32	0.31	0.02	0.18	442271	425373	27724	244122	**295896**
1996	3626000	1.41	1866121	0.800	1492897	55984	0.32	0.31	0.02	0.18	476575	458366	29874	263057	**320237**
1997	3660600	1.44	1924011	0.825	1587309	48100	0.30	0.31	0.02	0.18	476193	492066	31746	285716	**335836**
1998	3704900	1.46	1975653	0.853	1685766	80999	0.27	0.32	0.02	0.19	455204	547850	36142	323463	**370647**
1999	3744700	1.62	2214241	0.820	1815678	66427	0.27	0.34	0.02	0.19	490284	617330	38927	348390	**404911**
2000	3786900	1.77	2446527	0.790	1932756	73396	0.28	0.36	0.03	0.19	541172	695792	48319	370855	**452797**
2001	3838900	1.87	2625566	0.759	1992050	78469	0.29	0.37	0.03	0.19	577695	737059	59762	382232	**482334**
2002	3897000	1.87	2625566	0.750	1969175	78767	0.29	0.37	0.03	0.19	571061	728595	59075	377843	**477095**
2003	**3979000**	**1.87**	**2625566**	**0.750**	**1969175**	**78767**	**0.29**	**0.37**	**0.03**	**0.19**	**571061**	**728595**	**59075**	**377843**	**477095**

D = total MSW – street cleansings

P = G*0.25 + I*0.15 + M*0.4 + O*0.15

Table H.2. Potential CH_4 Production of Solid Wastes 1970-2003

Year	*DOC in MSW*	*DOC Managed SWDS*	*DOC Unmanaged SWDS*	*Fraction DOC Dissimilated*	*Fraction CH4 in Landfill*	*MCF Managed SWDS*	*MCF Unmanaged SWDS*	*Potential CH4* Managed SWDS	*Potential CH4* Unmanaged SWDS	*Potential CH4* Total SWDS
	tonnes	*%*	*%*					*tonnes*	*tonnes*	*tonnes*
A	B	B	D	E	F	G	H	I	J	K
1970	170949	0.40	0.60	0.60	0.50	1.00	0.40	27352	16411	43763
1971	173794	0.41	0.59	0.60	0.50	1.00	0.40	28502	16406	44908
1972	176638	0.42	0.58	0.60	0.50	1.00	0.40	29675	16392	46067
1973	179483	0.43	0.57	0.60	0.50	1.00	0.40	30871	16369	47240
1974	182327	0.44	0.56	0.60	0.50	1.00	0.40	32090	16337	48426
1975	185172	0.45	0.55	0.60	0.50	1.00	0.40	33331	16295	49626
1976	188017	0.46	0.54	0.60	0.50	1.00	0.40	34595	16245	50840
1977	190861	0.47	0.53	0.60	0.50	1.00	0.40	35882	16185	52067
1978	193706	0.48	0.52	0.60	0.50	1.00	0.40	37191	16116	53308
1979	196550	0.49	0.51	0.60	0.50	1.00	0.40	38524	16038	54562
1980	198744	0.50	0.50	0.60	0.50	1.00	0.40	39749	15900	55648
1981	200938	0.51	0.49	0.60	0.50	1.00	0.40	40991	15754	56745
1982	202073	0.52	0.48	0.60	0.50	1.00	0.40	42031	15519	57550
1983	203207	0.53	0.47	0.60	0.50	1.00	0.40	43080	15281	58361
1984	205209	0.54	0.46	0.60	0.50	1.00	0.40	44325	15103	59428
1985	211225	0.55	0.45	0.60	0.50	1.00	0.40	46470	15208	61678
1986	215044	0.56	0.44	0.60	0.50	1.00	0.40	48170	15139	63309
1987	218967	0.57	0.43	0.60	0.50	1.00	0.40	49924	15065	64989
1988	223363	0.58	0.42	0.60	0.50	1.00	0.40	51820	15010	66830
1989	233616	0.59	0.41	0.60	0.50	1.00	0.40	55133	15325	70459
1990	245783	0.60	0.40	0.60	0.50	1.00	0.40	58988	15730	74718
1991	252315	0.60	0.40	0.60	0.50	1.00	0.40	60556	16148	76704
1992	268838	0.60	0.40	0.60	0.50	1.00	0.40	64521	17206	81727
1993	279132	0.60	0.40	0.60	0.50	1.00	0.40	66992	17864	84856
1994	292280	0.60	0.40	0.60	0.50	1.00	0.40	70147	18706	88853
1995	295896	0.60	0.40	0.60	0.50	1.00	0.40	71015	18937	89952
1996	320237	0.60	0.40	0.60	0.50	1.00	0.40	76857	20495	97352
1997	335836	0.60	0.40	0.60	0.50	1.00	0.40	80601	21494	102094
1998	370647	0.61	0.39	0.60	0.50	1.00	0.40	90438	23128	113566
1999	404911	0.62	0.38	0.60	0.50	1.00	0.40	100418	24619	125037
2000	452797	0.63	0.37	0.60	0.50	1.00	0.40	114105	26806	140911
2001	482334	0.64	0.36	0.60	0.50	1.00	0.40	123478	27782	151260
2002	477095	0.65	0.35	0.60	0.50	1.00	0.40	124045	26717	150762
2003	**477095**	**0.66**	**0.34**	**0.60**	**0.50**	**1.00**	**0.40**	**125933**	**25954**	**151907**

E from GPG
G and H from IPCC Guidelines

I = B*C*E*F*G*16/12
J = B*D*E*F*H*16/12
K = I + J

Table H.3. Annual CH_4 Emissions 1969-2003 from Managed Landfills *(continued on following page)*

	Pot CH4 Managed	% CH4 pa	1968 26442	1969 26897	1970 27352	1971 28502	1972 29675	1973 30871	1974 32090	1975 33331	1976 34595	1977 35882	1978 37191	1979 38524	1980 39749		
1969	26897	6.00	0														
1970	27352	16.40	1586	0													
1971	28502	18.10	4336	1614	0												
1972	29675	7.90	4786	4411	1641	0											
1973	30871	5.60	2089	4868	4486	1710	0										
1974	32090	5.50	1481	2125	4951	4674	1781	0									
1975	33331	4.90	1454	1506	2161	5159	4867	1852	0								
1976	34595	4.40	1296	1479	1532	2252	5371	5063	1925	0							
1977	35882	4.40	1163	1318	1504	1596	2344	5588	5263	2000	0						
1978	37191	3.90	1163	1183	1340	1568	1662	2439	5808	5466	2076	0					
1979	38524	3.40	1031	1183	1203	1397	1632	1729	2535	6033	5674	2153	0				
1980	39749	3.40	899	1049	1203	1254	1454	1698	1797	2633	6262	5885	2231	0			
1981	40991	3.40	899	914	1067	1254	1306	1513	1765	1867	2733	6495	6099	2311	0		
1982	42031	2.90	899	914	930	1112	1306	1358	1572	1833	1937	2835	6732	6318	2385	0	0
1983	43080	2.60	767	914	930	969	1157	1358	1412	1633	1903	2009	2938	6973	6519	2459	0
1984	44325	2.30	687	780	930	969	1009	1204	1412	1467	1695	1974	2083	3043	7195	6723	2522
1985	46470	1.70	608	699	793	969	1009	1050	1251	1467	1522	1758	2046	2157	3140	7419	6893
1986	48170	1.30	450	619	711	827	1009	1050	1091	1300	1522	1579	1822	2119	2226	3238	7608
1987	49924	1.00	344	457	629	741	861	1050	1091	1133	1349	1579	1636	1888	2186	2296	3320
1988	51820	1.00	264	350	465	656	772	895	1091	1133	1176	1399	1636	1695	1948	2255	2354
1989	55133		264	269	356	485	683	803	931	1133	1176	1220	1450	1695	1749	2009	2312
1990	58988		**0**	**269**	**274**	**371**	**504**	**710**	**834**	**967**	**1176**	**1220**	**1265**	**1502**	**1749**	**1804**	**2060**
1991	60556		**0**	**0**	**274**	**285**	**386**	**525**	**738**	**867**	**1003**	**1220**	**1265**	**1310**	**1550**	**1804**	**1849**
1992	64521		**0**	**0**	**0**	**285**	**297**	**401**	**546**	**767**	**899**	**1041**	**1265**	**1310**	**1351**	**1599**	**1849**
1993	66992		**0**	**0**	**0**	**0**	**297**	**309**	**417**	**567**	**796**	**933**	**1079**	**1310**	**1351**	**1394**	**1639**
1994	70147		**0**	**0**	**0**	**0**	**0**	**309**	**321**	**433**	**588**	**825**	**967**	**1117**	**1351**	**1394**	**1429**
1995	71015		**0**	**0**	**0**	**0**	**0**	**0**	**321**	**333**	**450**	**610**	**855**	**1002**	**1153**	**1394**	**1429**
1996	76857		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**333**	**346**	**466**	**632**	**886**	**1033**	**1189**	**1429**
1997	80601		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**346**	**359**	**483**	**655**	**914**	**1066**	**1219**
1998	90438		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**359**	**372**	**501**	**676**	**943**	**1093**
1999	100418		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**372**	**385**	**517**	**697**	**967**
2000	114105		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**385**	**397**	**533**	**715**
2001	123478		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**397**	**410**	**546**
2002	124045		0	0	0	0	0	0	0	0	0	0	0	0	0	**410**	**420**
2003	125953		0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**420**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for managed landfills in the years 1990 to 2002

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
	40991	42031	43080	44325	46470	48170	49924	51820	55133	58988	60556	64521	66992	70147	71015
1983	2459	0													
1984	6723	2522	0												
1985	7419	6893	2585	0											
1986	3238	7608	7065	2660	0										
1987	2296	3320	7797	7269	2788	0									
1988	2255	2354	3403	8023	7621	2890	0								
1989	2009	2312	2412	3502	8411	7900	2995	0							
1990	**1804**	**2060**	**2369**	**2482**	**3671**	**8719**	**8188**	**3109**	**0**						
1991	**1804**	**1849**	**2111**	**2438**	**2602**	**3805**	**9036**	**8498**	**3308**	**0**					
1992	**1599**	**1849**	**1896**	**2172**	**2556**	**2698**	**3944**	**9379**	**9042**	**3539**	**0**				
1993	**1394**	**1639**	**1896**	**1950**	**2277**	**2649**	**2796**	**4094**	**9979**	**9674**	**3633**	**0**			
1994	**1394**	**1429**	**1680**	**1950**	**2045**	**2360**	**2746**	**2902**	**4356**	**10677**	**9931**	**3871**	**0**		
1995	**1394**	**1429**	**1465**	**1729**	**2045**	**2119**	**2446**	**2850**	**3087**	**4660**	**10961**	**10581**	**4020**	**0**	
1996	**1189**	**1429**	**1465**	**1507**	**1812**	**2119**	**2197**	**2539**	**3032**	**3303**	**4784**	**11678**	**10987**	**4209**	**0**
1997	**1066**	**1219**	**1465**	**1507**	**1580**	**1879**	**2197**	**2280**	**2702**	**3244**	**3391**	**5097**	**12125**	**11504**	**4261**
1998	**943**	**1093**	**1249**	**1507**	**1580**	**1638**	**1947**	**2280**	**2426**	**2890**	**3331**	**3613**	**5292**	**12697**	**11646**
1999	**697**	**967**	**1120**	**1285**	**1580**	**1638**	**1697**	**2021**	**2426**	**2595**	**2967**	**3549**	**3752**	**5542**	**12854**
2000	**533**	**715**	**991**	**1152**	**1348**	**1638**	**1697**	**1762**	**2150**	**2595**	**2664**	**3162**	**3685**	**3928**	**5610**
2001	**410**	**546**	**732**	**1019**	**1208**	**1397**	**1697**	**1762**	**1875**	**2301**	**2664**	**2839**	**3283**	**3858**	**3977**
2002	**410**	**420**	**560**	**754**	**1069**	**1252**	**1448**	**1762**	**1875**	**2006**	**2362**	**2839**	**2948**	**3437**	**3906**
2003	**420**	**431**	**576**	**790**	**1108**	**1298**	**1503**	**1875**	**2006**	**2059**	**2516**	**2948**	**3086**	**3480**	**4227**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for managed landfills in the years 1990 to 2002

	1996	1997	1998	1999	2000	2001	2002	CH4	CH4	CH4
	76857	80601	90438	100418	114105	123478		Production	Recovery	Emitted
1990								**43,242**	**0**	**43,242**
1991								**44,874**	**0**	**44,874**
1992								**46,834**	**0**	**46,834**
1993								**49,039**	**0**	**49,039**
1994								**51,253**	**0**	**51,253**
1995								**53,509**	**0**	**53,509**
1996								**55,948**	**0**	**55,948**
1997	**0**							**58,274**	**4,623**	**53,651**
1998	**4611**	**0**						**60,651**	**17,500**	**43,151**
1999	**12605**	**4836**	**0**					**63,404**	**25,000**	**38,404**
2000	**13911**	**13219**	**5426**	**0**				**66,969**	**19,320**	**47,649**
2001	**6072**	**14589**	**14832**	**6025**	**0**			**71,483**	**20,160**	**51,323**
2002	**4304**	**6367**	**16369**	**16469**	**6846**	**0**		**77,402**	**16,750**	**60,652**
2003	**4227**	**4514**	**7145**	**18176**	**18713**	**7409**	**0**	**84,278**	**13,776**	**70,502**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for managed landfills in the years 1990 to 2002

Table H.4. Annual CH_4 Emissions 1990-2002 from Unmanaged Landfills (continued on following page)

	Pot CH4	*% CH4*	*1968*	*1969*	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*
	Unmanaged	*pa*	*15865*	*16138*	*16411*	*16406*	*16392*	*16369*	*16337*	*16295*	*16245*	*16185*	*16116*	*16038*	*15900*
1969	16138	6.00	0												
1970	16411	16.40	952	0											
1971	16406	18.10	2602	968	0										
1972	16392	7.90	2872	2647	985	0									
1973	16369	5.60	1253	2921	2691	984	0								
1974	16337	5.50	888	1275	2970	2691	984	0							
1975	16295	4.90	873	904	1296	2970	2688	982	0						
1976	16245	4.40	777	888	919	1296	2967	2684	980	0					
1977	16185	4.40	698	791	903	919	1295	2963	2679	978	0				
1978	16116	3.90	698	710	804	902	918	1293	2957	2672	975	0			
1979	16038	3.40	619	710	722	804	902	917	1291	2949	2664	971	0		0
1980	15900	3.40	539	629	722	722	803	900	915	1287	2940	2654	967	0	
1981	15754	3.40	539	549	640	722	721	802	899	913	1283	2929	2643	962	0
1982	15519	2.90	539	549	558	640	721	720	800	896	910	1279	2917	2630	954
1983	15281	2.60	460	549	558	558	639	720	719	798	893	906	1273	2903	2608
1984	15103	2.30	412	468	558	558	557	638	719	717	796	890	903	1267	2878
1985	15208	1.70	365	420	476	558	557	557	637	717	715	793	886	898	1256
1986	15139	1.30	270	371	427	476	557	557	555	636	715	712	790	882	890
1987	15065	1.00	206	274	377	427	475	557	555	554	634	712	709	786	874
1988	15010	1.00	159	210	279	377	426	475	555	554	552	631	709	706	779
1989	15325		159	161	213	279	377	426	474	554	552	550	629	706	700
1990	15730		**0**	**161**	**164**	**213**	**279**	**376**	**425**	**473**	**552**	**550**	**548**	**626**	**700**
1991	16148		**0**	**0**	**164**	**164**	**213**	**278**	**376**	**424**	**471**	**550**	**548**	**545**	**620**
1992	17206		**0**	**0**	**0**	**164**	**164**	**213**	**278**	**375**	**422**	**469**	**548**	**545**	**541**
1993	17864		**0**	**0**	**0**	**0**	**164**	**164**	**212**	**277**	**374**	**421**	**467**	**545**	**541**
1994	18706		**0**	**0**	**0**	**0**	**0**	**164**	**163**	**212**	**276**	**372**	**419**	**465**	**541**
1995	18937		**0**	**0**	**0**	**0**	**0**	**0**	**163**	**163**	**211**	**275**	**371**	**417**	**461**
1996	20495		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**163**	**162**	**210**	**274**	**369**	**413**
1997	21494		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**162**	**162**	**210**	**273**	**366**
1998	23128		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**162**	**161**	**209**	**270**
1999	24619		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**161**	**160**	**207**
2000	26806		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**160**	**159**
2001	27782		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**159**
2002	26717		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2003	25954		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for unmanaged landfills in the years 1990 to 2002

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
	15754	15519	15281	15103	15208	15139	15065	15010	15325	15730	16148	17206	17864	18706	18937
1983	945	0													
1984	2584	931	0												
1985	2851	2545	917	0											
1986	1245	2809	2506	906	0										
1987	882	1226	2766	2477	912	0									
1988	866	869	1207	2734	2494	908	0								
1989	772	854	856	1193	2753	2483	904	0							
1990	**693**	**760**	**840**	**846**	**1201**	**2740**	**2471**	**901**	**0**						
1991	**693**	**683**	**749**	**831**	**852**	**1196**	**2727**	**2462**	**920**	**0**					
1992	**614**	**683**	**672**	**740**	**836**	**848**	**1190**	**2717**	**2513**	**944**	**0**				
1993	**536**	**605**	**672**	**665**	**745**	**833**	**844**	**1186**	**2774**	**2580**	**969**	**0**			
1994	**536**	**528**	**596**	**665**	**669**	**742**	**829**	**841**	**1211**	**2847**	**2648**	**1032**	**0**		
1995	**536**	**528**	**520**	**589**	**669**	**666**	**738**	**826**	**858**	**1243**	**2923**	**2822**	**1072**	**0**	
1996	**457**	**528**	**520**	**514**	**593**	**666**	**663**	**735**	**843**	**881**	**1276**	**3114**	**2930**	**1122**	**0**
1997	**410**	**450**	**520**	**514**	**517**	**590**	**663**	**660**	**751**	**865**	**904**	**1359**	**3233**	**3068**	**1136**
1998	**362**	**403**	**443**	**514**	**517**	**515**	**588**	**660**	**674**	**771**	**888**	**964**	**1411**	**3386**	**3106**
1999	**268**	**357**	**397**	**438**	**517**	**515**	**512**	**585**	**674**	**692**	**791**	**946**	**1000**	**1478**	**3428**
2000	**205**	**264**	**351**	**393**	**441**	**515**	**512**	**510**	**598**	**692**	**711**	**843**	**983**	**1048**	**1496**
2001	**158**	**202**	**260**	**347**	**395**	**439**	**512**	**510**	**521**	**613**	**711**	**757**	**875**	**1029**	**1060**
2002	**158**	**155**	**199**	**257**	**350**	**394**	**437**	**510**	**521**	**535**	**630**	**757**	**786**	**917**	**1042**
2003	**0**	**155**	**153**	**196**	**259**	**348**	**392**	**435**	**521**	**535**	**549**	**671**	**786**	**823**	**928**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for unmanaged landfills in the years 1990 to 2002

	1996	1997	1998	1999	2000	2001	2002	CH4	CH4	CH4
	80866	82172	90438	93404	95941	97856		Production	Recovery	Emitted
1990								**15,520**	**0**	**15,520**
1991								**15,465**	**0**	**15,465**
1992								**15,477**	**0**	**15,477**
1993								**15,572**	**0**	**15,572**
1994								**15,754**	**0**	**15,754**
1995								**16,050**	**0**	**16,050**
1996								**16,433**	**0**	**16,433**
1997	**0**							**16,813**	**0**	**16,813**
1998	**1230**	**0**						**17,233**	**0**	**17,233**
1999	**3361**	**1290**	**0**					**17,778**	**0**	**17,778**
2000	**3710**	**3525**	**1388**	**0**				**18,502**	**0**	**18,502**
2001	**1619**	**3890**	**3793**	**1477**	**0**			**19,329**	**0**	**19,329**
2002	**1148**	**1698**	**4186**	**4037**	**1608**	**0**		**20,323**	**0**	**20,323**
2003	**1127**	**1204**	**1827**	**4456**	**4396**	**1667**	0	**21,428**	**0**	**21,428**

Contributions from each year entered vertically and summed horizontally in this table to obtain total emissions for unmanaged landfills in the years 1990 to 2002

Table H.5. Annual Solid Waste Disposal and CH_4 Emissions 1990–2003

Year	MSW tonnes	Street Cleansing(t)	Total SW(t)	SW in Managed SWDS(%))	SW in Unmanaged SWDS(%)	SW in Managed SWDS(t)	SW in Unmanaged SWDS(t)	CH4 Emitted Managed SWDS(t)	CH4 Emitted Unmanaged SWDS(t)	CH4 Emitted All SWDS	Contributing Solid Waste Managed SWDS(t)	Contributing Solid Waste Unmanaged SWDS(t)	Contributing Solid Waste All SWDS
1970	801951	21385	823337	0.40	0.60	329335	494002						
1971	815295	21741	837037	0.41	0.59	343185	493852						
1972	828640	22097	850737	0.42	0.58	357309	493427						
1973	841984	22453	864437	0.43	0.57	371708	492729						
1974	855328	22809	878137	0.44	0.56	386380	491757						
1975	868672	23165	891837	0.45	0.55	401327	490510						
1976	882016	23520	905537	0.46	0.54	416547	488990						
1977	895361	23876	919237	0.47	0.53	432041	487196						
1978	908705	24232	932937	0.48	0.52	447810	485127						
1979	922049	24588	946637	0.49	0.51	463852	482785						
1980	932341	24862	957203	0.50	0.50	478602	478602						
1981	942632	25137	967769	0.51	0.49	493562	474207						
1982	947956	25279	973235	0.52	0.48	506082	467153						
1983	953279	25421	978700	0.53	0.47	518711	459989						
1984	962667	25671	988338	0.54	0.46	533703	454636						
1985	983205	32774	1015979	0.55	0.45	558788	457190						
1986	1008021	33601	1041622	0.56	0.44	583308	458314						
1987	1026406	34214	1060619	0.57	0.43	604553	456066						
1988	1054426	35148	1089573	0.58	0.42	631953	457621						
1989	1082390	36080	1118469	0.59	0.41	659897	458572						
1990	1139905	37010	1176915	0.60	0.40	706149	470766	43,242	15,520	58,762	459130	477497	936627
1991	1178399	38260	1216659	0.60	0.40	729995	486664	44,874	15,465	60,339	475933	476136	952069
1992	1253249	40168	1293418	0.60	0.40	776051	517367	46,834	15,477	62,311	494773	474974	969748
1993	1310400	42000	1352400	0.60	0.40	811440	540960	49,039	15,572	64,611	514114	474615	988729
1994	1386445	43326	1429772	0.60	0.40	857863	571909	51,253	15,754	67,007	535051	475812	1010863
1995	1385439	46791	1432230	0.60	0.40	859338	572892	53,509	16,050	69,559	557038	478224	1035261
1996	1492897	55984	1548880	0.60	0.40	929328	619552	55,948	16,433	72,381	580612	482231	1062843
1997	1587309	48100	1635410	0.60	0.40	981246	654164	53,651	16,813	70,464	603512	486350	1089862
1998	1685766	80999	1766765	0.61	0.39	1077727	689038	43,151	17,233	60,384	629151	492878	1122030
1999	1815678	66427	1882105	0.62	0.38	1166905	715200	38,404	17,778	56,182	656612	501227	1157838
2000	1932756	73396	2006152	0.63	0.37	1263876	742276	47,649	18,502	66,151	688107	511422	1199530
2001	1992050	78469	2070519	0.64	0.36	1325132	745387	51,323	19,329	70,652	723260	523043	1246303
2002	1969175	78767	2047941	0.65	0.35	1331162	716780	60,652	20,323	80,975	762524	536227	1298750
2003	**1969175**	**78767**	**2047941**	**0.66**	**0.34**	**1351641**	**696300**	**70,502**	**21,428**	**91,930**	**804102**	**549786**	**1353888**

Table H.6 Emissio ns of CH_4 from Individual Landfills in-2002.

		Flaring or Utilisation	CH4 before flaring/utilisation	Gas Volume	CH4 after flaring/utilisation	CH4 Flared
			kg	m3/hour	kg	kg
1	Balleally	Utilisation	18,998,000	6,506	10,448,000	
2	Dunsink Civic Amenity	Utilisation	10,415,000	3,567	5,415,000	
3	Ballyogan Landfill	Utilisation	10,167,000	3,482	7,116,000	
4	Kinsale Road Landfill	Utilisation	6,332,000	2,168	3,482,000	
5	Arthurstown Landfill	Flaring	6,070,087	2,079	100,000	5,970,087
6	Basketstown	Flaring	4,100,000	1,400	2,788,000	1,312,000
7	Dundalk 34-1	none	3,610,000	1,236	3,610,000	
8	Killurin Landfill Site	none	2,336,000	800	2,336,000	
9	Silliot Hill Landfill	Flaring	2,265,270	776	100,000	2,165,270
10	Kilbarry Landfill Site	none	1,989,000	681	1,989,000	
11	KTK	none	1,918,878	657	1,918,878	
12	Scotch Corner Landfill	none	1,777,069	609	1,777,069	
13	Neiphin Trading Ltd	none	1,761,600	603	1,761,600	
14	Derryclure Landfill	none	1,509,000	517	1,509,000	
15	Longpavement	none	1,500,000	514	1,500,000	
16	Doora Landfill	Flaring	1,507,500	516	173,965	1,333,535
17	Raffeen Landfill Site	none	1,470,000	503	1,470,000	
18	Gortadroma Landfill Site	none	1,396,000	478	1,396,000	
19	Whiteriver Landfill Site	none	1,393,029	477	1,393,029	
20	East Cork Landfill Site	none	1,300,000	445	1,300,000	
21	Ballymurtagh Landfill Facility	Flaring	1,179,500	404	353,850	825,650
22	Marlinstown Landfill	none	1,141,000	391	1,141,000	
23	Rathroeen Landfill	none	1,061,000	363	1,061,000	
24	Derrinumera Landfill	none	1,040,000	356	1,040,000	
25	North Kerry Landfill Site	Flaring	1,038,000	355	105,000	933,000
26	Churchtown Landfill	n	1,011,000	346	1,011,000	
27	Ballyguyroe Landfill Site	No	994,000	340	994,000	
28	Pollboy Landfill	none	953,000	326	953,000	
29	Ballaghveny Landfill	none	929,960	318	929,960	
30	Ballynacarrick Landfill Site	none	800,000	274	800,000	
31	Ballydonagh Landfill	Flaring	763,000	261	105,000	658,000
32	Dungarvan Waste Disposal Site	none	750,000	257	750,000	
33	Kyletalesha Landfill	none	716,000	245	716,000	
34	Corranure Landfill	none	600,000	205	600,000	
35	Benduff Landfill Site	none	570,000	195	570,000	
36	Youghal Landfill	none	535,600	183	535,600	
37	Tramore	none	858,000	294	858,000	
38	Donohill Landfill	none	481,000	165	481,000	
39	Powerstown Landfill Site	none	474,119	162	474,119	
40	Balbane Landfill Site	none	421,250	144	421,250	
41	Roscommon Landfill Facility	none	364,969	125	364,969	
42	Bailieborough Landfill	none	281,400	96	281,400	
43	Dunmore Landfill	none	259,490	89	259,490	
44	Ballaghaderreen Landfill	none	240,955	83	240,955	
45	Muckish Landfill Site	none	185,350	63	185,350	
46	Derryconnel Landfill	none	173,000	59	173,000	
47	Mohill Landfill	none	150,000	51	150,000	
48	Carrick On Shannon Landfill	none	140,306	48	140,306	
49	Glenalla Landfill Site	none	140,000	48	140,000	
50	Belturbet Landfill	none	80,000	27	80,000	
51	Ballyjamesduff Landfill	none	40,000	14	40,000	
52	Drumaboden	none	27,000	9	27,000	
53	Marrakesh Ltd.	none	192,000	66	192,000	
	Total		100,406,332		67,757,790	13,197,542

Table H.7. Emissions of N_2O from Human Sewage

Year	Protein	Days	Pop	N fraction	EF	N	N2O
	g/day		million			tonnes	kt
A	B	D	E	F	G	H	I
1990	114.3	365	3.523	0.16	0.01	235.164	0.3695
1991	115.2	365	3.550	0.16	0.01	238.833	0.3753
1992	118.5	366	3.565	0.16	0.01	247.388	0.3888
1993	115.5	365	3.570	0.16	0.01	240.804	0.3784
1994	112.5	365	3.580	0.16	0.01	235.206	0.3696
1995	108.6	365	3.600	0.16	0.01	228.321	0.3588
1996	108.7	366	3.626	0.16	0.01	230.812	0.3627
1997	111.1	365	3.660	0.16	0.01	237.470	0.3732
1998	112.2	365	3.685	0.16	0.01	241.459	0.3794
1999	114.2	365	3.725	0.16	0.01	248.431	0.3904
2000	117.2	366	3.750	0.16	0.01	257.371	0.4044
2001	114.8	365	3.850	0.16	0.01	258.116	0.4056
2002	114.2	365	3.897	0.16	0.01	259.902	0.4084
2003	114.2	365	3.979	0.16	0.01	265.371	0.4170

B : From FAO (previous year value

F : Default fraction from IPCC Guidelines

G : IPCC default emission factor

H : B*C*D*E*F*G

I : H*44/28000