IRELAND

NATIONAL INVENTORY REPORT 2003

GREENHOUSE GAS EMISSIONS 1990 - 2001 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 2003. It is an update of the 2002 report, extending the time series of inventory data to 2001 and it retains the structure adopted for the 2002 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 2001 for submission to the UNFCCC secretariat in April 2003. The results are available as a complete set of Common Reporting Format files, the electronic format adopted for data submissions. The nature and effects of recalculations carried out for inventories previously submitted in 2002 are fully described in the corresponding CRF tables. The annual inventories are substantially complete with respect to the coverage of the six greenhouse gases for which information is required and the IPCC source categories. However, emission estimates for HFC, PFC and SF_6 are available only for the years 1995 through 2001. 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.

The latest data show that emissions of greenhouse gases increased by 31 percent from 53.4 million tonnes CO_2 equivalent in 1990 to 70 million tonnes CO_2 equivalent in 2000. This is an enormous increase in the context of Ireland's commitment under the Kyoto Protocol, where growth in the first commitment period is to be limited to 13 percent over 1990 levels. The overall increase was driven by the growth in CO_2 emissions from energy use, which amounted to 46 percent over the 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. In 2001, the *Energy* sector accounted for 65 percent of total emissions, *Agriculture* contributed 27 percent while a further 6 percent emanated from *Industrial Processes* and 2 percent was due to *Waste*. Emissions of CO_2 accounted for 66 percent of the total of 70 million tonnes CO_2 equivalent in 2001, with CH_4 and N_2O contributing 18 percent and 15 percent, respectively. The CO_2 share in the total continues to increase, as the emissions of the other main gases remain relatively constant. Although the emissions of HFC, PFC and SF_6 showed some increase from 1995 to 2001, their combined total accounted for less than 1 percent of total emissions in 2001.

The application of uncertainty analysis for Irish greenhouse gas inventories indicates an overall uncertainty of 11 percent in the 2001 inventory and a trend uncertainty of 5 percent for the period 1990 to 2001. This outcome is determined largely by the 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 the order of 2 percent. The impact of HFC, PFC and SF_6 on inventory uncertainty in the year 2000 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 41 key emission sources in 2001. There were 26 key sources of CO_2, accounting for 64 percent of total emissions. There were six key source categories of CH_4 and seven key source categories of N_2O in level assessment, which accounted for 17 percent and 13 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 26 out of 41 key source categories identified by level assessment in 2001 and for 64 percent of total emissions. In trend assessment, they account for 16 out of 27 key source categories and for 54 percent of total emissions.

The present NIR documents ongoing and planned improvements across a wide range of issues that will impact positively on the quality and completeness of Irish inventory submissions to the Convention in the coming years. Major research is being conducted to facilitate the application of high-tier methods and more complete country-specific data for some key source categories already covered in *Agriculture* where there remains heavy reliance on Tier 1 methods and default emission factors. The research will also allow for the inclusion of some potentially important sources of emissions and removals under *Land-Use Change and Forestry* where no estimates have yet been provided. New initiatives are being pursued in the acquisition of primary inventory input data at national and source level and more complete application of the IPCC good practice guidance is a high priority. The inventory agency will put greater emphasis on quality assurance/quality control and documentation related to the inventory process. The agency will also continue to take account of the outcome and recommendations of the UNFCCC review process in further development of greenhouse gas inventories and in future editions of the NIR.

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 substantially improves the basis for further technical assessment and expert review of Irish greenhouse gas inventories. In this context, Ireland looks forward to the outcome of the in-country review of the 2003 submission planned for later this year.

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 2003 and sets out the status of Irish inventories with respect to the time-series submitted for the years 1990 to 2001, which is an integral part of the report. It is structured broadly in accordance with the format adopted in compiling the 2002 report (SBSTA, 2002) and thereby addresses the full range of reporting requirements related to annual inventories set down in the UNFCCC guidelines. The report improves considerably the basis for further 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 sustained 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 will be updated annually in accordance with the UNFCCC guidelines and published on the web site of the EPA. 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 material 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 produces 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 and Local Government (DELG) has designated the EPA as the focal point for the submission of emissions data to the UNFCCC Secretariat and to the UNECE Secretariat. The Agency compiles the national greenhouse gas emission inventories on behalf of DELG for submission under the Framework Convention on Climate Change and Decision 99/296/EEC (CEU, 1999a). 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 much of the important national activity data, such as energy balances and agricultural statistics, from the relevant Government departments and the Central Statistics Office. National data from Government departments are complemented by contributions from specific energy and industrial sub-sectors and by the availability of information from the EPA's own databases. The emissions of SO_2, NO_X and CO_2 from power plants operated by the Electricity Supply Board (ESB), Ireland's only electricity generator up to 2000, are obtained on a plant-by-plant basis and similar data are available for a number of large industrial sources.

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. The estimates of carbon emissions and removals associated with forest biomass are made by COFORD, the National Council for Forest Research and Development. Gas production and distribution companies supply estimates of the gas losses associated with natural gas. Information in the national waste database developed by the EPA and from the operators of landfill gas capture programmes is used to estimate methane emissions from landfills.

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 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 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 fora. All inventory data, including background information and support calculations, 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 1990-2001 inventories with respect to the six greenhouse gases covered by the UNFCCC guidelines and the IPCC Level 2 source-category split. 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 emission of either 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 *2.F Consumption of Halocarbons and SF_6* and the various sources are considered to be well covered for the years 1995 to 2001. 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 to CO_2. The annual VOC emission is 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 in the latest time-series 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 1990-2001 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 is being 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*.

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 2002 submission. 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 CRF time-series for 1990-2001, 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 1990-2000. 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 where 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 resources. The establishment of review procedures in accordance with the UNFCCC guidelines is well recognised as a key element in the improvement of inventories overall but formal arrangements in this regard are likely to be deferred for a few more years.

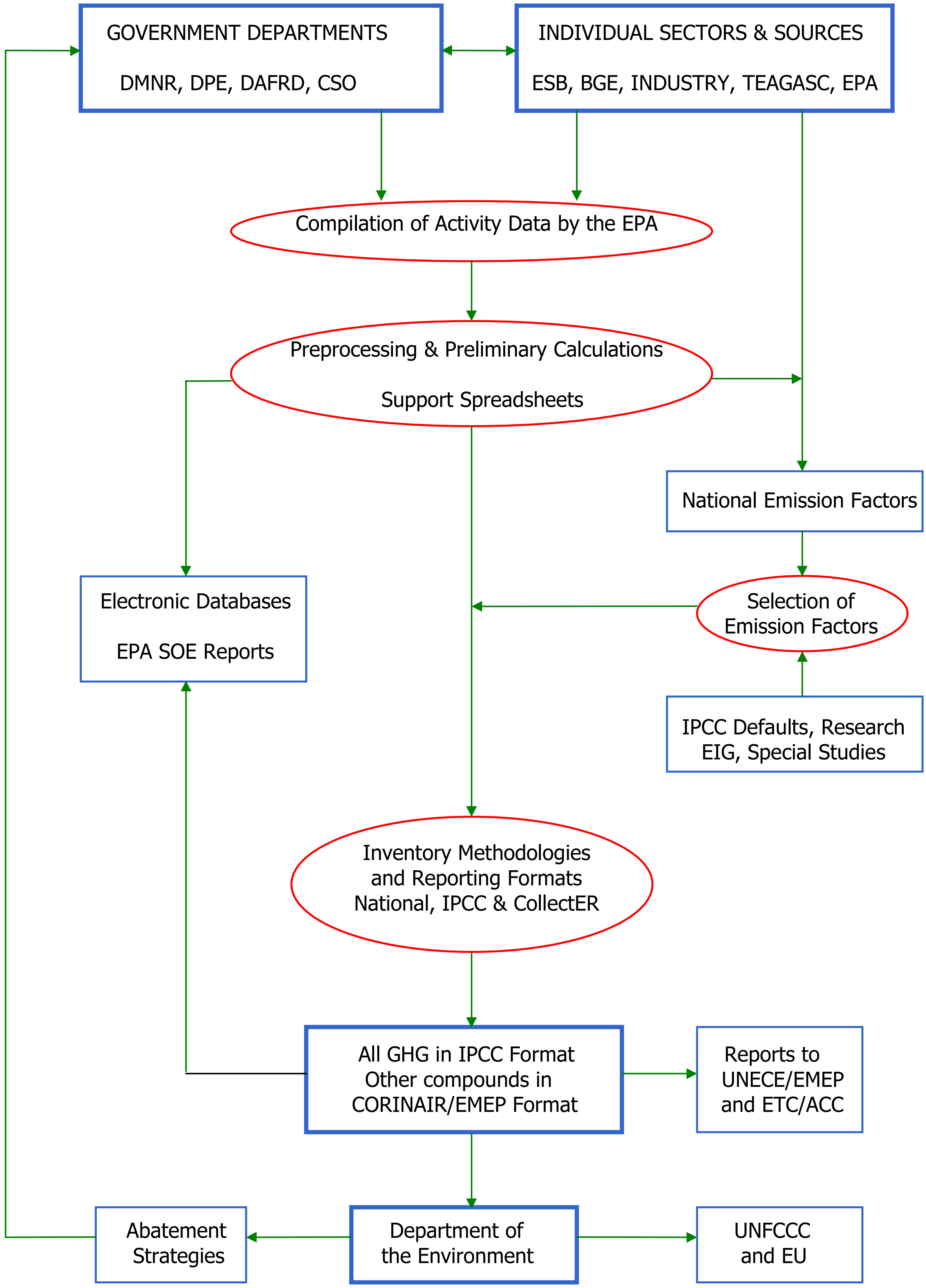
The inventory preparation process employed in Ireland does incorporate a number of activities that may be regarded as fundamental elements of quality control. The emission estimates for the most important source sectors (*Energy* and *Agriculture*) are produced in three computational systems simultaneously. 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 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 2001. 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 2001 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 derived 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 Guidebook.

The Tier 1 analysis results in an overall uncertainty of 11.4 percent in the 2001 inventory of greenhouse gases and a trend uncertainty of 5.5 percent for the period 1990 to 2001. This outcome is 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. This highlights the need for more reliable data on this particular emission source in Ireland. 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. When CH_4 is included, bringing the proportion up to 85 percent, the total uncertainty remains less than 4 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 2001 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 2001 is negligible because these gases account for less than 1 percent of total emissions.



DMNR : Department of the Marine & Natural Resources
DPE : Department of Public Enterprise
DAFRD : Department of Agriculture, Food & Rural Development
CSO : Central Statistics Office
ETC/ACC : European Topic Centre Air & Climate Change

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

IPCC Source Category		Gas	Emissions in 1990	Emissions in 2001	Activity Data (AD) Uncertainty	Emission Factor (EF) Uncertainty	Combined Uncertainty	Combined Uncertainty as % of Total Emissions in 2001	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	6021.41	1	5	5.10	0.44	0.19	-0.01	0.11	0.16	-0.03	0.16	0.03
	Energy-Peat	CO2	3064.65	2667.44	1	5	5.10	0.19	0.04	-0.03	0.05	0.07	-0.13	0.14	0.02
	Energy-Gas	CO2	1880.66	4185.52	1	2.5	2.69	0.16	0.03	0.03	0.08	0.11	0.08	0.14	0.02
	Energy-Other	CO2	1267.50	4270.39	1	2.5	2.69	0.16	0.03	0.05	0.08	0.11	0.12	0.17	0.03
1A2	Industry-Coal	CO2	970.37	249.52	2	5	5.39	0.02	0.00	-0.02	0.00	0.01	-0.10	0.10	0.01
	Industry-Pet Coke	CO2	0.00	692.13	1	10	10.05	0.10	0.01	0.01	0.01	0.02	0.13	0.13	0.02
	Industry-Gas	CO2	855.68	1226.02	1	2.5	2.69	0.05	0.00	0.00	0.02	0.03	0.01	0.03	0.00
	Industry-Oil	CO2	2007.12	2497.20	10	2.5	10.31	0.37	0.14	0.00	0.05	0.66	-0.01	0.66	0.44
1A3	Transport-Oil	CO2	4971.32	10954.73	1	2.5	2.69	0.42	0.18	0.08	0.20	0.29	0.21	0.36	0.13
1A4	Other-Coal and PC	CO2	2327.15	1196.52	5	10	11.18	0.19	0.04	-0.03	0.02	0.16	-0.34	0.38	0.14
	Other-Peat	CO2	3259.38	1247.13	10	20	22.36	0.40	0.16	-0.06	0.02	0.33	-1.13	1.17	1.38
	Other-Gas	CO2	469.25	1830.98	1	2.5	2.69	0.07	0.00	0.02	0.03	0.05	0.06	0.07	0.01
	Other-Oil	CO2	3670.18	6139.34	10	5	11.18	0.98	0.96	0.03	0.11	1.62	0.13	1.63	2.65
2A1	Cement Production	CO2	750.00	1650.00	1	5	5.10	0.12	0.01	0.01	0.03	0.04	0.06	0.08	0.01
2A2	Lime Production	CO2	191.42	182.63	1	5	5.10	0.01	0.00	0.00	0.00	0.00	-0.01	0.01	0.00
2B	Ammonia Production	CO2	989.17	1037.40	1	5	5.10	0.08	0.01	0.00	0.02	0.03	-0.02	0.04	0.00
5	Liming of Ag Lands	CO2	384.45	378.30	5	20	20.62	0.11	0.01	0.00	0.01	0.05	-0.05	0.07	0.00
	Total CO2		*31902.96*	*46426.66*				*1.34*	*1.80*					*2.21*	*4.87*
1A	Fuel Comb-All Fuels	CH4	149.94	110.67	2	50	50.04	0.08	0.01	0.00	0.00	0.01	-0.08	0.08	0.01
1B	Fugitive Emissions	CH4	150.78	103.32	2.5	10	10.31	0.02	0.00	0.00	0.00	0.01	-0.02	0.02	0.00
4A	Dairy Cattle	CH4	2847.60	2557.80	1	20	20.02	0.73	0.54	-0.02	0.05	0.07	-0.44	0.44	0.19
4A	Other Cattle	CH4	5172.30	5959.80	1	30	30.02	2.56	6.53	-0.01	0.11	0.16	-0.45	0.48	0.23
4A	Other Livestock	CH4	1160.46	1159.62	1	50	50.01	0.83	0.69	-0.01	0.02	0.03	-0.33	0.34	0.11
4B	Manure Management	CH4	1260.84	1395.66	10	50	50.99	1.02	1.03	0.00	0.03	0.37	-0.24	0.44	0.19
6A	Solid Waste	CH4	1158.15	1276.17	20	50	53.85	0.98	0.96	0.00	0.02	0.67	-0.22	0.71	0.50
	Total CH4		*11900.07*	*12563.04*				*3.12*	*9.76*					*1.11*	*1.24*
	Cumulative CO2 and CH4							*3.40*	*11.56*					*2.47*	*6.10*

Table 1.4. Tier 1 Uncertainty Estimates (continued)

1A	Fuel Comb-Road Traffic	N2O	56.11	341.93	1	25	25.02	0.12	0.01	0.01	0.01	0.01	0.13	0.13	0.02
1A	Fuel Comb-Other Sectors	N2O	895.20	1310.37	2	50	50.04	0.94	0.88	0.00	0.02	0.07	0.13	0.15	0.02
2B	Nitric Acid	N2O	1035.40	585.90	1	10	10.05	0.08	0.01	-0.01	0.01	0.02	-0.14	0.14	0.02
4B	Manure Management	N2O	626.82	682.00	20	100	101.98	0.99	0.99	0.00	0.01	0.36	-0.26	0.44	0.20
4D	Agricultural Soils	N2O	6870.08	7415.20	20	100	101.98	10.81	116.76	-0.03	0.14	3.92	-2.92	4.89	23.91
6B	Wastewater	N2O	60.14	65.10	10	10	14.14	0.01	0.00	0.00	0.00	0.02	0.00	0.02	0.00
	Total N2O		*9543.75*	*10400.50*				*10.89*	*118.64*					*4.92*	*24.16*
	Cumulative CO2, CH4, N2O							*11.41*	*130.21*					*5.50*	*30.26*
2F	Halocarbons & SF6	HFC	20.71	230.90	20	25	32.02	0.11	0.01	0.00	0.00	0.09	0.10	0.13	0.02
2F	Halocarbons & SF6	PFC	75.38	296.50	20	25	32.02	0.14	0.02	0.00	0.00	0.12	0.09	0.15	0.02
2F	Halocarbons & SF6	SF6	83.05	66.75	20	25	32.02	0.03	0.00	0.00	0.00	0.03	-0.02	0.03	0.00
	Total HFC, PFC & SF6		*179.14*	*594.15*				*0.17*	*0.03*					*0.20*	*0.04*
	Total all gases		*53525.92*	*69984.35*					*130.24*						*30.30*
					Level Uncertainty in emissions			***11.41***				***Trend Uncertainty***		***5.50***	

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*

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 1990-2001. These data are extracted from the trend tables of the 2001 CRF, which show some revisions on previous estimates of emissions for the years 1990 to 2000. The reasons for these revisions are described in Chapter Four.

Total emissions (excluding net CO_2 from *Land Use Change and Forestry*) increased from 53.4 million tonnes CO_2 equivalent in 1990 to 70 million tonnes CO_2 equivalent in 2000, an increase of 31 percent. The overall increase was driven by the growth in CO_2 emissions from energy use, which is well shown by the similarities between energy growth on Figure 2.1a and the CO_2 trend on Figure 2.1b. The increase in CO_2 amounted to 46 percent over the 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. The increase in emissions from 2000 to 2001 was 2.7 percent for the total and 5.4 percent for CO_2.

In 2001, the *Energy* sector accounted for 65 percent of total emissions, *Agriculture* contributed 27 percent while a further 6 percent emanated from *Industrial Processes* and 2 percent was due to *Waste*. Emissions of CO_2 accounted for 66 percent of the total of 70 million tonnes CO_2 equivalent in 2000, with CH_4 and N_2O contributing 18 percent and 15 percent, respectively. The CO_2 share in the total continues to increase, as the emissions of the other main gases remain relatively constant. Although the emissions of HFC, PFC and SF_6 show some increase from 1995 to 2001, their combined total accounted for less than 1 percent of total emissions in 2001.

2.2 Trends by Sector and Gas

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 associated CO_2 emissions from energy industries increased by 55 percent up to 2001. The CO_2 emissions from transport sources, which are largely accounted for by road traffic, increased by 120 percent between 1990 and 2001, 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 2000 but it may have been as high as 20 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 but nevertheless, CO_2 emissions in the industrial sector grew by approximately 23 percent between 1990 and 2001. Residential fuel combustion 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 15 percent from 1990 to 2000, the emissions in this sector have shown a modest decrease of 4 percent because of the decline in the use of carbon-intensive fuels, such as peat and coal.

There has been little change in agricultural policy or practice in Ireland over the past 35 years. Large livestock populations produce about 0.55 million tonnes of CH_4 annually through enteric fermentation while the sustained application of large amounts of chemical and organic nitrogen to soils results in the emission of approximately 25,000 tonnes N_2O. The trends in the principal components of agricultural emissions are shown on Figure 2.1d in terms of CO_2 equivalent. These emissions from *Agriculture,* equal to approximately 19 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 has decreased from 33 percent in 1990 to approximately 27 percent in 2001 due to the rapid CO_2 increase and a slight downturn in CH_4 and N_2O emissions from agriculture after 1998. Total emissions from Agriculture show a slight downturn after 1999, reflecting a decrease in cattle populations and some reduction in fertilizer use.

2.3 Trend Implications

The Framework Convention on Climate Change required developed countries to introduce policies and measures that would return emissions of greenhouse gases to their 1990 levels by the year 2000. Accordingly, the objective of EU climate change policy in the 1990s was to stabilise CO_2 emissions in the Community at their 1990 levels by the year 2000. The expected growth and particular circumstances of economic development of Ireland meant that such a target was inappropriate at the national scale and, consequently, the Irish CO_2 abatement strategy (DOE, 1995) aimed to limit CO_2 emissions to 20 per cent over the 1990 level by the end of the decade. The strategy envisaged that the net CO_2 increase in 2000 would be no more than 11 per cent if the planned increase in the carbon sink capacity of forests was taken into account. The Government's strategy on CO_2 has clearly been overwhelmed by unprecedented economic growth during the 1990s and higher than expected increases in population, which together have forced emissions ever upwards.

The emission reduction commitment of the EU under the Kyoto Protocol is eight per cent on 1990 levels by 2008-2012 (the first commitment period) for the basket of six greenhouse gases. Ireland's burden-sharing contribution to this objective is a growth limitation target of 13 per cent. It is now evident from the latest series of annual emission inventories that this level of increase had in fact already accrued by the time the Kyoto Protocol was signed in 1997 and the total increase up to 2001 was 31 percent. Although the growth rate has decreased from its highest level around 1997, it remains close to 3 per cent annually.

This rate of increase in emissions obviously has major implications for Ireland's ability to comply with the Kyoto Protocol primary objective and to demonstrate progress towards that goal by 2005. Even if Irish greenhouse gas emissions are curbed to comply with the Kyoto commitment, they will still be among the highest per-capita of all OECD countries by the end of the first commitment period. Ireland will then also have one of the wealthiest economies in the OECD. This means that obligations in subsequent commitment periods are almost certain to be very onerous indeed. The timely and complete implementation of Ireland's greenhouse gas abatement strategy is crucial to adequate preparation for this scenario.

2.4 Indirect Greenhouse Gases

The total emissions of NO_x, VOC, CO and SO_2 for the years 1990 to 2001 are summarised on Table 2.2. Decreases of varying extent have occurred in the emissions of SO_2, VOC and CO between 1990 and 2000 but emissions of NO_X increased slightly in this period. 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 (Figure 2.2). The bulk of VOC emissions emanate from road traffic and solvent use, with each sector contributing approximately 40 percent of total emissions.

Table 2.2. Emissions of SO_2, NO_X, VOC and CO 1990-2001 (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				

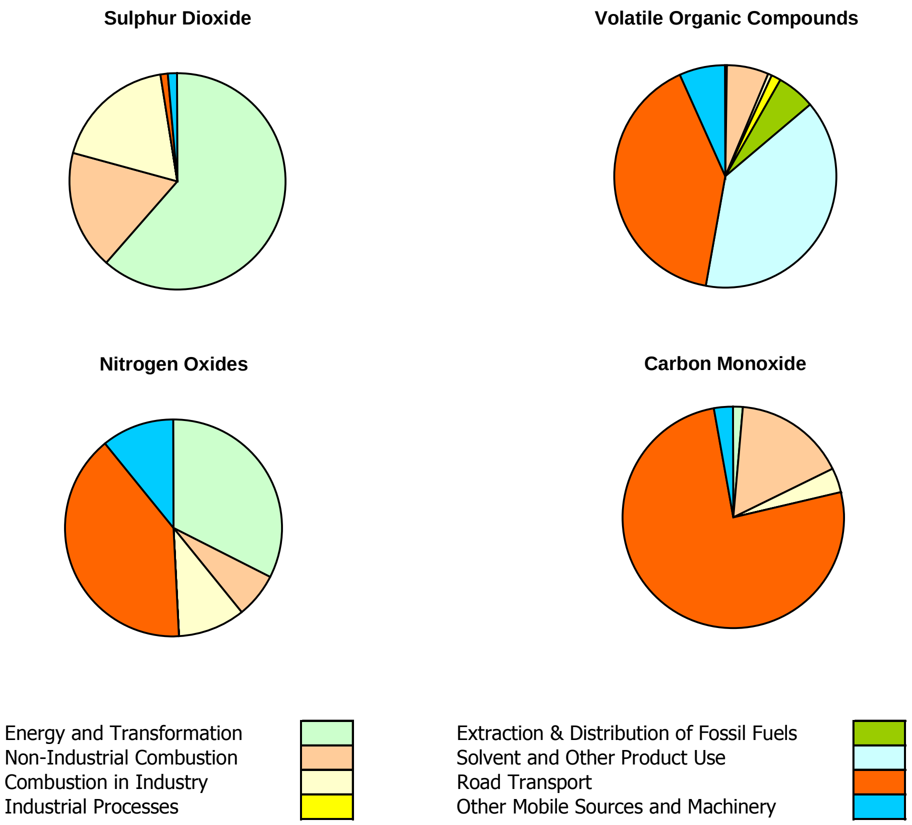


Figure 2.2. Emissions of SO2, NOX, VOC and CO by Main Source Category in 2001

Table 2.1. Greenhouse Gas Emission Trends in Ireland 1990-2001

(a) Emissions by Gas

GREENHOUSE GAS	**Base year(1)**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
							CO_2 equivalent(Gg)						
CO_2 (including net CO_2 from LUCF)	31,731.56	31,731.56	32,473.38	33,103.86	32,608.80	34,000.88	34,703.85	35,949.89	38,281.91	40,088.71	42,011.66	44,112.28	45,831.75
CO_2 (excluding net CO_2 from LUCF)	31,797.22	31,797.22	32,534.98	33,113.32	32,680.30	34,113.95	34,758.68	35,953.95	38,312.45	40,249.82	42,133.27	44,159.74	46,460.47
CH_4	11,899.86	11,899.86	12,183.36	12,344.22	12,441.24	12,505.50	12,595.17	12,768.84	12,954.69	12,970.02	12,884.76	12,784.59	12,562.83
N_2O	9,541.80	9,541.80	9,563.50	9,647.20	9,681.30	9,907.60	10,050.20	10,264.10	10,422.20	10,651.60	10,828.30	10,760.10	10,400.50
HFCs	20.71	0.00	0.00	0.00	0.00	0.00	20.71	58.04	78.62	104.14	151.70	190.08	230.90
PFCs	75.38	0.00	0.00	0.00	0.00	0.00	75.38	103.09	130.82	61.87	195.93	305.41	296.50
SF_6	83.05	0.00	0.00	0.00	0.00	0.00	83.05	101.03	132.09	90.59	63.46	51.89	66.75
Total (including net CO_2 from LUCF)	53,352.36	53,173.22	54,220.24	55,095.28	54,731.34	56,413.98	57,528.36	59,244.98	62,000.34	63,966.93	66,135.81	68,204.35	69,389.23
Total (excluding net CO_2 from LUCF)	53,418.02	53,238.88	54,281.84	55,104.74	54,802.84	56,527.05	57,583.19	59,249.04	62,030.88	64,128.04	66,257.42	68,251.81	70,017.95

(b) Emissions by Source Category

IPCC SOURCE CATEGORIES	**Base year(1)**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
							CO_2 equivalent (Gg)						
Energy	31,027.47	31,027.47	31,780.99	32,361.24	32,004.09	33,240.05	33,973.75	35,255.36	37,472.72	39,527.22	41,537.64	43,124.17	45,348.14
Industrial Processes	3,145.13	2,965.99	2,766.39	2,776.94	2,689.92	2,953.25	3,031.96	3,076.91	3,417.72	3,318.97	3,445.70	4,004.10	4,050.08
Solvent and Other Product Use	91.58	91.58	92.21	93.48	94.66	96.45	98.30	100.15	102.76	105.32	106.79	109.17	108.59
Agriculture	17,936.79	17,936.79	18,393.12	18,587.20	18,682.30	18,860.91	19,052.60	19,335.44	19,597.87	19,956.17	20,020.48	19,729.59	19,169.87
LUCF	-65.66	-65.66	-61.60	-9.46	-71.50	-113.07	-54.83	-4.06	-30.54	-161.11	-121.61	-47.46	-628.72
Waste	1,217.05	1,217.05	1,249.13	1,285.88	1,331.87	1,376.39	1,426.58	1,481.18	1,439.81	1,220.36	1,146.81	1,284.78	1,341.27
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (including net CO_2 from LUCF)	53,352.36	53,173.22	54,220.24	55,095.28	54,731.34	56,413.98	57,528.36	59,244.98	62,000.34	63,966.93	66,135.81	68,204.35	69,389.23

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

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

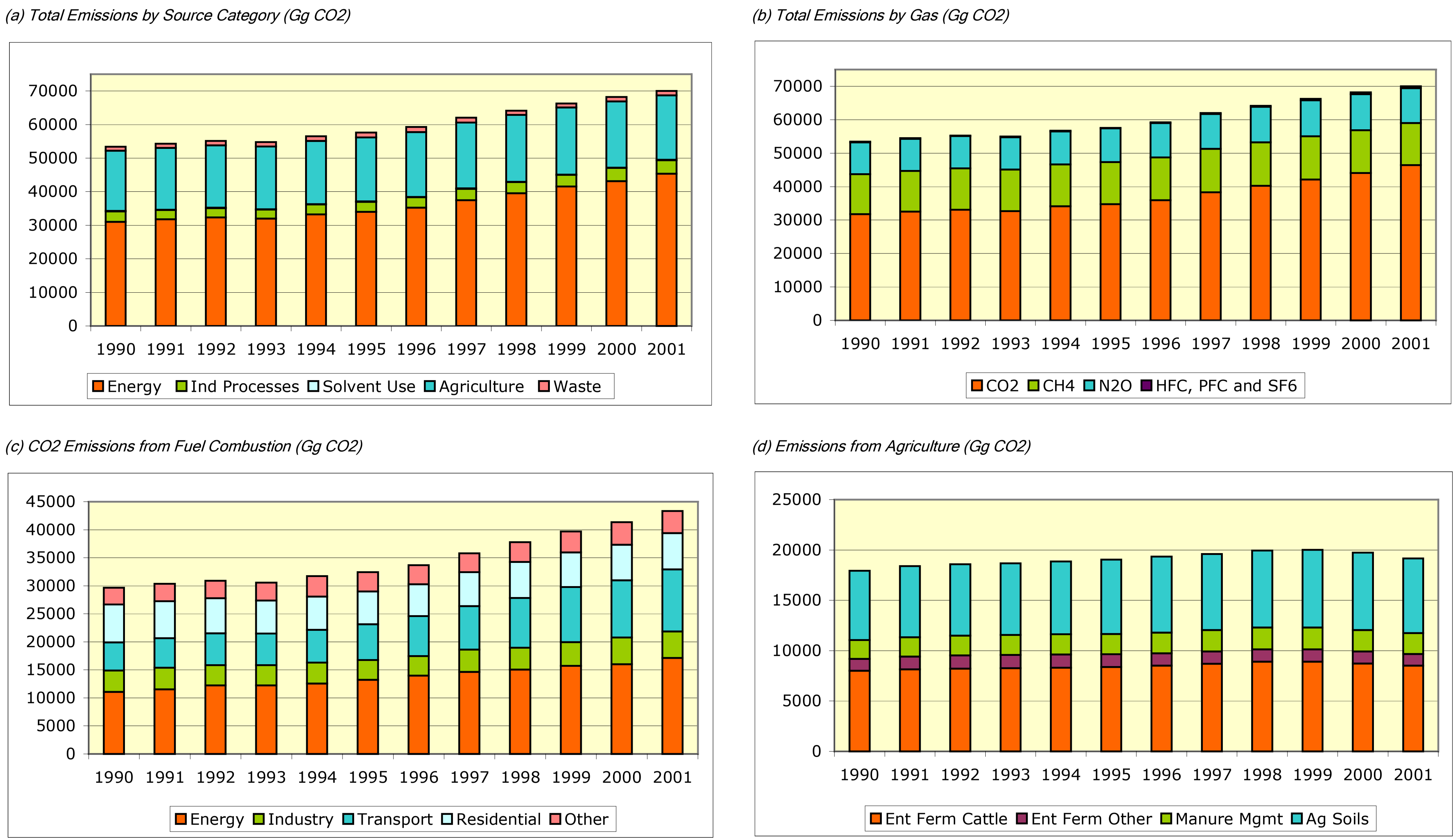


Figure 2.1. Trends in Greenhouse Gas Emissions 1990-2001

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 here 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.

The results at the IPCC Level 2 source category classification may be readily drawn from the CRF Summary 2 and those for 1990 and 2001 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 percent of total emissions in 2001. The corresponding total contribution from these six source categories in 1990 was similar at 85 percent of total emissions. In the case of both the 1990 and 2001 emissions, only five 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 15.8 percent in 2001, 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 CO2	1990 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO2	11057.48	20.70	20.70
1.A.4	Other Sectors	CO2	9725.97	18.21	38.91
4.A	Enteric Fermentation	CH4	9180.21	17.19	56.09
4.D	Agricultural Soils	N2O	6870.08	12.86	68.95
1.A.3	Transport	CO2	5019.62	9.40	78.35
1.A.2	Manufacturing Industries	CO2	3833.08	7.18	85.53
4.B	Manure Management	CH4	1260.83	2.36	87.89
6.A	Solid Waste Disposal	CH4	1158.21	2.17	90.05
2.B	Chemical Industry	N2O	1035.40	1.94	91.99
2.B	Chemical Industry	CO2	989.17	1.85	93.84
2.A	Mineral Products	CO2	941.42	1.76	95.61
IPCC Level 2 Source Category		GHG	Emissions in 2001 Gg CO2	2001 Level Assessment %	Cumulative Total of Level %
1.A.1	Energy Industries	CO2	17144.75	24.49	24.49
1.A.3	Transport	CO2	11062.84	15.80	40.29
1.A.4	Other Sectors	CO2	10413.97	14.87	55.16
4.A	Enteric Fermentation	CH4	9676.96	13.82	68.98
4.D	Agricultural Soils	N2O	7414.36	10.59	79.57
1.A.2	Manufacturing Industries	CO2	4726.29	6.75	86.32
2.A	Mineral Products	CO2	1832.63	2.62	88.94
4.B	Manure Management	CH4	1395.58	1.99	90.93
6.A	Solid Waste Disposal	CH4	1276.15	1.82	92.75
2.B	Chemical Industry	CO2	1037.40	1.48	94.23
4.B	Manure Management	N2O	683.52	0.98	95.21

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 2001 are presented in Table 3.2(a) and Table 3.2(b), respectively. Results for Tier 1 trend assessment for 2001 are shown in Table 3.3. The results for 2001 may be summarised as follows

(i) level assessment identifies 41 key source categories;

(ii) there are 26 key source categories of CO_2 in level assessment, accounting for 64.5 percent of total emissions;

(iii) there are six key source categories of CH_4 and seven key source categories of N_2O in level assessment, which account for 17 percent and 12.6 percent, respectively, of total emissions;

(iv) trend assessment identifies 29 key source categories;

(v) there are 16 key source categories of CO_2 in trend assessment, accounting for 73.4 percent of the total trend;

(vi) there are five key source categories of CH_4 and five key source categories of N_2O in trend assessment, which account for 10.5 percent and 10 percent, respectively, of the total trend;

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

(viii) in level assessment, *Energy* accounts for 26 key source categories, *Industrial Processes* for five, *Agriculture* for eight while *Land-Use Change and Forestry* and *Waste* contribute one each and

(ix) in trend assessment, *Energy* accounts for 15 key source categories, *Industrial Processes* for five, *Agriculture* for seven and *Waste* contributes one.

The list of key sources given by level assessment in 1990 is very similar to that for 2001 but the higher ranking of the main CO_2 sources in *Energy* is notable in 2001. The top ten key sources contributed 59 percent of total emissions in both years. The main findings of level assessment for 1990 emissions indicate that

(i) there was a total of 39 key source categories in that year, two less than in 2001;

(ii) there were 28 key source categories of CO_2, two more than in 2001, accounting for 58 percent of total emissions;

(iii) there were six key source categories of CH_4 and five key source categories of N_2O, which accounted for 21.3 percent and 15.3 percent, respectively, of total emissions and

(iv) *Energy* accounted for 25 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 27 out of 41 key source categories in 2001 each account for less than 2 percent of the total emissions and that only six 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 26 out of 41 key source categories identified by level assessment in 2001 and for 64 percent of total emissions. In trend assessment, they account for 16 out of 27 key source categories and for 54 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 ammonia 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	9.68	9.68
2 Energy Industries- Coal	CO2	4844.66	9.07	18.75
3 Residential Peat	CO2	3123.50	5.85	24.60
4 Energy Industries- Peat	CO2	3064.65	5.74	30.34
5 Enteric Fermentation - Dairy Cattle	CH4	2847.60	5.33	35.67
6 Animal Production	N2O	2780.70	5.21	40.87
7 Road Transport - Petrol	CO2	2760.03	5.17	46.04
8 Direct Soil Emissions	N2O	2659.80	4.98	51.02
9 Residential Coal	CO2	2023.92	3.79	54.81
10 Road Transport - Diesel	CO2	1901.14	3.56	58.37
11 Energy Industries- Natural Gas	CO2	1880.66	3.52	61.89
12 Commercial Gasoil	CO2	1482.29	2.77	64.66
13 Indirect Soil Emissions	N2O	1432.20	2.68	67.34
14 Solid Waste Disposal	CH4	1158.15	2.17	69.51
15 Enteric Fermentation - Sheep	CH4	1102.92	2.06	71.58
16 Energy Industries- Oil	CO2	1086.52	2.03	73.61
17 Nitric Acid Production	N2O	1035.40	1.94	75.55
18 Industrial Processes - Ammonia	CO2	989.10	1.85	77.40
19 Industry Natural Gas	CO2	855.68	1.60	79.00
20 Industrial Processes - Cement	CO2	750.00	1.40	80.41
21 Alumina Production - Fuel Oil	CO2	712.76	1.33	81.74
22 Manure Management - Other Cattle	CH4	662.13	1.24	82.98
23 Agriculture Gasoil	CO2	659.82	1.24	84.21
24 Industry Fuel Oil	CO2	623.67	1.17	85.38
25 Residential Gasoil	CO2	601.51	1.13	86.51
26 Cement Production - Coal	CO2	495.09	0.93	87.44
27 Industry - Coal	CO2	475.29	0.89	88.33
28 Commercial Fuel Oil	CO2	467.75	0.88	89.20
29 Industry Gasoil	CO2	466.48	0.87	90.07
30 Manure Management - Dairy Cattle	CH4	452.76	0.85	90.92
31 Liming of Agricultural Lands	CO2	384.45	0.72	91.64
32 Residential SSF	CO2	299.26	0.56	92.20
33 Residential Natural Gas	CO2	269.13	0.50	92.71
34 Residential Kerosene	CO2	248.12	0.46	93.17
35 Energy Industries- Coal	N2O	238.70	0.45	93.62
36 Commercial Natural Gas	CO2	200.12	0.37	93.99
37 Industrial Processes - Lime	CO2	191.42	0.36	94.35
38 Residential LPG	CO2	186.69	0.35	94.70
39 Industry LPG	CO2	165.35	0.31	95.01
40 Fugitive Emissions-Oil and Natural Gas	CH4	150.78	0.28	95.29
41 Railways	CO2	147.31	0.28	95.57
42 Fugitive Emissions-Oil and Natural Gas	CO2	138.90	0.26	95.83
43 Manure Management - Swine	CH4	123.90	0.23	96.06
44 Energy Industries Refinery Gas	CO2	119.74	0.22	96.28

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

Table 3.2 (b) Key Source Level Assessment 2001

Disaggregated[a] Emission Source	GHG	Emissions in 2001 Gg CO2	2001 Level Assessment[b] %	Cumulative Total of Level %
1 Energy Industries- Coal	CO2	6021.41	8.60	8.60
2 Enteric Fermentation - Other Cattle	CH4	5959.80	8.51	17.11
3 Road Transport - Diesel	CO2	5527.13	7.89	25.01
4 Road Transport - Petrol	CO2	4759.76	6.80	31.80
5 Energy Industries- Natural Gas	CO2	4185.52	5.98	37.78
6 Energy Industries- Oil	CO2	3925.34	5.61	43.39
7 Direct Soil Emissions	N2O	2935.70	4.19	47.58
8 Animal Production	N2O	2932.60	4.19	51.77
9 Energy Industries- Peat	CO2	2667.44	3.81	55.58
10 Enteric Fermentation - Dairy Cattle	CH4	2557.80	3.65	59.23
11 Residential Kerosene	CO2	1964.02	2.81	62.04
12 Commercial Gasoil	CO2	1789.18	2.56	64.59
13 Industrial Processes - Cement	CO2	1650.00	2.36	66.95
14 Indirect Soil Emissions	N2O	1546.90	2.21	69.16
15 Solid Waste Disposal	CH4	1276.15	1.82	70.98
16 Residential Peat	CO2	1230.57	1.76	72.74
17 Industry Natural Gas	CO2	1226.02	1.75	74.49
18 Residential Natural Gas	CO2	1108.71	1.58	76.07
19 Alumina Production - Fuel Oil	CO2	1077.73	1.54	77.61
20 Enteric Fermentation - Sheep	CH4	1072.89	1.53	79.14
21 Residential Coal	CO2	1061.47	1.52	80.66
22 Industrial Processes - Ammonia	CO2	1037.40	1.48	82.14
23 Agriculture Gasoil	CO2	853.16	1.22	83.36
24 Cement Production - Coal/Pet Coke	CO2	810.95	1.16	84.52
25 Residential Gasoil	CO2	776.44	1.11	85.63
26 Manure Management - Other Cattle	CH4	762.93	1.09	86.72
27 Commercial Natural Gas	CO2	722.27	1.03	87.75
28 Industry Gasoil	CO2	601.51	0.86	88.61
29 Nitric Acid Production	N2O	584.35	0.83	89.44
30 Commercial Fuel Oil	CO2	521.84	0.75	90.19
31 Railways	CO2	420.44	0.60	90.79
32 Manure Management - Dairy Cattle	CH4	406.77	0.58	91.37
33 Liming of Agricultural Lands	CO2	378.30	0.54	91.91
34 Road Transport	N2O	341.00	0.49	92.40
35 Industry Fuel Oil	CO2	328.70	0.47	92.87
36 Industry Kerosene	CO2	307.91	0.44	93.30
37 Consumption of Halocarbons	PFC	296.50	0.42	93.73
38 Energy Industries- Coal	N2O	296.36	0.42	94.15
39 Energy Industries Refinery Gas	CO2	239.49	0.34	94.49
40 Consumption of Halocarbons	HFC	230.90	0.33	94.82
41 Energy Industries - Oil	N2O	222.27	0.32	95.14
42 Manure Management - Swine	CH4	198.45	0.28	95.42
43 Industrial Processes - Lime	CO2	182.63	0.26	95.69
44 Fugitive Emissions-Oil and Natural Gas	CO2	134.00	0.19	95.88

a disaggregated to level of emission calculation
b percent of total emissions in 2001

Table 3.3. Key Source Trend Assessment

Disaggregated Emission Source	GHG	Emissions in 1990 Gg CO2	Emissions in 2001 Gg CO2	Level Assessment in 2001 %	Trend Assessment in 2001	Contribution to Trend %	Cumulative Total Contribution %
1 Residential Peat	CO2	3123.50	1276.10	1.82	3.07	10.92	10.92
2 Road Transport - Diesel	CO2	1901.14	4925.62	7.03	2.65	9.43	20.35
3 Energy Industries- Oil	CO2	1086.52	3484.39	4.98	2.24	7.98	28.33
4 Energy Industries- Peat	CO2	3064.65	2324.05	3.32	1.84	6.56	34.89
5 Energy Industries- Natural Gas	CO2	1880.66	4098.43	5.85	1.78	6.33	41.22
6 Residential Coal	CO2	2023.92	1140.69	1.63	1.65	5.86	47.08
7 Residential Kerosene	CO2	248.12	1760.74	2.51	1.56	5.56	52.64
8 Enteric Fermentation - Dairy Cattle	CH4	2948.13	2634.03	3.76	1.34	4.77	57.41
9 Enteric Fermentation - Other Cattle	CH4	5298.30	5871.18	8.39	1.17	4.16	61.57
10 Road Transport - Petrol	CO2	2760.03	4610.38	6.58	1.08	3.85	65.42
11 Animal Production	N2O	2889.20	2923.30	4.18	0.94	3.35	68.76
12 Solid Waste Disposal	CH4	1779.75	1539.72	2.20	0.86	3.07	71.84
13 Direct Soil Emissions	N2O	2681.50	2817.90	4.02	0.76	2.70	74.54
14 Residential Natural Gas	CO2	269.13	1009.80	1.44	0.72	2.55	77.08
15 Industrial Processes - Cement	CO2	750.00	1575.00	2.25	0.64	2.29	79.38
16 Energy Industries- Coal	CO2	4844.66	5760.44	8.23	0.64	2.29	81.66
17 Nitric Acid Production	N2O	1035.40	812.20	1.16	0.59	2.11	83.77
18 Enteric Fermentation - Sheep	CH4	1199.52	1072.47	1.53	0.54	1.94	85.71
19 Industry Fuel Oil	CO2	623.67	384.38	0.55	0.47	1.68	87.39
20 Industrial Processes - Ammonia	CO2	989.10	883.29	1.26	0.45	1.60	88.99
21 Commercial Natural Gas	CO2	200.12	673.97	0.96	0.45	1.60	90.59
22 Indirect Soil Emissions	N2O	982.70	923.80	1.32	0.40	1.41	92.00
23 Road Transport	N2O	56.10	308.76	0.44	0.26	0.91	92.91
24 Industry Kerosene	CO2	38.86	275.02	0.39	0.24	0.87	93.78
25 Consumption of Halocarbons	PFC	75.38	305.41	0.44	0.23	0.80	94.58
26 Railways	CO2	147.31	377.48	0.54	0.20	0.71	95.29
27 Industry Natural Gas	CO2	855.68	1292.73	1.85	0.19	0.66	95.95
28 Consumption of Halocarbons	HFC	20.71	190.08	0.27	0.18	0.63	96.59
29 Manure Management - Other Cattle	CH4	678.09	751.59	1.07	0.15	0.53	97.12
30 Manure Management - Dairy Cattle	CH4	468.72	481.81	0.69	0.14	0.51	97.63
31 Alumina Production - Fuel Oil	CO2	712.76	1050.69	1.50	0.13	0.45	98.08
32 Energy Industries - Oil	N2O	62.93	197.47	0.28	0.13	0.45	98.53
33 Commercial Fuel Oil	CO2	467.75	502.75	0.72	0.12	0.43	98.96
34 Liming of Agricultural Lands	CO2	361.35	374.81	0.54	0.11	0.38	99.34
35 Industry Petroleum Coke	CO2	495.09	743.16	1.06	0.10	0.37	99.70
36 Industrial Processes - Lime	CO2	191.42	186.23	0.27	0.07	0.25	99.95
37 Commercial Gasoil	CO2	1482.29	1933.42	2.76	0.01	0.04	99.99

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 and data availability are increased. 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. This chapter describes the recalculations that have been carried out for the 1990-2000 inventories to make them consistent with the 2001 inventory prepared for submission in 2003.

4.2 Recalculations in the 1990-2001 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 2001 inventory and, in order to maintain a consistent time-series, they have been incorporated in the inventories for all previous years. The changes reflect a continued response to the results and recommendations of the various stages of the UNFCCC review process and the application of more robust methods and data in a number of emission source categories. The previous and revised numerical values of the emissions estimates for all years 1990-2000, along with the changes related to methods, activity data and emission factors are presented here and detailed in Table 8(a) and Table 8(b) of the 1990-2000 CRF time-series.

The changes that result in the most recent round of recalculations include the coverage of some additional minor sources of emissions in *Energy* and *Agriculture*, a revised treatment of activity data in general for *Agriculture* and more in-depth analysis of the contribution of landfills to CH_4 production in the *Waste* source-category. The individual changes are

(a) the addition of first-time estimates of the emissions of CO_2 and CH_4 from natural gas production under sub-category *1.B.2.b Natural Gas* ;

(b) the inclusion of first-time estimates of emissions from domestic aviation in sub-category *1.A.3.a Civil Aviation*;

(c) revision of the three-year averaging of activity data in *Agriculture* so that the three-year period ends in the inventory year (previously the period was centred on the inventory year);

(d) accounting for the nitrogen contributions from nitrogen-fixing crops and crop residues in the estimation of direct N_2O emissions from soils;

(e) revision of $Frac_{LEACH}$, the proportion of input nitrogen leached from agricultural lands applied as part of the determination of indirect N_2O emissions, from 0.04 to 0.1;

(f) improved estimates of the historical time-series of municipal solid waste placed in landfills and of the associated degradable organic carbon that results in CH_4 emissions from this source.

4.3 Effects of Recalculations

A summary of the effects of the latest revisions on the total CO_2 equivalent emissions by IPCC source category and on total national emissions is provided in Table 4.1. The percentage differences are also estimated.

Emissions from *Energy* are increased by less than one percent due to the inclusion of emissions from sub-category *1.A.3.a Civil Aviation* and fugitive emissions from natural gas production under sub-category *1.B.2.b Natural Gas*. The decreasing contribution towards the latter end of the time-series reflects the decline in natural gas production after 1995.

The higher direct N_2O emissions from soils, due to inclusion of the nitrogen contributions from nitrogen-fixing crops and crop residues, and higher indirect N_2O emissions resulting from the increase in the value of $Frac_{LEACH}$, increase the total N_2O emissions from *Agriculture*. In addition, the revised three-year averaging has an appreciable effect on all elements of the inventories from *Agriculture*, which in some cases gives reductions in the emissions of either CH_4 or N_2O in some sub-categories. The cumulative effect of the changes is therefore quite variable, with an increase of 7.2 percent apparent in 2000 while a very slight decrease is given by the recalculation for 1990. The effect for the year 2000 is exaggerated to some degree by correcting a slight inconsistency in livestock population statistics that had developed for that year due to foot and mouth disease and the averaging scheme that had been employed up to the 2002 submission.

Ireland reports emissions of CO_2 from the liming of agricultural soils under *Land Use Change and Forestry*. The changes in statistical data for this activity resulting from the revised three-year averaging give rise to highly variable percentage differences between previous and latest estimates of the net emissions from *Land Use Change and Forestry,* which fluctuate from negative to positive values over the years 1990 to 2000. A more robust 30-year time-series of the amount of municipal solid waste placed in landfills has been derived for the 2001 inventory. A variable split between managed and unmanaged landfill sites has been incorporated in this time-series and the proportion of degradable organic carbon in solid wastes that is ultimately dissimilated has been changed from 70 percent to 60 percent, in accordance with the IPCC good practice guidance. The latest estimates of CH_4 emissions from landfills resulting from these changes are significantly lower than the previous estimates. The changes vary from about 20 percent in 2000 to about 34 percent in 1990.

The combined effect of the latest revisions on total emissions for the years 1990 to 2000 is very small. The change varies between a reduction of just under 1 percent in 1990 to an increase of 1.75 percent in 2000 for total emissions that exclude the net CO_2 emissions from LUCF. The increases in CO_2 and N_2O emissions due to the additional sources in *Energy* and *Agriculture* are largely offset by the reductions resulting in the recalculated estimates of CH_4 emissions from *Waste*.

4.4 Future Recalculations

There are two important reasons why further recalculations of Irish greenhouse gas inventories will need to be undertaken in the coming years. 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. 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. Changes in methodologies could also result from full implementation of the IPCC good practice guidance over time and the application of similar imminent guidance on *Land Use Change and Forestry*, which is an important aspect in relation to the work needed in this source category.

Ireland's 2003 submission is to be the subject of an in-country review in 2003. The inventory agency views the timing of this review as ideal, considering the current status of Irish greenhouse gas inventories and the extensive revisions and improvements that have been undertaken in the past few years. The availability of the present NIR will facilitate in-depth assessment and analysis of the inventory process so that the review should identify any outstanding issues related to methods, data and emission factors that may warrant corrections or recalculations in particular areas. The review report will be the basis on which the inventory agency can re-evaluate its performance to date in applying the UNFCCC guidelines and for consolidating the available time-series data before moving on to the more substantial recalculations mentioned in the previous paragraph.

Table 4.1. Summary of Changes in Emissions due to Recalculations 1990-1999

IPCC SOURCE/SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Previous Estimates (PE)						CO2 equivalent (Gg)					
1. Energy	30805.77	31555.22	32138.90	31754.79	32991.23	33716.07	34999.86	37233.86	39312.58	41320.57	42942.26
2. Industrial Processes	2965.99	2766.39	2776.94	2689.92	2953.25	3031.96	3076.91	3417.72	3318.97	3445.70	3935.90
3. Solvent and Other Product Use	91.58	92.21	93.48	94.66	96.45	98.30	100.15	102.76	105.32	106.79	109.17
4. Agriculture	17997.66	18020.06	17957.30	18174.88	18424.30	18777.27	19030.65	19165.84	19697.93	19411.09	18403.97
5. Land-Use Change and Forestry	-88.76	-114.36	-8.70	-86.67	-33.40	-12.59	47.22	-85.40	-194.72	-140.64	-32.52
6. Waste	1838.65	1878.29	1905.80	1929.53	1951.79	1970.06	1987.07	1902.44	1655.90	1583.40	1604.82
7. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total (including net CO2 from LUCF)	53610.89	54197.81	54863.72	54557.11	56383.62	57581.07	59241.86	61737.22	63895.98	65726.91	66963.60
Total (excluding net CO2 from LUCF)	53699.65	54312.17	54872.42	54643.78	56417.02	57593.66	59194.64	61822.62	64090.70	65867.55	66996.12
Latest Estimates (LE)						CO2 equivalent (Gg)					
1. Energy	31027.47	31780.99	32361.24	32004.09	33240.05	33973.75	35255.36	37472.72	39527.22	41537.64	43124.17
2. Industrial Processes	2965.99	2766.39	2776.94	2689.92	2953.25	3031.96	3076.91	3417.72	3318.97	3445.70	3935.90
3. Solvent and Other Product Use	91.58	92.21	93.48	94.66	96.45	98.30	100.15	102.76	105.32	106.79	109.17
4. Agriculture	17936.79	18393.12	18587.20	18682.30	18860.91	19052.60	19335.44	19597.87	19956.17	20020.48	19729.59
5. Land-Use Change and Forestry	-65.66	-61.60	-9.46	-71.50	-113.07	-54.83	-4.06	-30.54	-161.11	-121.61	-47.46
6. Waste	1217.05	1249.13	1285.88	1331.87	1376.39	1426.58	1481.18	1439.81	1220.36	1146.81	1284.78
7. Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Total (including net CO2 from LUCF)	53173.22	54220.24	55095.28	54731.34	56413.98	57528.36	59244.98	62000.34	63966.93	66135.81	68136.15
Total (excluding net CO2 from LUCF)	53238.88	54281.84	55104.74	54802.84	56527.05	57583.19	59249.04	62030.88	64128.04	66257.42	68183.61
Percent Difference 100*(LE-PE)/PE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1. Energy	0.72	0.72	0.69	0.79	0.75	0.76	0.73	0.64	0.55	0.53	0.42
2. Industrial Processes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Solvent and Other Product Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Agriculture	-0.34	2.07	3.51	2.79	2.37	1.47	1.60	2.25	1.31	3.14	7.20
5. Land-Use Change and Forestry	-26.03	-46.14	8.74	-17.50	238.53	335.50	-108.60	-64.24	-17.26	-13.53	45.94
6. Waste	-33.81	-33.50	-32.53	-30.97	-29.48	-27.59	-25.46	-24.32	-26.30	-27.57	-19.94
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total (including net CO2 from LUCF)	-0.82	0.04	0.42	0.32	0.05	-0.09	0.01	0.43	0.11	0.62	1.75
Total (excluding net CO2 from LUCF)	-0.86	-0.06	0.42	0.29	0.20	-0.02	0.09	0.34	0.06	0.59	1.77

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 inventories of greenhouse gas emissions for the years 1990 through 2001, submitted to the UNFCCC secretariat in April 2003. This description takes into account the revisions to source-category coverage and changes to methods and data that resulted in the recalculations outlined in Chapter Four. 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 the National Inventory Report and the Common Reporting Format 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.

Tables B.1 and B.2 of Appendix B show the national energy and oil balance sheets for 2001, published by the Department of Public Enterprise (DPE, 2001). These energy balances form the basis of all emission estimates related to the use of energy in Ireland. Similar data for all years from 1990 through 2000 may be viewed at http://www.irlgov.ie/tec/energy/. 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 2001.

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	NO	NO	NO
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 2001 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 2001 (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 those 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, and other sources of information must be used to make the detail of the fuel-sector matrix more compatible with the inventory reporting format 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. The liberalisation of the electricity market has, however, resulted in a number of new generating stations being built by other companies. Two such power stations came into service in 2000. Fuel use data and corresponding CO_2 emissions in 2001 were obtained by direct contact with the operators of these plants. The reported CO_2 emissions from the electricity companies have been aggregated on the basis of four 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;
- information on fuel consumption by a small number of energy intensive industries (alumina, cement and ammonia production) is obtained from their Annual Environmental Reports (AER) submitted to the EPA in accordance with their IPC licence conditions. These data source supplements 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, an arbitrary split is used (10 percent stationary sources and 90 percent mobile sources) 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 under own use/losses given in the balance sheet (Table B.1) and the amount of gas lost from the distribution network, reported under fugitive emissions in *1.B.2 (b) Natural Gas*;
- the fuel consumption associated with domestic civil aviation is determined from the number of domestic LTO cycles, the fuel consumption rates 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 usually 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 II 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. The COPERT II 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 2001 results have been converted to national average values per fuel type for the purpose of 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 2001 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 2002, 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 recently informed by BGE that natural gas losses from the distribution network are now so small that they cannot be measured.

Up to 2001, only one company was 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 1990-2001 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 also accounting for a small amount of flaring in some years, indicate a close relationship between emissions and the amount of gas produced. This relationship, in terms of the indicative emission rates of CO_2 and CH_4 per unit of gas extracted, has been applied 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 released as in combustion. The IPCC default value of 0.75 is used for the proportion of carbon stored in naphtha. Ireland's only oil refinery is a small hydroskimming refinery where there is no production of other petroleum products normally used for non-energy purposes, such as bitumen, lubricants, plastics and asphalt. The Reference Approach also accounts for potential carbon storage in fuels used as a process feedstock. A significant amount of natural gas feedstock is used in ammonia production in Ireland, which is then used in urea manufacture. According to the IPCC Guidelines, this end product does not result in sequestration of the carbon contained in the natural gas input. Consequently, a value of zero is used for the proportion of carbon stored in relation to natural gas feedstock.

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 2001 is presented in Table C.5 of Appendix C. Differences of 3.35 percent and 1.84 percent are indicated for total energy and CO_2 emissions, respectively. The largest differences are for gaseous fuels where they amount to 14.33 percent for energy and 12.38 percent for CO_2 emissions. The differences in respect of liquid and solid fuels are negligible.

For gaseous fuels, the difference is due to the inclusion of the amount of natural gas used as a feedstock for ammonia production (18,882 PJ in 2001) in the Reference Approach. As mentioned above, the feedstock carbon is ultimately released following urea manufacture, resulting in CO_2 emissions of 1,037.4 Gg. This emission is reported under *Industrial Processes* and is therefore excluded from *Energy* in the Sectoral Approach. According to the IPCC good practice guidance, such emissions should be subtracted from the Reference Approach total. If this adjustment is applied the overall differences are reduced to 0.08 percent for energy and 1.83 percent for CO_2 emissions.

5.2.5 Memo Items

The memo items of the IPCC reporting format (Table 5.2) refer to activities the emissions from which 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 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 now determined from the number of domestic LTO cycles, the length of the associated flights and the fuel consumption rates appropriate to the aircraft concerned, as given by the IPCC good practice guidance. This amount is deducted from the value given in the energy balance sheet to obtain aviation bunker fuel. The inclusion of emissions from domestic civil aviation is one of the changes introduced in the 2001 inventory that led to the recalculations described in Chapter Four.

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 adequately apportion 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. There is also a need to consider the IPCC good practice guidance as it relates to the assessment of the national energy balance so that full accounting of energy use is guaranteed and the difference in results between the Sectoral Approach and the Reference Approach are clearly understood and explained.

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 too be reviewed as they are recognised to differ significantly from the IPCC default values.

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 for 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 either direct or indirect greenhouse gases. The four industrial sources that do merit coverage in Ireland include cement and lime production under *2.A Mineral Products* and ammonia and nitric acid production under *2.B Chemical Industry*. Three of these production processes were key sources of emissions in 2001 (Chapter Three), accounting for almost 5 percent of total emissions.

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

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 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. 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 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, which is a very important source of CO_2 emissions (Chapter 3). Until very recently, 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 is therefore part of the recalculations that are included in the 2002 submission.

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 for the latest estimates of CO_2 from cement production for all years up to 2001, 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 IPC reporting obligations.

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).

5.3.2.2 Ammonia and Nitric Acid Production

Ammonia production in Ireland uses natural gas as the feedstock fuel. This is the only feedstock use of natural gas in the country and the amount is known from the national energy balance sheet (Appendix B). Ireland's first estimates of CO_2 emissions from ammonia production used an emission factor of 36.63 kg CO_2/TJ (equivalent to 1.54 tonne CO_2/tonne natural gas), on the assumption that one-third of the carbon in feedstock was sequestered in urea produced by the plant. However, this value was changed for the inventories from 1998 onwards to reflect the stipulation in the 1996 IPCC guidelines that carbon in urea is stored for a short time and it should be assumed that all feedstock carbon is emitted. The CO_2 emission factor now used is therefore the same as that used in *Energy* for the combustion of natural gas, i.e. the country-specific value of 54.94 kg CO_2/TJ, or 2.3 tonne CO_2/tonne natural gas.

Nitric acid is produced at one small plant in Ireland as an intermediary in the manufacture of calcium ammonium nitrate fertilizer. The company has operated under IPC licence since 1997 and, while N_2O emissions are not explicitly part of the company's Annual Environmental Report, this control has facilitated the acquisition of some useful data. Four production units at this plant produced 338,800 tonnes of nitric acid in 1990 and the associated N_2O emissions amounted to 3,337 tonnes. This emission was estimated from nitrogen loading and the type of catalyst used in the process and it implies an emission rate of 9.85 kg N_2O/tonne nitric acid. This rate is in line with the values given in Table 3.8 of the IPCC good practice guidance for plants without catalytic reduction. A new unit came into operation in 1993 and three of the older production units were shut down. The N_2O emissions reported by the company for this new arrangement was 2,620 tonnes in 1995. Based on relatively constant nitric acid production, this value of N_2O emissions has been retained for all years up to 2000. The company reported N_2O emissions of 1,890 tonnes for 2001.

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 a 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 1995-2001

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 obtained 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 f-gases. The time series is now extended to include 2001 estimates. The following paragraphs describe the main steps followed 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, 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. No sales data were obtained for 1999, 2000 or 2001. Therefore, for these years, 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.2 of Appendix D shows the usage and resulting emissions of HFCs in stationary refrigeration and air conditioning systems in Ireland for the years 1995 to 2000.

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 in 1991, usage would 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 was again assumed for 2001. 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.2 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 2001. 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 2001. Similarly, 'first-fill' emissions was the same for each of the years1995 to 2001 (see the 1998 Final Report for the calculation). Since HFCs were first introduced into MACs in Ireland in 1993, operation emissions from the HFC stock in vehicles was relevant to each of the years 1995 to 2001. 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 2001 for all vehicles (DELG, 2002). Vehicles include 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 the years concerned. 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 1999, 2000 and 2001, 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 2001) is between two and seven years this is not relevant to a significant degree, considering that the IPCC default vehicle lifetime 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 2000. 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 2001 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 2001 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 2001. Table D.3 and Table D.4 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 2001. Evidence of this is that one of the companies using HCFC-141b is switching over to pentane in 2002, 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 – 2001. 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 – 2001, the calculation of actual emissions from closed cell foam use in Ireland is as follows:

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

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 2001 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 2001.

D Fire Protection

One Irish company provided a very approximate estimate of HFC usage in fire protection systems in Ireland as currently running at 40 tonnes/annum (2002). The principal HFC used is HFC-227ea with 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 ago 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 to 2001. Annual emissions were calculated as 1 percent of the cumulative total HFC-227ea, as shown in Table D.5 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 2002, 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 current (2001) total market for MDIs in Ireland and the fraction occupied by HFC/CFC-based inhalers. Today (2002) there is 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. Ultimately, CFCs was replaced by either HFCs, or dry powder inhalers and nebulisers, with an expected complete changeover by 2005. The Tier 2 bottom up approach using the number of aerosol products sold and the average charge per container was used for the years 1996 to 2000 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 by the company and it was indicated that losses were of the order of 1.6 percent.

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 are estimated from the 1998 value of 5.7 tonnes and annual GDP growth. The estimate for 2001 is 14.934 tonnes.

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 ESB on actual SF_6 emissions from electrical transmission and distribution equipment for each of the years 1995 to 2000 (Table D.6(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% 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 2000 for use in the CRF tables.

I Semiconductor Manufacture
There are two major semiconductor manufacturing companies in Ireland that utilise PFC, HFC and SF_6. The individual companies provided usage data and their own estimates of emissions for the years 1995 to 2001. In the case of one company, actual data were not obtained for 1996 and therefore the usage of each gas was estimated as the average of that for 1995 and 1997. Tables D.6(a) and D.6(b) of Appendix D shows total usage and estimated emissions of PFC, HFC, and SF_6 in the two semiconductor manufacturing companies. 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 to 2001. The second company also provided emissions estimates for 1990 to 1996 for all gases, and for 2000 and 2001 for its principal gas PFC-116. These estimates are 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 2001. 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 are taken as two-thirds of SF_6 usage (51 kg tonnes SF_6 per year) for each of the years 1990 – 2001 and potential emissions are 764 kg SF_6 per year.

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 was the same as the 1998 estimate of 52 kg. 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. 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 2001 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.7 of Appendix D. The annual potential emissions are 52 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 emissions of HFC, PFC and SF_6 in the years 1995 through 2000 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.

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	

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 has 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 is now extended to inclde 2001. 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 is fully covered in the 2001 inventory and the emissions from *Agriculture* in all previous years have been revised to maintain consistency and comparability.

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. An important change introduced in compiling the 2001 inventory is the revision of all agricultural statistics on the basis of a three-year averaging period that ends in the inventory year where previously it was centred on the inventory year. This change was prompted by the late availability on occasion of the statistical data for the end year of the original three-year term, with the result that the necessary averaging could not always be applied consistently.

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 is 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 2001. 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 2001. 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. Much of the required information does exist in the country. However, a lack of involvement on the part of the Department of Agriculture and its reluctance to endorse some elements of the methodology or document some essential items of data, means that 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.

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

Irish statistical publications on agriculture (CSO, 2002) 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 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 wide variety of animals in this category is dominated by those less than two years old. Consequently, a weighted emission factor of 50 kg CH_4/head/year, determined by the 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.1 of Appendix F) shows all values of activity data, emission factors and CH_4 emissions for enteric fermentation in 2001.

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.

The calculation sheet for methane emissions from domestic livestock (Table F.1 of Appendix F) includes the derivation of the emission factors and the resultant CH_4 emissions from manure management in 2001. 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 REPS survey data have been used to quantify manure production and to determine the proportions of animal manures assigned to the various animal waste management systems (AWMS) in Table F.1, Appendix F. The CH_4 emissions from manure management in 2000 amounted to almost 15 percent of those from enteric fermentation.

5.5.4 N_2O Emissions from Agricultural Soils

Agricultural soils are the principal source of N_2O emissions in most countries. The direct and indirect emissions of N_2O from soils are key sources in Ireland (Chapter Three), accounting for a combined 6.4 percent of total CO_2 equivalent emissions in 2001, while N_2O emissions from nitrogen inputs from grazing animals contributed a further 4 percent of the total. The IPCC methodology for this source category is essentially an accounting exercise for all potential inputs of nitrogen to agricultural soils and the subsequent application of default rates of nitrogen lost to the atmosphere as N_2O. The accounting is accomplished by considering direct and indirect inputs individually, which can be followed through the calculation sheets provided in Appendix F.

5.5.4.1 Direct Emissions of N_2O

Direct emissions of N_2O are related to nitrogen inputs from chemical fertilizers, animal wastes, biological N-fixation by crops, crop residue mineralisation and soil nitrogen mineralisation due to the cultivation of organic soils. The inventories of direct N_2O emissions for the years 1990-2001 take into account the soil nitrogen inputs from all these sources. 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 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 system as needed for the IPCC methodology. The values of nitrogen excretion and the proportions allocated to each AWMS given in the calculation sheets (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 sheep. 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 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.

All nitrogen from animal wastes that are managed in storage or treatment systems has some potential to produce direct 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 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 annual statistics on nitrogen fertilizer use are obtained from the Department of Agriculture while the organic nitrogen inputs are known from the above analysis. A significant fraction of the nitrogen applied to agricultural soils is normally volatilized as NH_3 or NO_X. This fraction must be taken into account in order to determine the amount of nitrogen available for 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. This approach results in volatilization rates typically of 4 percent and 17 percent for synthetic fertilizers and organic nitrogen applications, respectively (Table F.9 and Table F.10 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. Annual crop production statistics, averaged in the same way as for other activity data in *Agriculture*, and the default values of nitrogen content are the basis of these estimates (Table F.4 of Appendix F).

The default emission factors available from the IPCC good practice guidance are used to estimate direct emissions of N_2O. The factors are 12.5 kg N_2O-N/tonne applied N for synthetic fertilizer and animal waste nitrogen and 20 kg N_2O-N/tonne N for nitrogen inputs from grazing animals. Total direct emissions of N_2O from agricultural soils in 2001 amounted to 9,470 tonnes, of which 81 percent came from chemical fertilizers and 15 percent was due to land spreading of animal manures. The nitrogen excreted at pasture by cattle and sheep accounted for N_2O emissions (9,457 tonnes) of similar amount to direct emissions from soils.

5.5.4.2 Indirect Emissions of N_2O

The IPCC methodology for indirect emissions is based on a simple approach that allocates emissions of N_2O due to the deposition resulting from NH_3 and NO_X emissions in agriculture and from nitrogen leaching to the country that generated the source nitrogen. The import of nitrogen through atmospheric transport and runoff is not considered. Ireland includes indirect emissions of N_2O in *Agriculture* by accounting for the contributions from nitrogen leached from agricultural lands and from the atmospheric deposition of nitrogen volatilized as NH_3 and NO_X. The IPCC approach is followed but a country-specific method is used to determine the amount of contributing nitrogen in each case. The nitrogen lost through volatilization, already estimated above as a deduction on the amount contributing to direct N_2O emissions, becomes the input quantity to calculate indirect emissions due to deposition of oxidised and reduced nitrogen. The estimation for this component is shown in Table F.7 of Appendix F.

For the inventories up to 2000, the amount of nitrogen leached was estimated from the results of studies into the relationship between agriculture practice and nitrate concentrations in Irish rivers (Neill, 1989). These results indicated annual leaching rates of 2 kg/ha and 76 kg/ha for grassland and tillage areas, respectively in the late 1980s. This approach implied that the annual loss of nitrogen through leaching is of the order of 4 percent of the combined fertilizer and manure nitrogen inputs. The default value for this fraction, known as $Frac_{LEACH}$ 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 applied agricultural nitrogen is lost through leaching. This is considered to be a more realistic estimate of $Frac_{LEACH}$ and it has now been adopted for the purposes of calculating indirect N_2O emissions. Recalculations to this effect are part of the recalculation exercise described in Chapter Four covering the years 1990 to 2000.

The IPCC default emission factors (10 kg N_2O-N/tonne NH_3-N emitted for synthetic fertilizer and animal waste nitrogen and 25 kg N_2O-N/tonne N leached) are used to estimate indirect N_2O emissions. Total indirect emissions in 2001 amounted to 4,990 tonnes N_2O (Table F.8 of Appendix F), or approximately 53 percent of direct emissions.

5.5.5 Good Practice Guidance and Improvements in *Agriculture*

While there remains heavy reliance on default values of emission factors and some other variables in this sector, many of the elements of good practice guidance are being applied (Table 5.7). It will soon be possible to achieve closer compliance with the guidance by the use of Tier 2 methods for CH_4 emissions from enteric fermentation and the application of much more country-specific data in relation to N_2O emissions.

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 contribution to the national total. 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. 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.

Ireland is pursuing this approach by conducting major research on emissions of CH_4 from enteric fermentation and direct N_2O emissions from soils and by re-assessment of the values adopted in the past for some other 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.

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 recalculation 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 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

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. Parallel research based on detailed 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. A key objective of this research is the development of reliable estimates of nitrogen excretion rates for farm animals, which are crucial to the emissions inventories for *Agriculture*. Detailed studies on the direct N_2O emissions from soils are being conducted to provide the basis on which to systematically account for the influence of soil type, fertilizer type and application rates, temperature and rainfall on N_2O losses from Irish soils. The results of these studies should facilitate thorough appraisal of the default emission factors related to the key sources of CH_4 and N_2O.

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 contribution of NO_X to such emissions 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.

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

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 include LUCF emissions and removals only in respect of temperate forests under source 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*.

5.6.2 Methodology for *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 this 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 is given in Appendix G, along with the 1990-2000 estimates of carbon stock increment and annual harvest. This method is again used for 2001 and the supporting calculation sheets are included in Appendix H.

Forest Area and Species
A time series of forest strata by area and age was constructed for the years 1990-2001 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 2001 were obtained by growing the forest estate forward in time, using data on planting and clearfell rates, while taking into account the progression of forested areas between the cleared, young and mature categories. The process was worked in reverse to determine consistent time-series data for the years 1990 to 1994. Annex I to Appendix G 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) of 1.3 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 density and carbon content of 0.37 and 0.4, respectively and a biomass expansion factor of 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 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 Soils

For all inventories 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 are obtained from the Department of Agriculture and the CO_2 emissions are calculated using the default emission factor of 120 kg CO_2/tonne lime.

5.6.4 Good Practice Guidance in *Land-Use Change and Forestry*

The IPCC good practice guidance referred to in foregoing sections of this report does not cover *Land-Use Change and Forestry*. The reporting of emissions and removals in this category under the Kyoto Protocol, particularly in respect of carbon uptake and release by forests, will be somewhat different and more extensive than that which currently applies under the Convention. In particular, it will have to take into account a range of specific modalities, rules and guidelines that have only recently been adopted in relation to forests and land management practices. A separate report on good practice guidance in *Land-Use Change and Forestry*, due for completion in 2003, will address these issues and other matters relating to the reporting of emissions and removals this complex category.

The coverage of sources of emissions and removals by Ireland in this category 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 H) 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.

5.6.5 Planned Improvements in *Land-Use Change and Forestry*

The major improvement now needed in *Land-Use Change and Forestry* is to achieve reporting completeness by including estimates of emissions and removals for all relevant sources and sinks. As already mentioned, major research is underway to provide the basis for this task. The objective is to produce models, methods and data that can 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. The results of this research will be combined with further development of the method for carbon accounting for forests (Appendix G) 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 sites where CH_4 is the gas concerned. Emissions from landfills is a key emission source in Ireland (Chapter Three) and the CH_4 emission estimates are reasonably well covered 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 is now reported following the inclusion of first estimates for this source as part of the recalculations reported in Chapter Four.

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 waste 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 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.

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 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.

5.7.2.1 Methodology

Prior to 1998, Ireland used the Tier 1 default method to estimate CH_4 emissions from solid waste disposal in which the emissions are determined by the amount of solid waste lanfilled in the inventory year. The development of a national waste management strategy (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 has been undertaken in estimating the 2001 emissions from this source, necessitating further revision of the previous estimates for the years 1990 to 2000 (Chapter Four).

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 fixed 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 2000, 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 I.

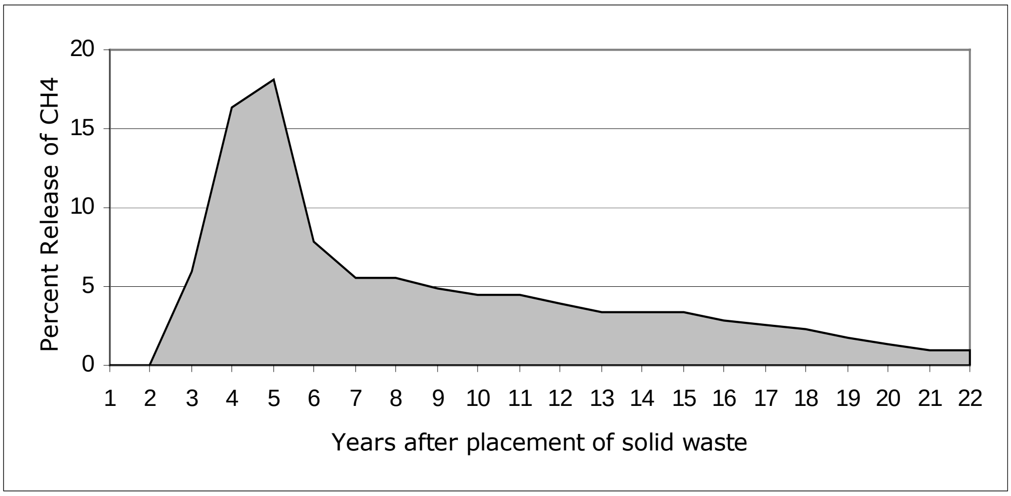


Figure 5.1. Typical CH_4 Production Pattern in Solid Waste Disposal Sites

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 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). Published national statistics generated from These database for 1995 (Carey *et al*, 1996) and 1998 (Crowe *et al*, 2000) have been used as the primary basis for establishing the historical time-series of MSW placed in landfills in Ireland needed for estimating CH_4 emissions from this source. These publications provide detailed descriptions of the methods employed to compile the waste database. The results of other less comprehensive surveys undertaken in previous years (Boyle, 1987, ERL, 1993, MCOS, 1994 and DOE, 1994) have also been used to some extent in compiling the MSW time-series.

The historical time series of wastes in SWDS and their associated DOC content used as the basis of CH_4 emission estimates from this source are included in the calculation sheets for *Waste* (Appendix I). The following paragraphs describe the steps and assumptions made in developing these data from the 1995 and 1998 statistics from the National Waste Database:

- the waste material contributing to DOC includes MSW (household and commercial refuse) and street cleansings, as given in the National Waste Database;
- the per-capita MSW generation rates indicated for 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 and 1998 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 and 1998 data;
- the waste constituents of MSW that contribute to DOC are organics, paper, textiles and the category other (fine elements, unclassified materials and wood wastes), as identified in the available breakdown for 1995 and 1998;
- 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 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 emitted;
- 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.

5.7.2.3 CH_4 Emissions

The calculation sheets for *Waste* 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 1990-2000 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 I.3 of Appendix I) and from solid wastes placed in unmanaged landfills (Table I.4 of Appendix I) 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.

The foregoing analysis indicates CH_4 production of 84,100 tonnes in landfills in 1990 from an annual average of 1.15 million tonnes of contributing municipal waste over the preceeding period of 20 years. In 2001, 73,320 tonnes of CH_4 was emitted with a further 22,500 tonnes recovered for energy purposes and the average contributing wastes amounted to approximately 1.36 million tonnes annually.

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 included as part of the recalculation exercise undertaken for the 2002 submission. The calculation sheet for this activity is provided in Table I.5 of Appendix I. The body weight and average protein intake of the population have been 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 N_2O emissions, amounting to approximately 200 tonnes annually between 1990 and 2001, 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.

5.7.5 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 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. Some 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 is examining the use of available models to estimate landfill gas emissions for a range of operating landfills as part of its work 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 have not yet been quantified. These elements of emissions from waste disposal will be a matter for further investigation and improvement in the immediate term.

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	QA and inventory review Completeness with respect to additional sources of organic waste including sludge and industrial wastes More robust time series DOC in solid waste
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 Completeness of Irish Inventories in 2002

Ireland has compiled a consistent time-series of greenhouse gas inventories for the years 1990 through 2001, incorporating recalculations wherever necessary in respect of previous estimates submitted for the years 1990-2000. The results were submitted to the UNFCCC Secretariat in April 2003 as a complete set of CRF files. The nature and effects of recalculations for each year are fully described in the submission. 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 2000.

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. 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.

6.2 Implementation of Good Practice Guidance

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. Ireland is of the view that the target to achieve full implementation of the IPCC good practice guidance for the submission due in 2003 was unrealistic.

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 will increase user confidence in the emissions data and prioritise specific areas for further improvement. The results will also be valuable in showing data suppliers in general that complete, consistent and reliable inputs on their part are crucial to the inventory improvement process.

6.3 Benefits from the UNFCCC Review 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 this 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. Issues specifically related to source coverage, emission factors, cross-country comparisons and key sources are quickly and efficiently identified through the annual Synthesis and Assessment Report. The response to the 2002 Synthesis and Assessment Report, submitted in October 2001, contained a number of clarifications on these issues, pertaining to the 2000 inventory. Some sources identified to be reported as NE (not estimated), such as fugitive emissions from gas production, have now been covered in the inventories.

Ireland's 2003 submission is to be the subject of an in-country review in 2003. The inventory agency views the timing of this review as ideal, considering the current status of Irish greenhouse gas inventories and the extensive revisions and improvements that have been undertaken in the past few years. The availability of the present NIR will facilitate in-depth assessment and analysis of the inventory process so that the review should identify any outstanding issues related to methods, data and emission factors that may warrant corrections or recalculations in particular areas. The review report will be the basis on which the inventory agency can re-evaluate its performance to date in applying the UNFCCC guidelines and for consolidating the available time-series data before inclusion of those elements mentioned in section 6.1.

6.4 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). A major research project is currently underway to substantially improve on inventory methods and emission factors being used for these sources.

The study is using a tracer technique employing SF_6 to measure methane production by representative animals in all important cattle groups and will relate CH_4 produced to information on their feed 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. 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 are being conducted in parallel with the research on CH_4 emissions from cattle. The results from this investigation 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 several default emission factors related to this source.

A second research project aims to establish 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*. This project will develop a system to estimate 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 have recently been commissioned under Phase 2 of the environmental research programme to consolidate the findings of the projects described above and to extend their applicability. These activities will 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 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 revised estimates of carbon removals 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.

6.5 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 the Central Statistics Office, Sustainable Energy Ireland, 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 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 national energy statistics and facilitate further disaggregation for the emissions estimation process.

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 issues 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.

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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	$c\text{-}C_4F_8$	8700
Perfluoropentane	C_5F_{12}	7500
Perfluorohexane	C_6F_{14}	7400
Sulphur Hexafluoride	SF_6	23900

(a) GWP (global warming potential) as provided by the IPCC in its Second Assessment Report

Table A.2. IPCC Reporting Format (Level 1 and Level 2)

IPCC SOURCE and SINK CATEGORIES	CO_2	CH_4	N_2O	HFC	PFC	SF6
1. Energy						
A. Fuel Combustion (Sectoral Approach)						
1. Energy Industries						
2. Manufacturing Industries and Construction						
3. Transport						
4. Other Sectors						
5. Other						
B. Fugitive Emissions from Fuels						
1. Solid Fuels						
2. Oil and Natural Gas						
2. Industrial Processes						
A. Mineral Products						
B. Chemical Industry						
C. Metal Production						
D. Other Production						
E. Production of Halocarbons and SF_6						
F. Consumption of Halocarbons and SF_6						
G. Other						
3. Solvent and Other Product Use						
A. Paint Application						
B. Degreasing and Dry Cleaning						
C. Chemical Products Manufacture & Processing						
D. Other						
4. Agriculture						
A. Enteric Fermentation						
B. Manure Management						
C. Rice Cultivation						
D. Agricultural Soils						
E. Prescribed Burning of Savannas						
F. Field Burning of Agricultural Residues						
G. Other						
5. Land-Use Change and Forestry						
A. 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 2001

Table B.1 (a) Energy Balance Sheet 2001 - Main Sectors

ENERGY BALANCE 2001 (Thousand TOE)	Coal	Peat	Peat Briquettes	Oil	Natural Gas	Hydro	Other Renewables	Electricity	Total
Ind. Production	0	883		0	660	51	208		1802
Imports	2089			9304	2931			3	14327
Exports	6		8	1327				25	1365
Mar. Bunkers				127					127
Stock Change	41	-10		-586					-555
TPER	2042	885		8436	3140	51	208		14761
Elec. Generation	1527	583		1171	1855	51	52	2118	3121
Briquetting		130	119						11
Gasworks									
Own use/losses			-2	123	47		0	295	463
TFC	515	179	113	7142	1238	0	156	1823	11166
Industry	215	0	0	809	442	0	109	677	2252
(Feedstock)					451				451
Transport	0	0	0	4309	0	0	0	2	4311
Residential	300	179	109	987	482	0	43	583	2682
Commercial	0	0	4	759	314	0	0	510	1587
Agricultural	0	0	0	278	0	0	4	52	334

Table B.1 (b) Energy Balance Sheet 2001 - Sub-sectors

2001	Coal	Pet Coke	Sod Peat	Peat Briq	Petrol	Kerosene	Fueloil	LPG	Gasoil	Natural Gas	Ren'bles	Elec	Total
Final Consumption	**318**	**197**	**179**	**113**	**1626**	**1460**	**626**	**157**	**3269**	**1206**	**156**	**1824**	**11167**
Industry	**50**	**164**				**103**	**442**	**68**	**197**	**442**	**109**	**677**	**2252**
Iron and Steel								5	3	**4**		**27**	39
Chemical						79	35	4	16	**150**		**88**	372
Nonferr. Met							239					**27**	266
Nonmet. Min.	**30**	**164**					18	8	21	**35**		**54**	330
Transp. Equip.							4	4	4			**7**	19
Machinery						8	22	4	24			**81**	139
Mining							5		27	**27**		**27**	86
Food etc.	**20**					4	84	2	78	**150**		**156**	494
Paper etc.							5	1	4			**14**	24
Wood etc.							4	1	2		**109**	**20**	136
Construction												**7**	7
Textiles etc.						4	18	3	12			**34**	71
Non-Specified						8	8	36	6	**76**		**135**	269
(Feedstocks)										451			451
Transport					**1626**	**700**	**20**	**5**	**1958**			**2**	**4311**
Air					**1**	**700**							701
Road					**1625**			**5**	1801				3431
Rail									137			**2**	139
Inland Navig.							20		20				40
Non-Specified													
Other Sectors	**268**	**33**	**179**	**113**	**0**	**657**	**164**	**88**	**1114**	**796**	**47**	**1145**	**4604**
Agriculture									278		**4**	**52**	334
Comm. And Publ.				**4**			164	12	583	**314**		**510**	1587
Residential	268	33	179	109		657		76	253	482	43	583	2683
Non-Specified													

Table B.2. Oil Balance Sheet 2001

OIL BALANCE 2001 (Thousand TOE)	**Crude**	**Refinery Gas**	**Petrol**	**Kerosene**	**Fueloil**	**LPG**	**Gasoil**	**Naphta**	**Total**
Production	0	88	706	255	1155	67	1232	13	3475
From Other Sources	0	0	0	0	0	0	0	0	
Import	3429	0	987	1173	1650	119	1947	0	9304
Export	0	0	132	16	1080	19	49	30	1327
Marine Bunkers	0	0	0	0	36	0	127	0	127
Stock Changes	-46	0	-65	-49	-110	2	-299	-18	-585
	0	0	0	0	0	0	0	0	0
DOMESTIC SUPPLY	0	88	1626	1460	1794	164	3302	0	8434
TRANSFORMATION SECTOR	0	0	0	0	1144	0	27	0	1171
Publ. Electr.	0	0	0	0	1144	0	27	0	1171
Autoproducers									0
CHP Plants									0
Gas Works									
ENERGY SECTOR	0	88	0	0	25	4	5	0	123
Oil Refineries	0	88	0	0	25	4	5	0	123
FINAL CONSUMPTION	0	0	1626	1460	626	161	3269	0	7141
INDUSTRY	0	0	0	103	442	68	196	0	809
									0
TRANSPORT	0	0	1626	700	20	5	1958	0	4309
OTHER SECTORS	0	0	0	657	164	88	1114	0	2024
Agriculture	0	0	0	0	0	0	278	0	278
Comm. and Publ.	0	0	0	0	164	11	583	0	759
Residential	0	0	0	657	0	76	253	0	987

Appendix C

Calculation Sheets for Energy

Year 2001

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[a]	CH4	N2O
	Sector/Fuel	kTOE	TJ					Gg	Mg	Mg
1	Public Power Plants Peat	571	23906.63	111577	0	12	*kg/TJ*	2667.44	0	277
2	Public Power Plants Coal	1514	63388.15	94993	0	14	*kg/TJ*	6021.41	0	956
3	Public Power Plants Fuel Oil	1171	49027.43	80064	0	14	*kg/TJ*	3925.34	0	717
4	Public Power Plants Gasoil		0.00		0	14	*kg/TJ*	0.00	0	0
5	Public Power Plants Natural Gas	1765	73897.02	56640	0	3	*kg/TJ*	4185.52	0	211
6	Electricity Landfill Gas	24	1004.83	54940	0	0	*kg/TJ*	55.21	0	0
7	**Public Electricity Total**	**5045**	**211224.06**					**16799.70**	**0**	**2161**
8	Refinery Gas	88	3684.38	65000	0	3	*kg/TJ*	239.49	0	11
9	Refinery Fueloil	25	1046.70	76000	0	10	*kg/TJ*	79.55	0	10
10	Refinery Gasoil	5	209.34	73300	2	10	*kg/TJ*	15.35	0	2
11	Refinery LPG	4	167.47	63700	2	3	*kg/TJ*	10.67	0	1
12	**Refinery Total**	**122**	**5107.90**					**345.05**	**1**	**24**
13	Residential Peat	179	7494.37	104000	50	5	*kg/TJ*	779.42	375	37
14	Residential Peat Briquettes	109	4563.61	98860	50	5	*kg/TJ*	451.16	228	23
15	Residential Coal	268	11220.62	94600	100	12	*kg/TJ*	1061.47	1122	135
16	Residential Petroleum Coke	32	1339.78	100800	50	12	*kg/TJ*	135.05	67	16
17	Residential Gasoil	253	10592.60	73300	5	10	*kg/TJ*	776.44	53	106
18	Residential Kerosene	657	27507.28	71400	5	10	*kg/TJ*	1964.02	138	275
19	Residential Natural Gas	482	20180.38	54940	5	2	*kg/TJ*	1108.71	101	40
20	Residential LPG	76	3181.97	63700	0	2	*kg/TJ*	202.69	0	6
21	Residential Biomass	43	1800.32	110000	30	4	*kg/TJ*	198.04	54	7
22	**Residential Total**	**2099**	**87880.93**					**6478.95**	**2137**	**646**
23	Commercial Peat	0	0.00	104000	50	5	*kg/TJ*	0.00	0	0
24	Commercial Briquettes	4	167.47	98860	50	5	*kg/TJ*	16.56	8	1
25	Commercial Coal	0	0.00	94600	100	12	*kg/TJ*	0.00	0	0
26	Commercial Gasoil	583	24409.04	73300	5	10	*kg/TJ*	1789.18	122	244
27	Commercial Kerosene	0	0.00	71400	5	10	*kg/TJ*	0.00	0	0

28	Commercial Fueloil	164	6866.35	76000	0	10	*kg/TJ*	521.84	0	69
29	Commercial Nat Gas	314	13146.55	54940	5	2	*kg/TJ*	722.27	66	26
30	Commercial LPG	12	502.42	63700	0	2	*kg/TJ*	32.00	0	1
31	Commercial Biomass	0	0.00	110000	30	4	*kg/TJ*	0.00	0	0
32	**Commercial Total**	**1077**	**45091.84**					**3081.86**	**196**	**341**
33	Industry Coal	20	837.36	94600	15	12	*kg/TJ*	79.21	13	10
34	Cement Petroleum Coke	49	2051.53	100800	5	10	*kg/TJ*	206.79	10	21
35	Cement Petroleum Coke	115	4814.82	100800	5	10	*kg/TJ*	485.33	24	48
36	Cement Coal	30	1256.04	94600	15	5	*kg/TJ*	118.82	19	6
37	Industry Gasoil	196	8206.13	73300	2	10	*kg/TJ*	601.51	16	82
38	Industry Kerosene	103	4312.40	71400	2	10	*kg/TJ*	307.91	9	43
39	Industry Fueloil	103.3	4324.96	76000	0	10	*kg/TJ*	328.70	0	43
40	Alumina Fuel Oil (Boilers)	229.4	9604.52	76000	0	10	*kg/TJ*	729.94	0	96
41	Alumina Fuel Oil (Calciners)	109.3	4576.17	76000	0	10	*kg/TJ*	347.79	0	46
42	Industry Natural Gas	442	18505.66	54940	2	3	*kg/TJ*	1016.70	37	56
43	Industry LPG	68	2847.02	63700	2	3	*kg/TJ*	181.36	6	9
44	Industry Biomass	109	4563.61	110000	30	4	*kg/TJ*	502.00	137	18
45	CHP Coal	13	544.28	94600	15	12	*kg/TJ*	51.49	8	7
46	CHP Peat	13	544.28	112823	0	12	*kg/TJ*	61.41	0	7
47	CHP Natural Gas	91	3809.99	54940	0	3	*kg/TJ*	209.32	0	11
48	**Industry Total**	**1691**	**70798.79**					**4726.28**	**279**	**502**
49	Road Transport Petrol	1625	68035.50	69960	34	10	*kg/TJ*	4759.76	2334	677
50	Road Transport Diesel	1801	75404.27	73300	3	6	*kg/TJ*	5527.13	205	426
51	Road Transport LPG	5	209.34	63700	5	0	*kg/TJ*	13.34	1	0
52	**Road Transport Total**	**3431**	**143649.11**					**10300.23**	**2540**	**1103**
53	Railways Diesel	137	5735.92	73300	5	30	*kg/TJ*	420.44	29	172
54	Navigation Fuel Oil	20	837.36	76000	5	30	*kg/TJ*	63.64	4	25
55	Navigation Gasoil	20	837.36	73300	5	30	*kg/TJ*	61.38	4	25
56	Gas Distribution-Use	47	1967.80	54940	5	3	*kg/TJ*	108.11	10	6
57	Civil Aviation (LTO & Cruise)	37	1527.22	71400	1.11	2.45	*kg/TJ*	109.04	2	4
58	**Other Transport Total**	**261**	**10905.66**					**762.61**	**49**	**232**

59	Agriculture Stationary Gasoil	250	10467.00	73300	5	10	*kg/TJ*	767.23	52	314
60	Agriculture Machinery Gasoil	28	1172.30	73300	5	30	*kg/TJ*	85.93	6	12
61	Agriculture Biomass	4	167.47	110000	30	4	*kg/TJ*	18.42	5	1
62	**Agriculture Total**	**282**	**11806.77**					**853.16**	**63**	**327**
63	**Total Energy**	**14007**	**586465.06**					**43347.85**	**5265**	**5336**
64	Air Bunkers	665	27822.25	71400	1.25	2.37	*kg/TJ*	1986.45	35	66
65	Marine Bunkers Fuel Oil	0	0	76000	0	0	*kg/TJ*	0	0	0
66	Marine Bunkers Gasoil	127	5317.24	73300	0	0	*kg/TJ*	389.75	0	0
67	Marine Bunkers Kerosene	0	0.00	71400	0	0	*kg/TJ*	0.00	0	0
68	CO2 from Biomass							**773.66**		

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

	Allocation by IPCC Source Category			Implied Emission Factors (kg/TJ)				Emissions		
	Source Category/Fuel	kTOE	TJ	CO2	CH4	N2O		CO2 (Gg)	CH4 (Mg)	N2O (Mg)
A	1.A.1 Energy Industries	5167	216331.96	79252	0	10	*kg/TJ*	17144.75	1	2185
B	(a) Solid Fuels	2085	87294.78	99530	0	14	*kg/TJ*	8688.84	0	1233
C	(b) Liquid Fuels	1293	54135.32	78880	0	14	*kg/TJ*	4270.39	0	741
D	(c) Gaseous Fuels	1765	73897.02	56640	0	3	*kg/TJ*	4185.52	0	211
E	(d) Biomass	24	1004.83	54940	0	0	*kg/TJ*	55.21	0	0
F	1.A.2 Manufacturing Industries	1691	70798.79	66757	4	7	*kg/TJ*	4726.29	279	502
G	(a) Solid Fuels	76	3181.97	97720	12	9	*kg/TJ*	310.93	40	30
H	(b) Liquid Fuels	973	40737.56	78290	2	9	*kg/TJ*	3189.33	65	388
I	(c) Gaseous Fuels	533	22315.64	54940	2	3	*kg/TJ*	1266.02	37	67
J	(d) Biomass	109	4563.61	110000	30	4	*kg/TJ*	502.00	137	18
K	1.A.3 Transport	3692	154554.76	71579	17	9	*kg/TJ*	11062.84	2589	1335
L	(a) Solid Fuels	NO	NO	NA	NA	NA	*kg/TJ*	0.00	0	0
M	(b) Liquid Fuels	3645	152586.96	71793	17	9	*kg/TJ*	10954.73	2579	1329
N	(c) Gaseous Fuels	47	1967.80	54940	5	3	*kg/TJ*	108.11	10	6
O	(d) Biomass	0	0.00	NA	NA	NA	*kg/TJ*	0.00	0	0
P	1.A.4 Other Sectors	3458	144779.54	71930	17	9	*kg/TJ*	10413.97	2397	1313
Q	(a) Solid Fuels	560	23446.08	98464	74	8	*kg/TJ*	2308.60	1733	196
R	(b) Liquid Fuels	2055	86038.74	72925	5	12	*kg/TJ*	6274.39	438	1043
S	(c) Gaseous Fuels	796	33326.93	54940	5	2	*kg/TJ*	1830.98	167	66
T	(d) Biomass	47	1967.80	110000	30	4	*kg/TJ*	216.46	59	8
U	1.A.5 Other	0	0.00	NA	NA	NA	*kg/TJ*	0.00	0	0
V	1.A Fuel Combustion	14007	586465.05					43347.85	5265	5336
W	Air Bunkers	665	27822.24					1986.45	35	66
X	Marine Bunkers	127	5317.24					389.75	NE	NE
Y	CO2 from Biomass	180	7536.24					773.66		

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 + 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	33 + 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 + 54 + 55 + 57
N	(c) Gaseous Fuels	56
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 + 30 + 59+60
S	(c) Gaseous Fuels	19 + 29
T	(d) Biomass	21 + 31 + 61
U	1.A.5 Other	NO
V	1.A Fuel Combustion (V = A+F+K+P+U)	
W	Air Bunkers	64
X	Marine Bunkers	65+66+67
Y	CO2 from Biomass	68

Table C.4. Emissions of CO_2 from Reference Approach in 2001 [CRF 20001 Table 1.A(b); Biomass excluded]

FUEL TYPES			Prod'n kTOE	Imports kTOE	Exports kTOE	Int'l bunkers kTOE	Stock Change KTOE	Apparent Consumption kTOE	Apparent Consumption (TJ)	Carbon EF (t C/TJ)	Carbon content (Gg C)	Carbon stored (Gg C)	Net carbon emissions (Gg C)	Actual CO_2 emissions (Gg CO_2)
Liquid Fossil	Primary Fuels	Crude Oil		3429			-46	3475	145,491.30	20.00	2,909.83		2,909.83	10,669.36
		Orimulsion						0	0.00		0.00		0.00	0.00
		Natural Gas Liquids					0	0	0.00	17.73	0.00		0.00	0.00
	Secondary Fuels	Gasoline		987	132	1	-65	919	38,476.69	19.08	734.14		734.14	2,691.83
		Jet Kerosene		700		663.52		36.48	1,527.34	19.47	29.74		29.74	109.04
		Other Kerosene		473	16		-49	506	21,185.21	19.47	412.52		412.52	1,512.57
		Shale Oil						0	0.00		0.00		0.00	0.00
		Gas / Diesel Oil		1947	49	127	-299	2070	86,666.76	19.99	1,732.56	0.00	1,732.56	6,352.70
		Residual Fuel Oil		1650	1080	0	-110	680	28,470.24	20.73	590.10		590.10	2,163.71
		LPG		119	19		2	98	4,103.06	17.37	71.28	0.00	71.28	261.37
		Ethane						0	0.00		0.00	0.00	0.00	0.00
		Naphtha			30		-18	-12	-502.42	20.00	-10.05	0.00	-10.05	-36.84
		Bitumen						0	0.00		0.00	0.00	0.00	0.00
		Lubricants						0	0.00		0.00	0.00	0.00	0.00
		Petroleum Coke		197	0		0	197	8,248.00	27.49	226.75		226.75	831.40
		Refinery Feedstocks						0	0.00		0.00		0.00	0.00
		Other Oil						0	0.00		0.00		0.00	0.00
Liquid Fossil Totals									333,666.19		6,696.85		6,696.85	24,555.13
Solid Fossil	Primary Fuels	Anthracite [2]						0	0.00		0.00		0.00	0.00
		Coking Coal						0	0.00		0.00	0.00	0.00	0.00
		Other Bit. Coal		1892	6		41	1845	77,246.46	25.80	1,992.96		1,992.96	7,307.52
		Sub-bit. Coal						0	0.00		0.00		0.00	0.00
		Lignite						0	0.00		0.00		0.00	0.00
		Oil Shale						0	0.00		0.00		0.00	0.00
		Peat	883				-10	893	37,388.12	29.57	1,105.57		1,105.57	4,053.75
	Secondary Fuels	BKB & Patent Fuel			8			-8	-334.94	26.96	-9.03		-9.03	-33.11
		Coke Oven/Gas Coke						0	0.00		0.00		0.00	0.00
Solid Fuel Totals									114,299.64		3,089.50	0.00	3,089.50	11,328.15
Gaseous Fossil		Natural Gas (Dry)	660	2931	0		0	3591	150,347.99	14.98	2,252.81	0.00	2,252.81	8,260.32
Total									**598,313.82**		**12,039.16**	**0.00**	**12,039.16**	**44,143.60**

Table C.5. Comparisons of Results from Sectoral Approach and Reference Approach for 2000 [CRF 2000 Table 1.A(c)]

	Reference Approach (RA)		Sectoral Approach (SA)		Difference (RA-NA/NA)*100	
	Energy Consumption TJ	CO2 Emissions Gg	Energy Consumption TJ	CO2 Emissions Gg	Energy Consumption %	CO2 Emissions %
Liquid Fuels (excluding international bunkers)	333,666.19	24,555.13	333,289.25	24,675.51	0.11	-0.49
Solid Fuels (excluding international bunkers)	114,299.64	11,328.15	113,922.83	11,308.38	0.33	0.17
Gaseous Fuels	150,347.99	8,260.32	131,507.39	7,350.64	14.33	12.38
Other [3]			209.34	13.34	- -100.00	- -100.00
Total [3]	**598,313.82**	**44,143.60**	**578,928.93**	**43,347.85**	**3.35**	**1.84**

Appendix D

Calculation Sheets for Industrial Processes

Years 1990-2001

1995-2001 (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	500	1650	243.50	750	182.63	451	18882.468	54.94	1037.40	260	7.27	1.89

Table D.2. HFC emissions from Stationary Refrigeration and Air Conditioning

	Refrigeration and Air Conditioning					Manufacture of Transport Refrigeration			Total				
	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	28.25	5.948	33.39	1.478	57.547	234.697	245.828	161.218
2000	0.142	40.351	198.160	239.910	151.690	25.31	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
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

Table D.3. HFC Emissions from Mobile Air Conditioning

	First-Fill			Operating			Total		
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
2001	0.45	1.19	0.53	75.081	109.072	244.965	75.531	93.723	245.495
2000	0.45	1.19	0.53	47.212	88.501	198.765	47.662	76.271	199.295
1999	0.45	1.19	0.53	27.423	55.651	124.987	27.873	48.402	125.517
1998	0.45	1.19	0.53	14.346	32.325	72.598	14.796	28.613	73.128
1997	0.45	1.19	0.53	6.544	16.910	37.979	6.994	15.536	38.509
1996	0.45	1.19	0.53	2.585	7.714	17.325	3.035	7.734	17.855
1995	0.45	1.19	0.53	2.585	3.047	6.843	3.035	3.775	7.373
Emissions		*Consumption*0.95*0.005*			*From Table D.4*				
2001	0.0021	0.0057	0.0025	7.5081	10.9072	24.4965	7.510	9.259	24.499
2000	0.0021	0.0057	0.0025	4.7212	8.8501	19.8765	4.723	7.514	19.879
1999	0.0021	0.0057	0.0025	2.7423	5.5651	12.4987	2.744	4.727	12.501
1998	0.0021	0.0057	0.0025	1.5781	3.2325	7.2598	1.580	2.748	7.262
1997	0.0021	0.0057	0.0025	0.7853	1.8601	4.1777	0.787	1.584	4.180
1996	0.0021	0.0057	0.0025	0.3360	0.9257	2.0790	0.338	0.791	2.082
1995	0.0021	0.0057	0.0025	0.3360	0.3961	0.8895	0.338	0.342	0.892

Table D.4. 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
2001	176988	72	90	114688	526844	0.8	352.034	10	35.203	447.017	92.533	245.412	109.072
2000	250145	70	90	157591	412156	0.8	289.204	10	28.920	362.710	75.081	198.765	88.501
1999	208309	65	78	105613	254564	0.8	181.257	10	18.126	228.079	47.212	124.987	55.651
1998	179094	60	66	70921	148952	0.8	107.518	10	10.752	132.478	27.423	72.598	32.325
1997	168005	47	54	42640	78030	0.8	57.058	11	6.276	69.304	14.346	37.979	16.910
1996	154592	33	42	21426	35391	0.8	26.075	12	3.129	31.616	6.544	17.325	7.714
1995	125323	20	30	7519	13964	0.8	10.269	13	1.335	12.486	2.585	6.843	3.047
1994	117256	20	20	4690	6445	0.8	4.945	14	0.692	6.016	1.245	3.297	1.468
1993	87735	20	10	1755	1755	0.8	1.404	15	0.211	1.724	0.357	0.945	0.421
	Goods Vehicles									**All Vehicles : HFC Emissions**			
										Total t	HFC-125 t	HFC-134a t	HFC-143a t
										O	P	Q	R
2001	37072	72	90	24023	93342	1.2	94.983	10	9.498	44.702	9.253	24.541	10.907
2000	41490	70	90	26139	69319	1.2	73.506	10	7.351	36.271	7.508	19.877	8.850
1999	40037	65	78	20299	43180	1.2	46.822	10	4.682	22.808	4.721	12.499	5.565
1998	29588	60	66	11717	22882	1.2	24.960	10	2.496	13.248	2.742	7.260	3.232
1997	24201	47	54	6142	11165	1.2	12.247	11	1.347	7.623	1.578	4.178	1.860
1996	21713	33	42	3009	5023	1.2	5.541	12	0.665	3.794	0.785	2.079	0.926
1995	18013	20	30	1081	2013	1.2	2.218	13	0.288	1.623	0.336	0.890	0.396
1994	16632	20	20	665	932	1.2	1.071	14	0.150	0.842	0.174	0.462	0.206
1993	13359	20	10	267	267	1.2	0.321	15	0.048	0.259	0.054	0.142	0.063

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.5. HFC Emissions from Fire Protection Equipment

A	B	C	D	E
	Growth Rate %	HFC-227ea Use t	Cumulative HFC-227ea t	HFC-227ea Emissions t
			$C_{year\ t}$ + $(D - E)_{year\ t-1}$	E=D*0.01
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.6. Company Estimates of HFC, PFC and SF6 Emissions

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

	HFC-23	HFC-32	HFC-125	HFC-134a	PFC-14	PFC-116	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

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

	HFC-23	HFC-32	HFC-125	HFC-134a	PFC-14	PFC-116	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

(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

Table D.7. 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

$D = B*0.33$

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

$G = E*0.01$

$H = (D + G)/1000$

Appendix E

Calculation Sheets for Solvents

Years 1990 - 2001

Table E.1. Estimation of CO2 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

Total VOC (Mg) contribution to CO2 (Gg) estimated as CO2 =0.85*VOC*44/12000

Appendix F

Calculation Sheets for Agriculture

Year 2001

Extracted from the IPCC Software Module for Agriculture

Table F.1 CH_4 Emissions from Agriculture

	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	1217.983	100	121,798.30	15.90	19,365.93	141.164
Non-dairy Cattle	5675.917	50	283,795.85	6.40	36,325.87	320.122
Buffalo	0.00	0	0.00	0.00	0.00	0.00
Sheep	6385.883	8	51,087.06	0.00	0.00	51.087
Goats	13.50	5	67.50	0.00	0.00	0.068
Camels	0.00	0	0.00	0.00	0.00	0.00
Horses	75.50	18	1,359.00	0.00	0.00	1.359
Mules & Asses	7.30	10	73.00	0.00	0.00	0.073
Swine	1750.033	1.5	2,625.05	5.40	9,450.18	12.075
Poultry	13143.533	0	0.00	0.10	1,314.35	1.314
Totals			460,805.76		66,456.33	527.262

**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.2 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	**2001**

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	5,675,917	50	0.02	5,675,917.00
Dairy Cattle	1,217,983	92.5	0.02	2,253,268.55
Poultry	13,143,533	0.6	0.2	1,577,223.96
Sheep	6,385,883	8	0	0.00
Swine	1,750,033	12	0	0.00
Others				0.00
			TOTAL	9,506,409.51

Table F.2 (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	**2001**

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	5,675,917	50	0.15	42,569,377.50
Dairy Cattle	1,217,983	92.5	0.28	31,545,759.70
Poultry	13,143,533	0.6	0.8	6,308,895.84
Sheep	6,385,883	8	0	0.00
Swine	1,750,033	12	1	21,000,396.00
Others	0	0	0	0.00
			TOTAL	101,424,429.04

Table F.2 (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	**2001**

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	5,675,917	50	0.18	51,083,253.00
Dairy Cattle	1,217,983	92.5	0.12	13,519,611.30
Poultry	13,143,533	0.6	0	0.00
Sheep	6,385,883	8	0	0.00
Swine	1,750,033	12	0	0.00
Others	0	0	0	0.00
			TOTAL	64,602,864.30

Table F.2 (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	**2001**

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	5,675,917	50	0.65	184,467,302.50
Dairy Cattle	1,217,983	92.5	0.58	65,344,787.95
Poultry	13,143,533	0.6	0	0.00
Sheep	6,385,883	8	1	51,087,064.00
Swine	1,750,033	12	0	0.00
Others	0	0	0	0.00
			TOTAL	300,899,154.45

Table F.3 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	**2001**

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	9,506,409.51	0.001	0.01
Liquid systems	101,424,429.04	0.001	0.16
Daily spread	0.00		
Solid storage & drylot	64,602,864.30	0.02	2.03
Pasture range and paddock	300,899,154.45		
Other	0.00		0.00
Total	476,432,857.30		2.205

Table F.4 N_2O Emissions from Crops in 2001

	Production Mt	Residue/Prod Ratio	Fraction Dry Matter	Fraction Nitrogen	FBN kg N	Fcr kg N	N_2O-N kg	EF_1 kg/kg	N_2O Gg
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Pulses	14730	1.8	0.87	0.014	502352	322941	825,292	0.0125	0.016
Potatoes	440270	0.4	0.85	0.011		1646610	1,646,610	0.0125	0.032
Sugarbeet	1516770	0.3	0.85	0.023		8895856	8,895,856	0.0125	0.175
Barley	1287770	1.2	0.85	0.004		5254102	5,254,102	0.0125	0.103
Oats	127367	1.3	0.92	0.007		1066317	1,066,317	0.0125	0.021
Wheat	698060	1.3	0.85	0.003		2314069	2,314,069	0.0125	0.045
									0.392

B : Production Statistics from CSO
C, D, E : from GPG Table 4.16
F : from GPG Equation 4.26 [Tier 1b]
G : from GPG Equation 4.29[Tier 1b]
H : F + G
I : from GPG Table 4.17
*J : H*I*44/28000000*

Table F.5 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	**2001**

	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})	390,544,634.00	0.0125	4.88
Animal waste (F_{AW})	71,464,928.60	0.0125	0.89
N-fixing crops (F_{BN})	502,352.00	0.0125	0.01
Crop residue (F_{CR})	19,499,893.00	0.0125	0.24
		Total	6.03

F_{SN} from Table F.7 [A less C]
F_{AW} from Supplemental Table below
F_{BN} and F_{cr} from Table F.4 above

MODULE	**AGRICULTURE**
SUBMODULE	**AGRICULTURAL SOILS**
WORKSHEET	**4-5A (SUPPLEMENTAL)**
SHEET	**1 OF 1 MANURE NITROGEN USED**
COUNTRY	**Ireland**
YEAR	**2001**

A Total Nitrogen Excretion (kg N/yr)	B Fraction of Nitrogen Burned for Fuel (fraction)	C Fraction of Nitrogen Excreted During Grazing (fraction)	D Fraction of Nitrogen Excreted Emitted as NOX and NH3 (fraction)	E Sum (fraction)	F Manure Nitrogen Used (corrected for NOX and NH3 emissions), FAW (kg N/yr)
				E = 1 - (B + C + D)	F = (A x E)
476,432,857.30	0	0.65	0.20	0.15	71,464,928.60

Table F.6. 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	**2001**

	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]/1 000 000
Pasture range & paddock	300,899,154.45	0.02	9.457

Table F.7 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	**2001**

	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	406,394,000	0.039	15,849,366.00	476,432,857.30	0.17	80,993,585.74	0.01	0.968

$Frac_{GASFS}$ from Table F.10
$Frac_{GASM}$ from Table F.9

Table F.8 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	**2001**

	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	406,394,000.00	476,432,857.30	0.10	0.025	2.21	4.99	23.915

Table F.9. Emissions of NH_3 from Organic Nitrogen in 2001

	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	N		kg N per AWMS			Total N	N excreted	*NH_3-N*	N to	*NH_3-N*	Mineral N	*NH_3-N*	*NH_3-N*	*Total*	NH3
	3-year	excretion	Aerobic	Liquid	Solid	Pasture		in stable	*in stable*	storage	*from storage*	for spreading	*spreading*	*grazing*	*NH_3-N*	Emissions
	average	kg/head	Lagoons		Storage		kg	kg	*kg*	kg	*kg*	kg	*kg*	*kg*	*kg*	tonnes
							e+f+g+h	e+f+g							k+m+o+p	q*17/14000
Dairy Cattle	1,217,983	92.5	2,253,269	31,545,760	13,519,611	65,344,788	112,663,428	47,318,640	*5,678,237*	41,640,403	*2,498,424*	19,570,989	*7,828,396*	*5,227,583*	*21,232,640*	**25,782**
Other Cattle	5,675,917	50	5,675,917	42,569,378	51,083,253	184,467,303	283,795,850	99,328,548	*11,919,426*	87,409,122	*5,244,547*	41,082,287	*16,432,915*	*14,757,384*	*48,354,272*	**58,716**
Pigs	1,750,033	12	8,400,158	12,600,238	0	0	21,000,396	21,000,396	*3,570,067*	17,430,329	*1,045,820*	8,192,254	*3,276,902*	*0*	*7,892,789*	**9,584**
Sheep	6,385,883	8	0	0	0	51,087,064	51,087,064	0	*0*	0	*0*	0	*0*	*2,043,483*	*2,043,483*	**2,481**
Poultry	13,143,533	0.6	1,577,224	6,308,896	0	0	7,886,120	7,886,120	*1,577,224*	6,308,896	*252,356*	2,422,616	*1,211,308*	*0*	*3,040,888*	**3,693**
			17,906,568	**93,024,271**	**64,602,864**	**300,899,154**	**476,432,857**	175,533,703	*22,744,954*	152,788,749	*9,041,147*	71,268,147	*28,749,520*	*22,028,450*	*82,564,071*	**100,256**
		% AWMS	*3.8*	*19.6*	*13.5*	*63.1*	**Percentage of total animal waste N lost as NH_3 [100*(total of q/total of I)]**								**17.33**	

Table F.10. Emissions of NH_3 from Chemical Fertilizers in 2001

Fertilizer Type	kg N applied	kg NH_3-N per kg N*	NH_3-N kg	NH_3 Tonnes
Ammonium Sulphate	567,000	0.08	45,360	55.1
Ammonium Nitrate		0.02	0	0
Calcium Ammonium Nitrate	134,410,000	0.02	2,688,200	3264.2
Anhydrous Ammonia		0.04	0	0
Urea	52,463,000	0.15	7,869,450	9555.8
Mono-ammonium Phosphate		0.02	0	0
Di-ammonium Phosphate		0.05	0	0
Other NPK Fertilizers	180,590,000	0.02	3,611,800	4385.8
Nitrogen Solution		0.08	0	0
ASN	636,000	0.05	31,800	25
Total	**368,667,000**		**14,246,610**	**17299.5**
Weighted Fertilizer NH_3 EF		**0.039**		

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 al*, 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[1]	CUC	180,777	*Unclassified young forest plantations*
TOTAL FOREST SERVICE AREA		576,108	

[1] 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 (a)	Standing volume m^3ha^{-1} (b)	Reduced volume m^3ha^{-1} (c= bx.85)	Biomass expansion factor (BEF) (d)	Dry density (e)	Carbon content (f)	Carbon tha^{-1} (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[2] (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

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

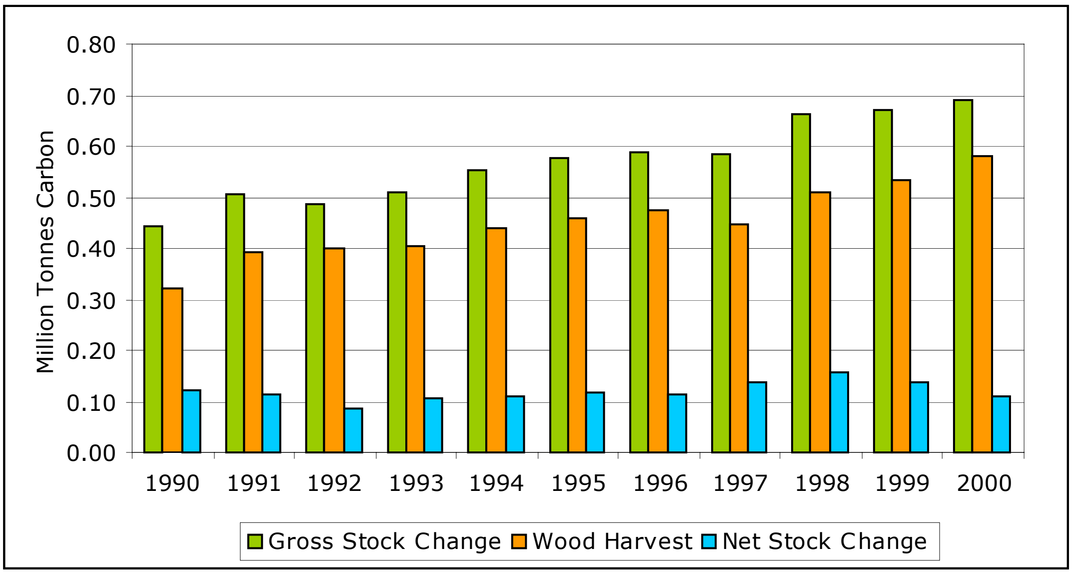

Figure G.1. Wood Harvest and Carbon Stock Change 1990-2000

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.

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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

Calculation Sheets for Land-Use Change and Forestry

Years 2000 and 2001

Table H.1. Carbon Removals by Forests in 2000

A		B	C	D	E	F	G	H	I	J
FIPS Category	FIPS Code	Standing Volume Stemwood m^3/ha	Reduced Volume Stemwood m^3/ha	Biomass Expansion Factor	Dry Density	Whole Tree Volume m^3/ha	Carbon Content kg/m^3	Carbon Uptake t/ha	Category Area in 2000 ha	Carbon Uptake of Category kt
			*C=B*0.85*			*F=C*D*E*		*H=F*G*		*J=H*I/1000*
Conifer spruce young	CYS	57.00	48.45	1.3	0.350	22.04	0.40	8.8179	127,481	1,124.114
Conifer larch young	CYL	46.00	39.10	1.3	0.440	22.37	0.40	8.9461	1,654	14.798
Conifer pine young	CYP	40.00	34.00	1.3	0.400	17.68	0.40	7.0720	40,322	285.159
Conifer pine/spruce young	YPS	47.93	40.74	1.3	0.375	19.86	0.40	7.9444	14,102	112.036
Conifer other young	CYO	52.00	44.20	1.3	0.400	22.98	0.40	9.1936	9,733	89.483
Broadleaf oak young	BYK	10.00	8.50	1.3	0.550	6.08	0.45	2.7349	256	0.701
Broadleaf beech young	BYB	10.00	8.50	1.3	0.550	6.08	0.45	2.7349	214	0.584
Broadleaf other young	BYO	10.00	8.50	1.3	0.550	6.08	0.45	2.7349	7,096	19.406
Mixed young	MXY	30.00	25.50	1.3	0.480	15.91	0.42	6.6830	5,264	35.180
Conifer spruce mature	CMS	256.00	217.60	1.3	0.350	99.01	0.40	39.6032	100,347	3,974.067
Conifer larch mature	CML	206.00	175.10	1.3	0.440	100.16	0.40	40.0629	3,419	136.971
Conifer pine mature	CMP	190.00	161.50	1.3	0.400	83.98	0.40	33.5920	33,997	1,142.026
Conifer pine/spruce mature	MPS	220.80	187.68	1.3	0.375	91.49	0.40	36.5976	24,337	890.682
Conifer other mature	CMO	233.00	198.05	1.3	0.400	102.99	0.40	41.1944	9,335	384.547
Broadleaf oak mature	BMK	255.00	216.75	1.3	0.550	154.98	0.45	69.7393	5,665	395.060
Broadleaf beech mature	BMB	256.00	217.60	1.3	0.550	155.58	0.45	70.0128	3,123	218.624
Broadleaf other mature	BMO	160.00	136.00	1.3	0.550	97.24	0.45	43.7580	44,789	1,959.872
Mixed mature	MXM	175.00	148.75	1.3	0.480	92.82	0.42	38.9844	25,649	999.929
Other	O	150.00	127.50	1.3	0.550	91.16	0.45	41.0231	1,900	77.944
TOTAL FIPS Area									**458,684**	**11,861.183**
		S	R	Q	P	O	N	M	L	K
CRF Category		*Area-weighted values by CRF category*						*Reallocation to CRF Categories*		
		S=R/0.85	*R=O/(P*Q)*			*O=M/N*		*M=K*1000/L*		
Quercus		244.39	207.73	1.3	0.550	148.53	0.45	66.84	5,921	395.761
Fagus		240.25	204.22	1.3	0.550	146.01	0.45	65.71	3,336	219.208
Other Broadleaf		139.49	118.56	1.3	0.550	84.77	0.45	38.15	51,885	1,979.278
Pinus		119.10	101.23	1.3	0.392	51.54	0.40	20.62	93,539	1,928.543
Picea		143.11	121.64	1.3	0.358	56.66	0.40	22.67	247,048	5,599.540
Other Coniferous		139.64	118.69	1.3	0.420	64.81	0.40	25.92	24,141	625.799
Mixed Broadleaf/Coniferous		150.31	127.76	1.3	0.480	79.72	0.42	33.48	30,914	1,035.109
Other		150.00	127.50	1.3	0.550	91.16	0.45	41.02	1,900	77.944
									458,684	**11,861.183**

Table H.2. Carbon Removals by Forests in 2001

A		*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
FIPS Category	FIPS Code	Standing Volume Stemwood m^3/ha	Reduced Volume Stemwood m^3/ha	Biomass Expansion Factor	Dry Density	Whole Tree Volume m^3/ha	Carbon Content kg/m^3	Carbon Uptake t/ha	Category Area in 2001 ha	Carbon Uptake of Category kt
			*C=B*0.85*			*F=C*D*E*		*H=F*G*		*J=H*I/1000*
Conifer spruce young	CYS	57.00	48.45	1.3	0.350	22.04	0.40	8.82	121,291	1,069.534
Conifer larch young	CYL	46.00	39.10	1.3	0.440	22.37	0.40	8.95	1,544	13.813
Conifer pine young	CYP	40.00	34.00	1.3	0.400	17.68	0.40	7.07	38,339	271.131
Conifer pine/spruce young	YPS	47.93	40.74	1.3	0.375	19.86	0.40	7.94	13,480	107.092
Conifer other young	CYO	52.00	44.20	1.3	0.400	22.98	0.40	9.19	9,269	85.212
Broadleaf oak young	BYK	10.00	8.50	1.3	0.550	6.08	0.45	2.73	250	0.683
Broadleaf beech young	BYB	10.00	8.50	1.3	0.550	6.08	0.45	2.73	204	0.559
Broadleaf other young	BYO	10.00	8.50	1.3	0.550	6.08	0.45	2.73	6,913	18.905
Mixed young	MXY	30.00	25.50	1.3	0.480	15.91	0.42	6.68	5,126	34.259
Conifer spruce mature	CMS	256.00	217.60	1.3	0.350	99.01	0.40	39.60	98,463	3,899.430
Conifer larch mature	CML	206.00	175.10	1.3	0.440	100.16	0.40	40.06	3,151	126.234
Conifer pine mature	CMP	190.00	161.50	1.3	0.400	83.98	0.40	33.59	33,601	1,128.708
Conifer pine/spruce mature	MPS	220.80	187.68	1.3	0.375	91.49	0.40	36.60	24,975	914.027
Conifer other mature	CMO	233.00	198.05	1.3	0.400	102.99	0.40	41.19	9,340	384.758
Broadleaf oak mature	BMK	255.00	216.75	1.3	0.550	154.98	0.45	69.74	5,651	394.092
Broadleaf beech mature	BMB	256.00	217.60	1.3	0.550	155.58	0.45	70.01	3,111	217.830
Broadleaf other mature	BMO	160.00	136.00	1.3	0.550	97.24	0.45	43.76	44,457	1,945.366
Mixed mature	MXM	175.00	148.75	1.3	0.480	92.82	0.42	38.98	25,400	990.192
Other	O	150.00	127.50	1.3	0.550	91.16	0.45	41.02	1,900	77.944
TOTAL FIPS Area									**446,464**	**11,679.770**
		S	*R*	*Q*	*P*	*O*	*N*	*M*	*L*	*K*
CRF Category		*Area-weighted values by CRF category*						*Reallocation to CRF Categories*		
		S=R/0.85	*R=O/(P*Q)*			*O=M/N*		*M=K*1000/L*		
Quercus		244.63	207.94	1.3	0.550	148.68	0.45	66.90	5,901	394.775
Fagus		240.84	204.72	1.3	0.550	146.37	0.45	65.87	3,316	218.389
Other Broadleaf		139.82	118.84	1.3	0.550	84.97	0.45	38.24	51,370	1,964.271
Pinus		121.05	102.89	1.3	0.392	52.39	0.40	20.95	91,167	1,910.399
Picea		144.77	123.05	1.3	0.358	57.32	0.40	22.93	238,981	5,479.524
Other Coniferous		141.01	119.86	1.3	0.420	65.44	0.40	26.18	23,304	610.017
Mixed Broadleaf/Coniferous		150.65	128.05	1.3	0.480	79.90	0.42	33.56	30,526	1,024.451
Other		150.00	127.50	1.3	0.550	91.16	0.45	41.02	1,900	77.944
									446,464	**11,679.770**

Table H.3. Forest Carbon Emissions and Removals 2001

Total growing stock 2001 [Gg C]							12137.35
[Gg CO_2]							44503.56
Total growing stock 2000 [Gg C]							11862.69
[Gg CO_2]							43496.54
Annual growth increment after harvest [Gg C]							274.64
[Gg CO_2]							1007.02
		Amount of biomass removed				**Carbon emission factor**	**Carbon release**
		Stemwood overbark [m^3]	Expansion factor stemwood volume to total tree biomass	Conversion factor biomass volume to dry matter [t dm/m^3]	[t dm/ha]	[t C/t dm]	[Gg C]
Total biomass removed in Commercial harvest		2882001	1.30	0.37	1386839	0.40	555.757
Traditional Fuelwood Consumed							
Total Other Wood Use							
Total Biomass Consumption from Stocks [Gg C]							555.757
[Gg CO_2]							2037.776
Annual growth before harvest [Gg C]							830.399
[Gg CO_2]							3044.798

Note : The values of carbon in growing stock are slightly different to those in Tables H.1 and H.2 due to minor differences in the areas finally used for some forest categories and in the way the area weighting was performed.

Appendix I

Calculation Sheets for Waste

Years 1990 - 2001

Table I.1. Time Series of Solid Waste Disposal Contributing to CH_4 Emissions

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**
1968	2832010	1.00	1033684	0.750	775263	20674	0.36	0.28	0.03	0.19	279095	217074	23258	147300	**165260**
1969	2880756	1.00	1051476	0.750	788607	21030	0.36	0.28	0.03	0.19	283899	220810	23658	149835	**168105**
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	0.850	1385439	46791	0.32	0.31	0.02	0.18	442271	425373	27724	244122	**295896**
1996	3600000	1.41	1852740	0.850	1574829	55582	0.32	0.31	0.02	0.18	502730	483522	31514	277494	**336943**
1997	3626000	1.44	1905826	0.850	1619952	47646	0.30	0.31	0.02	0.18	485986	502185	32399	291591	**342382**
1998	3660000	1.48	1975653	0.850	1685766	80999	0.27	0.32	0.02	0.19	455204	547850	36142	323463	**370647**
1999	3685000	1.50	2017538	0.850	1714907	80702	0.27	0.32	0.02	0.19	463073	557320	36767	329055	**376629**
2000	3725000	1.50	2039438	0.850	1733522	81578	0.27	0.32	0.02	0.19	468099	563370	37166	332626	**380718**
2001	3740000	1.50	2047650	0.850	1740503	81906	0.27	0.32	0.02	0.19	469984	565639	37316	333966	**382251**

Table I.2. Potential CH_4 Production of Solid Wastes

Year	*DOC in MSW tonnes*	*DOC Managed SWDS %*	*DOC Unmanaged SWDS %*	*Fraction DOC Dissimilated*	*Fraction CH4 in Landfill*	*MCF Managed SWDS*	*MCF Unmanaged SWDS*	*Potential CH4 Managed SWDS tonnes*	*Unmanaged SWDS tonnes*	*Total SWDS tonnes*
A	B	B	D	E	F	G	H	I	J	K
1968	165260	0.40	0.60	0.60	0.50	1.00	0.40	26442	15865	42307
1969	168105	0.40	0.60	0.60	0.50	1.00	0.40	26897	16138	43035
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	336943	0.60	0.40	0.60	0.50	1.00	0.40	80866	21564	102431
1997	342382	0.60	0.40	0.60	0.50	1.00	0.40	82172	21912	104084
1998	370647	0.61	0.39	0.60	0.50	1.00	0.40	90438	23128	113566
1999	376629	0.62	0.38	0.60	0.50	1.00	0.40	93404	22899	116303
2000	380718	0.63	0.37	0.60	0.50	1.00	0.40	95941	22538	118479
2001	382251	0.64	0.36	0.60	0.50	1.00	0.40	97856	22018	119874

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

Table I.3. Annual CH_4 Emissions 1990-2001 from Managed Landfills (continued on following pages)

	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*
1968	26442	0.00		26897											
1969	26897	6.00	0		27352										
1970	27352	16.40	159	0		28502									
1971	28502	18.10	4336	161	0		29675								
1972	29675	7.90	4786	4411	164	0		30871							
1973	30871	5.60	2089	4868	4486	171	0		32090						
1974	32090	5.50	1481	2125	4951	4674	178	0		33331					
1975	33331	4.90	1454	1506	2161	5159	4867	185	0		34595				
1976	34595	4.40	1296	1479	1532	2252	5371	5063	193	0		35882			
1977	35882	4.40	1163	1318	1504	1596	2344	5588	5263	200	0		37191		
1978	37191	3.90	1163	1183	1340	1568	1662	2439	5808	5466	208	0		38524	
1979	38524	3.40	1031	1183	1203	1397	1632	1729	2535	6033	5674	215	0		39749
1980	39749	3.40	899	1049	1203	1254	1454	1698	1797	2633	6262	5885	223	0	
1981	40991	3.40	899	914	1067	1254	1306	1513	1765	1867	2733	6495	6099	231	0
1982	42031	2.90	899	914	930	1112	1306	1358	1572	1833	1937	2835	6732	6318	238
1983	43080	2.60	767	914	930	969	1157	1358	1412	1633	1903	2009	2938	6973	6519
1984	44325	2.30	687	780	930	969	1009	1204	1412	1467	1695	1974	2083	3043	7195
1985	46470	1.70	608	699	793	969	1009	1050	1251	1467	1522	1758	2046	2157	3140
1986	48170	1.30	450	619	711	827	1009	1050	1091	1300	1522	1579	1822	2119	2226
1987	49924	1.00	344	457	629	741	861	1050	1091	1133	1349	1579	1636	1888	2186
1988	51820	1.00	264	350	465	656	772	895	1091	1133	1176	1399	1636	1695	1948
1989	55133		264	269	356	485	683	803	931	1133	1176	1220	1450	1695	1749
1990	**58988**		**0**	**269**	**274**	**371**	**504**	**710**	**834**	**967**	**1176**	**1220**	**1265**	**1502**	**1749**
1991	**60556**		**0**	**0**	**274**	**285**	**386**	**525**	**738**	**867**	**1003**	**1220**	**1265**	**1310**	**1550**
1992	**64521**		**0**	**0**	**0**	**285**	**297**	**401**	**546**	**767**	**899**	**1041**	**1265**	**1310**	**1351**
1993	**66992**		**0**	**0**	**0**	**0**	**297**	**309**	**417**	**567**	**796**	**933**	**1079**	**1310**	**1351**
1994	**70147**		**0**	**0**	**0**	**0**	**0**	**309**	**321**	**433**	**588**	**825**	**967**	**1117**	**1351**
1995	**71015**		**0**	**0**	**0**	**0**	**0**	**0**	**321**	**333**	**450**	**610**	**855**	**1002**	**1153**
1996	**80866**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**333**	**346**	**466**	**632**	**886**	**1033**
1997	**82172**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**346**	**359**	**483**	**655**	**914**
1998	**90438**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**359**	**372**	**501**	**676**
1999	**93404**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**372**	**385**	**517**
2000	**95941**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**385**	**397**
2001	**97856**		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**397**
2002															

Contributions from each year entered vertically and summed horizontally to obtain total emissions for the years 1990 to 2001

	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
1968															
1969															
1970															
1971															
1972															
1973															
1974															
1975															
1976															
1977															
1978															
1979															
1980															
1981															
1982	0														
1983	246	0													
1984	6723	252	0												
1985	7419	6893	258	0											
1986	3238	7608	7065	266	0										
1987	2296	3320	7797	7269	279	0									
1988	2255	2354	3403	8023	7621	289	0								
1989	2009	2312	2412	3502	8411	7900	300	0							
1990	**1804**	**2060**	**2369**	**2482**	**3671**	**8719**	**8188**	**311**	**0**						
1991	**1804**	**1849**	**2111**	**2438**	**2602**	**3805**	**9036**	**8498**	**331**	**0**					
1992	**1599**	**1849**	**1896**	**2172**	**2556**	**2698**	**3944**	**9379**	**9042**	**354**	**0**				
1993	**1394**	**1639**	**1896**	**1950**	**2277**	**2649**	**2796**	**4094**	**9979**	**9674**	**363**	**0**			
1994	**1394**	**1429**	**1680**	**1950**	**2045**	**2360**	**2746**	**2902**	**4356**	**10677**	**9931**	**387**	**0**		
1995	**1394**	**1429**	**1465**	**1729**	**2045**	**2119**	**2446**	**2850**	**3087**	**4660**	**10961**	**10581**	**402**	**0**	
1996	**1189**	**1429**	**1465**	**1507**	**1812**	**2119**	**2197**	**2539**	**3032**	**3303**	**4784**	**11678**	**10987**	**421**	**0**
1997	**1066**	**1219**	**1465**	**1507**	**1580**	**1879**	**2197**	**2280**	**2702**	**3244**	**3391**	**5097**	**12125**	**11504**	**426**
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

Contributions from each year entered vertically and summed horizontally to obtain total emissions for the years
1990 to 2001

	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*
	80866	*82172*	*90438*	*93404*	*95941*	*97856*	
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990	**0**	**0**	**0**	**0**	**0**	**0**	
1991	**0**	**0**	**0**	**0**	**0**	**0**	
1992	**0**	**0**	**0**	**0**	**0**	**0**	
1993	**0**	**0**	**0**	**0**	**0**	**0**	
1994	**0**	**0**	**0**	**0**	**0**	**0**	
1995	**0**	**0**	**0**	**0**	**0**	**0**	
1996	**0**	**0**	**0**	**0**	**0**	**0**	
1997	**0**	**0**	**0**	**0**	**0**	**0**	
1998	**485**	**0**	**0**	**0**	**0**	**0**	
1999	**13262**	**493**	**0**	**0**	**0**	**0**	
2000	**14637**	**13476**	**543**	**0**	**0**	**0**	
2001	**6388**	**14873**	**14832**	**560**	**0**	**0**	
2002	4529	6492	16369	15318	576	**0**	
2003	4448	4602	7145	16906	15734	587	
2004	3962	4519	5065	7379	17365	16048	
2005							

	CH4 Prod'n	*CH4 Recovery*	*CH4 Emitted*
1968			
1969	**Contributions for each year**		
1970			
1971	**summed horizontally**		
1972			
1973	**For managed landfills**		
1974			
1975			
1976			
1977			
1978			
1979			
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988			
1989			
1990	**40,444**	**0**	**40,444**
1991	**41,897**	**0**	**41,897**
1992	**43,649**	**0**	**43,649**
1993	**45,769**	**0**	**45,769**
1994	**47,768**	**0**	**47,768**
1995	**49,892**	**0**	**49,892**
1996	**52,160**	**0**	**52,160**
1997	**54,439**	**4,623**	**49,816**
1998	**56,525**	**17,500**	**39,025**
1999	**59,718**	**25,000**	**34,718**
2000	**63,068**	**22,500**	**40,568**
2001	**66,620**	**22,500**	**44,120**
2002			
2003			
2004			
2005			

Table I.4. Annual CH_4 Emissions 1990-2001 from Unmanaged Landfills (continued on following pages)

	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
1968	15865	0.0		16138											
1969	16138	6.0	0		16411										
1970	16411	16.4	95	0		16406									
1971	16406	18.1	2602	97	0		16392								
1972	16392	7.9	2872	2647	98	0		16369							
1973	16369	5.6	1253	2921	2691	98	0		16337						
1974	16337	5.5	888	1275	2970	2691	98	0		16295					
1975	16295	4.9	873	904	1296	2970	2688	98	0		16245				
1976	16245	4.4	777	888	919	1296	2967	2684	98	0		16185			
1977	16185	4.4	698	791	903	919	1295	2963	2679	98	0		16116		
1978	16116	3.9	698	710	804	902	918	1293	2957	2672	97	0		16038	
1979	16038	3.4	619	710	722	804	902	917	1291	2949	2664	97	0		15900
1980	15900	3.4	539	629	722	722	803	900	915	1287	2940	2654	97	0	
1981	15754	3.4	539	549	640	722	721	802	899	913	1283	2929	2643	96	0
1982	15519	2.9	539	549	558	640	721	720	800	896	910	1279	2917	2630	95
1983	15281	2.6	460	549	558	558	639	720	719	798	893	906	1273	2903	2608
1984	15103	2.3	412	468	558	558	557	638	719	717	796	890	903	1267	2878
1985	15208	1.7	365	420	476	558	557	557	637	717	715	793	886	898	1256
1986	15139	1.3	270	371	427	476	557	557	555	636	715	712	790	882	890
1987	15065	1.0	206	274	377	427	475	557	555	554	634	712	709	786	874
1988	15010	1.0	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**			**161**	**164**	**213**	**279**	**376**	**425**	**473**	**552**	**550**	**548**	**626**	**700**
1991	**16148**				**164**	**164**	**213**	**278**	**376**	**424**	**471**	**550**	**548**	**545**	**620**
1992	**17206**					**164**	**164**	**213**	**278**	**375**	**422**	**469**	**548**	**545**	**541**
1993	**17864**						**164**	**164**	**212**	**277**	**374**	**421**	**467**	**545**	**541**
1994	**18706**							**164**	**163**	**212**	**276**	**372**	**419**	**465**	**541**
1995	**18937**								**163**	**163**	**211**	**275**	**371**	**417**	**461**
1996	**21564**									**163**	**162**	**210**	**274**	**369**	**413**
1997	**21912**										**162**	**162**	**210**	**273**	**366**
1998	**23128**											**162**	**161**	**209**	**270**
1999	**22899**												**161**	**160**	**207**
2000	**22538**													**160**	**159**
2001	**22018**														**159**
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*
15754														
	15519													
0		15281												
95	0		15103											
2584	93	0		15208										
2851	2545	92	0		15139									
1245	2809	2506	91	0		15065								
882	1226	2766	2477	91	0		15010							
866	869	1207	2734	2494	91	0		15325						
772	854	856	1193	2753	2483	90	0		15730					
693	**760**	**840**	**846**	**1201**	**2740**	**2471**	**90**	**0**		16148				
693	**683**	**749**	**831**	**852**	**1196**	**2727**	**2462**	**92**	**0**		17206			
614	**683**	**672**	**740**	**836**	**848**	**1190**	**2717**	**2513**	**94**	**0**		17864		
536	**605**	**672**	**665**	**745**	**833**	**844**	**1186**	**2774**	**2580**	**97**	**0**		18706	
536	**528**	**596**	**665**	**669**	**742**	**829**	**841**	**1211**	**2847**	**2648**	**103**	**0**		18937
536	**528**	**520**	**589**	**669**	**666**	**738**	**826**	**858**	**1243**	**2923**	**2822**	**107**	**0**	
457	**528**	**520**	**514**	**593**	**666**	**663**	**735**	**843**	**881**	**1276**	**3114**	**2930**	**112**	**0**
410	**450**	**520**	**514**	**517**	**590**	**663**	**660**	**751**	**865**	**904**	**1359**	**3233**	**3068**	**114**
362	**403**	**443**	**514**	**517**	**515**	**588**	**660**	**674**	**771**	**888**	**964**	**1411**	**3386**	**3106**
268	**357**	**397**	**438**	**517**	**515**	**512**	**585**	**674**	**692**	**791**	**946**	**1000**	**1478**	**3428**
205	**264**	**351**	**393**	**441**	**515**	**512**	**510**	**598**	**692**	**711**	**843**	**983**	**1048**	**1496**
158	**202**	**260**	**347**	**395**	**439**	**512**	**510**	**521**	**613**	**711**	**757**	**875**	**1029**	**1060**
158	155	199	257	350	394	437	510	521	535	630	757	786	917	1042

1996	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*		*CH4*	*CH4*	*CH4*
21564	*21912*	*23128*	*22899*	*22538*	*22018*			*30724*	*Prod'n*	*Recovery*	*Emitted*
								1968			
								1969	Contributions for each year		
								1970			
								1971	summed horizontally		
								1972			
								1973	for unmanaged landfills		
								1974			
								1975			
								1976			
								1977			
								1978			
								1979			
								1980			
								1981			
								1982			
								1983			
								1984			
								1985			
								1986			
								1987			
								1988			
								1989			
								1990	**14,709**	**0**	**14,709**
								1991	**14,637**	**0**	**14,637**
								1992	**14,627**	**0**	**14,627**
								1993	**14,700**	**0**	**14,700**
								1994	**14,825**	**0**	**14,825**
21564								**1995**	**15,085**	**0**	**15,085**
	21912							**1996**	**15,423**	**0**	**15,423**
0		23128						**1997**	**15,790**	**0**	**15,790**
129	**0**		22899					**1998**	**16,133**	**0**	**16,133**
3537	**131**	**0**		22538				**1999**	**16,796**	**0**	**16,796**
3903	**3594**	**139**	**0**		22018			**2000**	**17,516**	**0**	**17,516**
1704	**3966**	**3793**	**137**	**0**				**2001**	**18,149**	**0**	**18,149**
1208	1731	4186	3755	135	0						

Table I.5. Emissions of N_2O from Human Sewage

Year	Protein	Body Weight	Days	Population	N fraction in protein	EF	N	N2O
	g/kg body weight/day	kg		millions			tonnes	kt
A	B	C	D	E	F	G	H	I
1990	0.75	80	365	3.523	0.16	0.01	123.446	0.194
1991	0.75	80	365	3.550	0.16	0.01	124.392	0.195
1992	0.75	80	365	3.565	0.16	0.01	124.918	0.196
1993	0.75	80	365	3.570	0.16	0.01	125.093	0.197
1994	0.75	80	365	3.580	0.16	0.01	125.443	0.197
1995	0.75	80	365	3.600	0.16	0.01	126.144	0.198
1996	0.75	80	365	3.626	0.16	0.01	127.055	0.200
1997	0.75	80	365	3.660	0.16	0.01	128.246	0.202
1998	0.75	80	365	3.685	0.16	0.01	129.122	0.203
1999	0.75	80	365	3.725	0.16	0.01	130.524	0.205
2000	0.75	80	365	3.750	0.16	0.01	131.400	0.206

B Food Safety Authority recommended dietary allowance for adults
F Default fraction from IPCC Guidelines
G IPCC default emission factor
H H = B*C*D*E*F*G
I I = H*44/28000