epa

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

The Environmental Protection Agency

Ireland's Informative Inventory Report 2021

Air Pollutant Emissions in Ireland 1990-2019

ENVIRONMENTAL PROTECTION AGENCY
The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

The work of the EPA can be divided into three main areas:

Regulation: *We implement effective regulation and environmental compliance systems to deliver good environmental outcomes and target those who don't comply.*

Knowledge: *We provide high quality, targeted and timely environmental data, information and assessment to inform decision making at all levels.*

Advocacy: *We work with others to advocate for a clean, productive and well protected environment and for sustainable environmental behaviour.*

Our Responsibilities

Licensing
We regulate the following activities so that they do not endanger human health or harm the environment:
- waste facilities *(e.g. landfills, incinerators, waste transfer stations)*;
- large scale industrial activities *(e.g. pharmaceutical, cement manufacturing, power plants)*;
- intensive agriculture *(e.g. pigs, poultry)*;
- the contained use and controlled release of Genetically Modified Organisms *(GMOs)*;
- sources of ionising radiation *(e.g. x-ray and radiotherapy equipment, industrial sources)*;
- large petrol storage facilities;
- waste water discharges;
- dumping at sea activities.

National Environmental Enforcement
- Conducting an annual programme of audits and inspections of EPA licensed facilities.
- Overseeing local authorities' environmental protection responsibilities.
- Supervising the supply of drinking water by public water suppliers.
- Working with local authorities and other agencies to tackle environmental crime by co-ordinating a national enforcement network, targeting offenders and overseeing remediation.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Prosecuting those who flout environmental law and damage the environment.

Water Management
- Monitoring and reporting on the quality of rivers, lakes, transitional and coastal waters of Ireland and groundwaters; measuring water levels and river flows.
- National coordination and oversight of the Water Framework Directive.
- Monitoring and reporting on Bathing Water Quality.

Monitoring, Analysing and Reporting on the Environment
- Monitoring air quality and implementing the EU Clean Air for Europe (CAFÉ) Directive.
- Independent reporting to inform decision making by national and local government *(e.g. periodic reporting on the State of Ireland's Environment and Indicator Reports)*.

Regulating Ireland's Greenhouse Gas Emissions
- Preparing Ireland's greenhouse gas inventories and projections.
- Implementing the Emissions Trading Directive, for over 100 of the largest producers of carbon dioxide in Ireland.

Environmental Research and Development
- Funding environmental research to identify pressures, inform policy and provide solutions in the areas of climate, water and sustainability.

Strategic Environmental Assessment
- Assessing the impact of proposed plans and programmes on the Irish environment *(e.g. major development plans)*.

Radiological Protection
- Monitoring radiation levels, assessing exposure of people in Ireland to ionising radiation.
- Assisting in developing national plans for emergencies arising from nuclear accidents.
- Monitoring developments abroad relating to nuclear installations and radiological safety.
- Providing, or overseeing the provision of, specialist radiation protection services.

Guidance, Accessible Information and Education
- Providing advice and guidance to industry and the public on environmental and radiological protection topics.
- Providing timely and easily accessible environmental information to encourage public participation in environmental decision-making *(e.g. My Local Environment, Radon Maps)*.
- Advising Government on matters relating to radiological safety and emergency response.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

Awareness Raising and Behavioural Change
- Generating greater environmental awareness and influencing positive behavioural change by supporting businesses, communities and householders to become more resource efficient.
- Promoting radon testing in homes and workplaces and encouraging remediation where necessary.

Management and structure of the EPA
The EPA is managed by a full time Board, consisting of a Director General and five Directors. The work is carried out across five Offices:
- Office of Environmental Sustainability
- Office of Environmental Enforcement
- Office of Evidence and Assessment
- Office of Radiation Protection and Environmental Monitoring
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet regularly to discuss issues of concern and provide advice to the Board.

IRELAND

INFORMATIVE INVENTORY REPORT 2021

AIR POLLUTANT EMISSIONS IN IRELAND 1990–2019 REPORTED TO THE SECRETARIAT OF THE UNECE CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION AND TO THE EUROPEAN UNION

B. Hyde, P. Duffy, A.M. Ryan, J. Murphy, D. Fahey, S. Monaghan and A. Kehoe

Contents

List of Tables

List of Figures

Acknowledgements

EXECUTIVE SUMMARY

As a Party to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP), Ireland is required to annually report emission data for a wide range of air pollutants and other substances released into the atmosphere. The data are needed to support the work of the Convention in addressing well-known environmental problems such as urban pollution, acidification and trophospheric ozone formation arising from classic pollutants, such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs), ammonia (NH_3), carbon monoxide (CO) and particulate matter (PM), and for the implementation of its Protocols on Heavy Metals and Persistent Organic Pollutants.

The UNECE revised 2014 Reporting Guidelines, Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution[1], describe the scope and reporting of the emission inventories and projections under the Convention. They specify the methodologies and procedures to be followed for submitting consistent and comparable data on an annual basis in a timely, efficient and transparent manner to meet the needs of the Convention. Under the Guidelines, Parties are strongly encouraged to submit an Informative Inventory Report (IIR) to support the evaluation of their up-to-date annual inventories and projections. The objective of the IIR is to describe the methodologies, input data, background information and the entire process of inventory compilation for transboundary air pollutant emissions and to give explanations for any improvements and recalculations of the inventories reported in previous submissions. The report is needed by expert review teams to assess the transparency, completeness and overall quality of the inventories as part of the review process of submissions from Parties to the Convention.

Member States of the European Union are required to report an Informative Inventory Report annually under Article 8(3) of Directive (EU) 2016/2284. This Directive sets out reduction commitments of certain atmospheric pollutants and repeals Directive 2001/81/EC. This report to the European Union fulfils this reporting obligation.

The Environmental Protection Agency (EPA) in Ireland has overall responsibility for national air emission inventories and projections pursuant to the establishment of the National Atmospheric Inventory System (NAIS) in 2007. The EPA Office of Environmental Sustainability (OES) performs the role of inventory agency in Ireland and undertakes all aspects of inventory preparation and management and is responsible for the submission of the results to CLRTAP. The present report constitutes Ireland's twelfth IIR submitted under the Convention, covering annual inventories for the period 1990–2019. The report aims to provide a comprehensive description of the procedures, methodologies and activity data used for the compilation of Ireland's air emission inventories and projections as presented in Ireland's 2021 submission under CLRTAP and to the European Union under Directive (EU) 2016/2284. The report shows how Ireland follows the guidelines for estimating and reporting of emission data to ensure the transparency, accuracy, consistency, comparability and completeness of the reported emissions. In addition to complying with reporting requirements in this

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[1] Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution

regard, the 2021 IIR is intended to inform the Government Departments and institutions involved, as well as other stakeholders in Ireland, of the level of emissions and the state of the art of Ireland's emission inventories and projections as they address the challenges to comply with commitments already established for air pollutants and to control emissions in general. An attempt has been made to give adequate descriptions of all methodological approaches and to provide pertinent information to facilitate the assessment of the emission estimates and the understanding of emission trends. The IIR is published on the web site of the EPA (http://www.epa.ie/pubs/reports/air/airemissions/airpollutantemissions/). It will be further developed for future submissions and updated annually in accordance with the UNECE Reporting Guidelines and Directive (EU) 2016/2284.

Chapter One Introduction

1.1 Convention on Long-Range Transboundary Air Pollution

The Convention on Long-Range Transboundary Air Pollution (CLRTAP) came into being in 1979 following the recognition that co-operation at international level was necessary to address environmental problems such as acidification associated with the transboundary transport and deposition of acidifying gases emitted into the atmosphere. The Convention was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis. Besides laying down the general principles of international co-operation for air pollution abatement, the Convention sets up an institutional framework bringing together research and policy. The Executive Secretary of the United Nations Economic Commission for Europe (UNECE) acts as Secretariat to CLRTAP, and the Convention entered into force in 1983.

The aim of the Convention is that Parties shall endeavour to limit and, as far as possible, gradually reduce and prevent air pollution, including long-range transboundary air pollution. This objective is pursued under eight protocols that identify specific measures to be taken by Parties to cut their emissions of a wide range of air pollutants. The extent to which Parties to the Convention have ratified the various protocols varies. Of the eight protocols to date, Ireland has ratified the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions and the 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides.

1.2 Inventory Reporting and Review under the Convention on Long-Range Transboundary Air Pollution (CLRTAP)

The Guidelines for Reporting Emissions and Projections Data under the Convention on Long-Range Transboundary Air Pollution (ECE/EB.AIR/125)[2] specify the scope, methodologies, formats and deadlines for annual inventory submissions by Parties to the Convention. These Guidelines were adopted by the Executive Body in December 2013 (ECE/EB.AIR/122/Add.1, decisions 2013/3 and 2013/4) and published in 2014. They are a revised version of the 2009 Guidelines for Reporting Emission data under the Convention (ECE/EB.AIR/97), which were approved by the Executive Body in 2008 (ECE/EB.AIR/96, para. 83 (b)). While the Guidelines make it clear that Parties are required to report only on the substances and for the years set forth in the protocols that they have ratified and that have entered into force, Ireland endeavours to estimate and report emissions for the full range of substances set down in Annex I of the Guidelines. These substances are nitrogen oxides (NO_x), sulphur oxides (SO_x), non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), ammonia (NH_3), particulate matter (PM), black carbon (BC), heavy metals (HM) and persistent organic pollutants (POPs).

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[2] The Guidelines for Reporting Emissions and Projections Data under the Convention on Long-Range Transboundary Air Pollution (ECE/EB.AIR/125)

The Guidelines state that an Informative Inventory Report (IIR) should be prepared for inclusion in the annual submission and it is also required under Article 8(3) of Directive (EU) 2016/2284. The objective of the IIR is to describe the methodologies, input data, background information and the entire process of inventory compilation for air pollutants, as well as any improvements and recalculations of the inventories reported in previous submissions. The report is needed to support the evaluation of emission trends and is used by expert review teams to assess the transparency, completeness and overall quality of the inventories as part of the review process established for submissions by the Parties to CLRTAP and the review process established under the NECD.

The present report constitutes Ireland's IIR for 2021, the twelfth such report. It contains specific information on the national inventory for the years 1990–2019 as submitted to CLRTAP in February 2021, including descriptions of methods, data sources, quality assurance/quality control (QA/QC) activities and trend analysis. The structure of the report follows the structure proposed in Annex II to the reporting guidelines.

The IIR focuses on the year 2019 and the status of the inventories achieved for the time series up to 2019 and is the basis for methodological description for the purposes of facilitating technical review and general assessment of Ireland's emission inventories. The IIR is designed to capture the cyclical nature of the reporting process and to clarify the chronology of changes and revisions that are part of normal inventory development. In this way, the report provides the basis for technical assessment and expert review of Ireland's air pollutant inventories. An attempt has been made to give adequate descriptions of all methodological approaches and to provide all the pertinent inventory information to facilitate the assessment of the emission estimates and the understanding of emission trends.

The IIR will be further developed and updated annually in accordance with the UNECE guidelines and is published on the web site of the EPA (http://www.epa.ie/pubs/reports/air/airemissions/airpollutantemissions/). Such updating is necessary to keep the UNECE Secretariat and other interested parties informed of the status of Ireland's air pollutant inventories and to document on-going improvements, recalculations and other developments affecting the estimates of emissions. Ireland is contributing to the Stage 3 in-depth review process for transboundary emission inventories by not only providing this IIR, but also providing expert reviewers to evaluate the submissions from other Parties to the Convention.

1.3 Inventory Reporting and Review under Directive (EU) 2016/2284

Directive (EU) 2016/2284[3] came into force on the 31st of December 2016. This inventory report and data submission fulfils Ireland's reporting requirements as set out in Article 10(2) of the directive. The inventory submission is fully consistent with the submission under the LRTAP Convention and will be subject to review in accordance with Article 10(3) of the directive.

Ireland's national total emissions of nitrogen oxides (NO_x), ammonia (NH_3) and non-methane volatile organic compounds (NMVOCs) are not in compliance with the ceilings in Article 4(1) and Annex I to

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[3] DIRECTIVE (EU) 2016/2284 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

Directive 2001/81/EC[4]. Ireland has established adjusted annual national emission inventories for NO_x and NMVOCs as allowed for under the flexibilities outlined in Articles 21(2) and 5(1) of the Directive 2016/2284. The adjusted inventories are established in accordance with Part 4 of Annex IV of the directive and are explained in detail in chapter 9 of this report.

1.4 Inventory Reporting by the Environmental Protection Agency

Under Section 52 of the Environmental Protection Agency Act, 1992 (DOE, 1992), the Agency is required to establish and maintain databases of information on the environment and to disseminate such information to interested parties. Section 55 of the Act states that the Agency must provide, of its own volition or upon request, information and advice to Ministers of the Government in the performance of their duties. This includes making available such data and materials as are necessary to comply with Ireland's reporting obligations and commitments within the framework of international agreements. These requirements are the regulatory basis on which the EPA prepares annual inventories of air pollutants in Ireland. The activities related to the compilation and reporting of air pollutant emissions constitute one specific on-going project in the Agency's work programme.

The Department Environment, Climate and Communications (DECC) has designated the EPA as the agency with responsibility for the submission of emission data to international bodies, including the Secretariat for CLRTAP and the European Union. The Agency's Office of Environmental Sustainability (OES) currently compiles the national air pollutant emission inventories on behalf of the DECC for submission under CLRTAP and NECD.

1.4.1 National Atmospheric Inventory System

In 2005, UK consultants from the National Environmental Technology Centre (NETCEN) carried out a scoping study to identify the essential elements and structure of a national inventory system for Ireland to meet the needs of Decision 280/2004/EC (EP and CEU, 2004a) and to comply with obligations under Articles 5 and 7 of the Kyoto Protocol. The report (Thistlethwaite et al., 2005) describes how institutional arrangements among the EPA, its parent government department and other stakeholders may be reorganised, extended and legally consolidated across all participating institutions to strengthen inventory capacity within the EPA and to ensure that more formal and comprehensive mechanisms of data collection and processing are established for long-term implementation. The report sets out the extent of institutional participation, resource requirements and the form of legal arrangements necessary to perform the functions prescribed in the guidelines for national systems and enable Ireland to meet the objectives specified in those guidelines. The scoping study developed a QA/QC system as an integral part of the national system and the report made recommendations on internal inventory review and proposed a database system to facilitate more efficient data management and reporting. Whilst developed to meet the needs of Decision 280/2004/EC and the Kyoto Protocol, Ireland's national system is also implemented to achieve emission inventories for transboundary gases for submission under CLRTAP and NECD.

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[4] DIRECTIVE 2001/81/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2001 on national emission ceilings for certain atmospheric pollutants

The National Atmospheric Inventory System (NAIS) for Ireland was adopted by Government decision in April 2007. It establishes the necessary institutional, legal and procedural arrangements for the compilation of robust inventories of emissions of greenhouse gases (GHGs) and air pollutants to the atmosphere. It sets out formal procedures for the planning, preparation and management of the national atmospheric inventory and identifies clearly the roles and responsibilities of all the organisations involved in inventory compilation, reporting and review. A schematic overview of the national system is presented in Figure 1.1.

The principal objective of the NAIS is to ensure that Ireland can compile robust and verifiable annual inventories of emissions and report its emission estimates in accordance with relevant international obligations. The NAIS also facilitates the formal review of information submitted under international obligations, including the Kyoto Protocol, protocols under CLRTAP and the NECD. Implementation of the national system ensures the transparency, consistency, comparability, completeness and accuracy of the national inventory in accordance with the established reporting guidelines, which incorporate methodological guidance and good practice.

Within the NAIS, the EPA's Office of Environmental Sustainability (OES) is designated as the single national entity with overall responsibility for the national emission inventory in Ireland. The OES also performs the role of inventory agency, i.e. the Office compiles the annual inventory and delivers Ireland's submissions to the various international organisations (European Commission (EC), European Environment Agency (EEA), United Nations Framework Convention on Climate Change (UNFCCC) and UNECE in accordance with agreed deadlines and reporting formats. In addition to the primary data received from the Key Data Providers (KDPs), the inventory team obtains considerable supplementary information from other teams in the OES, the Office of Evidence and Assessment and the Office of Environmental Enforcement within the EPA. These sources include Annual Environmental Reports (AERs) submitted by licensed facilities and the National Waste Database. The inventory team also draws on national research related to air pollutant emissions and special studies undertaken from time to time to acquire the information needed to improve the estimates for categories and gases. The approval of the completed annual inventory involves sign-off by the QA/QC manager and the inventory manager before it is transmitted to the Board of Directors of the EPA via the Programme Manager of OES. Any issues arising from the Board of Directors' examination of the estimates are communicated to the inventory experts for resolution before final adoption of the inventory for submission and publication.

1.4.2 Scope of Inventories under the LRTAP Convention and Directive (EU) 2016/2284

The scope of Ireland's emission inventories under LRTAP Convention and Directive (EU) 2016/2284 is provided in this report. It covers a wide range of air pollutants and other substances, which are reported in a standard electronic format for a predefined nomenclature of source categories set down in the UNECE Reporting Guidelines. The air pollutants are referred to in seven groups as follows:

1. Main pollutants (NO_X, NMVOCs, SO_X, NH_3, CO);

2. Particulate matter ($PM_{2.5}$, PM_{10}, total suspended particulates (TSP), black carbon (BC));

3. Priority heavy metals (lead (Pb), cadmium (Cd), mercury (Hg));

4. Other heavy metals (arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), zinc (Zn));

5. Annex I Persistent Organic Pollutants: the POPs listed in Annex I to the Protocol on POPs which are substances scheduled for elimination;

6. Annex II Persistent Organic Pollutants: the POPs listed in Annex II to the Protocol on POPs which are substances scheduled for restrictions on use;

7. Annex III Persistent Organic Pollutants: the POPs listed in Annex III to the Protocol on POPs which are substances referred to in Article 3, Para. 5 (a), of the Protocol. Polycyclic aromatic hydrocarbons (PAHs): for the purpose of the emission inventories, the following four indicator compounds should be used: benzo[b]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene and indeno [1,2,3-cd] pyrene. Hexachlorobenzene (HCB) is also included in Annex I to the Protocol as a substance for elimination.

The list of source categories for inventory purposes is known as the NFR (Nomenclature for Reporting). It comprises coded activities across all socio-economic sectors identified as sources of one or more of the substances listed above and provides for the inclusion of other activities that may be specific to individual countries. Many of the NFR categories are split into a varying number of subcategories, which are designed to reflect their importance as sources of one or more pollutants and to provide an adequate level of transparency. In the compilation of annual inventories, significant subdivision of the given NFR categories is normally applied for the process of calculating the relevant emissions. The NFR facilitates the comparison of emissions among reporting countries and the synthesis and assessment of submissions at the UNECE level. The current version of the NFR, NFR 19 is a revision of NFR14, which was included in Annex I of the Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution (ECE/EB.AIR/125), which were adopted by the Executive Body in December 2013. This revised NFR was approved by the Steering Body of the European Monitoring and Evaluation Programme (EMEP) during its 5th Joint Session in September 2019 and should be used for reporting under CLRTAP for 2020 onwards.

The 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. The notable emission sources excluded from the reported national total for transboundary gases and included as Memo Items are emissions from international and domestic aviation during the cruise phase of a flight, and international shipping.

KEY DATA PROVIDERS

OTHER EPA OFFICES

SUPPLEMENTARY DATA SOURCES

MoUs

Input Data Preparation and Pre-processing

ACTIVITY DATA and ETS DATA COMPILATION

Research, Special Studies

QA/QC

National Emission Factors

ESTIMATION OF EMISSIONS and NFR OUTPUT

SELECTION OF EMISSION FACTORS

QA/QC

Default Emission Factors, EMEP/EEA emission inventory guidebook

External Review and Consultation

Inventory Time Series and Informative Inventory Report

Inventory Manager

Programme Manager

QA/QC Manager

EPA Board of Directors

European Commission

Dept. of Environment, Climate and Communications

UNECE Secretariat

Figure 1.1. National Atmospheric Inventory System Overview

A set of notation keys has been adopted for use in completing the NFR templates to provide explanation and transparency where a numerical value does not appear for a particular pollutant and/or category combination. The notation keys are as follows:

(a) NO (not occurring) for activities that do not occur in the country;
(b) NE (not estimated) where emissions do occur but are not estimated, usually because they are considered negligible or the necessary data cannot be obtained;
(c) NA (not applicable) for activities that do not generate emissions of a particular pollutant;
(d) IE (included elsewhere) for emissions relating to a subcategory that are reported in another subcategory, usually at the next highest level;
(e) C (confidential) for emissions that could lead to the disclosure of confidential information;
(f) NR (not relevant) for emissions that are not required by the ratified protocols.

At four year intervals from 2017 onwards, the inventory submissions under CLRTAP should include compilations of emissions for a list of defined large point sources and aggregated sectoral gridded data for the European Monitoring and Evaluation Programme (EMEP) grid cells overlying the national territory. This information is used in EMEP models for evaluating long-range transport of air pollutants and for assessing emission deposition relationships in Europe. Ireland's 2021 submission contains data for large point sources and sectoral gridded data of emissions on the EMEP grid. This information is provided in chapter 7 of this report.

Parties to the Gothenburg Protocol shall report national projections every four years from 2015 onwards, for the years 2020, 2025 and 2030 and where available, also for 2040 and 2050, by 15th March for the pollutants: SO_x (as SO_2), NO_x, NMVOCs, NH_3 and $PM_{2.5}$, with voluntary reporting for black carbon. Other Parties are encouraged to provide projections for these pollutants. The Directive (EU) 2016/2284 requires emission projections every two years from 2017 onwards from European Member States. Information on emission projections is provided in chapter 8 of this report.

1.4.3 Inventory Preparation

The air pollutant emission inventory database normally contains information on measured emission quantities, activity statistics (populations, fuel consumption, vehicle/kilometres of travel, industrial production and land areas), emission factors and the associated emission estimates for the NFR list of source categories. In practice, very few measured emission data are available for the range of gases covered and, consequently, the emissions from most activities are estimated by applying emission factors for each source/gas combination to appropriate activity data for the activity concerned. Virtually all emissions may be ultimately derived on the basis of the product of activity data and emission factor. Even in the case where emission estimates for particular categories are reported directly to the inventory agency they will normally have been derived in this manner.

The reporting guidelines provide the general guidance for the preparation and reporting of annual inventories by Parties. They incorporate the methodologies given in the EMEP/EEA (European Environment Agency) Emission Inventory Guidebook, hereafter referred to as the Inventory Guidebook. The inventory preparation process involves the acquisition of the required statistical data for the inventory year concerned and the application of emission factors that characterise the rate of emission of the gases concerned. Some data analysis and preparatory calculations are generally

needed to make available suitable combinations of activity data and emission factors at the level of disaggregation that gives the best estimate of emissions in the individual emission source categories. 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 Inventory Guidebook use a tiered system. This provides methodologies at different levels of detail and sophistication, which take account of these issues and other factors, such as data availability, technical expertise, inventory capacity and other circumstances, which may vary considerably across countries.

1.4.4 Data Acquisition

In its capacity as the inventory agency, the OES of the EPA acquires the principal items of activity data from identified Key Data Providers (KDP) relevant to each of the NFR sectors. Most KDPs provide data directly to the OES, but some secondary KDPs provide their input to one of the primary KDPs for processing and incorporation into the information subsequently transmitted to the OES. Some KDPs may also deliver estimates of emissions or removals for their particular area of coverage or expertise. Table 1.1 lists the KDPs and the data they supply for use in transboundary air pollutant emission inventories.

The NAIS provides for a formal Memorandum of Understanding (MoU) between each KDP and the inventory agency regarding the scope, quality and submission date of the data to be provided for the purposes of the national emission inventory compilation. In the majority of cases, the data concerned are already routinely collected and published by the KDPs under existing mandates and established reporting programmes. Additional MoUs may be developed under the NAIS in cases where new or supplementary data sources need to be targeted. Under Section 69 of the EPA Act 1992, formal legal powers are assigned to the EPA, whereby the Agency may require any public body to provide information related to environmental quality and may make arrangements with other bodies for the provision of similar information. This provision can also be invoked by the OES to acquire specific information for inventory purposes as the need arises.

The Emissions Trading Unit was established under the EPA Office of Licensing and Guidance (OLG) in late 2003 to implement Directive 2003/87/EC (EP and CEU, 2003) in Ireland. The Emissions Trading Unit currently forms part of the OES and is another key component of the national system. Information compiled for participants in the Emissions Trading Scheme (ETS) under Directive 2003/87/EC is an important source of activity-specific and company-specific data on GHG emissions for approximately 100 installations in Ireland. The inventories for transboundary air pollutants draw on relevant information regarding fuel quantities and fuel properties available under the ETS for these installations and fuel data are used for reconciliation with the national energy balance for major categories and matching of activity data for GHG emission inventories. The inventory agency in the OES obtains useful support and activity data from other EPA offices and programme areas, including the Environmental Licensing Programme, Office of Environmental Enforcement, and the Environmental Research Programme. These programmes and offices make various contributions that are used to determine or substantiate the activity data or emission factors for particular categories or individual activities, which ensures that country-specific information is exploited to the maximum extent possible. In all cases, consistency is maintained with data application for GHG emission inventories and vice versa.

1.4.5 Quality Assurance and Quality Control (QA/QC)

Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation and development process. Reviews, preferably by independent third parties, should be performed upon a finalised inventory following the implementation of QC procedures. Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks, given the current state of scientific knowledge and data available, and support the effectiveness of the QC programme.

A QA/QC spreadsheet tool has been developed to manage and maintain Ireland's QA/QC system. This tool consists of several spreadsheets that provide procedures, guidance, forms and templates as required for the general QA/QC functions. The supporting manual (Thistlethwaite et al., 2005) provides a general overview to the QA/QC system and guidance on the application of the plan and procedures. The QA/QC plan identifies the specific data quality objectives related to the principles of transparency, consistency, completeness, comparability and accuracy required for Ireland's national inventory and provides specific guidance and documentation forms and templates for the practical implementation of QA/QC procedures. The spreadsheets include a brief introduction and a statement of the data quality objectives (DQOs) and how they will be met through the QA/QC system with reference to the relevant spread sheet tool template sheets and forms. The Introduction sheet links to the QA/QC plan which provides the schedules and procedures for the QA/QC system and lists all of the QA/QC activities that exist or are planned to make up Ireland's QA/QC system. The Plan sheet consists of tables that contain three different categories of QA/QC activity:

1. General activities covering the planning and management practices and procedures;

2. Activities that should be undertaken on an annual basis for management and preparation of the inventory;

3. Periodic activities that should be undertaken in response to specific events in the inventory and for periodic peer review or verification.

The inventory agency has implemented this approach to QA/QC for fifteen annual reporting cycles. This involved the allocation of responsibilities linked to the national system and the use of the template spreadsheet system to record the establishment and maintenance of general inventory checking and management activities covering the overall compilation process, as well as the undertaking of specific annual activities and any necessary periodic activities in response to specific events or outcomes in inventory reporting and review. The system facilitates record keeping related to the chain of activities from data capture, through emission calculations and checking, to archiving and the identification of improvements.

Ireland's calculation spreadsheets in all sectors are structured on a time-series basis. This organisation is designed to facilitate the QA/QC process as well as more efficient trend analysis and to ensure ease of transfer of the outputs to the NFR tables. The inventory compilation is directly linked to the primary statistical inputs, which facilitates rapid year-on-year extension of the time series and efficient updating and recalculation, where appropriate, in the annual reporting cycle. Internal aggregation to various levels corresponding to the NFR tables provides immediate and complete checks of the results.

Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

(i) Provide routine and consistent checks to ensure data integrity, correctness, and completeness;

(ii) Identify and address errors and omissions;

(iii) Document and archive inventory material and record all QC activities.

Quality control activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardised procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher-tier QC activities include technical reviews of source categories, activity and emission factor data, and methods.

In recent years, the inventory agency has created and implemented a number of QA\QC tools. These spreadsheet-based tools are used to better inform the QA\QC process whilst providing transparent descriptions of the outcomes of checks. In each spreadsheet-based tool comments are added to explain anything highlighted by the checking process. The text from these tools (such as the recalculations assessment) then helps inform the update of the IIR. The tools used include:

1. Recalculations assessment – this spreadsheet tool calculates the percentage change of emission estimates between the current and previous inventory submissions using conditional formatting to highlight the significant changes. There is a separate table for each pollutant in which the entire time series is evaluated for all NFR codes. This check highlights the recalculations that have been made in the inventory so that they can be verified and justified by the inventory agency.

2. Trend assessment – this spreadsheet tool calculates the percentage change between the most recent year and the preceding year of the current inventory submission using conditional formatting to highlight the significant changes. There is a separate table for each pollutant in which the entire time series is evaluated for all NFR codes. This check helps identify any time series inconsistency with the newly reported data of the most recent year. Provided this is run annually and alongside the recalculations check, time series consistency should be maintained.

3. Pollutant specific assessments – there are two tools that check the following rules that should be maintained in an inventory: $TSP \geq PM_{10} \geq PM_{2.5}$; Total PAHs (1-4) = B(a)p + B(b)F + B(k)P + I(123)-cd. These simple checks help maintain the accuracy of the inventory.

4. Data value assessment – two tools check the entire time series for all pollutants to ensure that none of the following are reported: zero values, errors, negative values. These simple checks help maintain the accuracy and transparency of the inventory.

5. Annex I reporting template assessment – this tool evaluates whether all compiled Annex I reporting template files are comparable in structure and content to the template. This helps maintain the comparability of the inventory.

6. Notation keys assessment – this tool summarises the use of the different notation keys within the inventory. This tool has been implemented for all NEC pollutants across the entire time series. The tool helps the inventory agency evaluate, justify and document the use of notation

keys in the inventory. By increasing the accuracy of the notation keys, the transparency of the inventory is improved and this allows the inventory agency to clearly identify areas where potential improvements could be made (e.g. the use of IE or NE).

The online tool provided by the Centre on Emissions Inventories and Projections (CEIP), RepDab, is used by the inventory agency to check the format, completeness and internal consistency of the Annex I reporting template submission files. Further details regarding the checks that are carried out can be found on the CEIP website.

In the 2021 reporting cycle, the inventory agency updated some of the default emission factors in accordance with the EMEP/EEA Air Pollutant Emission Inventory Guidebook (2019) and implemented suggested changes/requests for further information as presented in the Final NECD Review Report of the 2020 Comprehensive Technical Review of National Emission Inventories. These are outlined in the sectoral chapters of this report.

Table 1.1 Key Data Providers and Information Covered by Memoranda of Understanding

Key Data Provider	Data Supplied	Deadline	Sector in which Data are Used
Sustainable Energy Authority of Ireland (SEAI)	National Energy Balance; Detailed national energy consumption disaggregated by economic sector and fuel	30 September	Energy, Waste
Department of Agriculture Food and the Marine (DAFM)	Nitrogen fertiliser sales, cattle populations from the AIM (Animal Identification and Movement) database, sheep statistics, poultry statistics	30 September	Agriculture
Central Statistics Office (CSO)	Annual population, livestock populations, crop statistics, housing survey data	30 September	Agriculture, Industrial Processes, Waste
Gas Networks Ireland (GNI)	Analysis results for indigenous and imported natural gas	30 September	Energy
Marine Institute	Annual report on discharges, spills and emissions from offshore gas production installations	30 October	Energy
Emissions Trading Unit (OES, EPA)	Verified CO_2 estimates and related fuel and production data for installations covered by the EU ETS	30 April	Energy, Industrial Processes
Department of Environment, Climate and Communications (DECC)	National Oil Balance (as a component of the energy balance)	30 September	Energy
Road Safety Authority (RSA)*	Road transport statistics from the National Car Testing (NCT) Service	30 April	Energy

*These bodies have MoUs with the SEAI rather than with the OES.

1.4.6 Inventory Compilation

The source data, calculation workbooks and outputs for all emissions to air are held on EPA servers. The annual inventory compilation for transboundary gases is undertaken in separate *Data Processing* folders for each sector, which are linked to the *Source Data* folders for the respective sectors at the same level. The *Outputs* folder and the *QA/QC* folder are also at this level. The *Outputs* folder contains the files used for the official submissions to the EU and the UNECE and for preparing summary reports and relevant media statements at national level. All calculation workbooks for the individual sectors contain a QA/QC worksheet, which are compiled collectively in the *QA/QC* folder. Data processing to compute the emission estimates is carried out at the most detailed level of aggregation possible, consistent with data availability and the outputs needed to populate the reporting template format for the category concerned. These outputs are primarily the estimates of emissions and the corresponding activity data for each category.

Quality control procedures are an integral part of the inventory preparation and reporting cycle. Within the inventories team, quality control for each sector is undertaken by an inventory compiler

who has not produced the emission estimates for that sector. Quality control involves a series of checks covering the data inputs and any necessary pre-processing, the calculation of emissions, and the generation of the output records that are subsequently compiled in the NFR templates. The checks cover such items such as the comparison of inputs with those of previous years, the identification of errors and omissions, validating internal linking and calculation algorithms, replicating the aggregation of subcategories and ensuring an adequate level of completeness in NFR files to achieve transparency for external review purposes. A colour code system is used to distinguish between such elements as data taken from another spread sheet, calculated values, extrapolated or interpolated values, outputs for the NFR, and checks and annotations.

1.5 Key Category Analysis

Key category analysis for transboundary air emissions is explained in the Inventory Guidebook (EMEP/EEA, 2019), and is the same concept as that presented in the Intergovernmental Panel on Climate Change (IPCC) 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). This defines a key emission 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. The Inventory Guidebook provides several methods for undertaking the analysis of key categories that can be applied at any appropriate level of source aggregation, depending on the information available. The simplest approach (Approach 1) – identification based on contribution to emission level – is used here for the inventories of all substances to highlight which sources of emissions are the most important in Ireland.

In level assessment, key categories are those categories whose combined contribution to the total emission level, determined from the ranking of all categories on the basis of their individual contributions to the level, is 80 per cent. Information about key categories is considered to be crucial to the choice of methodology for individual sources and to the management and reduction of overall inventory uncertainty. The identification of such categories is recommended in order that inventory agencies can give them priority in the preparation of annual inventories, especially in cases where resources may be limited. Information on key categories is clearly also vital for the development of policies and measures for emissions reduction.

It is well established that fuel combustion in a small number of economic sectors is the major source of most air pollutants. This is true for classic pollutants such as SO_x and NO_x, which are reasonably well quantified in emission inventories and for which emissions have decreased considerably, and also for other substances (PM, POPs) for which inventories have much higher levels of uncertainty. The relative contributions of key categories are clearly shown by the results of the simple key category analysis shown in Table 1.2 and Annex A.2, Tables 1-15, which summarises NFR Level 2 key categories by pollutant. The dominance of categories under 1A (Energy: Combustion) highlights the importance of combustion sources. The four key categories (1A1a, 1A2f, 1A3b and 1A4b) dominate the results of the key category analysis presented in Table 1.2. Agriculture sources (3B, 3D) are the main sources of emissions for NH_3, NMVOC's and particulate matter and the additional categories 2D and 2H for NMVOCs. Waste sector sources are the main driver of emissions for As, Cr, dioxins and PCBs. *Table 1.2. Key Category Analysis of Ireland's Air Pollutant Inventory 2019*

Pollutant	Key Categories									Total (%)
NOₓ	3Da1 13.94%	1A3biii 12.51%	3Da3 11.36%	1A3bi 10.13%	1A3bii 7.45%	3Da2a 7.05%	1A3dii 6.71%	1A1a 5.93%	1A4bi 5.18%	80.26%
CO	1A3bi 33.82%	1A4bi 29.33%	1A1a 8.93%	1A2f 6.39%	1A3biii 4.81%					83.28%
NMVOC	2H2 25.70%	3B1b 20.74%	2D3a 9.77%	3B1a 9.44%	1A4bi 6.76%	3De 4.12%	3B3 2.53%	2D3d 2.13%		81.20%
SOₓ	1A4bi 60.35%	1A1a 20.57%								80.92%
NH₃	3Da2a 32.08%	3B1b 27.99%	3B1a 11.57%	3Da3 10.87%						82.49%
TSP	2D3b 47.07%	1A4bi 11.36%	3Da1 11.07%	2A5a 7.82%	2A5b 4.61%					81.95%
PM₁₀	3Da1 25.35%	1A4bi 23.77%	2D3b 14.37%	2A5a 8.77%	1A3bvi 3.82%	2A5b 3.17%	1A2f 2.80%			82.04%
PM₂.₅	1A4bi 54.77%	1A2f 5.98%	1A3bvi 4.87%	1A2gviii 3.59%	3B1b 2.67%	1A3bvii 2.54%	3Da1 2.28%	5E 2.09%	2A5a 2.05%	80.84%
Pb	1A4bi 41.30%	1A3bvi 28.73%	1A3aii(i) 10.87%							80.90%
Cd	1A2gviii 26.89%	2D3i 14.57%	1A4bi 14.48%	1A1a 14.07%	2G 7.71%	1A2e 5.26%				82.98%
Hg	1A4bi 26.12%	1A2f 23.26%	1A1a 16.79%	5A 6.47%	1A1c 5.05%	1A2b 4.00%				81.70%
As	5C1bi 57.92%	1A1a 20.14%	1A2f 13.93%							91.99%
Cr	5C1bi 27.25%	1A3bvi 21.64%	1A2f 11.38%	1A4bi 8.57%	1A2gviii 7.10%	1A1a 6.76%				82.70%
Cu	1A3bvi 57.60%	2D3i 32.19%								89.79%
Ni	1A4ai 33.55%	1A2gviii 16.34%	1A1a 14.01%	1A2f 11.23%	1A2e 6.39%					81.50%
Se	1A4bi 69.24%	1A1a 22.41%								91.66%
Zn	1A3bvi 22.73%	1A4bi 19.17%	2D3i 17.86%	1A2gviii 13.10%	1A2f 12.90%					85.76%
PCDD/F	1A4bi 68.69%	5E 16.41%								85.10%
PCBs	5E 39.57%	1A4bi 32.73%	5C2 18.02%							90.32%
HCB	3Df 86.95%									86.95%
PAHs	1A4bi 90.48%									90.48%
	1 Energy		2 IPPU		3 Agriculture		5 Waste			

1.6 Uncertainty Assessment

Undertaking a quantitative estimate of emissions uncertainty requires a substantial amount of detailed data on the uncertainty of both activity data and emissions factors for a diverse range of source types. It has not been possible to collect these data in full. However, it has been possible to characterise the uncertainties associated with sources in a more approximate way.

A semi-quantitative uncertainty analysis has been used to determine the overall emissions uncertainty for a number of pollutants for 2019 data. This uses a Tier 1 propagation of errors to obtain an uncertainty for the total emission. However, the uncertainty assigned to the activity data and emission factor for each individual source is obtained from a combination of expert judgement and ranges of uncertainty obtained from the EMEP/EEA emission inventory guidebook. The results provide a good indication as to which sources are contributing the most to the overall uncertainty, and therefore where improvement effort should be targeted.

The methodology and results of the Tier 1 uncertainty analysis are presented in detail in Annex G, tables G.1 to G.6. The results can be summarised as follows:

Table 1.3 Emissions Uncertainties

Pollutant	Emission (kilotonnes, 2019)	Uncertainty in 2019 (%)	Trend Uncertainty 1990-2019 (%)
NO_X	101.03	46.8	15.9
SO_2	10.88	12.8	0.6
NMVOC	113.90	72.7	22.2
NH_3	125.42	89.7	12.0
CO	68.33	19.5	1.7
$PM_{2.5}$	11.90	96.6	15.1

The total uncertainty in the NO_X emission in 2019 is dominated by the contribution of inorganic N-fertilisers (3.D.a.1), animal manure applied to soils (3.D.a.2.a) and urine and dung deposited by grazing animals (3.D.a.3), ±200 per cent for each sub category of 3.D. These three categories combined account for 98.2 per cent of the total NO_x emissions uncertainty. The next largest contributor to uncertainty for NO_x emissions is landfill gas used as a fuel in Public electricity and Heat Production with an emission factor uncertainty of over 300 per cent.

Emissions of SO_2 are well characterised when compared to NO_X for most emissions because they are combustion related, with emission factors for SO_2 (i.e. the sulphur content of the fuel) more readily determined than for NO_X. Solid fuel combustion, coal, biomass and peat in the residential sector combined account for 96.5 per cent of the overall uncertainty.

Emissions of NMVOC from non-combustion sources are typically high in uncertainty because they are difficult to characterise by measurement. Manure management from cattle (3.B.1.a & 3.B.1.b) contributes to 88.4 per cent of the overall uncertainty because of the magnitude of the emission of these categories (30.2 per cent in 2019) and, as with all manure management categories, has poorly characterised emission factors (±300 per cent). Fugitive NMVOC losses from fuel extraction and

distribution (1.B.2) and domestic solvent use (2.D.3.a) are large contributors because they have poorly characterised emission factors and activity data, respectively.

The uncertainty associated in NH_3 emissions are driven by the emission factors, with the activity data; number of livestock and nitrogen amounts, typically being well characterised by comparison. The sources making the largest contributions to the overall uncertainty are ammonia losses from inorganic N-fertiliser use (3.D.a.1), animal manure applied to soils (3.D.a.2.a) and urine and dung deposited by grazing animals (3.D.a.3). The emission factors for these sources are currently assigned an uncertainty of ±200 per cent, and they contribute to 96.9 per cent of the overall uncertainty.

Emissions of $PM_{2.5}$ are generally high in uncertainty because many combustion sources are either not well characterised, or are variable in emission, with small changes to combustion conditions having very large impacts on $PM_{2.5}$ emissions. Residential coal, biomass and peat combustion (1.A.4.b) and road paving with asphalt (2.D.3.b) are the largest contributors to the overall uncertainty, contributing 98.4 per cent and 0.8 per cent respectively. These are relatively large sources with very uncertain emission factors.

It is interesting to note that electricity generation and industrial combustion do not feature as major contributors to the overall uncertainty for any pollutants. This is because the use of point specific data allows the emission estimates to be particularly well characterised.

Chapter Two

Analysis of Key Emission Trends

2.1 Introduction

Ireland's 2021 submission under the CLRTAP and the Directive (EU) 2016/2284 includes emission estimates for the period 1990–2019 in respect of all substances listed in Section 1.4.2 above. The primary emission time series is prepared on the basis of Ireland's published national energy balances, which record the amounts of fuels sold in the country. In recognition of the significant cross-border movement that occurs with respect to automotive fuels in some parts of Europe, the reporting guidelines allow for the reporting of emissions from road transport on the basis of fuels used within the country. This may result in a significant decrease in the national total emissions for some pollutants and the adjusted total is considered more appropriate for the assessment of performance in relation to certain protocols. This issue is relevant to Ireland in the case of the Sofia Protocol on NO_X emissions and, to facilitate the assessment, Ireland has also submitted inventories in which the estimates for road transport are based on fuels used in the country. Emission inventories based on fuel sold and fuel used are provided in this submission for all pollutants for the period 1990–2019 and for the year 1987, the base year for the Sofia Protocol.

This chapter provides an overview of the emission trends for the period 1990–2019 for all substances included in Ireland's 2021 submission under the CLRTAP and NECD. The general analysis of trends is performed only in respect of emissions estimated on the basis of fuels used in Ireland.

2.2 Main Pollutants

2.2.1 Sulphur Dioxide (SO₂)

Total sulphur dioxide emissions decreased by 94.1 per cent, from 183.64 kt in 1990 to 10.87 kt in 2019 (Figure 2.1). The Commercial/Institutional and Residential (1A4a and 1A4b) sectors combined account for 62.1 per cent of the total in 2019, and decreased by 82.2 per cent between 1990 (38.03 kt) and 2019 (6.75 kt). The Public Electricity and Heat Production (1A1a) sector remains one of the main sources of SO_2 emissions, contributing 20.6 per cent of the total in 2019, and decreased by 97.8 per cent between 1990 (103.04 kt) and 2019 (2.24 kt). An increase in consumption of coal, peat and oil in this sector in 1994 followed by decreased peat and oil consumption the following year caused a peak in emissions in 1994.

In 1998 an increase in consumption of coal followed by a decrease the following year caused another peak in emissions in 1998. Combustion sources in the Manufacturing Industries and Construction (1A2) sector largely account for the remainder of the emissions, with contribution of 13.4 per cent in 2019. Emissions in this sector peaked in 1994 due to an increase in SO_2 from oil combustion in the

installation which is the main contributor to emissions in Non-ferrous metals (1A2b). Emissions in Manufacturing Industries and Construction (1A2) have decreased in the 1990-2019 time series by 95.6 per cent. Combustion in Agriculture/Forestry/Fishing (1A4c) sector accounts for 0.2 per cent and Transport (1A3) combustion sources account for 2.2 per cent of national total emissions of SO_2 in 2019. The remainder of the SO_2 emissions arise from combustion sources in the Petroleum Refining (1A1b) and Manufacture of Solid Fuels and Other Energy Industries (1A1c) sectors, Other Product Use (2G) Waste Incineration (5C1), which combined account for 1.5 per cent of the total in 2019 and are presented in Other NFR sectors in Figure 2.1. In 1990, coal combustion accounted for 51.4 per cent of SO_2 emissions and fuel oil contributed 30.3 per cent. By 2019, the share of SO_2 emissions from coal had decreased to 42.0 per cent and that from fuel oil had decreased to 9.9 per cent.
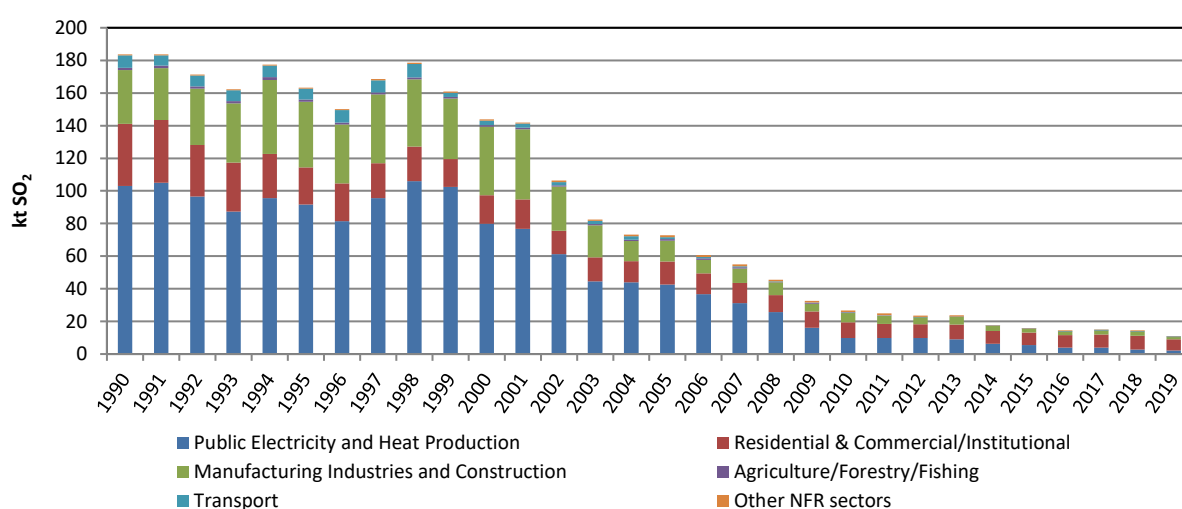
Figure 2.1 Emission Trend for Sulphur Dioxide 1990−2019

2.2.2 Nitrogen Oxides (NOx)

Total nitrogen oxides emissions have decreased by 44.5 per cent, from 176.63 kt in 1990 to 98.03 kt in 2019 (Figure 2.2). Road Transport (1A3b) is the principal source of NO_X emissions, contributing 35.5 per cent (and 30.43 kt) of the total in 2019, with the transport sector as a whole accounting for 38.6 per cent (and 37.87 kt) of the national total. The Manufacturing Industries and Construction (1A2) sector accounts for an increasing percentage of the national total. The contribution of the sector in 1990 to the national total was 5.2 per cent (9.11 kt), which increased to 11.0 per cent share in 2007 (and 17.34 kt) as a result of the increases in cement production for construction during the economic boom in Ireland over the previous decade then reduced to 7.1 per cent share (7.48 kt) of the national total in 2011 due to the economic crisis impacting upon the sector. In 2019 the sector contribution increased to a 8.4 per cent share (and 8.24 kt) of the national total largely driven by an increase in cement production.

The Public Electricity and Heat Production (1A1a) sector is another main source of NO_X emissions, accounting for 6.1 per cent of emissions in 2019. Emissions from this sector have decreased by 87.1 per cent between 1990 (46.37 kt) and 2019 (5.99 kt). Commercial/Institutional and Residential (1A4a and 1A4b) sectors combined account for 7.8 per cent of the total and combustion sources in Agriculture/Forestry/Fishing (1A4c) sector account for 4.1 per cent in 2019. The remainder of the combustion sources of NO_x arise in the Petroleum Refining (1A1b) and Manufacture of Solid Fuels and

Other Energy Industries (1A1c) sectors, as well as combustion sources in Other product Use (2G) and the Waste sector (5C1), which are presented in Other NFR sectors that together account for 0.5 per cent of the total in 2019. Agricultural sources of NO_x, accounted for 34.4 per cent of emissions in 2019 (33.75 kt), having increased by 4.2 per cent since 1990 (32.38 kt).

The largest sources of NO_x emissions within agriculture are associated with Inorganic nitrogen fertilizer application (3Da1) and Urine and Dung Deposited by grazing animals (3Da3).

The reductions in NO_x emissions arising from the use of catalytic converters in cars and heavy-duty vehicles have only become apparent in recent years, as the technology has been offset by large increases in vehicle numbers in the past decade. This effect is exaggerated in later years by so-called fuel tourism, whereby a proportion of the automotive fuel sold in Ireland – the basis for the emission time series given in Figure 2.2 – is used by vehicles in other countries. The estimated level of fuel tourism is given in Annex A.3, together with the adjusted annual NO_x emissions based on fuels used in Ireland, which is relevant to the assessment of obligations in relation to the Sofia Protocol on NO_x emissions.
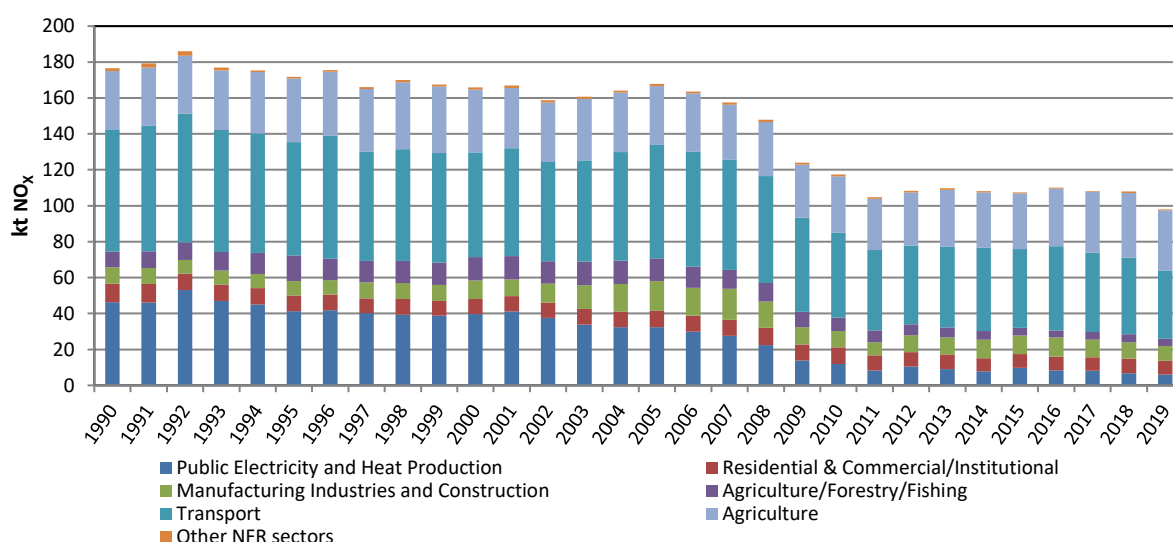
Figure 2.2 Emission Trend for Nitrogen Oxides 1990–2019

2.2.3 Ammonia (NH₃)

Agriculture accounted for 99.4 per cent of total ammonia emissions in 2019. National total emissions have increased by 14.4 per cent, from 109.61 kt in 1990 to 125.40 kt in 2019 (Figure 2.3). Livestock production has historically accounted for the bulk of national total ammonia emissions in Ireland and, in 2019, Manure Management (3B) and Animal manure applied to soil (3Da2a) and nitrogen from urine and dung deposition by grazing animals combined accounted for 90.6 per cent of the national total. In 2019, Manure Management at 59.39 kt and 47.4 per cent share of the total in 2019 showed an increase by 22.2 per cent from 48.59 kt in 1990. Organic fertiliser use covers emissions from the two sectors: Animal Manure applied to soils (3Da2a) and Sewage Sludge applied to soils (3Da2b), which combined at 40.57 kt accounted for 32.3 per cent of the total ammonia emissions in 2019 (indicating an 19.2 per cent increase from 34.03 kt in 1990). Urine and Dung deposited by grazing

animals (3Da3) accounted for 10.9 per cent of total emissions in 2019 (13.63 kt), having increased by 5.0 per cent since 1990. Inorganic/synthetic N-fertilizers applied to soils (sector 3Da1) decreased by 19.5 per cent from 1990 (13.69 kt) and at 11.02 kt in 2019 accounted for 8.8 per cent of the national total. The small contribution by Transport (1A3) sources peaked in 2005, the main driver of which has been the increased use of cars with early generation three way exhaust catalysts in Road Transport (1A3b). Transport emissions have increased from 0.06 kt in 1990 to 0.54 kt (and 0.4 per cent share of the total) in 2019. The remainder of the ammonia emissions arise from Commercial/Institutional and Residential (1A4a and 1A4b) sectors combined (0.1 per cent share) and Other NFR sectors (Combustion in Manufacturing Industries and Construction (1A2), Combustion in off road Agricultural machinery (1A4cii), Other Product Use (2G), Biological Treatment of Waste (5B1)) that together account for 0.1 per cent of the total in 2019.

Within livestock production, Manure Management (3B) at 59.39 kt in 2019 is the largest source of NH_3. In Ireland, approximately two-thirds of animal manure is excreted at pasture annually, reflecting the relatively short period that the main livestock categories (cattle and sheep) are housed.
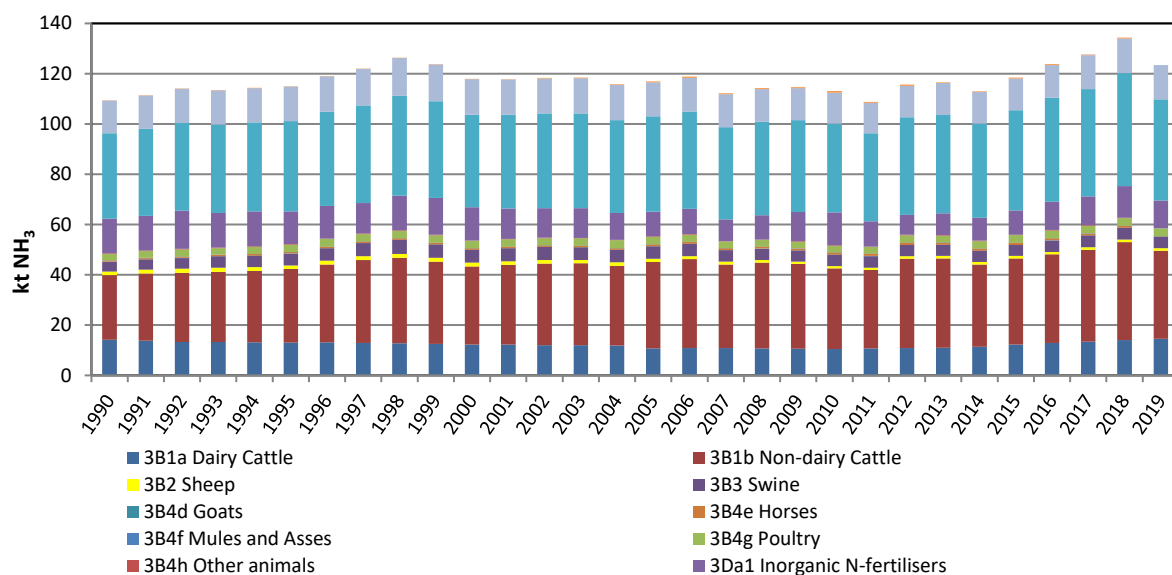
Figure 2.3 Emission Trend for Ammonia from agriculture 1990−2019

Dairy Cattle (3B1a) and Non-Dairy Cattle (3B1b) account for the major part (39.8 per cent) of Agriculture sector ammonia emissions in 2019. Other livestock, which includes Sheep (3B2), Swine (3B3), Goats (3B4d), Horses (3B4e), Mules and asses (3B4f), Poultry (3B4g) and Other animals (3B4h), combined account for 7.8 per cent of total ammonia emissions from agriculture in 2019 (Figure 2.3). Throughout the 1990s, the cattle herd increased to reach a peak in 1998 of 7.6 million head, which along with associated increases in fertiliser nitrogen consumption increased ammonia emission totals from the whole agriculture sector, from 109.30 kt in 1990 to 126.24 kt in 1998. As a result of reforms to the Common Agricultural Policy (CAP), animal numbers and associated fertiliser nitrogen use subsequently reduced, and ammonia emissions in agricultural sectors had fallen to 108.83 kt in 2011. However, in response to growth plans for the agriculture sector in Ireland, emissions have increased in recent years with a total of 124.60 kt in 2019 largely as a result of increased dairy cattle and other cattle populations, increased fertilizer use and continued use of urea as an inorganic nitrogen fertilzer.

2.2.4 Non-Methane Volatile Organic Compounds (NMVOCs)

Total non-methane volatile organic compound emissions have decreased by 22.6 per cent, from 147.05 kt in 1990 to 113.75 kt in 2019 (Figure 2.4). The NMVOC emissions are determined largely by the Agriculture sectors: 3B Manure Management and 3Da1 Inorganic N-fertilizers and emissions from solvents and other product use and the food and beverages industry. The Agriculture categories combined accounted for 40.0 per cent of the national total and showed an increase of 10.4 per cent between 1990 (41.18 kt) and 2019 (45.46 kt). The combined solvents use (2D and 2G) and fugitive emissions from th oil sector (1.B.2.a) produced 19.7 per cent of the 2019 total of NMVOC emissions in Ireland, having decreased by 16.2 per cent between 1990 (26.79 kt) and 2019 (22.45 kt). The Food and Beverage Industry (2H2) contributed to 25.7 per cent of total emissions in 2019, having increased by 204.3 per cent from 9.62 kt in 1990 to 29.27 kt in 2019.

Combustion sources in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors are also important sources, accounting for 7.3 per cent of national total NMVOC emissions in 2019, a reduction of 71.4 per cent between 1990 (28.97 kt) and 2019 (8.28 kt). Technological controls for volatile organic compounds (VOCs) emitted by motor vehicles have been more successful than in the case of NO_X and have contributed to a significant reduction in emissions from Road Transport (1A3b), with the total transport sector's contribution having decreased by 88.9 per cent between 1990 (36.17 kt) and 2018 (4.01 kt). This equates to contributions to the national total of 24.6 per cent in 1990, falling to 3.5 per cent in 2019. A total of five NFR source categories make up the source Other NFR sectors (Figure 2.4) contributing 0.6 per cent of national total NMVOC emissions in 2019. The largest source of emissions within this categorisation is Solid waste disposal on land sector (5A).
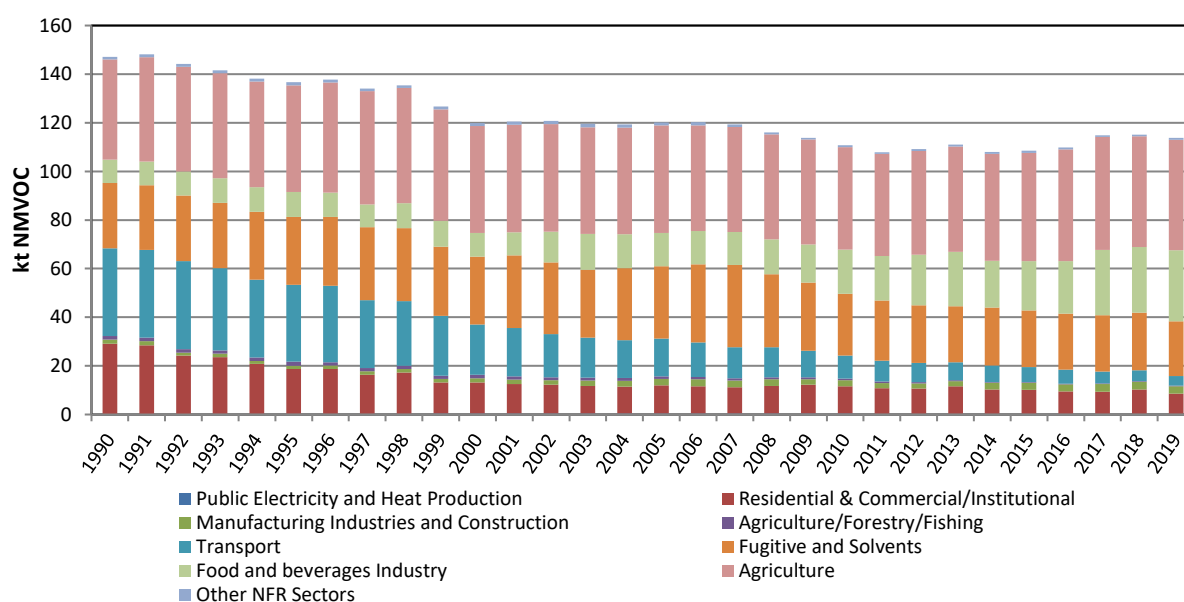
Figure 2.4 Emission Trend for Non-Methane Volatile Organic Compounds 1990−2019

2.2.5 Carbon Monoxide (CO)

Carbon monoxide emissions continue to decline, driven by major reductions due to three way exhaust catalysts in gasoline vehicles in Road Transport (1A3b), which is the principal source of CO, and a large decrease in the use of solid fuels for space heating in the Residential (1A4b) sector (Figure 2.5). National total CO emissions have reduced from 368.20 kt in 1990 to 67.60 kt in 2019, a reduction of 81.6 per cent.

The Transport sector accounted for 44.2 per cent of national total emissions in 2019, a major reduction (89.0 per cent) from 271.28 kt in 1990 to 29.85 kt in 2019. Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined are another important source, accounting for 31.3 per cent of national total CO emissions in 2019, a reduction of 66.6 per cent between 1990 (63.39 kt) and 2019 (21.17 kt). Public Electricity and Heat Production (1A1a) sector reached its peak in 2001 (23.82 kt) and has decreased by 74.4 per cent to reach 6.10 kt in 2019, a reduction of 66.4 per cent on 1990 levels (18.14 kt). Combustion sources from Manufacturing Industries and Construction (1A2) account for 12.8 per cent of the national total in 2019 and at 8.67 kt showed a 22.2 per cent decrease on their 1990 levels (11.13 kt). Agriculture/Forestry/Fishing (1A4c) combustion sources account for 1.9 per cent of the total CO emissions in 2019. Petroleum refining (1A1b), Manufacture of soil fuels and other energy industries (1A1c), Other Product Use (2G), Biological Treatment of waste (5B1) and Waste incineration (5C) emissions form the Other NFR sectors category and combined account for the remainder of CO emissions (0.8 per cent of the total) in 2019.
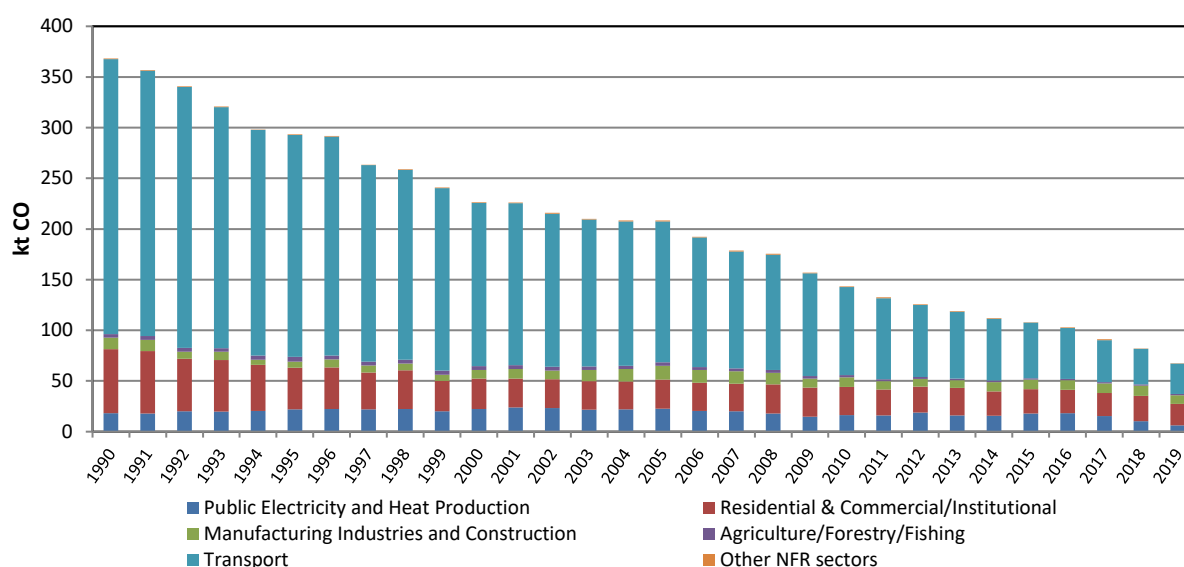
Figure 2.5 Emission Trend for Carbon Monoxide 1990−2019

2.3 Particulate Matter

Particulate matter emission estimates include PM with diameter less than 10 μm (PM_{10}), PM with diameter less than 2.5 μm ($PM_{2.5}$) and total suspended particulates (TSP).

2.3.1 Particulate Matter <10 μm Diameter (PM$_{10}$)

Emissions of particulate matter <10 μm diameter amounted to 27.69 kt in 2019, a 41.7 per cent reduction from 47.52 kt in 1990 (Figure 2.6). The main determinant of the trend in PM$_{10}$ emissions is Agriculture sector with 31.8 per cent share of the national total, and combustion in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined with 24.7 per cent share of the total in 2018.

Emissions from Agriculture arise from Inorganic N-fertilizers (3Da1), Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc), Off-farm storage, handling and transport of bulk agricultural products (3Dd) and Manure Management (3B) categories that together in 2019 at 8.81 kt indicated a 4.6 per cent increase on their 1990 levels. Part replacement of coal and peat in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors are the second largest contributor to the total PM$_{10}$ emissions, with 72.6 per cent reduction in emissions from these sectors, from being the largest contributor to the PM$_{10}$ emissions (52.5 per cent of national total emissions) at 24.95 kt in 1990, emissions have fallen to 6.83 kt in 2019 (and 24.7 per cent of the national total emissions). Emissions from Transport (1A3), at 8.0 per cent share of the total in 2019 increased throughout the 1990s with increased total vehicle kilometre travel particularly of diesel vehicles. However, the effect of the increase in vehicle numbers seen over the last decade has been offset somewhat by changes in the age structure of the national fleet and developments in diesel fuel technology resulting in Transport emissions decreasing by 26.3 per cent (from 3.00 kt in 1990 to 2.21 kt in 2019).

Manufacturing Industries and the Construction sector (1A2) used to account for an increasing percentage of the national total PM$_{10}$, until reaching its peak of 2.48 kt in 2005. This is also evident with some other pollutants, and is due to the increase in cement production post-2000 following the entry into the market of two new plants. Emissions for this sector have decreased since 2005, and accounted for 5.3 per cent of the national total in 2019 (1.46 kt), representing a decrease across the 1990-2019 time series of 21.0 per cent. Public Electricity and Heat Production (1A1a) sector emissions accounted for 1.3 per cent of the national total in 2019 and at 0.36 kt reduced by 62.2 per cent from 1990 levels (0.96 kt). The decrease was due to the increased use of natural gas and wind for electricity generation, in proportion to coal and peat which still account for a large share of the fuel mix used. More recently Ireland's only coal fired electricity generation station has been running at much reduced capacity levels. Petroleum refining (1A1b), Manufacture of solid fuels and other energy industries (1A1c), Fugitive emissions from soil fuels: Coal mining and handling (1B1a), Quarrying and mining of minerals other than coal (2A5a), Construction and demolition (2A5b), Road paving with asphalt (2D3b), Other solvent use (2D3i), Other product use (2G), Biological treatment of waste – solid waste (5A), Incineration (5C) and Other waste (5E) are included under the other NFR sectors heading, which combined accounted for 28.5 per cent of national emission in 2019. The largest contributors are within the other NFR grouping are Quarrying and mineral of minerals other than coal (2A5a) and Road paving with asphalt (2D3b).
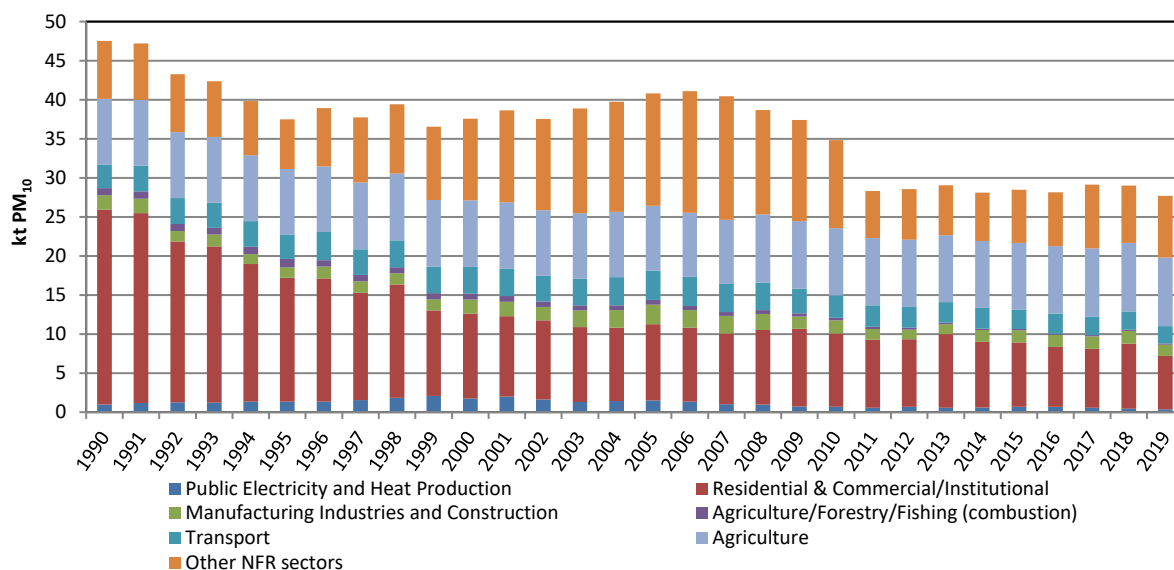
Figure 2.6 Emission Trend for Particulate Matter <10 μm in Diameter 1990−2019

2.3.2 Particulate Matter <2.5 μm Diameter (PM$_{2.5}$)

National total emissions of particulate matter <2.5 μm diameter amounted to 11.79 kt in 2019, a 63.5 per cent reduction on 32.30 kt in 1990 (Figure 2.7). Emissions from Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined are the main determinant of the trend with their 56.7 per cent share of the national total PM$_{2.5}$ emissions in 2019. There has, however, been a reduction of 72.6 per cent in emissions from these sectors between 1990 (24.45 kt and 75.7 per cent share) and 2019 (6.69 kt). Reduced use of coal and peat, with increased use of gasoil, kerosene and natural gas in the two sectors has resulted in lower emissions and a reduction in the contribution to the national total.

Emissions from Agriculture arise from Manure Management (3B), Inorganic N-fertilizers (3Da1), Farm level agricultural operations including storage, handling and transport of agricultural products (3Dc), Off-farm storage, handling and transport of bulk agricultural products (3Dd) sectors that together in 2019 at 0.92 kt accounted for 7.8 per cent of the national total and indicated a 7.7 per cent increase on their 1990 levels (0.86 kt). Transport (1A3) contributed 1.51 kt (12.8 per cent share) to the national total in 2019. Emissions from Transport sector (1A3), dominated by Road Transport (1A3b) increased from 1990 (2.68 kt) to a peak in 1996 (3.17 kt), but have been decreasing since 2005, with a 43.7 per cent reduction between 1990 and 2019 which is largely due to technological advances and the age structure of the national fleet which in turn have been balanced by the increases in vehicle numbers over the time series (see comments in section 2.3.1 on the trends of PM$_{10}$ emissions). Emissions from Manufacturing Industries and Construction (1A2) at 1.35 kt in 2019 are 15.4 per cent below those in 1990.

Electricity and Heat Production (1A1a) sector accounted for 2.0 per cent of the national total emissions in 2019, a reduction of 62.7 per cent from 0.65 kt in 1990 and 0.24 kt in 2019. Combustion from the Agriculture/Forestry/Fishing sector accounted for 1.1 per cent of national total PM$_{2.5}$ emissions in 2019 and have reduced by 86.4 per cent from 1990 when emissions were 0.93 kt, compared to 0.13 kt in 2019. The remainder of the PM$_{2.5}$ emissions arise from Petroleum refining (1A1b), Manufacture of soil

fuels and other energy industries (1A1c), Fugitive emissions from solid fuels: Coal mining and handling (1B1a), Quarrying and mining of minerals other than coal (2A5a), Construction and demolition (2A5b), Storage, handling and transport of mineral products (2A5c), Road paving with asphalt (2D3b), Other solvent use (2D3i), Other product use (2G), Biological treatment of waste – solid waste (5A), Incineration (5C) and Other waste (5E) are included under the other NFR sectors heading, which combined accounted for 8.1 per cent of national emission in 2019.
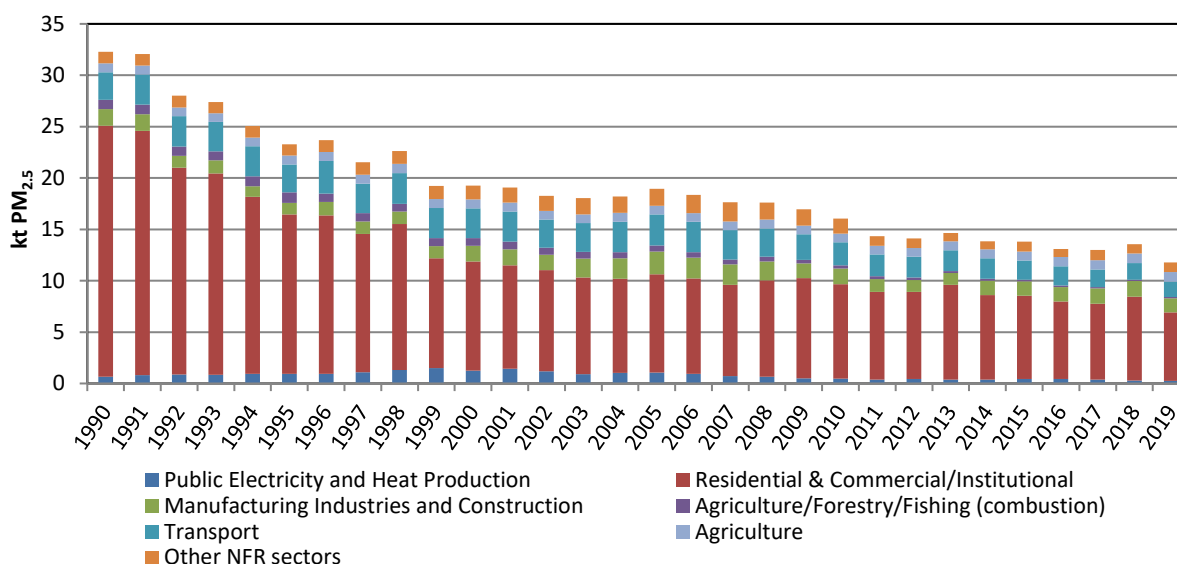
Figure 2.7 Emission Trend for Particulate Matter <2.5 μm in Diameter 1990−2019

2.3.3 Total Suspended Particulates (TSP)

Total suspended particulate emissions have decreased by 25.4 per cent, from 85.10 kt in 1990 to 63.51 kt in 2018 (Figure 2.8). The main driver of the TSP trend is emissions is Other NFR sectors which includes a wide range of source categories namely Petroleum refining (1A1b), Manufacture of soil fuels and other energy industries (1A1c), Fugitive emissions from solid fuels: Coal mining and handling (1B1a), Quarrying and mining of minerals other than coal (2A5a), Construction and demolition (2A5b), Storage, handling and transport of mineral products (2A5c), Road paving with asphalt (2D3b), Other solvent use (2D3i), Other product use (2G), Biological treatment of waste – solid waste (5A), Incineration (5C) and Other waste (5E) which combined accounted for 60.9 per cent of the national total in 2019. Road paving with asphalt (2D3b) accounts for the majority of emissions within this grouping (77.5 per cent). Emissions from the Other NFR sectors have reduced by 1.1 per cent from 39.11 kt in 1990 to 38.69 kt in 2019. Emissions from the agriculture (NFR 3) sector were 12.04 kt (and 19.0 per cent share of the total) in 2019, a 10.1 per cent increase from 1990 levels (10.93 kt). Combined emissions from Residential (1A4b) and Commercial/Institutional (1A4a) sectors were the third largest contributor to the total TSP emission in 2019. There has been, similar to emissions from both PM$_{10}$ and PM$_{2.5}$, a reduction of 72.6 per cent in emissions from these sectors between 1990 (27.44 kt) and 2019 (7.50 kt). In the time series, the part replacement of coal and peat with natural gas, gasoil and kerosene has resulted in the contribution of these sectors falling from 32.2 per cent of the national total in 1990 to 11.8 per cent in 2019.
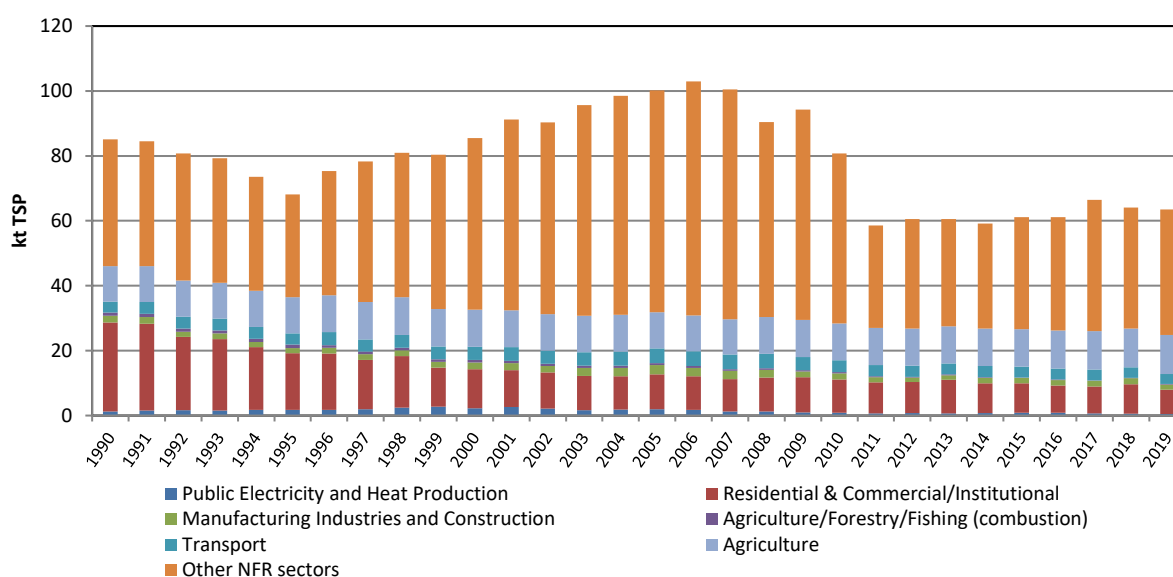
Figure 2.8 Emission Trend for Total Suspended Particulates 1990−2019

Emissions from Transport (1A3) decreased by 9.1 per cent to 2019 (3.07 kt and 4.8 per cent share of national total) compared to 1990 (3.38 kt and 4.0 per cent share). Manufacturing Industries and Construction (1A2) account for an increasing proportion of emissions post-2000 as a result of the entry into the market of two new cement production plants (Non-metallic minerals, 1A2f). Emissions from the 1A2 sector had their peak in 2005 (2.82 kt) and although have been generally declining since, emissions increased 15.2 per cent between 2013 and 2019. At 1.61 kt in 2019 (2.5 per cent of the total) emissions have decreased from 2005 by 43.2 per cent and by 23.1 per cent from 1990 (2.09 kt). Public Electricity and Heat Production sector (1A1a) emissions have decreased by 61.6 per cent over the time series, from 1.23 kt in 1990 to 0.47 kt (and 0.7 per cent share of the total emissions) in 2019. Emissions from Agriculture/Forestry/Fishing in 2019 (0.14 kt, 0.2 per cent of the national total) have decreased by 85.4 per cent since 1990 (0.94 kt).

2.3.4 Black Carbon (BC)

Black Carbon emissions have decreased by 60.6 per cent, from 4.02 kt in 1990 to 1.59 kt in 2019 (Figure 2.9). The main driver of the BC trend is emissions from Transport (1A3). Emissions from the sector have reduced by 53.3 per cent between 1990 (1.24 kt) and 2019 (0.58 kt). Combined emissions from Residential (1A4b) and Commercial/Institutional (1A4a) sectors were the second largest contributor to total BC emissions in 2019. In 2019, combined emissions from the sectors were 0.53 kt (33.6 per cent share) and have reduced by 70.4 per cent since 1990 (1.80 kt). Manufacturing Industry and Construction (1A2) emissions accounted for 21.0 per cent of the total in 2019 (0.33 kt) having decreased by 6.3 per cent since 1990 (0.34 kt). Emissions from Agriculture/Forestry/Fishing in 2019 were 0.06 kt, which equates to an 87.5 per cent reduction on 1990 (0.51 kt). Public Electricity and Heat Production (1A1a) emissions have decreased by 71.1 per cent over the time series, from 0.02 kt in 1990 to 0.01 kt in 2019. The remaining 4.5 per cent in 2019 accounts for emissions from Petroleum refining (1A1b), Manufacture of solid fuels and other energy industries (1A1c), Road paving with asphalt (2D3b), Other product use (2G), and Industrial waste incineration (5C1bi).
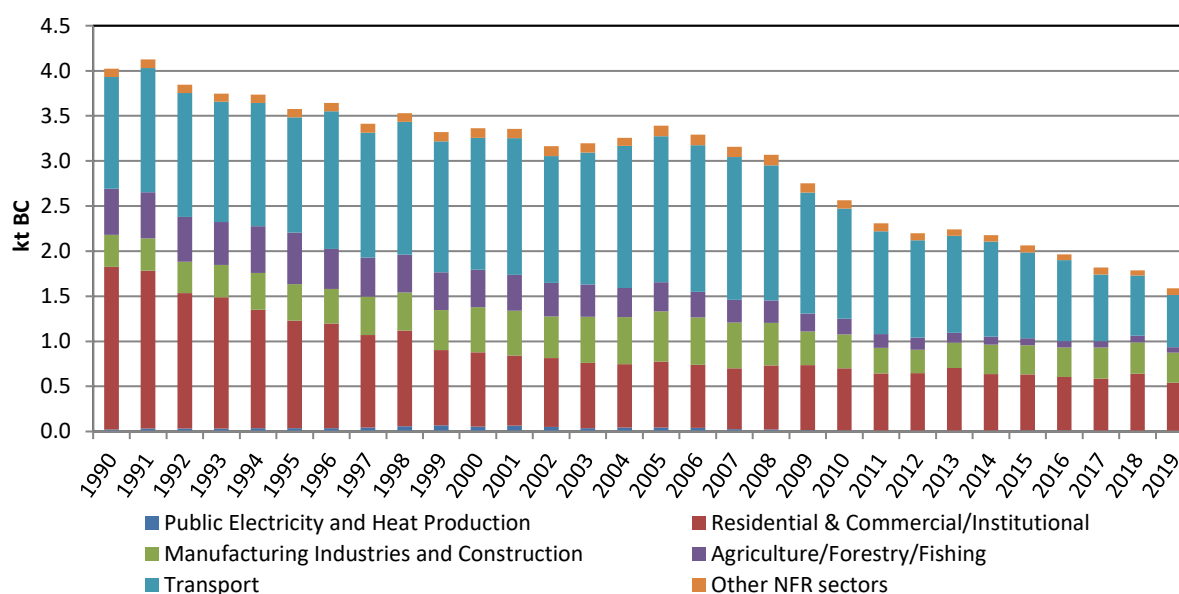
Figure 2.9 Emission Trend for Black Carbon 1990−2019

2.4 Priority Metals

2.4.1 Lead (Pb)

Over the 1990−2019 time series, total national Pb emissions have decreased by 97.2 per cent, from 170.04 t in 1990 to 4.70 t in 2019 (Figure 2.10). The Pb emissions trend is largely determined by Road Transport (1A3b). Emissions of Pb have decreased considerably since 1990. There was a marked decrease between 1999 and 2000 when the lead content of petrol was reduced. In addition there was an increase in the use of unleaded gasoline in road transport throughout the 1990s and the subsequent phasing out of leaded gasoline in 2000/2001. The contribution of Transport (1A3) to the much-reduced national total emissions has decreased by 98.8 per cent, from 156.21 t (91.9 per cent share) in 1990 to 1.82 t (38.7 per cent share) in 2019.

The largest contributors to Pb emissions at 45.3 per cent share of national total in 2019 were the Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined. The use of coal and peat in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors is being part replaced with natural gas, gasoil or kerosene. Emissions from these sources have fallen from 7.96 t in 1990 to 2.13 t in 2019, a reduction of 73.2 per cent. Combustion in Manufacturing Industries and Construction (1A2) accounted for 7.9 per cent share of the total in 2019, and emissions from Public Electricity and Heat Production sector (1A1a) were responsible for 6.9 per cent share in 2019. Emissions from Metal Production (2C) have decreased in recent years due to the closure of a number of foundries and were negligible in 2019. Similarly, emissions from Waste Incineration (5C) have also decreased to almost zero as a result of an outright ban on the incineration of clinical wastes in the mid-1990s. Incineration in 5C is now solely in relation to the destruction of vapours.
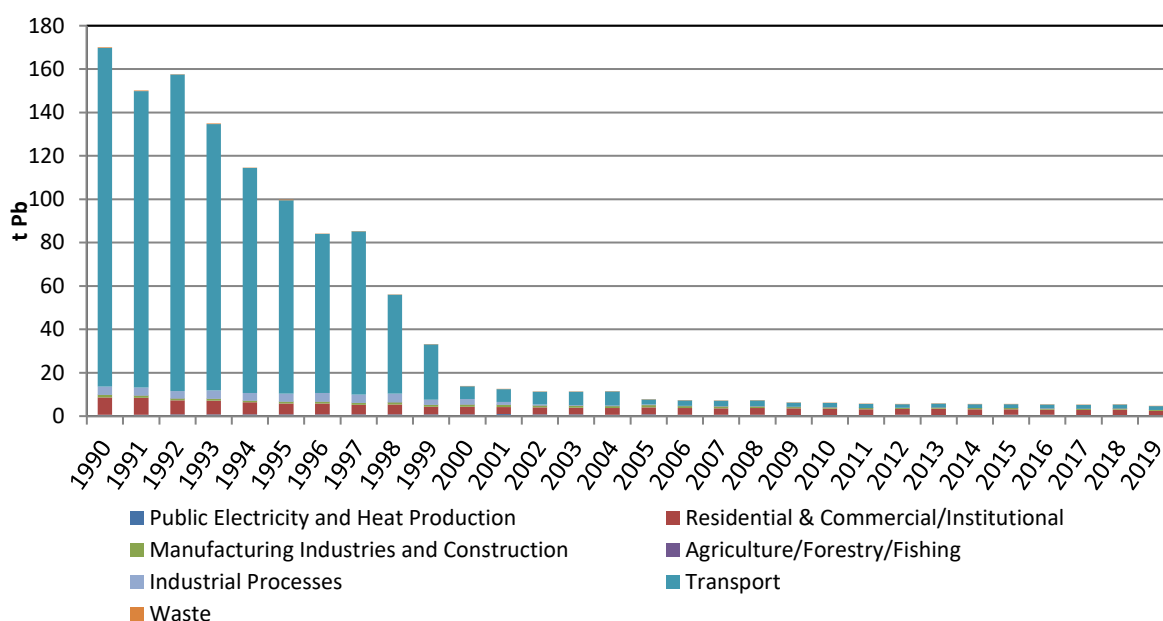
Figure 2.10 Emission Trend for Lead 1990−2019

2.4.2 Cadmium (Cd)

Total national emissions of Cd have decreased from 0.59 t in 1990 to 0.25 t in 2019 (Figure 2.11), a reduction of 58.0 per cent. Emissions of cadmium are largely determined by the Manufacturing Industries and Construction (1A2) sector, specifically combustion sources in Non-Ferrous Metals (1A2b). Manufacturing Industries and Construction (1A2) accounted for 37.4 per cent of total emissions in 2019 having increased by 72.4 per cent since 1990 (0.05 t and 9.1 per cent share). Public Electricity and Heat Production (1A1a) decreased from 1990 by 53.1 per cent and accounted for 17.4 per cent of the national total in 2019. Emissions from this source increased throughout the 1990s as a result of the combustion of increasing quantities of coal and peat for electricity generation. The use of coal has reduced across the time series.

Residential (1A4b) and Commercial/Institutional (1A4a) combustion is also an important source of Cd emissions, with combined emissions from these sectors accounting for 18.6 per cent of the national total in 2019 due to the continued use of the fossil fuels (coal, peat and oil); however, emissions from the sector have fallen by 60.9 per cent, from 0.12 t in 1990 to 0.05 t in 2019. Transport (1A3) sector emissions have been increasing in the time series (by 98.2 per cent) and in 2019 it accounted for 3.1 per cent of the national total cadmium emissions. Combustion sources from Agriculture/Forestry/Fishing (1A4c) sector accounted for 0.8 per cent of the total Cd emissions in 2019. As a result of the closure of the Irish Steel plant in late 2001, emissions from Metal Production (2C) accounted for a 22.4 per cent share in 2019 compared to a 51.9 per cent share (and main contributor to the total) in 1990.
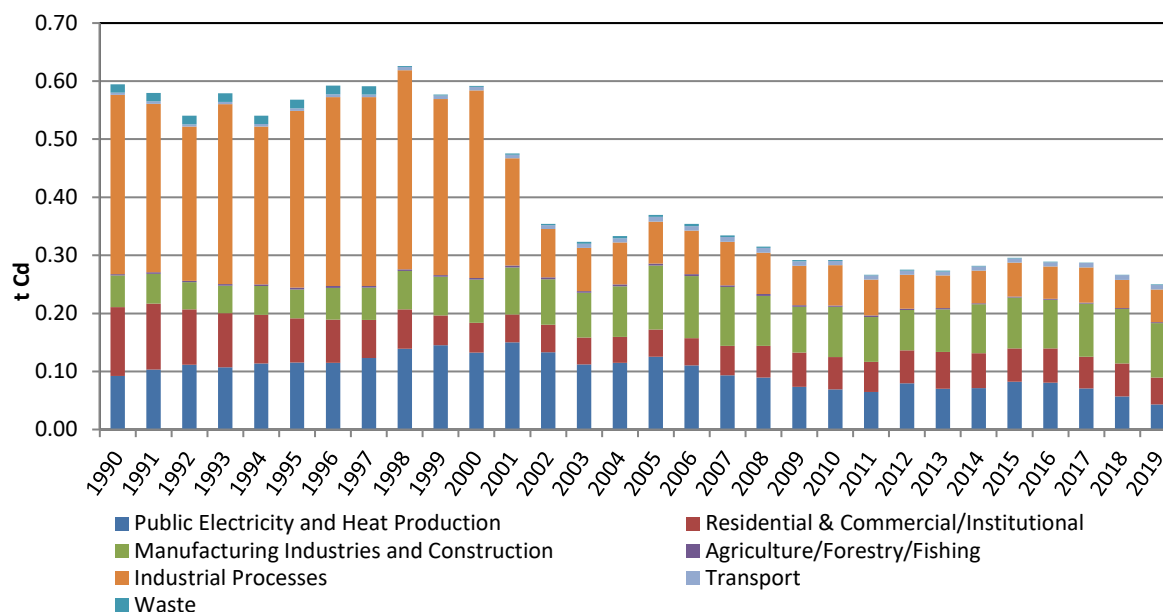
Figure 2.11 Emission Trend for Cadmium 1990−2019

2.4.3 Mercury (Hg)

Total national emissions of Hg have decreased from 0.82 t in 1990 to 0.33 t in 2019, a reduction of 60.3 per cent (Figure 2.12). Emissions from Public Electricity and Heat Production (1A1a) decreased by 48.4 per cent in the trend and accounted for 22.4 per cent (the third largest source) of national total mercury emissions in 2019 (0.07 t). Emissions from Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined account for the second largest share of national total mercury emissions (27.3 per cent in 2019), having decreased by 70.9 per cent between 1990 and 2019 as a result of an increase in the use of natural gas, kerosene and gasoil and a decrease in the use of coal and peat. Combustion sources in Manufacturing Industries and Construction (1A2) are the largest source and accounted for 33.2 per cent of total emissions in 2019, a 38.6 per cent increase since 1990. Emissions from this sector are largely dependent on the increased use of petroleum coke and coal as a fuel source in the cement industry after the entry of a number of additional cement producers into the Irish market post-2000.

Biological treatment of waste – Solid waste disposal on land (5A) and Waste Incineration (5C) combined accounted for a 9.9 per cent share of total emissions in 2019. The Transport (1A3) sector accounted for 7.1 per cent and combustion sources from Agriculture/Forestry/Fishing (1A4c) sector accounted for 0.2 per cent of the total Hg emissions in 2019. Glass Production (2A3) and Metal Production (2C) are no longer occurring due to plant closures (glass since 2010 and metal since 2002).
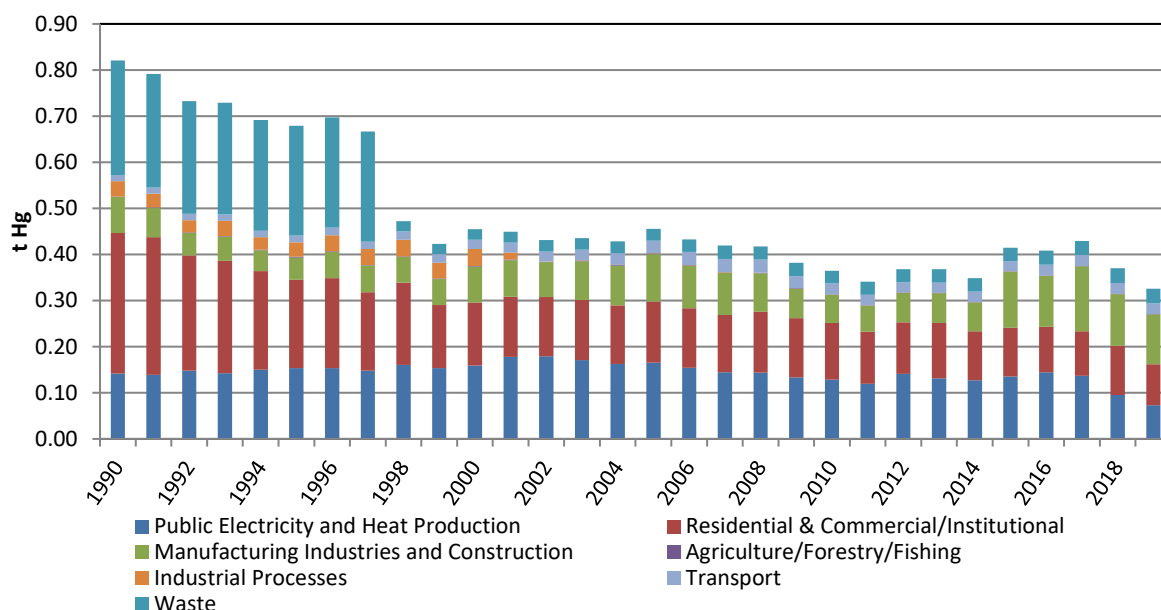
Figure 2.12 Emission Trend for Mercury 1990−2019

2.5 Other Metals

2.5.1 Arsenic (As)

Emissions of arsenic have decreased by 31.1 per cent from 1.66 t in 1990 to 1.14 t in 2019 (Figure 2.13). These emissions are largely dominated by incineration of hazardous and clinical wastes and crematoria in Waste Incineration sector (5C). Waste Incineration accounted for 58.0 per cent of national total arsenic emissions, having increased by 20.1 per cent from 0.55 t in 1990 to 0.66 t in 2019. The absolute and percentage contributions of this sector are increasing largely due to the increase in the number of cremations undertaken in Ireland which has increased since 1990 and incineration of wood products historically treated with a preservative containing arsenic. Continued (but decreasing) use of coal, peat and fuel oil as part of the fuel mix contributes largely (20.8 per cent share of the total in 2019) to the trend in emissions from Public Electricity and Heat Production (1A1a); however, arsenic emissions from the sector have decreased by 61.4 per cent over the time series due to the replacement of less-efficient peat plants with new plant, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy.

The continued use of fossil fuels in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined results in the sectors accounting for 4.5 per cent of national total emissions in 2019, however, they have decreased by 70.0 per cent in the trend. Within the Manufacturing Industries and Construction (1A2) sector, the sub-sector Non-metallic minerals (1A2f) is responsible for the majority of total sector's emissions due to the increase in cement production and associated fuel use in the sector, in particular petroleum coke post-2000 with the entry into the market of new cement plants and reflecting more recent post-recession decrease in production and consequential lower emissions from the sector. The sector's As emissions contributed 14.9 per cent the total in 2019, an increase of 84.2 per cent on the 1990 level. Metal Production (2C) is no longer an important source of As emissions, following the closure of the Irish Steel plant in 2001 and a reduction in emissions from Integrated Pollution Prevention and Control (IPPC)-licensed facilities. Emissions from this sector

accounted for 13.1 per cent in 1990 (third largest contributor) and are reported as not occurring in 2019 due to the closure of the foundry which was a responsible for emissions from this sector between 2001 and 2013.
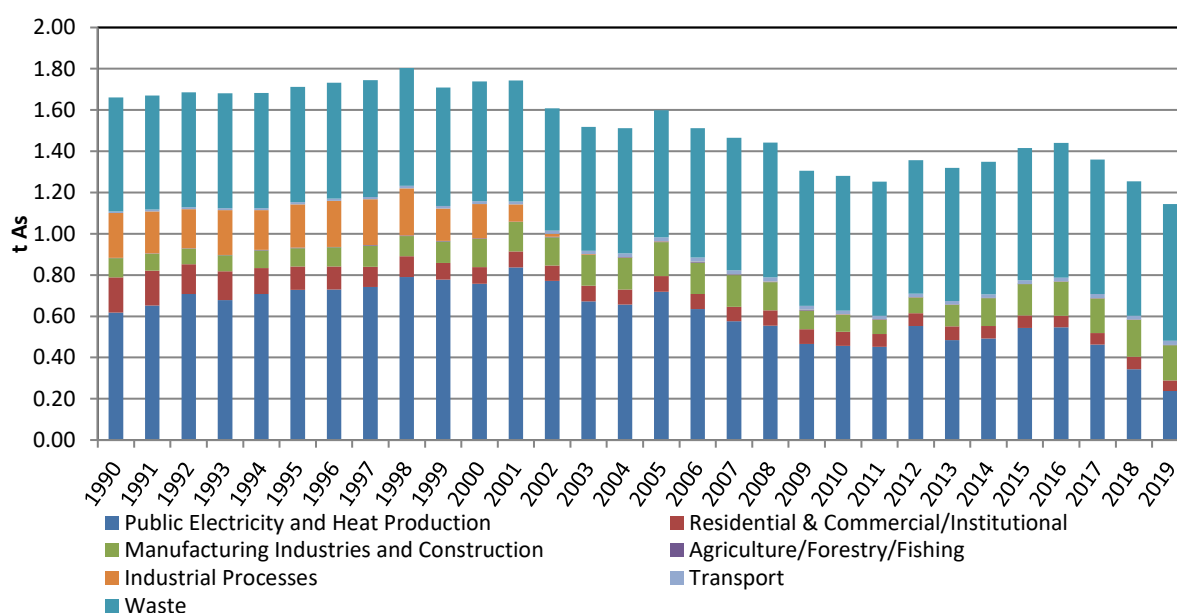
Figure 2.13 Emission Trend for Arsenic 1990−2019

2.5.2 Chromium (Cr)

Emissions of Cr have decreased by 48.6 per cent from 4.51 t in 1990 to 2.31 t in 2019 (Figure 2.14). Transport (1A3) and Waste Incineration (5C) sectors are the main two drivers of the chromium trend. The Transport (1A3) sector accounted for 21.9 per cent of estimated national total emissions in 2019. Emissions from this source category have increased by 110.2 per cent over the time series between 1990 (0.24 t) and 2018 (0.51 t) due to the large increase in vehicle numbers in Ireland. The incineration of hazardous and clinical wastes and crematoria contribute to emissions from Waste Incineration (5C). The sector is the largest source of chromium emissions and accounted for 27.7 per cent of 2019 national chromium emissions, an increase of 19.9 per cent in the trend. The absolute and percentage contributions of this sector are increasing largely due to an increase in industrial waste incineration (5C1bi) which includes the incineration of wood that has historically been treated with preservative containing chromium.

Continued use of coal, peat and fuel oil as part of the fuel mix for Public Electricity and Heat Production (1A1a) means that the sector contributed 8.0 per cent to the emissions total in 2019. However, there has been a reduction in emission levels of 53.9 per cent between 1990 and 2019 as a result of the replacement of less-efficient peat plants with new plant, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy. Emissions from Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined accounted for 13.8 per cent of the national total in 2019, having decreased, by 67.8 per cent over the time series, reflecting the part replacement of coal and peat with natural gas, gasoil and kerosene. Within the Manufacturing Industries and Construction (1A2) sector, the sub-sector Other (1A2f) is responsible for the majority of emissions largely due to the cement industry, as is evident with other heavy metal estimates.

Emissions in 1A2 accounted for 21.2 per cent of national total chromium emissions and have decreased by 8.0 per cent in the whole trend. Similar to other heavy metals estimates, the closure of the Irish Steel plant in 2001 has significantly reduced the effect of Iron and Steel Production (2C1) on emission trends, from 39.5 per cent share of the total (and the main contributor to chromium emissions) in 1990 to a 6.7 per cent share in 2019.
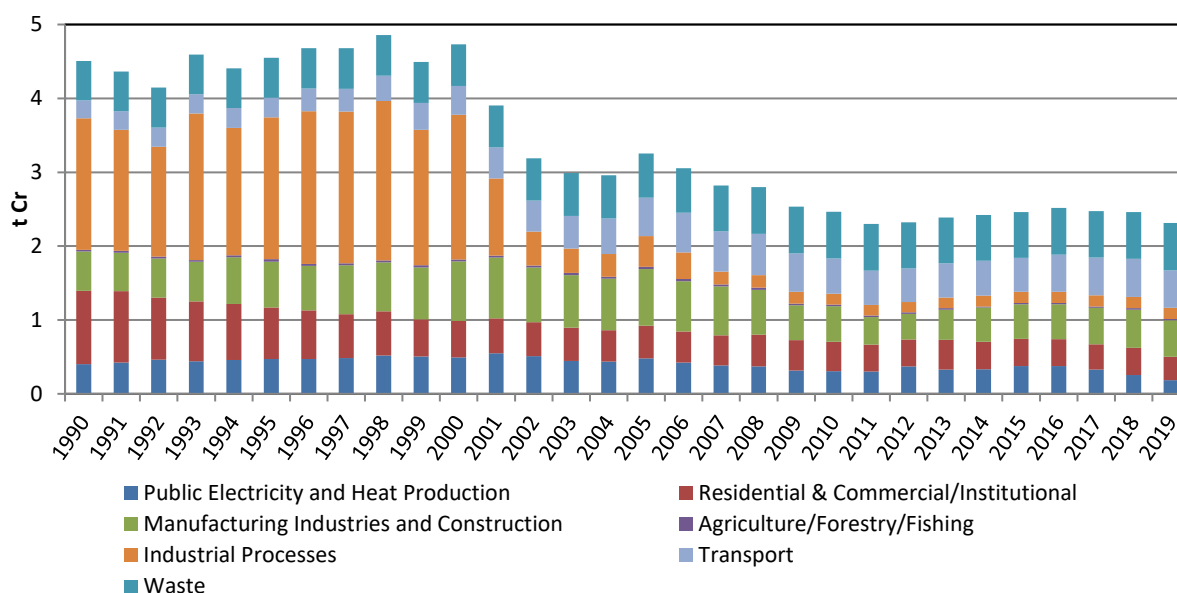
Figure 2.14 Emission Trend for Chromium 1990−2019

2.5.3 Copper (Cu)

Total copper emissions in Ireland were steadily increasing over the 1990−2008 period and have been steadily decreasing since (Figure 2.15). Total emissions in 2019 (18.54 t) were 10.6 per cent lower than in their peak in 2008 (20.72 t) but they are 76.1 per cent higher than in 1990 (10.5 t). This trend is determined mostly by the Transport (1A3) sector that accounted for 56.4 per cent of estimated national total copper emissions in 2019. Emissions from this source category have increased by 121.5 per cent form 4.72 t in 1990 to 10.46 t in 2019 due to the increase in vehicle number across the timeseries.

Continued use of coal, peat and fuel oil as part of the fuel mix results in a contribution of 1.7 per cent to the total emissions from Public Electricity and Heat Production (1A1a) in 2019. However, a reduction in emission levels of 56.3 per cent is evident between 1990 and 2019 as a result of the replacement of older less-efficient generation plants, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy. The Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined accounted for 2.2 per cent of emissions in 2019, showing a 72.0 per cent decrease in the trend. Waste Incineration (5C) emissions accounted for 1.9 per cent of the national total in 2019, having increased by 11.2 per cent since 1990 (0.32 t). Combustion sources from Agriculture/Forestry/Fishing (1A4c) sector accounted for 1.5 per cent of the total Cu emissions in 2019 (18.4 per cent decrease since 1990). The Manufacturing Industries and Construction (1A2) sector has increased by 20.5 per cent between 1990 and 2019 (accounting for 2.6 per cent of the total in 2019). Emissions from the sector were increasing proportionately since 1990 reaching their peak in 2005 as a result of the entry into the market of new operators in the cement

production sub-sector post-2000. The use of fossil fuels for combustion decreasing since 2005 as a result of economic circumstances and increasing used or waste as a fuel. Emissions from Industrial Processes, specifically Other solvent use (2D3i) and Other product use (2G) combined accounted for 33.7 per cent of the total in 2019. Emissions from 2D3i and 2G combined have increased by 142.0 per cent across the timeseries. The sources of emissions in these categories are lubricants in the case of category 2D3i and Tobacco and Fireworks in the case of category 2G.
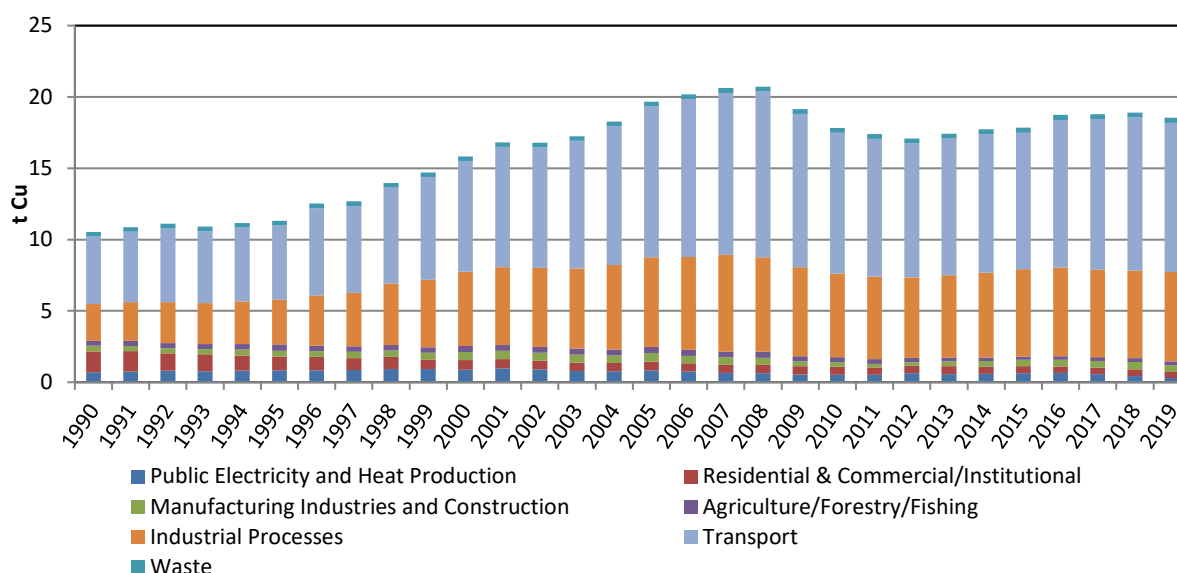
Figure 2.15 Emission Trend for Copper 1990−2019

2.5.4 Nickel (Ni)

National total emission estimates of nickel were steadily increasing over the 1990−1999 period and have been generally decreasing from 1999 onwards (Figure 2.16). Total emissions in 2019 (6.28 t) were 81.7 per cent lower than in their peak in 1999 (34.30 t) and 71.3 per cent lower than in 1990 (21.85 t). The main contributor to the trend is Manufacturing Industries and Construction (1A2) with a 38.4 per cent share in 2019 (2.41 kt) having reduced by 65.6 per cent since 1990 (7.02 kt). The second largest contributor to total Ni emissions in 2019 is emissions from the combined Residential (1A4b) and Commercial/Institutional (1A4a) sectors accounting for 36.7 per cent. A switch within these sectors from solid fuels (coal and peat) to less carbon intensive liquid fuels and natural gas has resulted in a reduction of 65.9 per cent in emissions since 1990. Public Electricity and Heat Production (1A1a) sector accounted for a 14.5 per cent share of the total nickel emissions in 2019. However, a reduction in emission levels of 77.8 per cent is evident between 1990 and 2019 as a result of the replacement of older less-efficient generation plants, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy.

Combustion sources from Agriculture/Forestry/Fishing (1A4c) sector accounted for 3.6 per cent in 2019. Similar to other heavy metals estimates, the closure of the Irish Steel plant in 2001 has significantly reduced the effect of Metal Production (2C) on emission trends, from 13.9 per cent share of the total (and fourth largest contributor to nickel emissions) in 1990. Emissions in 2019 were 0.27 t contributing to a 4.2 per cent share having reduced by 91.2 per cent since 1990.
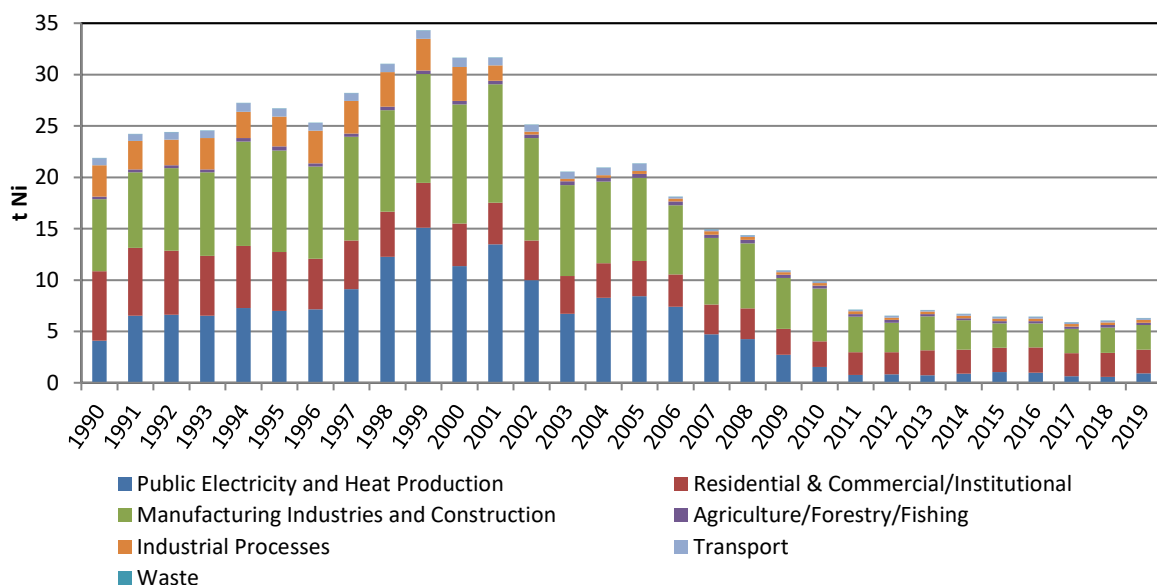
Figure 2.16 Emission Trend for Nickel 1990−2019

2.5.5 Selenium (Se)

National total emission estimates of Se have decreased by 70.3 per cent, from 8.77 t in 1990 to 2.60 t in 2019 (Figure 2.17). The main contributor to the trend has been fuel combustion in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors which combined accounted for 69.4 per cent of selenium emissions in 2019, having decreased by 73.4 per cent since 1990. The second largest contributor to the trend is the Public Electricity and Heat Production (1.A.1.a) sector and in 2019 it accounted for 22.7 per cent share of total selenium emissions. Emissions from this sector have decreased by 67.2 per cent from their 1990 level of 1.80 t to 0.59 t in 2019 due to the replacement of older less-efficient generation plants, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy.

Transport (1A3) sector has been increasing in the time series and with its 0.5 per cent share of the national total in 2019, it has increased by 96.2 per cent since 1990. Emissions from Manufacturing Industries and Construction accounted for 6.0 per cent of the total, having increased by 181.8 per cent from 1990. The remainder of the selenium emissions arise from combustion in Agriculture/Forestry/Fishing (1A4c) sector with its 0.1 per cent share of the national total in 2019. Glass production (2A3) under Industrial Processes and Product Use (IPPU) sector used to be an important contributor to the selenium emissions trend throughout the 1990s and up to 2002, accounting for an average of 1.4 per cent of the national total in that period. In 2019 Industrial Processes accounted for 1.4 per cent of national total emissions.
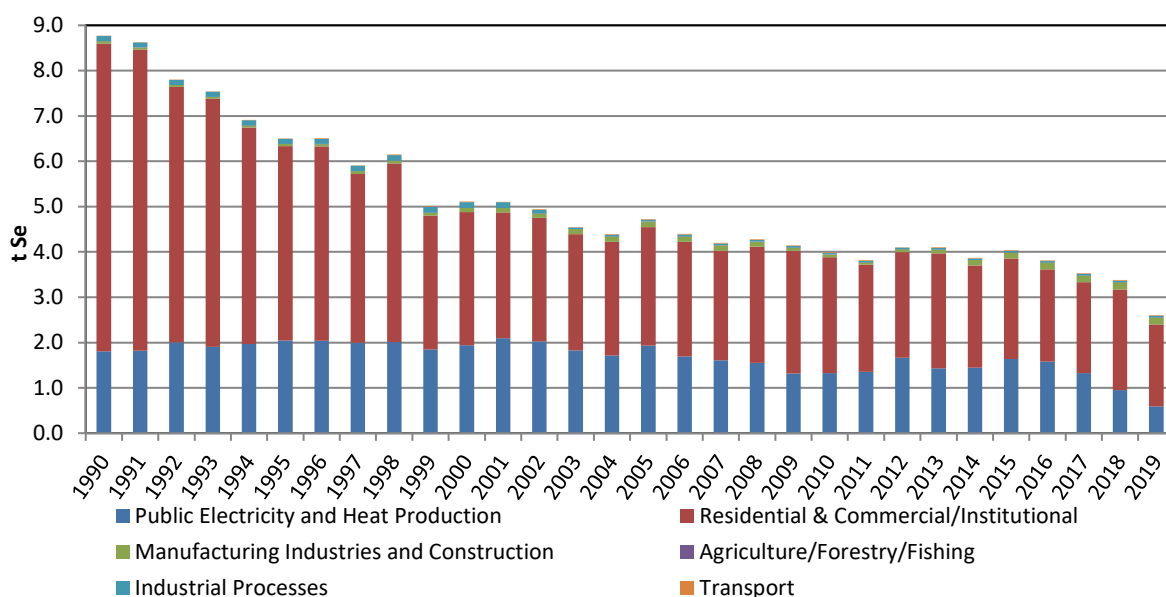
Figure 2.17 Emission Trend for Selenium 1990–2019

2.5.6 Zinc (Zn)

National total emissions of Zn amounted to 53.24 t in 1990 and have fallen by 62.7 per cent to 19.84 t in 2019. In the 1990–2001 period, the main determinant of the trend in zinc emissions was Metal Production (2C), accounting on average for 55.0 per cent of national total emissions throughout that period (Figure 2.18). However, following the closure of Ireland's only steel plant in 2001, emissions from this source sector are now almost negligible and limited to relatively small IPPC-licensed foundries and galvanising plants. The main determinant for the trend since 2002 has been the Transport (1A3) sector (23.4 per cent of national total zinc emissions in 2019) specifically Road Transport (1A3b) sub-sector has increased significantly since 1990 as a result of the increase in the number of vehicles on Irish roads. As a result, emissions from Transport sector have increased substantially (122.9 per cent), from 2.08 t in 1990 to 4.65 t in 2019.

The largest source in 2019 is emissions from combustion in Manufacturing Industries and Construction (1A2) which accounts for 29.1 per cent share of emissions in 2019 having increased from 3.26 t (6.1 per cent share) in 1990 to 5.77 t in 2019 (77.1 per cent increase). Residential (1A4b) and Commercial/Institutional (1A4a) combined accounted for 21.4 per cent of the national total in 2019. However, reduced use of coal and peat through part replacement with natural gas and gasoil has resulted in the reduction of zinc emissions from these sectors by 69.4 per cent, from 13.87 t in 1990 to 4.25 t in 2019. Emissions from combustion in. Public Electricity and Heat Production (1A1a) emissions have decreased by 51.2 per cent since 1990 and accounted for a 6.9 per cent share of national total in 2019. Similar to other pollutants the reduction is due the replacement of older less-efficient generation plants, reductions in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy. The remainder of the zinc emissions arise from combustion in Agriculture/Forestry/Fishing (1A4c) sector with its 0.9 per cent share of the national total in 2019. Waste Incineration (5C) accounted for 0.1 per cent of the national total in 1990 however, following an outright ban on incineration of clinical waste in hospitals in 1997, emission from Clinical Waste Incineration 5Cbiii are no longer a source.
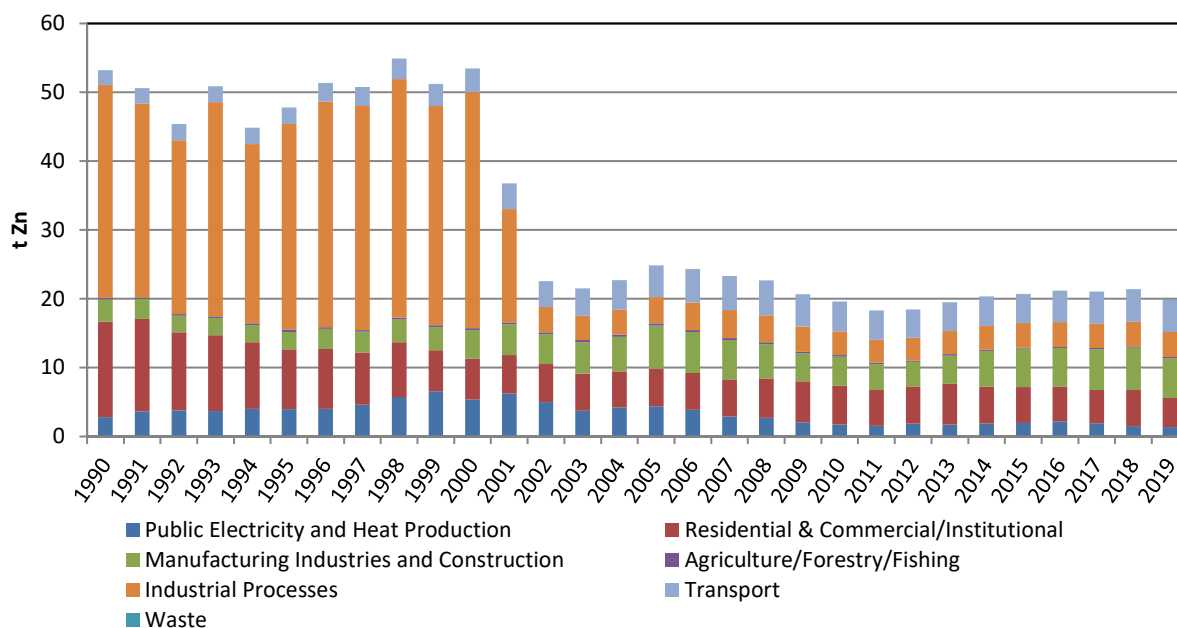
Figure 2.18 Emission Trend for Zinc 1990−2019

2.6 Persistent Organic Pollutants (POPs)

As part of Ireland's emission inventory improvement programme, the inventory agency tendered a project in 2007 to develop an inventory of persistent organic pollutants in Ireland. The project report (AEA/CTC, 2008) provides detailed information in relation to the methodological choice and activity data for the diverse range of sources that give rise to emissions of POPs within Ireland. For the purposes of identifying the major contributors to the trend in PCDD/F, PCBs, HCB and PAHs, some of this information is provided in the following sections. The approach has been updated subsequently as new versions of EMEP/EEA Inventory Guidebook have been published.

2.6.1 Dioxins and Furans (PCDD/F)

Dioxin and furan emission levels decreased from 59.54 g I-TEQ in 1990 to 18.50 g I-TEQ in 2019 (68.9 per cent reduction on 1990 levels). The main contributors to the trend are the Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined with a 69.5 per cent share of total emissions in 2019; however, emissions from these sectors have reduced (by 72.5 per cent) from 46.78 g I-TEQ (and 78.6 per cent share) in 1990 to 12.86 g I-TEQ in 2019 (Figure 2.19).

The second largest contributor to the trend is the Waste sector which is dominated by emissions from the Other Waste (5E) sector, where building and vehicle fires and residential burning of waste are the emission sources. Total emissions from the waste sector accounted for 23.2 per cent (4.29 g I-TEQ) of national total emissions in 2019, a reduction of 51.5 per cent on 1990 levels (8.84 g I-TEQ). Emissions from the sector peaked in 2003 (8.92 g I-TEQ) due to an increase in the assumed combustion of household waste that remains unaccounted for in national statistics. The introduction of unleaded petrol and technological improvements in road vehicles has offset increased numbers of vehicles in the national fleet, with a 3.7 per cent share of national total emissions for emissions in Transport (1A3) in 2019. Process emissions from the manufacture of cement (2A1) in Industrial Processes and Product Use sector, accounting for 0.1 per cent of national emissions in 2019 (0.02 g I-TEQ), a 98.8 per cent

reduction on 1990 levels (1.45 g I-TEQ). Combustion in Agriculture/Forestry/Fishing (1A4c) sector accounted for 1.9 per cent of emissions in 2019 (0.35 g I-TEQ) a decrease of 70.2 per cent on the 1990 emissions (1.17 g I-TEQ). Public Electricity and Heat Production (1A1a) emissions have decreased by 50.1 per cent from their 1990 level of 0.59 g I-TEQ to 0.30 g I-TEQ and are responsible for a 1.6 per cent share of national total in 2019 due to the replacement of older less-efficient generation plants, reduction in the quantities of coal combusted and fuel switching from oil to natural gas and wind energy.
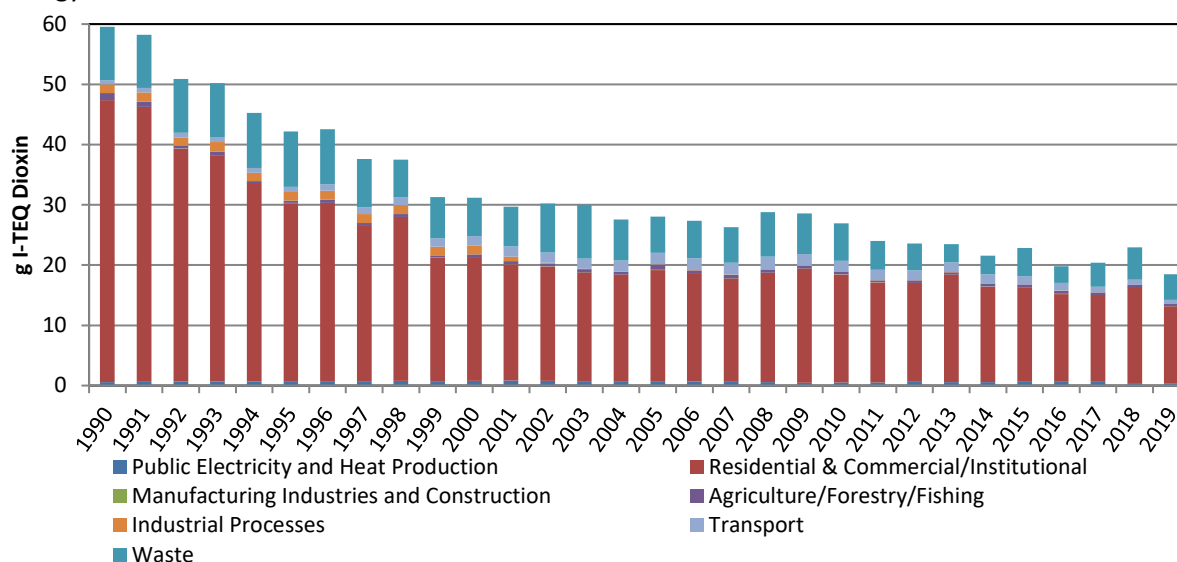
Figure 2.19 Emission Trend for Dioxins and Furans 1990−2019

2.6.2 Hexachlorobenzene (HCB)

Figure 2.20 outlines the trend in hexachlorobenzene emissions in Ireland across the 1990−2019 time series. The graph indicates that HCB emissions from Secondary Aluminium Processing (2C) which, for the period up to and including 1996, dominated the inventory with a contribution of 40 kg per year and is no longer a source of HCB emissions within Ireland due to the banning of hexachloroethane (HCE)-based cover gas use (HCB was present as a contaminant in such cover gases). Emissions since 1997 are more relevant to trend analysis up to 2019.

There is very limited information on the release of HCB to air for most source sectors in Ireland. The main source is the use of pesticides in agricultural practices significantly increasing up to 2004 (7.94 kg), reaching its peak in 2004 (8.03 kg) and decreasing to 2.03 kg in 2005 following a ban on the use of certain pesticides. Subsequently emission have increased up to 2012, before subsequently decreasing and in 201 were 2.04 kg representing an 87.0 per cent share. The Public Electricity and Heat Production (1A1a) sector was the second largest source in 2019 accounting for 0.24 kg and a 10.0 per cent share of the national total, having decreased by 51.8 per cent between 1990 and 2019.

Incineration of hazardous and clinical wastes and crematoria included in the waste incineration (5C) accounted for 0.2 per cent share of national emissions in 2019, a decrease of 90.8 per cent since 1990. The remainder of the HCB emissions arise mainly from combustion in the Residential (1A4b) and Commercial/Institutional (1A4a), Manufacturing Industries and Construction (1A2) and Agriculture/Forestry/Fishing (1A4c) sectors, which combined are presented as "Other" NFR sectors in

Figure 2.20 and account for 2.5 per cent of the total in 2019. Transport (1A3) accounted for 0.3 per cent of national emissions in 2019.
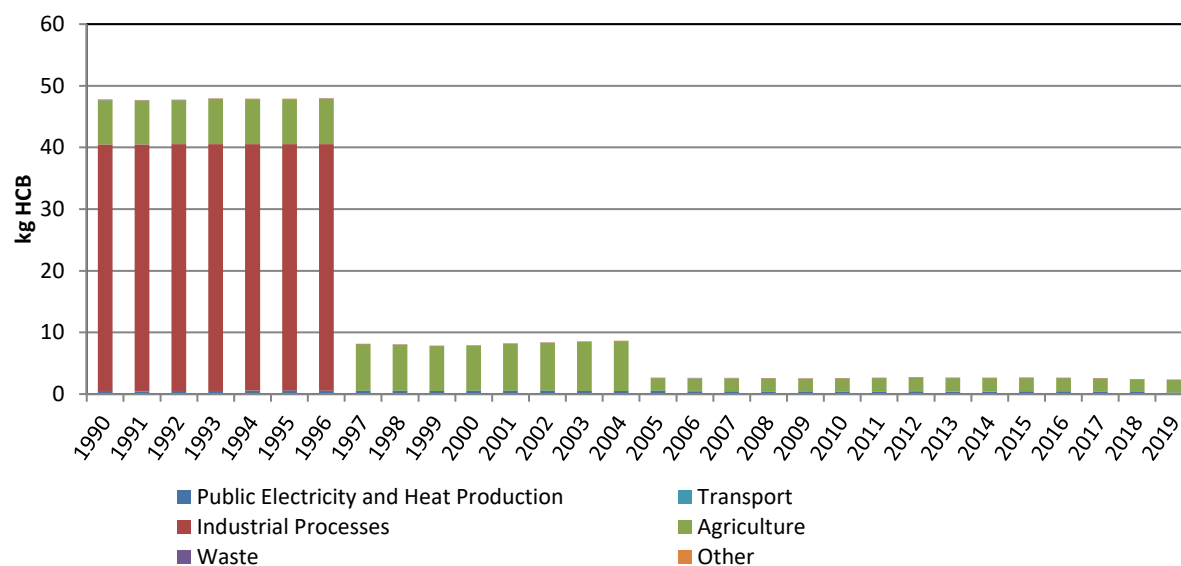
Figure 2.20 Emission Trend for Hexachlorobenzene 1990−2019

2.6.3 Polychlorinated Biphenyls (PCBs)

Estimated national total emissions of polychlorinated biphenyls have decreased by 80.0 per cent from 39.10 kg in 1990 to 7.80 kg in 2019. Emissions peaked in 2003 (67.69 kg) (Figure 2.21). Other Waste (5E) is the largest contributor to the trend in PCB emissions in Ireland accounting for 3.09 kg in 2019. In 2019, the emissions from the Waste sector a whole were 4.55 kg (58.3 per cent of national total emissions), a decrease of 70.9 per cent compared to 1990 (15.62 kg). Emissions from the Waste sector peaked in 2003 (59.93 kg) due to an estimated increase in the quantity of household waste that remains unaccounted for in national statistics and which is assumed to be burned. Combined emissions from the Residential (1A4b) and Commercial/Institutional (1A4a) sectors accounted for 32.8 per cent of the national total in 2019 (2.56 kg), a 74.0 per cent decrease from those estimated for 1990 (9.85 kg).

Of particular note for PCB emissions is the contribution of the NFR Sector 2L (Other Production, consumption, storage, transportation or handling of bulk products), which in Ireland's inventory covers PCB use as dielectric fluid in electrical equipment such as transformers and capacitors. However, through the introduction of Hazardous Waste Management Plans and the Waste Electrical and Electronic Equipment (WEEE) Regulations, emissions since 2006 have been decreasing in general.

Public Electricity and Heat Production (1A1a) emissions were 0.01 kg in 2019 and contributed 0.2 per cent of the total. Increases in cement production have led to increases in fuel combustion based emissions in Manufacturing Industries and Construction (1A2) up until 2005. This source category's emissions have decreased by 35.7 per cent between 1990 (1.06 kg) and 2019 (0.68 kg), with a contribution of 8.7 per cent to the national total in 2019.
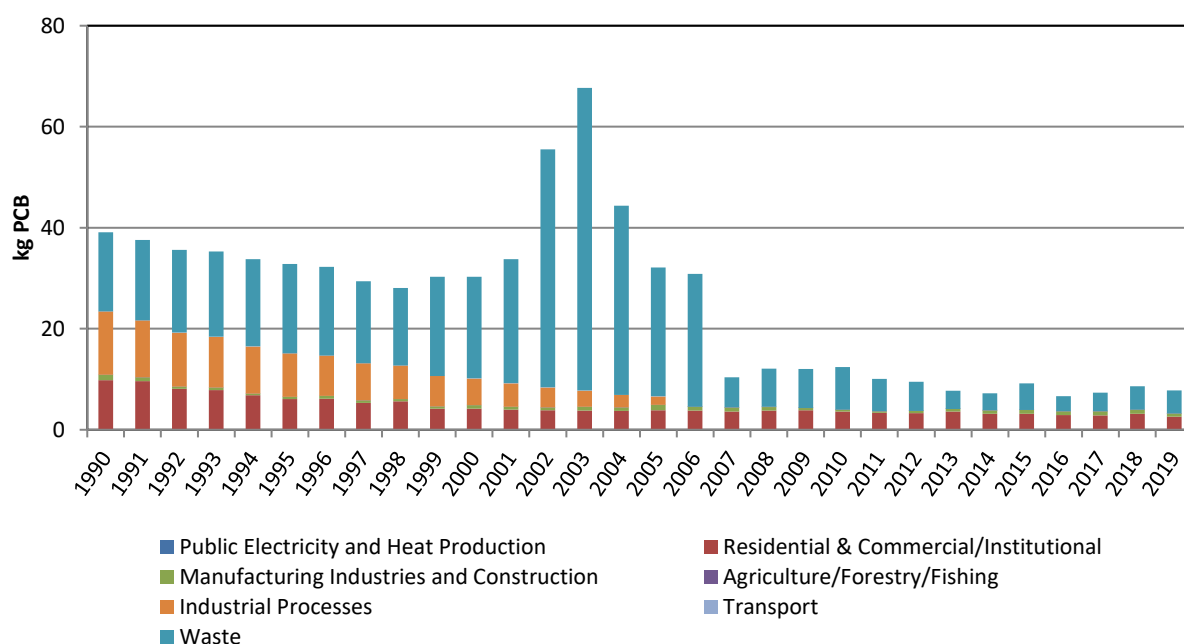
Figure 2.21 Emission Trend for Polychlorinated Biphenyls 1990−2019

2.6.4 Polycyclic Aromatic Hydrocarbons (PAHs)

For the purposes of this report, total PAHs in the form of the sum of emissions of benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd] pyrene are presented in Figure 2.22. All together the emissions from these combined four pollutants decreased by 71.9 per cent between 1990 (48.22 t) and 2019 (13.55 t). For all four PAHs, the main source sectors are the same. The inventories are dominated by emissions from combustion in the Residential (1A4b) and Commercial/Institutional (1A4a) sectors. In the Residential (1A4b) sector (main driver of the trend), the lack of combustion controls or abatement, together with relatively low-temperature combustion conditions, leads to high emissions of PAHs. Even though national total emissions of PAHs have generally declined across the time series, the Residential (1A4b) and Commercial/Institutional (1A4a) sectors combined accounted for 92.9 per cent of the national total in 2019, having decreased by 73.0 per cent from 46.58 t in 1990 to 12.58 t in 2019. The decline in emission levels is due primarily to the decline in the use of coal and sod peat for residential space heating, as reported in the National Energy Balance.

Combustion emissions in Manufacturing Industries and Construction (1A2) sector accounted for 4.4 per cent of the total in 2019 (0.60 t), a decrease of 58.1 per cent since 1990 (1.43 t). Emissions from Transport (1A3) have increased by 157.7 per cent) to 0.28 t representing a 2.1 per cent share of the national total in 2019 for all four PAHs as compared to 0.2 per cent 1990 (0.11 t). Other Waste (5E) is the main driver in the Waste sector resulting in the Waste sector accounting for 0.3 per cent in the total PAHs emissions in 2019, a 19.7 per cent reduction since 1990.
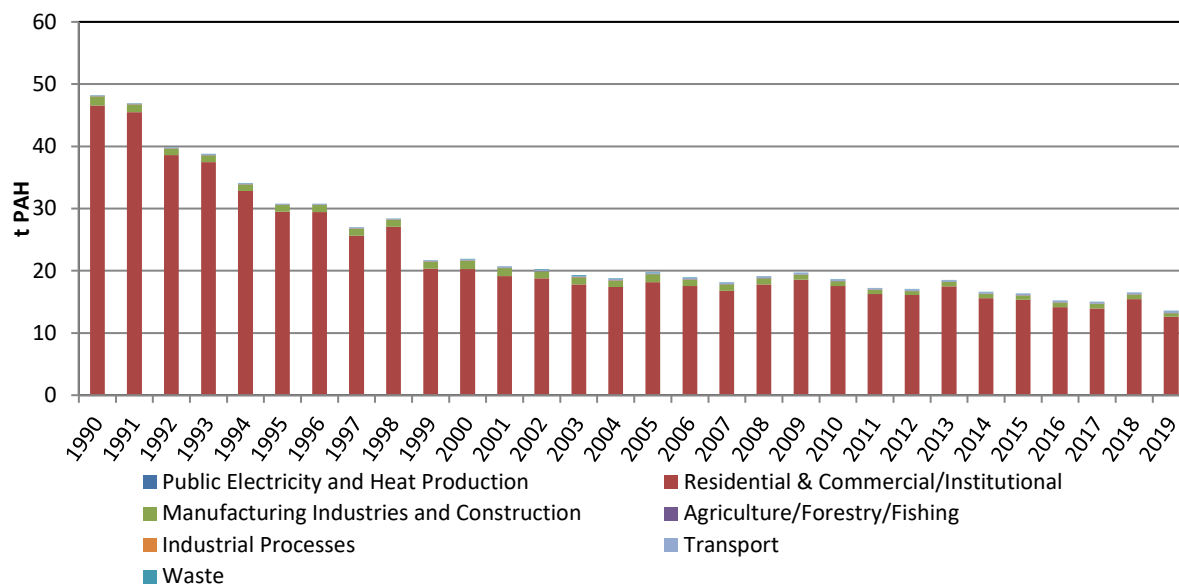
Figure 2.22 Emission Trend for Polycyclic Aromatic Hydrocarbons 1990−2019

Chapter Three

Energy

3.1 Overview of the Energy (NFR 1) Sector

The Energy sector covers combustion and fugitive sources of emissions associated with the production, transport, conversion and use of fossil fuels. Emissions from combustion in this sector account for the bulk of total national emissions for the majority of substances covered in this IIR. Estimates of the various pollutants are included for all emission sources that occur in the country and the required level of disaggregation is achieved for sufficiently detailed completion of the NFR tables.

Annual energy balance sheets published by Sustainable Energy Authority Ireland (SEAI) are the principal source of activity data for computing the emissions in the Energy sector. Ireland's energy statistics are compiled using a combination of top–down and bottom–up methods and the annual energy balances have undergone major improvement over recent years to take account of emission inventory requirements and more harmonised reporting to Eurostat and the International Energy Agency (IEA). The annual submission of up-to-date energy balances from SEAI to the inventory agency is one of the primary data inputs covered by a MoU in Ireland's national system (Chapter One). A fully consistent set of energy balance sheets for the years 1990–2019 underlies the time-series estimates of emissions for *Energy* in this submission. The 2019 energy balance is provided in Annex B.

Substantial plant-level fuel-use data are also available for many important categories in the Energy sector, especially for more recent years, which allows bottom–up estimates to be derived for some pollutants using Tier 3 methods. These data are obtained through direct arrangements with the operators of certain plants through their returns under Chapter III the Large Combustion Plant (LCP) of the Industrial Emissions Directive and the EU ETS and under environmental reporting related to their IPPC permits.

The emissions of SO_2 from fuel combustion are determined from the fuel properties, and fully representative emission factors are readily obtained for the fossil fuels used in most emission categories in Ireland. In general, other pollutants emitted from combustion sources are heavily reliant on emission factors from non-national sources and are taken from the Inventory guidebook (EMEP/EEA, 2009, 2019). The Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance (CEPMEIP), which is aimed at supporting national experts in reporting PM emission inventories, serves as the reference for emission factors in the category 1A3a for the different forms of Particulate Matter (PM). Particulate Matter emission factors for other sectors are derived from the Inventory Guidebook (EMEP/EEA, 2019). In the past, emission inventories for heavy metals and POPs received little attention in Ireland and special studies were necessary to compile national emission estimates for reporting purposes. The separate detailed studies on emissions of heavy metals and POPs in Ireland were undertaken by consultants (AEA/CTC, 2008; Netcen/CTC, 2006) and they made use of the best available emission factors for many emission

sources, with strong dependence on UK information sources. The results from these studies were the basis for developing time-series emissions of heavy metals and POPs in the Energy sector in previous submissions. In this submission, many of the EFs for heavy metals and POPs are from the Inventory Guidebook (EMEP/EEA, 2019).

3.2 Public Electricity and Heat Production (NFR 1A1a)

The production of electricity and heat from fossil fuels has traditionally been the most important source of key pollutants such as SO_2 and NO_X in most countries. Approximately 71 per cent of electricity production in Ireland (SEAI, 2020) is dependent on fossil fuels and Category 1A1a therefore remains one of the major emission categories. Emissions of SO_2, NO_X, CO, three particulate matter pollutants, BC, all nine heavy metals and POPs have decreased more or less significantly since 1990. NMVOCs were the only emissions that have increased in the time series due to the increase use of natural gas. The level of emissions in Sector 1A1a depends heavily on the mix of fossil fuels and renewables used for electricity production. In 1990, heavy fuel oil (HFO), coal, peat and natural gas were the principal fuels used. The use of HFO, coal and peat has declined as natural gas became the preferred fossil fuel during latter years. For example, in 2019 coal used for electricity generation fell by 69 percent year on year following a 44 per cent decrease in 2018. Incineration emissions from Ireland's waste-to-energy plants, however small, have been increasing since the first such installation came into operation in 2011 and a second in 2017.

3.2.1 Emissions of Sulphur Dioxide and Nitrogen Oxides

Until 2000, the Electricity Supply Board (ESB) operated all public electricity power plants in Ireland. After 2000, several new gas-fired plants and one peat-fired plant were built by other operators, while the ESB replaced old peat-burning stations with new stations also burning peat and has been engaged in a major retrofit and improvement programme for plants in general. The shift to natural gas and the use of low-sulphur coal, combined with a decline in the sulphur content of fuel oil, have reduced SO_2 emissions by 97.8 per cent from 103.04 kt in 1990 to 2.24 kt in 2019. The sector's contribution to the overall SO_2 emissions in 2019 was 20.6 per cent as opposed to 56.1 per cent share in 1990. Incineration of non-renewable waste in MSW accounted for 1.1 per cent of SO_x emissions from power generation in 2019.

At the same time, the changed fuel mix, together with the application of extensive NO_X emission control technology and the more modern plants, has decreased NO_X emissions by 87.1 per cent from 46.37 kt (and 26.3 per cent share of total NO_X emissions) in 1990 to 5.99 kt (and 5.9per cent share of the total) in 2019. In comparison to the year 2018, NO_X emissions decreased by 11 per cent in 2019, and SO_2 emissions decreased in 2019 by 21.2 per cent. The ESB has supplied estimates of SO_2 and NO_X on a plant-by-plant basis to the inventory agency for all years since 1990, mainly for the purpose of compiling SO_2 and NO_X inventories under Chapter III of the IED Directive. The emissions for power plants operated by other companies are obtained either directly from their LCP, AER or PRTR submissions or they can be estimated by the inventory agency from fuel data made available under the ETS. Ireland sought clarification from these power plants regarding the reporting of emission using validated average figures (after subtracting the value of the confidence interval). Three plants were discovered to be underreporting their emissions as a result of this exercise and corrected figures were

supplied without subtraction of the confidence interval and reported in the 2020 submission. In this submission all relevant plants have reported correctly to the inventory agency. Incineration of non-renewable waste in MSW accounted for 6.6 per cent of NO_x emissions from power generation in 2019.
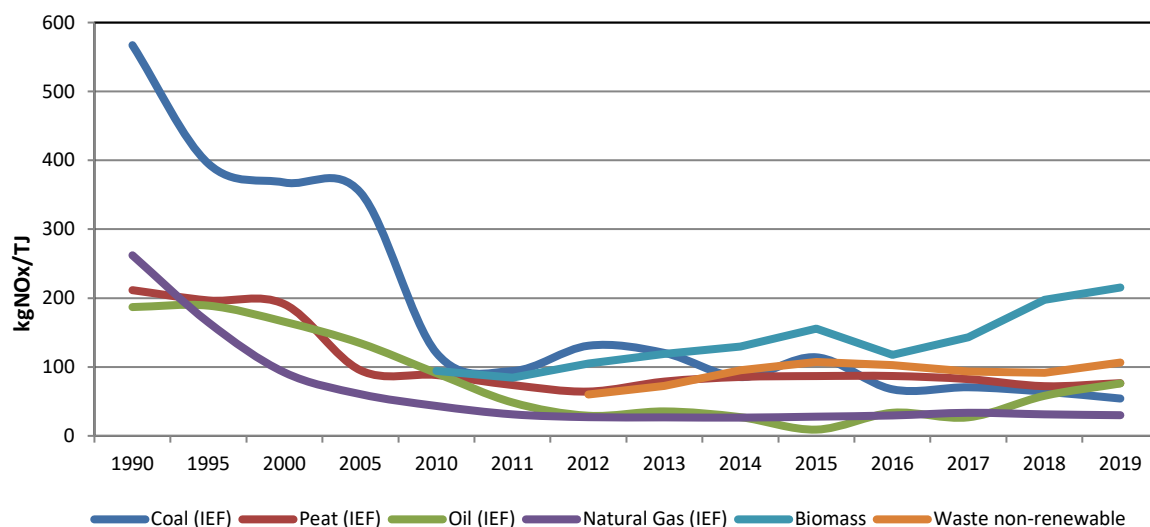
Figure 3.1 Nitrogen Oxide Implied Emission Factors for Category 1A1a

The weighted average emission factors of SO_2 and NO_x per fuel type (coal, peat, oil, natural gas, biomass and waste (MSW)) in Category 1A1a are given in Figures 3.1 and 3.2 as implied emission factors (IEFs) to illustrate the level of decrease due to the factors mentioned above. The SO_2 emission factors reflect the sulphur content and net calorific value of the fuels used in the particular year and they account for sulphur retention levels in the fuel ash of 5 per cent and 10 per cent for coal and peat, respectively. The NO_x emission factors (apart from landfill gas) are compiled from plant-level estimates that are determined from measurement, unit load factor and plant performance. Emission factors for landfill gas are default values as per the revised Inventory Guidebook (EMEP/EEA, 2019).
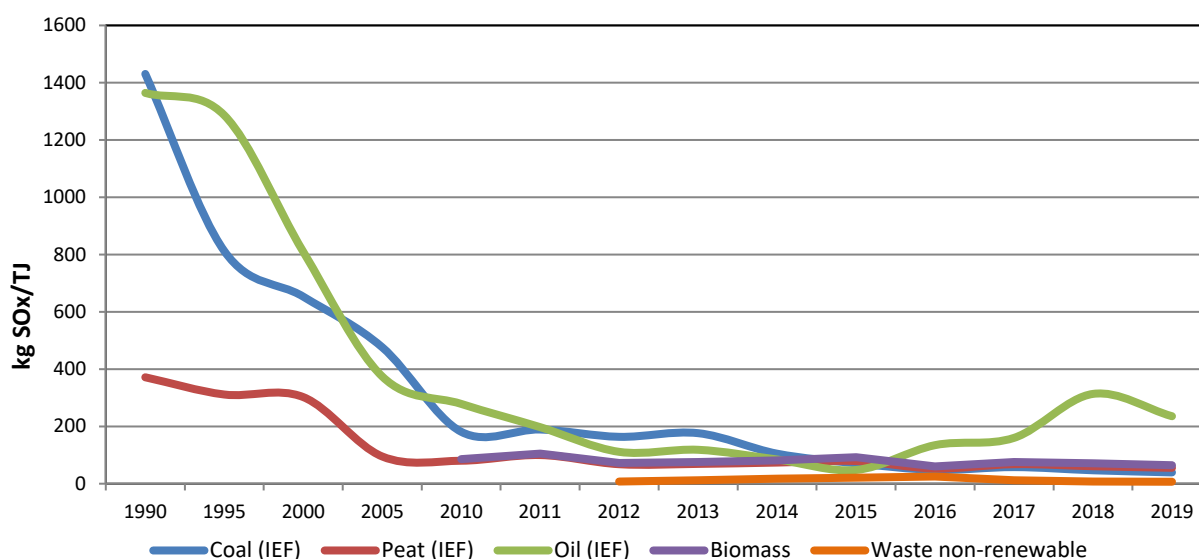
Figure 3.2 Sulphur Dioxide Implied Emission Factors for Category 1A1a

3.2.2 Emissions of Other Substances

The emissions of all substances other than SO_2 and NO_X in Category 1A1a are estimated by the inventory agency using the fuel-use energy data given by the national energy balance and appropriate emission factors taken from the Inventory Guidebook (EMEP/EEA, 2019) and plant-specific factors for non-renewable wastes from waste incineration. For the pollutants Cd, Hg, Pb, Dioxins, PCB, PAH and HCB Ireland utilises the emission factors presented in the 2019 EMEP/EEA Inventory Guidebook. Specifically, the emission factors for coal and peat are taken from Table 3-15, fuel oil from table 3-11, natural gas and landfill gas from table 3-4. These emission factors are presented in Table C.1 Annex C. The activity data for 1A1a follows the format of that presented in Table B.1 Annex B for all years. Dioxins emissions for Peat power plants are estimated with plant specific emission factors. Furthermore, for Oil, there are no emission factors available for BaP, PCB and HCB in the 2019 EMEP/EEA Inventory guidebook. For natural gas and landfill gas there are no emission factors available for PCB and HCB in the 2019 EMEP/EEA Inventory guidebook. Ireland uses the same activity data for all air pollutant and greenhouse gas emission calculations to maintain consistency in approaches across inventories (see section 3.1). The emission factors for 2019 (split by pollutants and fuel type) and their sources are listed in Table C.1 of Annex C.

3.3 Petroleum Refining (NFR 1A1b)

Emissions from fuel combustion at one small oil refinery in Ireland are estimated in this source category. Detailed information on the fuels used in different parts of the refinery in recent years is available through the company's AER, PRTR and ETS submissions. This allows for the selection of appropriate emission factors from national data and from international literature sources recognised as being fit for purpose by the emissions inventory community. In the case of heavy metals and POPs, the estimates are based on emission factors from the Inventory Guidebook (EMEP/EEA, 2019). The emission factors used and their sources are listed in Table C.2 of Annex C.

3.4 Manufacture of Solid Fuels and Other Energy Industries (NFR 1A1c)

Emissions from this source category refer to combustion emissions from the production of peat briquettes from milled peat at two plants, one natural gas production platform and one new natural gas refinery in Ireland. As in the case of the oil refinery, the energy balance fuel-use data are supplemented by information reported by the plants under the ETS, which again allows for the selection of appropriate emission factors using national data and high-quality international sources. The estimates for heavy metals and POPs are based on emission factors from the Inventory Guidebook (EMEP/EEA, 2019). The emission factors used and their sources are listed in Table C.3 of Annex C.

3.5 Manufacturing Industries and Construction (NFR 1A2)

This category covers emissions from combustion in manufacturing industries and construction activities. Category 1A2 is split into the following seven subcategories:

1.A.2.a Iron and Steel
1.A.2.b Non-Ferrous Metals
1.A.2.c Chemicals
1.A.2.d Pulp, Paper and Print
1.A.2.e Food Processing, Beverages and Tobacco
1.A.2.f Non-metallic minerals
1.A.2.g Other Industry

Where it is possible to separate process emissions from those associated with fuel use, the process emissions associated with these industrial groups are reported in the Industrial Processes (NFR 2) sector (Chapter Four). The relevant process emissions in Ireland are those related some metal industries.

Comparison of the Sustainable Energy Authority of Ireland (SEAI) Energy Balance data with ETS fuel-use data indicates that the combustion activities within the 1.A.2 category are dominated by a limited number of large industrial processing plants. It is assumed that all biomass reported as fuel use within the SEAI Energy Balance is clean untreated wood and wood-processing waste. The ETS data for major wood-processing facilities indicate the use of large-scale biomass boilers, fired using wood biomass, chippings, pulp and wood dust. Knowledge of these installations, indicates that none of these wood-based fuels are pre-treated and hence emission factors applicable to clean wood use in large-scale boilers have been used to estimate POP emissions from these sources.

The Iron and Steel (1A2a) sector was dominated in the 1990s by fuel use and emissions from one electric arc furnace but, since its closure in 2001, the fuel use reported in 2002 in this sector related to a small number of iron foundries, which in total used only a very small amount of gasoil and LPG and since 2003 combustion emissions are not occurring. For 1A2a 1990 was the only year in the timeseries for which coal was combusted as a fuel in the category (29 ktoe). The emission factors used are those presented in Table 3.2 of the Inventory Guidebook (EMEP/EEA, 2019). The emission factor for coal is significantly higher than the emission factors associated with the other fuels combusted in the category, thus the combustion of coal in the category for the year 1990 has a significant influence

on emissions for that year. The process emissions from this industrial activity are described in chapter 4, section 4.4.1.

The Non-Ferrous Metal (1A2b) subcategory is dominated by the very significant fuel use (mainly natural gas replacing fuel oil) reported at a single large alumina plant, whilst the Chemicals (1A2c) subcategory includes natural gas, kerosene, fuel oil, gasoil and LPG use at large chemical plants. The Food Processing, Beverages and Tobacco (1A2e) sector covers a diverse range of industrial plants, much of which is related to agriculture, with just under 30 installations reporting to the EU ETS and using predominantly natural gas and liquid fuels. The bulk of the fuel use reported in the energy balance under the 1A2f subcategory is accounted for by major cement works, lime producers, a small number of brickworks and fuel use at boiler plant within industries such as the pharmaceutical, glass and tile manufacturing sectors. There are at present four cement plants in Ireland, all of which use the dry kiln process, and they are currently fuelled by coal, petroleum coke and fuel oil, while meat and bone-meal, solid recovered fuels (SRF) and tyre derived fuels are co-incinerated at three of the four plants. The Inventory Guidebook (EMEP/EEA, 2019), provide some POP emission factors on an overall grams of pollutant per tonne of clinker produced basis. The guidebook states that these emissions should be allocated to combustion in cement manufacture. These emission factors have been used to determine the total emissions from cement plants. Fuel-use data are available from plant operators as part of their reporting requirements under the EU ETS (Directive 2003/87/EC). Residual fuel not used in the cement manufacture sector but used in other manufacturing industries in 1A2f is calculated and emissions from fuel use are calculated using combustion emission factors in 1A2f, while the fuel use data from cement manufacture is removed to ensure there is no double counting. The same method is used for heavy metals in 1A2f. Emissions for individual cement plants were collected for all available years for Cadmium, Mercury and Lead and a plant specific g/t emission factor was determined using clinker production. This was then used to calculate emissions for years where plant emissions data was not available. For other metals As, Cr, Cu, Ni, Se, Zn the Tier 2 emission factors from Table 3-24 Chapter 1A2 of the Inventory guidebook (EMEP/EEA, 2019) were used with plant clinker production to estimate emissions. Residual fuel not used in the cement manufacture sector but used in other manufacturing industries in 1A2f is calculated and emissions from fuel use are calculated using combustion emission factors in 1A2f. The fuel use data from cement manufacture is removed to ensure there is no double counting. All other industrial fuel use is reported under subcategory 1A2g. This sector covers a diverse range of manufacturing branches ranging from textile and leather, through machinery, transport equipment, wood products, mining (excluding fuel mining) and quarrying to other manufacturing businesses. Ireland's national Energy statistics do not provide an estimate of fuel used in mobile construction. All emissions associated with the category 1A2g are reported in 1A2gviii, and mobile emissions, 1A2gvii, are reported as "included elsewhere" (IE) in 1A2gviii. Currently all fuel is assumed to be stationary as the energy balance does not provide an estimate for fuels used in mobile machinery. The inventory agency has tendered research to be undertaken to quantify the extent and amounts of fuel used by mobile combustion on construction sites and when available will include the results of this research in the national energy balance in consultation with the energy balance provider and estimate emissions accordingly.

The revised and expanded energy balance sheets developed by SEAI incorporate a mapping of industrial fuel use in combustion into the NFR subcategories 1A2a through 1A2g under sector 1A2 Manufacturing Industries and Construction. This facilitates the complete disaggregation of emissions

at subcategory level. In addition, information on fuel consumption was obtained in respect of a small number of energy-intensive industries (e.g. alumina production and cement manufacture) from their ETS returns, allowing their respective energy use amounts to be reconciled with the breakdown given in the national energy balance. Emissions in subcategories 1A2a through 1A2g are estimated on a top−down basis using disaggregated fuel use from the energy balance and the mix of country-specific and default emission factors as shown in Tables C.4 through C.10 of Annex C. The estimates for heavy metals and POPs are based on emission factors from the Inventory Guidebook (EMEP/EEA, 2019). Emission factors for heavy metals and POPs (including references) for NFR 1A2 (a−g) are shown in Table C.11 of Annex C.

Ireland used the emission factors from the Inventory Guidebook (EMEP/EEA, 2019) for liquid fuels. The Tier 1 EFs for liquid fuels are an average of Tier 2 EFs and are not considered representative considering one of the liquid fuel values for NOx is 942g/GJ based on reciprocating engines which are not present in Ireland. The Tier 1 value of 100 g/GJ used by Ireland is still valid, as all the guidebook editions reference Chapter B216 of older editions of guidebook. A generic emission factor of 100 g/GJ was applied for all liquid fuels for sectors 1A2f, which was obtained from "Table 3-4: Tier 1 emission factors for 1.A.2 combustion in industry using liquid fuels", for "'Other' Liquid Fuels" in page 16, 1.A.2 Manufacturing industries and construction (combustion), EMEP/EEA emission inventory guidebook 2009. Reference EMEP/CORINAIR B216. Table 1-1 of the Guidebook 2019 refers to the appropriate chapters for EFs, either 1A1, 1A2 or 1A4. Very few EFs were used from Chapter 1A2 as Ireland does not have these types of industry. EFs were again mainly sourced from the small combustion chapter (1A4) for boilers, as these are the most appropriate for the boiler types used in Ireland. The average of Tier 2 EFs are not applicable as Ireland has no reciprocating engines or turbines.

Regarding NMVOC emissions in 1A2gviii, the fuel used for 3 large plants for all years where data is available (2005-2019, EU ETS), was subtracted from the total fuel use and a Tier 2 EF was used, 12kg/TJ for NMVOC and all other pollutants, EMEP/EEA 2019, 1.A.4 Small Combustion, Table 3-48, 'wood'. The residual amount of biomass fuel uses the Tier 1 EF.

3.6 Transport (NFR 1A3)

As abatement measures continue to reduce emissions of key pollutants from major stationary combustion sources, transport in general, and road transport in particular, has become more important as a source of atmospheric emissions in many countries. The effects of technological emission controls for passenger cars and other vehicles in Ireland have, to a large extent, been offset by the substantial increases in vehicle numbers, with the result that major reductions in the emissions of pollutants such as NO_X did not occur until 2007 when the economic situation caused an overall decrease in most emissions evident from 2008. In 2019 NO_X emissions from this sector reached 40.86 kt (40.4 per cent share of total) reflecting a decrease by 34.3 per cent on 62.23 kt emissions (and 36.5 per cent share) in 1990.

Road transport in Ireland is a larger source of NO_X than electricity production, and road traffic also continues to be the major source of CO, BC, Pb, Cr, Cu and Zn, although BC, Pb, Cr, Cu and Zn emissions are very small in absolute terms.

3.6.1 Domestic and International LTOs (NFRs 1A3aii(i) and 1A3ai(i))

As a relatively small island state, aviation emissions are dominated by the international component. Under the LRTAP Convention, only the landing and take-off (LTO) component of emissions for both domestic and international flights is reported in the national total. The cruise component, domestic and international, is reported as a memo item. After the motorway network to Dublin from Galway and Cork was completed around 2008/09 and the upgrades of the Cork to Dublin rail line, domestic air travel was no longer competitive, leading to cessation of specific routes. Almost all flights ceased from Galway airport post 2011.

The fuel consumption associated with domestic and international LTOs is estimated using a Tier 3b approach (Table 3.6.2, 2006 IPCC guidelines) based on origin and destination data for domestic air travel provided by EUROCONTROL (Eurocontrol, 2016), using an Advanced Emission Model (AEM) to estimate fuel burned and emissions for the full trajectory of each flight segment using aircraft and engine specific information. This new approach is used for all years from 2005 to 2019 where EUROCONTROL data is available. For the years 1990-2004, the number of flights for each airport was estimated based on domestic passenger and aircraft movement statistics as well as the relationship between all Irish airports and Dublin airport which is the principal destination of all domestic flights. Domestic LTO and Cruise fuel consumption rates for 1990-2004 are based on an average (2005 to 2011) for each departure airport using EUROCONTROL consumption rates.

Figures 3.3 and 3.4 and Table C.12 of Annex C present the number of LTOs, domestic and international, from Irish airports for all years from 1990 to 2019.
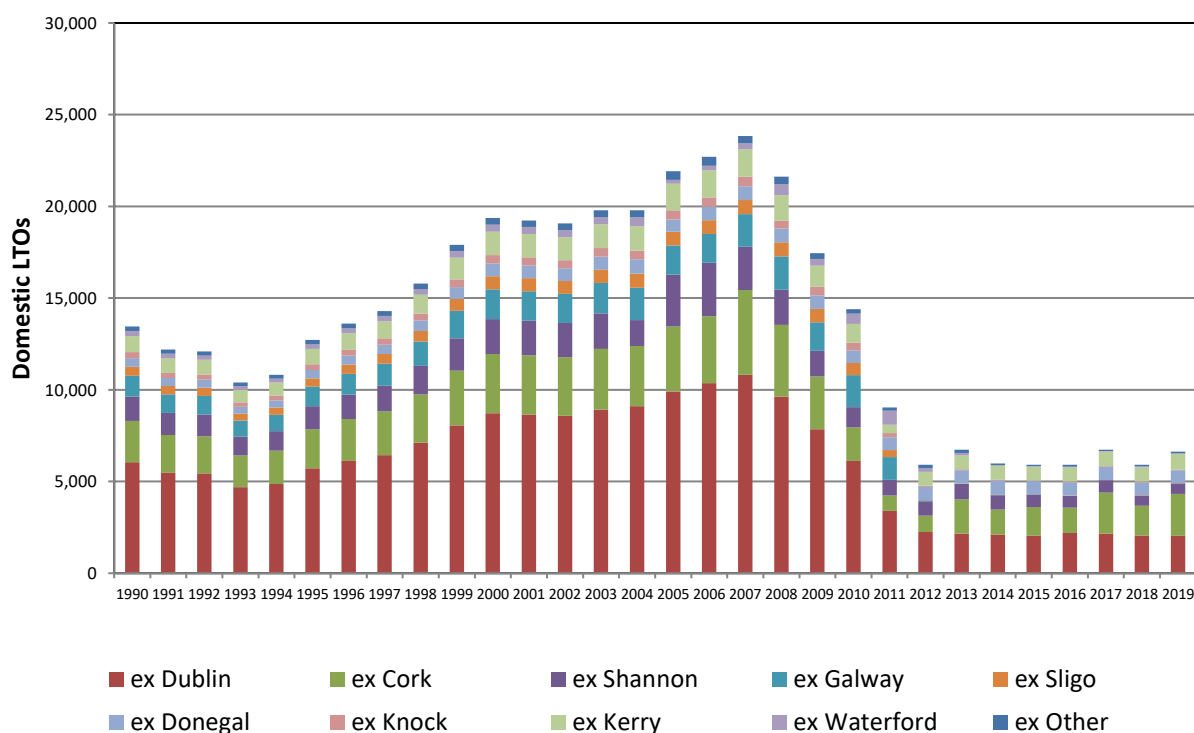
Figure 3.3 Number of Domestic LTOs from Irish airports 1990-2019

For data handling purposes, the inventory agency aggregated approximately 15 small regional airport/aerodrome pairs to "Other" which account for approximately 1.0 per cent of all domestic flights along with nine Irish airports which account for the remaining 99.0 per cent of all domestic flights in 2019. Emission factors associated with aviation emissions are presented in Annex C tables C.13 to C.18.

Legend: ex Dublin, ex Cork, ex Shannon, ex Galway, ex Sligo, ex Donegal, ex Knock, ex Kerry, ex Waterford, ex Other
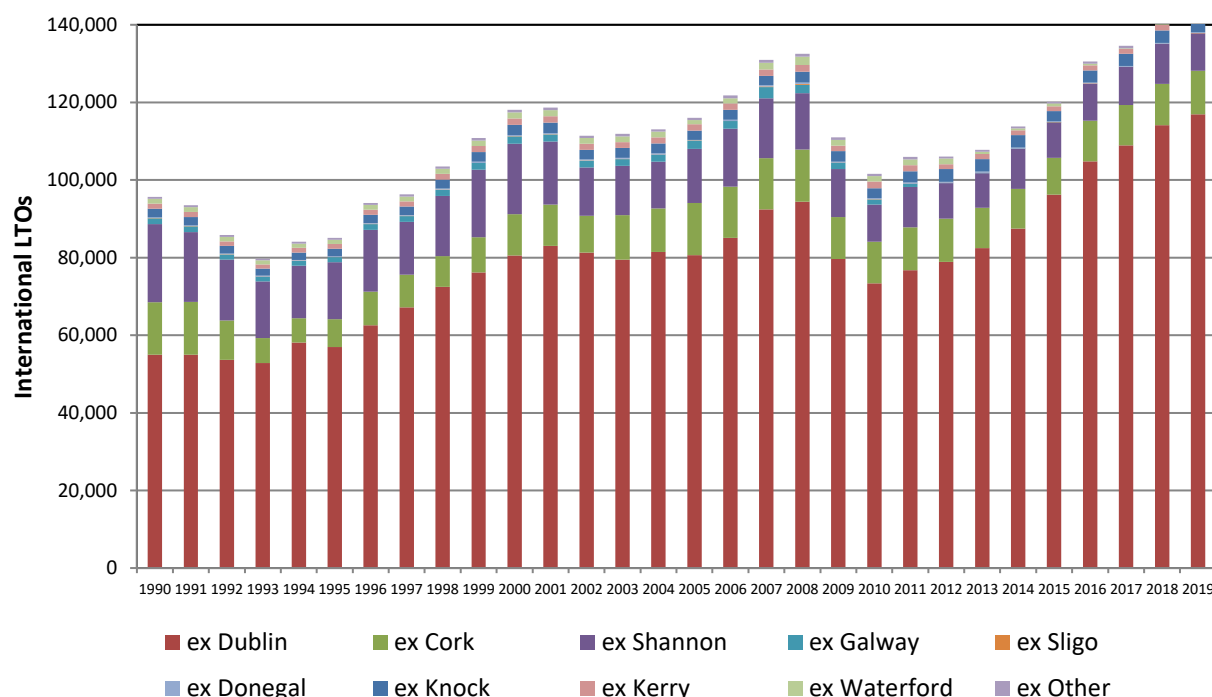
Figure 3.4 Number of International LTOs from Irish airports 1990-2019

3.6.2 Road Transport (NFR 1A3b)

The emissions of nine well-known pollutants (SO_2, NO_X, NMVOCs, NH_3, CO, TSP, PM_{10}, $PM_{2.5}$, BC) as well as seven heavy metals (Pb, Cd, Cu, Cr, Ni, Se, Zn) and POPs (Dioxins and Furans, PAHs) reported under sub-category 1.A.3.b Road Transport are estimated directly from the COPERT 5 model (Pastramas N. et al., 2014) developed within the CORINAIR programme for estimating a range of emissions from this important source.

The national total emissions in all cases are determined by the quantity of fuel sold in the country, as given by the energy balance. Approximately 65.82 petajoule (PJ) equivalent fuel energy from petrol, diesel, liquefied petroleum gas (LPG) and biofuels was consumed by road transport in Ireland in 1990. Consumption went up to 190.86 PJ in 2007 followed by a sharp decline to 145.88 PJ in 2012 and subsequently increasing to 165.71 PJ in 2019. The energy share in biofuel has continued to increase since its introduction in 2005 and increased to 6.78 PJ in 2019. It is known that significant proportions, e.g. 0.4 per cent of petrol and 8.1 per cent of diesel in 2019 sold in Ireland are consumed outside the country (referred to as fuel tourism) and therefore separate estimates of emissions are produced

based on fuel amounts used within Ireland. The use of compressed natural gas (CNG) in road transport is recorded in national energy statistics for 2014 -2019, however, the emissions were not estimated as the fuel amounts were considered negligible. For some countries, including Ireland, the national totals determined by fuels used are the basis for assessment of their performance in relation to relevant Protocols under CLRTAP. Annex A.3 outlines the methodology used to estimate the quantities of automotive fuels used in Ireland and includes the adjusted annual emissions for 1987 and the years 1990–2019.

The emissions of SO_2 for road transportation are computed from the amounts of petrol and diesel used by motor vehicles, as reported in the energy balance, and the sulphur content of the fuels. For the other substances, the COPERT 5 model estimates emissions based on distance travelled using a detailed bottom−up approach (Tier 3) that accounts for such factors as fuel type, fuel consumption, engine capacity, driving speed and a wide range of applicable technological emission controls that may be applied across the different vehicle categories according to the age of vehicles.

A total of 225 vehicle categories are determined by these variables in COPERT 5. Annex C shows the trend in emission factors for NO_X, SO_2, NH_3 and NMVOCs, CO and Particulate Matter per vehicle type for road transportation over the period 1990–2019 determined by the COPERT variables for the vehicle fleet in Ireland. For $PM_{2.5}$, PM_{10} and TSP, non-exhaust emission that includes brake and tyre wear emissions and road abrasion emissions for $PM_{2.5}$, PM_{10} and TSP are also presented as estimated using the COPERT model.

The primary model inputs for each year are the populations of vehicles in the relevant categories, their annual kilometres of travel in three selected speed classes, total fuel amounts and the fuel specifications. The numbers of vehicles are taken from annual bulletins of vehicle and driver statistics (e.g. DTTAS, 2019) and these are allocated to the different control technologies (Euro I, Euro II, etc.) based on their age and the application dates of the controls in Ireland. Information to assign values of annual kilometres of travel for the three speed classes (corresponding to urban, rural and highway driving) used for the individual vehicle categories is taken from the National Roads Authority (NRA) and odometer records from the National Car Testing (NCT) and the Commercial Vehicle Roadworthiness Test (CVRT) Service. Before the emissions are estimated in COPERT 5, fuel balancing is undertaken in the model using inbuilt consumption rates for the different vehicle categories to ensure that the total fuel amounts calculated from annual kilometres and consumption rates for all vehicle categories match the input fuel quantities (the fuel sold as given in the energy balance or the fuel used as determined by Annex A.3) and therefore that emissions relate to the relevant total fuel amount. This fuel balancing may involve some adjustment to kilometres travelled or to the shares of total kilometres in the different road classes.

3.6.2.1 Trends in emissions in Road Transport

For NH_3, COPERT generated NH_3 emission factors (g/km) for gasoline passenger car in 2005 for emission technology Euro 1 & Euro 2 are 30 percent and 52 per cent higher, respectively than those for 2004. This can be explained by a change in sulphur content from 2004 (150ppm) to 2005 (109 ppm) for gasoline and from 208ppm to 37ppm for diesel in 2004 and 2005, respectively. In addition, gasoline

use increased by 5.3 per cent between 2004 and 2005. This causes a resultant increase of 36 increase in emissions of NH_3 in 2005.

There was an increase in emissions of $PM_{2.5}$ and PM_{10} from diesel passenger cars between 2006 and 2013 which can be explained by a combination of an increase in diesel passenger cars between the years 2006 and 2013, in part due to the indirect effect of motor taxation policy and economic growth leading to increased number of diesel cars less than 2L in the vehicle population, which more than offset reductions associated with the introduction of Euro 4 and 5 technology in the fleet.

The fluctuations in NH_3 emissions for Light duty vehicles occurs because both gasoline fueled and diesel fueled light duty vehicles exist in Ireland. The NH_3 IEF (g/km) for gasoline and diesel fueled LDVs is between 0.001 and 0.004 g/km for the entire time series using the Tier 3 COPERT 5 model. These are similar to the Tier 2 diesel exhaust emission factors presented in the EMEP/EEA 2019 inventory guidebook. Furthermore, it should be noted that in 1990, 87.2 per cent of the total mileage for LDVs was from diesel fueled vehicles with the remainder being petrol fueled. This has grown to 99.8 per cent in 2019. The introduction of Euro 6 LDV vehicles in 2015 which have an increased emission factor (g/km) above Euro 1, 2, 3 and 4 associated with a 4 per cent increase in total mileage for diesel powered LDVs between 2013 and 2019 explains the increase in emissions of NH_3.

Fluctuations in NH_3 emissions for Heavy Duty Vehicle (HDV) is due an increase in mileage by stock from 1996-2000 of 20 per cent on average over these four years. This level of activity was maintained at this level from 2001-2007 after which there was a decrease from 2008-2012 of 12 per cent on average for these four years due to the economic recession in Ireland. As a result, emissions fluctuated with the increasing and decreasing HDV activity. A recovery can be seen in 2013,2014, 2015 and 2016 where there was an increase in HDV mileage x stock (5 per cent,2 per cent, 8 per cent and 13 per cent respectively). Despite this increase in activity in HDVs NOx emissions from HDVs have decreased in 2015-2019, and this is mainly due to the move from activity in older technologies into the newer Euro IV-VI classes for HDV which have improved emissions standards and hence lower emissions. For example 37 per cent of HDV activity was in the Conventional, Euro I, II and III classes in 2012, whereas in 2019, 8 per cent of HDV activity is in these older Euro classes and 92 per cent is in Euro IV-Euro VI.

Lubricant emissions from the road transport sector were estimated using COPERT 5 where the lubricant used was considered as an input in the model. Thus, emissions from lubricant for all engines including 2 and 4 stroke engines were included in COPERT output and reported under relevant categories in the NFR.

3.6.3 Railways (NFR 1A3c), National Navigation (NFR 1A3dii) and Other Transportation (NFR 1A3e)

The emissions under sub-categories 1A3c Railways and 1A3d National Navigation are calculated from the amounts of fuel used by these activities and the country-specific SO_x emission factors and default Inventory Guidebook (EMEP/EEA, 2019) emission factors for oil. No solid fuels have been used in railways since 1970. All emission factors for railways and navigation are given in Table C.20 of Annex C. These are minor sources of emissions in Ireland. Emissions from military shipping are allocated to 1A3d, national navigation. or 1A3di(i), international maritime navigation, as appropriate.

The emissions reported in sub-category 1A3e Other Transportation refer to the use of natural gas in pipeline compressor stations and emission factors (country-specific and default values) for this sub-category are given in Table C.21 of Annex C. The fuel use is estimated as the difference between the value given for natural gas under own use/losses in the energy balance sheets (Annex B) and the amount of gas estimated to be lost from the distribution network.

3.7 Other Sectors (NFR 1A4)

The NFR Subcategory 1A4 Other Sectors covers combustion sources in the Commercial/Institutional (1A4a), the Residential (1A4b), and Agriculture/Forestry/Fishing (1A4c) sectors. The Residential sector remains the most important source of emissions for most substances in this subcategory in Ireland, while Agriculture/Forestry/Fishing is a major contributor to NO_X emissions, largely because of the influence of agricultural (off-road) machinery. The activity data for all 1A4 subcategories are taken directly from the energy balance. As there are no fuels allocated to the sector 1A4aii Commercial/Institutional: Mobile or 1A4bii Residential: Household and Gardening (Mobile) in national energy statistics, it is accounted for in category 1A3b Road Transport were gasoline fuel is fully accounted. Sector Residential (1A4b) Tier 1 emission factors from the Inventory guidebook (EMEP/EEA, 2019) are used for all fuels with the exception of Biomass. A Tier 2 method is applied to emissions from Woody Biomass using emission factors from Chapter 1A4 Table 3-44 for wood pellets and Table 3-43 for logs/wood briquettes. The emission factors for sub-category 1A4 Other Sectors are given in Tables C.22 through C.28 of Annex C.

3.7.1 Commercial / Institutional (NFR 1A4a) and Residential (1A4b)

Combustion in the residential sector is one of the principal sources of emissions, contributing 60 per cent of SO_2 emissions, 29 per cent of CO emissions and 55 per cent of $PM_{2.5}$ in 2019. This sector also contributes 41 per cent of Pb and 26 per cent of Hg emissions in 2019. This sector is also one of the principal sources of emissions of Dioxins and PAHs contributing 69 per cent and 90 per cent respectively in 2019. Coal burning in the residential sector is also an important but declining source of NMVOC emissions as coal consumption decreases. Significant fuel switching has been seen in the residential sector since 1990. Reduced use of coal (72 per cent) and peat (75 per cent), with increased use of liquid fuels gasoil and kerosene (200 per cent) and natural gas (404 per cent) and renewables (62 per cent) in these sectors has resulted in significant decreases in emissions since 1990. Between 1990 and 2019 decreases have been seen in SO_2 emissions (82 per cent), NMVOC emissions (71 per cent), CO (67 per cent), $PM_{2.5}$ (73 per cent), Pb (73 per cent), Hg (71 per cent), Dioxins (73 per cent) and PAHs (73 per cent) in the commercial/institutional and residential sectors.

3.7.2 Agriculture/Forestry/Fishing (NFR 1A4ci and ii)

This subcategory covers both stationary combustion (1A4ci) and mobile combustion (1A4cii) in Agriculture. The energy balance does not currently provide information on the end use of gasoil in agriculture. However, based on information received from agricultural experts, 90 per cent of total gasoil in the sector is assigned to mobile machinery with the remainder assigned to stationary

combustion. For both stationary and mobile combustion, the emission factors used are presented in Table C.26 of Annex C.

Ireland utilises the Tier 2 approach outlined in the Inventory Guidebook (EMEP/EEA, 2019) to estimate emissions of NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$ and TSP from mobile combustion in this sector. The Tier 2 emission factors are based on data from the Danish Inventory (Winther and Nielsen, 2006). The emission factors are grouped according to the EU emission legislation stages, and three additional layers are added to cover the emissions from engines prior to the first EU legislation stages. The country-specific SO_x emission factors and default Inventory Guidebook (EMEP/EEA, 2019) emission factors for NH_3 and BC are used for this sub-category. The implied emission factors are presented in Table C.27 of Annex C. Emission Factors for Heavy Metals and POPs are based on emission factors from the Inventory Guidebook (EMEP/EEA, 2009, 2019). The category 1A4ci Agriculture/Forestry/Fishing: Stationary, the NO_x Tier 1 liquid fuel emission factors from the Inventory Guidebook (EMEP/EEA, 2019) are an average of Tier 2 EFs and are not considered representative for Ireland for the same reasons as described in section 3.5.

3.7.4 Agriculture/Forestry/Fishing: National Fishing (NFR 1A4ciii)

Emissions from this sub-category were reported for the first time in the 2013 submission. The national energy balance now includes marine diesel used in national fishing for the all years from 1990 to 2019. The emission factors used for this sub-category are country-specific (SO_x) and Inventory Guidebook (EMEP/EEA, 2019) default values for all other pollutants and are presented in Table C.28 of Annex C.

3.8 Other Stationary and Mobile (including military) (NFR 1A5)

Ireland does not report any emissions under category 1A5. For NFR categories 1A5a and 1A5b notation key IE is used to indicate that military emissions (mobile and stationary) are included elsewhere as emissions are allocated in 1A4a and 1A3 (aviation and road). All stationary emissions from military are reported in sector 1A4a and all mobile military emission are reported under 1A3 (aviation and road).

3.9 Fugitive emissions from Solid Fuels (NFR 1B1)

3.9.1 Coal mining and handling (1B1a)

Emissions from the NFR subcategory 1B1a Coal mining are reported in this submission. The national energy balance includes coal mined in the years 1990 to 1995 when the last commercial coal mine was closed in Ireland. The emission factors used and the resulting time series of NMVOC, TSP, PM_{10} and $PM_{2.5}$ emissions are based on the Inventory Guidebook (EMEP/EEA, 2019) default values and are presented in Table 3.1.

Emissions of $PM_{2.5,}$ PM_{10} and TSP from the handling and storage of coal other than the domestic production has been estimated using an estimate of the area of coal storage and tonnes of coal handled in Ireland's only coal burning power plant and emission factors from Inventory Guidebook (EMEP/EEA, 2019).

Table 3.1. Fugitive Emissions from Coal mining and handling

Activity Data		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal mining	kt	25.00	1.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Area of coal storage	ha	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20	31.20
Coal handling	kt	1,867	2,248	2,145	2,130	1,305	1,373	1,745	1,459	1,417	1,695	1,656	1,305	735	228
Emission Factors															
Coal mining	kg NMVOC/t	0.80	0.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coal mining	kg TSP/t	0.09	0.09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coal mining	kg PM_{10}/t	0.04	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coal mining	kg $PM_{2.5}$/t	0.01	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Coal storage	t $PM_{2.5}$/ha	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Coal storage	t PM_{10}/ha	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
Coal storage	t TSP/ha	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
Coal handling	g $PM_{2.5}$/t	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Coal handling	g PM10/t	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Coal handling	g TSP/t	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Emissions															
Coal mining	kt NMVOC	0.020	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal mining	kt TSP	0.002	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal mining	kt PM_{10}	0.001	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal mining	kt $PM_{2.5}$	0.000	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal storage	kt $PM_{2.5}$	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Coal storage	kt PM_{10}	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128	0.128
Coal storage	kt TSP	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320
Coal handling	kt $PM_{2.5}$	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Coal handling	kt PM10	0.006	0.007	0.006	0.006	0.004	0.004	0.005	0.004	0.004	0.005	0.005	0.004	0.002	0.001
Coal handling	kt TSP	0.014	0.017	0.016	0.016	0.010	0.010	0.013	0.011	0.011	0.013	0.012	0.010	0.006	0.002

3.10 Fugitive emissions from Oil and Natural Gas (NFR 1B2)

3.10.1 Oil (NFR 1B2a)

The NFR subcategory 1B2a is an important source of fugitive NMVOC emissions. Emissions of NMVOCs are estimated from two sources, Refining/Storage (1B2aiv) and Distribution of Oil Products (1B2av). Emissions from Refining/Storage are estimated using a Tier 3 methodology using plant specific data for years 2007-2019 from Ireland's only refinery. An implied emission factor of 0.8818 kg/t was used for years before 2007 using an average of 2007-2016 implied emission factors and the crude oil throughput for the refinery.

The emissions from 1B2av, which is a key category, were estimated using a Tier 2 approach using emission factors and abatement efficiencies from the Inventory Guidebook (EMEP/EEA, 2019). The Stage I and Stage II abatement controls were applied as appropriate to the implementation of legislation in Ireland. The resulting time series of NMVOC emissions are presented in Table 3.2. Emissions of NMVOCs from these subcategories nearly doubled in the period from 1990 to 2007 in line with the increases in crude oil throughput for the refinery and petrol distribution for the transport sector but have since decreased due to the economic situation and the implementation of abatement controls in petrol distribution causing an overall decrease in most emissions. A slight increase in emissions in the Refining/Storage source can be seen from 2014 to 2017 due to increased crude oil throughput. The 2019 emissions have decreased in line with a decrease in crude oil throughput.

The refinery responded to a previous query from the inventory agency that the only fugitive emissions to air are for NMVOCs (emissions that occur through leakage, evaporation or other uncontrolled losses). The estimate is based on throughput, mass balance and industry (e.g. API) guideline emissions factors at the plant, tankage, jetty, road-loading and Waste Water Treatment Plant. Emissions from flaring are included in the totals for the other pollutants, as site emissions are calculated based on total metered fuel use. Therefore, reporting under 1A1b is complete for the plant and there should be no additional reporting under 1B2aiv except for NMVOC. The notation key "IE" included elsewhere is used for 1B2aiv for Cd, Hg and PCDD/F as all emissions from refineries including flaring are reported under category 1A1b. No heavy metal or dioxins to air are reported under LCP/PRTR/IPPC returns to the EPA in Ireland.

3.10.2 Natural Gas (NFR 1B2b)

Fugitive losses of NMVOC from pipelines and distribution systems are now estimated and reported for this the 2021 submission. These emissions are based on activity data of fugitive methane releases and gas analysis reports which give gas composition supplied by Gas Networks Ireland (GNI) in the greenhouse gas emission inventory. The description of this methodology is in section 3.3.2.2.3 of Irelands NIR (EPA 2021). Ireland has used existing information about leakage from greenhouse gas fugitive reporting to UNFCCC to estimate NMVOC emissions under this source category.

Table 3.2. Fugitive Non-Methane Volatile Organic Compound Emissions

Activity Data		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Crude to refineries	kt	1,804	2,229	3,278	3,309	2,905	2,949	3,068	2,838	2,752	3,366	3,200	3,181	3,024	2,531
Petrol distribution	kt	885	1,037	1,493	1,711	1,387	1,314	1,195	1,124	1,064	1,009	942	849	771	727
Emission Factors															
Crude to refineries	kg NMVOC/t	0.88	0.88	0.88	0.88	0.92	0.84	0.81	0.86	0.95	0.83	0.85	0.85	0.90	0.89
Petrol distribution	kg NMVOC/t	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Emissions															
Crude to refineries	kt NMVOC	1.59	1.96	2.89	2.92	2.66	2.49	2.48	2.45	2.62	2.80	2.73	2.72	2.73	2.25
Petrol distribution	kt NMVOC	1.79	2.10	3.30	3.81	3.15	2.97	2.60	2.22	2.12	1.95	1.76	1.77	1.37	1.30
Total emissions	kt NMVOC	3.37	4.06	6.18	6.72	5.80	5.46	5.08	4.67	4.74	4.75	4.50	4.49	4.10	3.55

3.10.2 Venting and flaring (oil, gas, combined oil and gas) (NFR1B2c)

Regarding the flares at refineries, all emissions have been included within the category 1A1b Petroleum Refining, as site emissions were calculated based on total metered fuel use.

3.11 Recalculations in the Energy Sector

The results of recalculations for the combustion categories 1A1, 1A2, 1A3 and 1A4 are given in Tables 3.3 through 3.7 below. Ireland carried out a review of emission factors and updated all air pollutant, heavy metals and POPs to the most recent version of Inventory guidebook (EMEP/EEA, 2019) where appropriate.

1A1b Petroleum refining There were recalculations to heavy metals Pb, Cd and Hg emissions in this category due to updates to refinery gas and natural gas emission factors in table 4.2 and 4.6 of the Inventory guidebook (EMEP/EEA, 2019).

1A2 Manufacturing Industry and Construction sector and 1A4 Other sectors

In this submission, there are extensive recalculation changes based on significant revisions to the historical energy balances going back as far as 1990. This is because the national energy balance provided by SEAI now incorporates a major new data set on business energy use. This Business Energy Use Survey (BEUS), was first published by the Central Statistics Office (CSO) in December 2018. This valuable new data source provides a new basis for the breakdown of energy use in the commercial services, public services and industrial sectors, at a level of detail not previously available. SEAI have revised the National Energy Balances from 1990 to 2018 incorporating this new improved data. In some cases, the revisions to estimates of business energy use have had knock on effects in other sectors, particularly the residential, leading to revisions there also.

The national energy balance was previously based on a top down approach whereas the new Business Energy use survey compiles aggregated data based on a bottom up approach with individual businesses grossed to national level. The revised bottom up approach now draws on a cross-sourcing of data using the emissions trading scheme, and various energy efficiency measures such as the large industry energy network, public sector energy programme, census of industrial production and others. The revised approach (BEUS) has focused on data from 2009 to 2017 with energy data for 2018 and 2019 based on the 2017 breakdowns between sectors.

In the Manufacturing Industry and Construction sector 1.A.2, there has been an extensive redistribution of oil and natural gas between the energy sub-sectors. From 1990-1996, oil use in this sector increased as a result of reallocating oil use within the commercial/institutional sector 1.A.4.a to 1.A.2. From 1997-2018, there was a significant redistribution of oil from 1.A.2 to 1.A.4.a and 1.A.4.b. In turn, there was a significant redistribution of natural gas from 1.A.4.a to 1.A.2 from 2001 to 2018 (with the exception of 2004 and 2006, where the quantities in these two years were allocated to 1.A.4.a).

The disaggregated trend differences revolves around the redistribution of oil and natural gas. Generally, there is now less oil allocated to 1A2b, 1A2c, 1A2d, 1A2e and 1A2f across the timeseries with more attributed to 1A2g from 1990-2004 and less thereafter. In terms of Natural gas, the significant changes occur where there is less allocated to 1A2b from 2011 and 1A2g from 2009 onwards. Increases in gas allocation is now attributed to 1A2c and 1A2e from 2007-2019.

The changes to the energy balance resulted in a reduction in emissions in 1A2 for NOx (3.5 per cent on average), SO$_2$ (1.6 per cent on average) for each year of the entire time series 1990-2018.

In addition, for category 1A2f Stationary Combustion in Manufacturing Industries and Construction; Non-metallic minerals a review recommendation (IE-1A2f-2018-0002) was made to calculate the Cd and Hg emissions using Tier 2 or Tier 3 methods. It was not possible to implement a Tier 2 approach for the entire sector 1A2f as fuel data is not available for every operation within this category. However, for the cement sector with 4 plants, fuel data was available for the years 2005 to 2019 from the EU Emissions Trading Scheme. Ireland has now implemented an approach for POPs and heavy metals in the cement sector for these years using EFs based on clinker production from Table 3-24 of the Inventory guidebook (EMEP/EEA, 2019). The results of this are discussed in section 3.5 Manufacturing industries and Construction (NFR 1A2). The methodology for estimating emissions from cement manufacture in 1A2f was updated using plant specific emissions for Pb, Cd and Hg. This resulted in recalculations for Pb -41.1%, Cd -8.5%, Hg +18.7% on average for the entire time series 1990-2018. For other metals As, Cr, Cu, Ni, Se, Zn the Tier 2 emission factors from Table 3-24 Chapter 1A2 were used with plant clinker production to estimate emissions.

1A3 Transport

This submission includes a number of improvements in input data specifically related to Ireland's vehicle fleet and km travel distribution. The passenger diesel cars now contain a medium category which is a significant improvement in representation given the high proportion of diesel cars that fall into this category in Ireland. The distribution of HGVs is now better aligned to their relevant COPERT laden categories which also provides more credible data in terms of output emissions. The result of this change means we now have a greater number of HGVs in the heavier categories.

As a result of the above changes, there are numerous recalculations at a disaggregated level for air pollutant emissions within this submission using COPERT 5.4.36 compared to the previous submission.

- NOx: Overall, NOx emissions have increased by on average 7.9 per cent per year across the time series 1990-2018. The redistribution has meant that LDV and HGV emissions have both increased. LDV diesel increased by 1.7 per cent per annum and HGV diesel increased by 7.7 per cent each year on average across the time series 1990-2018.

- NH$_3$ emissions: Overall ammonia emissions have increased on average by 3.2 per cent per year over the 1990-2018 timeseries. Diesel cars and buses both declined on average 1.4 per cent and 0.8 per cent, respectively each year whilst LDV diesel increased by 0.4 per cent and HGV diesel increased by 6.2 per cent, respectively each year on average across the time series 1990-2018.

- Heavy metal emissions: Pb, Cd and Hg all decreased slightly across the time series and there are reductions in Pb (1.9 per cent on average), Cd (3.5 per cent on average) and Hg (2.4 per cent on average) across the timeseries 1990-2018 as a result of improvements and changes to the input data.

1B2b Fugitive emissions from Natural gas

For fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other) (NFR 1B2b), a review of the reporting under this category was undertaken in conjunction with the operator of the natural gas refinery. In response to a question raised during the

2019 NECD review (IE-1B2b-2017-0001), the company which operates the 'Bellanaboy Bridge Gas Terminal' provided a statement in which it is stated that 'no significant VOC emissions were observed' when using a LIDAR system for measuring ambient NMVOC emissions. Ireland has used existing information about leakage from greenhouse gas fugitive emission reporting to the UNFCCC to estimate NMVOC emissions. Fugitive losses of NMVOC from pipelines and distribution systems are estimated in this submission.

Overall recalculations are presented in Tables 3.3-3.7 below

Table 3.3. Recalculations in Energy NFR 1A1

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
1A1a Public Electricity and Heat Production	NOx	kt	46.37	41.39	39.72	32.38	13.78	11.92	8.37	10.53	9.09	7.81	9.82	8.31	8.12	6.74
	SO2	kt	103.04	91.63	79.87	42.50	16.11	9.78	9.73	9.84	8.95	6.20	5.51	3.96	3.98	2.84
	NMVOC	kt	0.19	0.25	0.36	0.37	0.35	0.37	0.31	0.30	0.27	0.26	0.26	0.30	0.30	0.29
	Pb	t	0.63	0.75	0.78	0.73	0.45	0.44	0.44	0.54	0.47	0.48	0.54	0.52	0.45	0.35
	Cd	t	0.09	0.11	0.12	0.11	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	0.04
	Hg	t	0.12	0.13	0.13	0.13	0.09	0.09	0.09	0.11	0.09	0.10	0.11	0.11	0.10	0.07
1A1b Petroleum Refining	NOx	kt	0.47	0.52	0.77	0.94	0.75	0.80	0.63	0.68	0.58	0.54	0.38	0.32	0.26	0.33
	SO2	kt	0.48	0.51	0.78	0.91	0.88	0.67	0.90	0.43	0.57	0.01	0.03	0.02	0.03	0.03
	NMVOC	kt	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01
	Pb	t	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	Cd	t	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A1c Manufacture of Solid Fuels and Other Energy Industries	NOx	kt	0.16	0.12	0.15	0.29	0.25	0.32	0.21	0.18	0.22	0.22	0.24	0.32	0.11	0.20
	SO2	kt	0.13	0.10	0.12	0.16	0.14	0.21	0.25	0.24	0.19	0.03	0.09	0.25	0.11	0.10
	NMVOC	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pb	t	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02
Submission 2021																
1A1a Public Electricity and Heat Production	NOx	kt	46.37	41.39	39.72	32.38	13.78	11.92	8.37	10.53	9.09	7.81	9.82	8.31	8.12	6.74
	SO2	kt	103.04	91.63	79.87	42.50	16.11	9.78	9.73	9.84	8.95	6.20	5.51	3.96	3.98	2.84
	NMVOC	kt	0.19	0.25	0.36	0.37	0.35	0.37	0.31	0.30	0.27	0.26	0.26	0.30	0.30	0.29
	Pb	t	0.63	0.75	0.78	0.73	0.46	0.45	0.46	0.57	0.51	0.52	0.57	0.59	0.52	0.41
	Cd	t	0.09	0.11	0.12	0.11	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	0.05
	Hg	t	0.12	0.13	0.13	0.13	0.09	0.10	0.09	0.11	0.10	0.10	0.11	0.12	0.11	0.07
1A1b Petroleum Refining	NOx	kt	0.47	0.52	0.77	0.94	0.75	0.80	0.63	0.68	0.58	0.54	0.38	0.32	0.26	0.33
	SO2	kt	0.48	0.51	0.78	0.91	0.88	0.67	0.90	0.43	0.57	0.01	0.03	0.02	0.03	0.03
	NMVOC	kt	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01
	Pb	t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
	Cd	t	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A1c Manufacture of Solid Fuels and Other Energy Industries	NOx	kt	0.16	0.12	0.15	0.29	0.25	0.32	0.21	0.18	0.22	0.22	0.24	0.32	0.11	0.53
	SO2	kt	0.13	0.10	0.12	0.16	0.14	0.21	0.25	0.24	0.19	0.03	0.09	0.25	0.11	0.37
	NMVOC	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pb	t	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02

Table 3.3. Recalculations in Energy NFR 1A1 (continued)

% Change in Emissions	Pollutant		1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1A1a Public Electricity and Heat Production	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.4%
	Pb	%	0.0%	0.0%	0.0%	0.0%	1.9%	4.0%	5.3%	5.8%	8.6%	9.9%	6.5%	14.1%	15.8%	18.0%
	Cd	%	-0.1%	-0.1%	-0.1%	-0.2%	0.8%	2.1%	3.2%	3.6%	5.6%	6.5%	4.1%	9.3%	10.6%	12.3%
	Hg	%	0.0%	0.0%	0.0%	0.0%	0.7%	1.4%	1.9%	2.1%	3.1%	3.6%	2.3%	4.8%	5.0%	6.7%
1A1b Petroleum Refining	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	-0.1%	-0.2%	0.3%	30.1%	38.4%	3.1%	-6.3%	0.9%	-5.8%	1.0%	3.5%
	Pb	%	-5.1%	-6.0%	-4.9%	-5.5%	-6.0%	-7.1%	56.5%	85.8%	-2.2%	-18.5%	-8.4%	-17.7%	-7.7%	-4.4%
	Cd	%	124.2%	140.9%	120.7%	132.5%	143.5%	174.3%	422.4%	531.3%	227.1%	169.7%	212.1%	180.1%	207.1%	211.7%
	Hg	%	88.4%	105.9%	96.9%	109.2%	145.7%	168.3%	203.7%	254.1%	187.1%	133.4%	224.7%	170.2%	181.2%	172.0%
1A1c Manufacture of Solid Fuels and Other Energy Industries	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	164.7%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	257.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pb	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Cd	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Hg	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 3.4. Recalculations in Energy NFR 1A2

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
1A2 Manufacturing Industries and Construction	NOx	kt	8.93	8.05	10.53	17.31	10.35	9.93	8.46	10.46	10.53	10.98	10.96	11.18	10.16	9.42
	SO2	kt	32.79	40.18	42.03	13.13	5.11	5.87	5.24	4.49	4.87	3.34	2.46	2.57	2.63	2.67
	NMVOC	kt	1.67	1.27	1.77	2.78	2.34	2.46	2.25	2.23	2.28	2.76	2.88	2.90	3.07	3.12
	Pb	t	1.73	1.10	1.51	2.09	1.24	1.24	1.03	0.97	0.90	1.04	1.03	1.04	1.03	1.07
	Cd	t	0.06	0.05	0.08	0.12	0.09	0.10	0.09	0.08	0.09	0.10	0.11	0.11	0.12	0.12
	Hg	t	0.09	0.04	0.06	0.09	0.06	0.06	0.06	0.06	0.05	0.06	0.07	0.07	0.07	0.07
Submission 2021																
1A2 Manufacturing Industries and Construction	NOx	kt	9.11	8.03	10.32	16.48	9.63	9.07	7.48	9.31	9.50	10.35	10.34	10.64	9.79	9.20
	SO2	kt	33.04	40.22	42.02	12.74	4.86	5.81	4.92	4.20	4.63	3.22	2.37	2.45	2.53	2.67
	NMVOC	kt	1.69	1.26	1.72	2.69	2.32	2.48	2.20	2.14	2.22	2.74	2.85	2.90	3.09	3.14
	Pb	t	1.20	0.85	1.08	1.16	0.61	0.65	0.52	0.48	0.49	0.50	0.52	0.48	0.49	0.50
	Cd	t	0.05	0.05	0.07	0.11	0.08	0.09	0.08	0.07	0.07	0.08	0.09	0.08	0.09	0.09
	Hg	t	0.08	0.05	0.08	0.10	0.06	0.06	0.06	0.06	0.06	0.06	0.12	0.11	0.14	0.11
% Change in Emissions																
1A2 Manufacturing Industries and Construction	NOx	%	2.1%	-0.2%	-2.0%	-4.8%	-6.9%	-8.7%	-11.5%	-11.0%	-9.8%	-5.7%	-5.7%	-4.8%	-3.6%	-2.4%
	SO2	%	0.8%	0.1%	0.0%	-3.0%	-4.9%	-1.0%	-6.1%	-6.3%	-5.0%	-3.7%	-3.4%	-4.6%	-3.7%	0.0%
	NMVOC	%	1.1%	-0.8%	-2.4%	-3.0%	-0.9%	0.6%	-2.4%	-3.7%	-2.5%	-0.5%	-0.9%	-0.1%	0.6%	0.9%
	Pb	%	-30.4%	-22.6%	-28.1%	-44.6%	-51.1%	-47.4%	-48.9%	-50.7%	-45.5%	-51.9%	-50.0%	-53.7%	-52.4%	-53.9%
	Cd	%	-6.0%	0.3%	-0.8%	-5.2%	-13.3%	-11.1%	-12.2%	-16.4%	-15.5%	-19.3%	-18.7%	-21.2%	-20.9%	-21.7%
	Hg	%	-10.0%	18.6%	30.8%	9.2%	6.8%	-0.2%	-3.1%	8.4%	19.3%	-2.8%	85.7%	67.5%	115.0%	65.5%

Table 3.5. Recalculations in Energy NFR 1.A.3 (a & b)*

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
1A3a(i) & (ii) International and Domestic Aviation	NOx	kt	4.80	5.15	8.10	11.08	9.90	10.00	8.80	7.44	8.74	9.81	11.17	11.46	13.63	14.56
	SO2	kt	0.30	0.32	0.50	0.68	0.61	0.63	0.56	0.47	0.54	0.60	0.68	0.69	0.81	0.88
	NMVOC	kt	0.24	0.24	0.37	0.43	0.44	0.48	0.42	0.38	0.41	0.42	0.44	0.45	0.47	0.48
1A3b Road Transportation	NOx	kt	55.09	55.54	61.81	56.79	43.18	38.50	37.22	35.44	37.00	38.63	39.48	39.28	37.24	35.97
	SO2	kt	5.37	5.13	1.66	0.54	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05
	NMVOC	kt	33.55	31.32	23.08	15.60	10.40	9.05	8.19	7.33	6.88	6.42	5.95	5.27	4.41	3.86
	NH3	kt	0.04	0.42	1.70	2.50	1.80	1.53	1.35	1.17	1.06	0.96	0.89	0.80	0.68	0.61
	PM2.5	kt	2.29	2.61	3.47	3.10	2.56	2.35	2.19	2.04	2.06	2.05	2.03	1.91	1.65	1.57
	Pb	t	143.97	87.50	5.76	1.57	1.46	1.34	1.32	1.27	1.32	1.35	1.42	1.45	1.43	1.45
	Cd	t	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Hg	t	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Submission 2021																
1A3a(i) & (ii) International and Domestic Aviation	NOx	kt	4.80	5.15	8.10	11.08	9.90	10.00	8.80	7.44	8.74	9.81	11.17	11.46	13.63	14.56
	SO2	kt	0.30	0.32	0.50	0.68	0.61	0.63	0.56	0.47	0.54	0.60	0.68	0.69	0.81	0.88
	NMVOC	kt	0.24	0.24	0.37	0.43	0.44	0.48	0.42	0.38	0.41	0.42	0.44	0.45	0.47	0.48
1A3b Road Transportation	NOx	kt	56.88	57.80	67.84	63.67	48.55	43.38	41.34	39.28	40.70	41.95	42.36	41.57	37.68	34.76
	SO2	kt	5.37	5.13	1.66	0.54	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.04
	NMVOC	kt	33.15	31.00	23.11	15.99	10.75	9.30	8.43	7.52	7.00	6.53	6.05	5.36	4.48	3.92
	NH3	kt	0.05	0.42	1.72	2.51	1.82	1.54	1.38	1.19	1.08	0.98	0.90	0.81	0.68	0.61
	PM2.5	kt	2.20	2.52	3.56	3.21	2.52	2.28	2.14	1.99	2.02	2.01	1.98	1.85	1.62	1.53
	Pb	t	143.94	87.46	5.68	1.50	1.44	1.33	1.30	1.24	1.27	1.31	1.37	1.38	1.37	1.38
	Cd	t	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Hg	t	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
% Change in Emissions																
1A3a(i) & (ii) International and Domestic Aviation	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1A3b Road Transportation	NOx	%	3.2%	4.1%	9.8%	12.1%	12.4%	12.7%	11.1%	10.8%	10.0%	8.6%	7.3%	5.8%	1.2%	-3.4%
	SO2	%	0.0%	0.0%	0.0%	0.0%	-2.0%	-2.6%	-2.8%	-2.5%	-3.0%	-3.4%	-3.4%	-3.0%	-4.1%	-3.9%
	NMVOC	%	-1.2%	-1.0%	0.2%	2.5%	3.4%	2.8%	2.9%	2.6%	1.7%	1.7%	1.7%	1.6%	1.7%	1.6%
	NH3	%	23.2%	2.0%	1.3%	0.6%	1.1%	1.0%	1.8%	1.2%	1.5%	1.5%	1.5%	1.1%	0.5%	0.1%
	PM2.5	%	-4.0%	-3.6%	2.5%	3.5%	-1.7%	-3.0%	-2.3%	-2.1%	-2.1%	-2.0%	-2.4%	-3.0%	-1.7%	-2.1%
	Pb	%	0.0%	0.0%	-1.4%	-4.8%	-1.8%	-1.4%	-1.8%	-1.8%	-3.3%	-3.5%	-3.7%	-4.3%	-4.5%	-4.8%
	Cd	%	-4.2%	-4.8%	-4.4%	-3.4%	-1.3%	-1.1%	-1.5%	-1.5%	-2.9%	-3.1%	-3.3%	-3.8%	-3.9%	-4.1%
	Hg	%	0.0%	0.0%	0.0%	0.0%	-4.2%	-5.6%	-5.9%	-5.5%	-6.3%	-6.8%	-7.3%	-6.8%	-8.7%	-8.4%

* Emissions from both LTO and cruise are included here to capture all possible recalculations. However, the cruise component is reported as a memo item under the LRTAP Convention.

Table 3.6. Recalculations in Energy NFR 1A3 (c, d & e)

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
1A3c Railways	NOx	kt	2.20	1.84	2.03	2.02	2.03	2.01	2.03	1.95	1.94	1.78	1.81	1.85	1.91	1.93
	SO2	kt	0.25	0.14	0.12	0.11	0.06	0.06	0.06	0.06	0.05	0.02	0.02	0.01	0.01	0.00
	NMVOC	kt	0.20	0.16	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.16	0.16	0.16	0.17	0.17
	PM2.5	kt	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Pb	t	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1A3d(ii) National Navigation	NOx	kt	2.14	2.29	3.78	5.20	4.88	4.90	4.25	4.49	4.39	5.50	5.43	6.52	5.76	6.37
	SO2	kt	1.16	1.26	1.22	0.67	0.10	0.10	0.08	0.09	0.08	0.05	0.03	0.03	0.09	0.11
	NMVOC	kt	0.07	0.08	0.13	0.18	0.17	0.17	0.15	0.16	0.16	0.20	0.19	0.23	0.21	0.23
	PM2.5	kt	0.12	0.13	0.17	0.17	0.09	0.09	0.08	0.08	0.08	0.10	0.10	0.12	0.10	0.11
	Pb	t	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3e(i) Pipeline Compressors	NOx	kt	0.06	0.11	0.05	0.13	0.13	0.14	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.12
Submission 2021																
1A3c Railways	NOx	kt	2.20	1.84	2.03	2.02	2.03	2.01	2.03	1.95	1.94	1.78	1.81	1.85	1.91	1.93
	SO2	kt	0.25	0.14	0.12	0.11	0.06	0.06	0.06	0.06	0.05	0.02	0.02	0.01	0.01	0.00
	NMVOC	kt	0.20	0.16	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.16	0.16	0.16	0.17	0.17
	PM2.5	kt	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Pb	t	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1A3d(ii) National Navigation	NOx	kt	2.14	2.29	3.78	5.20	4.88	4.90	4.25	4.49	4.39	5.50	5.43	6.52	5.76	6.37
	SO2	kt	1.16	1.26	1.22	0.67	0.10	0.10	0.08	0.09	0.08	0.05	0.03	0.03	0.09	0.11
	NMVOC	kt	0.07	0.08	0.13	0.18	0.17	0.17	0.15	0.16	0.16	0.20	0.19	0.23	0.21	0.23
	PM2.5	kt	0.12	0.13	0.17	0.17	0.09	0.09	0.08	0.08	0.08	0.10	0.10	0.12	0.10	0.11
	Pb	t	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A3e(i) Pipeline Compressors	NOx	kt	0.06	0.11	0.05	0.13	0.12	0.14	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.12
% Change in Emissions																
1A3c Railways	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PM2.5	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pb	%	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Hg	%	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1A3d(ii) National Navigation	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PM2.5	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pb	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Hg	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1A3e(i) Pipeline Compressors	NOx	%	-1.0%	-0.5%	-1.0%	-0.4%	-1.1%	-1.3%	-1.0%	-0.6%	-0.4%	-0.1%	0.0%	0.2%	0.2%	0.3%

Table 3.7. Recalculations in Energy NFR 1A4

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
1A4a Commercial/Institutional	NOx	kt	3.06	2.84	3.16	3.31	3.12	3.12	2.86	2.87	2.67	2.44	2.46	2.60	2.75	2.92
	SO2	kt	11.52	5.54	2.38	1.93	0.71	0.67	0.61	0.59	0.46	0.20	0.16	0.12	0.33	0.37
	NMVOC	kt	0.47	0.42	0.53	0.63	0.60	0.62	0.55	0.57	0.56	0.53	0.55	0.59	0.62	0.67
	NH3	kt	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.04	0.03	0.03
	PM2.5	kt	0.56	0.40	0.39	0.48	0.31	0.30	0.29	0.28	0.25	0.22	0.20	0.21	0.22	0.22
	Pb	t	0.58	0.38	0.37	0.49	0.29	0.27	0.27	0.25	0.22	0.19	0.17	0.18	0.19	0.19
	Cd	t	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01
	Hg	t	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4b Residential	NOx	kt	7.33	5.79	5.43	5.92	6.14	6.34	5.43	5.16	5.35	4.76	4.97	4.94	4.66	5.01
	SO2	kt	26.76	17.32	15.07	12.22	9.15	8.80	8.05	7.62	8.29	7.00	6.69	6.66	6.16	5.97
	NMVOC	kt	28.52	18.05	12.35	10.99	11.38	10.75	9.97	9.73	10.46	8.93	8.68	8.05	7.24	7.55
	NH3	kt	0.15	0.10	0.06	0.05	0.06	0.06	0.05	0.06	0.07	0.06	0.06	0.06	0.06	0.06
	PM2.5	kt	23.91	15.16	10.34	9.21	9.55	9.03	8.37	8.19	8.81	7.53	7.33	6.82	6.13	6.39
	Pb	t	7.40	4.67	3.20	2.84	2.96	2.79	2.59	2.52	2.70	2.31	2.25	2.08	1.87	1.95
	Cd	t	0.11	0.07	0.05	0.04	0.05	0.05	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04
	Hg	t	0.29	0.19	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.09	0.09	0.08	0.08
1A4c Agriculture/Forestry/Fishing	NOx	kt	8.76	14.31	12.91	12.76	8.57	7.43	6.56	6.19	5.55	4.84	4.27	4.05	4.21	4.50
	SO2	kt	1.41	1.34	0.94	0.86	0.42	0.37	0.06	0.09	0.08	0.05	0.04	0.04	0.05	0.03
	NMVOC	kt	1.38	1.71	1.35	1.09	0.69	0.60	0.53	0.48	0.40	0.34	0.30	0.29	0.29	0.30
	NH3	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PM2.5	kt	0.93	1.05	0.76	0.60	0.37	0.32	0.28	0.25	0.21	0.17	0.15	0.14	0.14	0.14
	Pb	t	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Submission 2021																
1A4a Commercial/Institutional	NOx	kt	2.88	2.70	2.58	2.56	2.15	2.26	2.16	2.26	2.36	2.24	2.32	2.37	2.29	2.40
	SO2	kt	11.27	5.37	1.84	1.33	0.34	0.35	0.31	0.27	0.28	0.16	0.14	0.16	0.24	0.21
	NMVOC	kt	0.46	0.42	0.49	0.58	0.48	0.51	0.50	0.54	0.54	0.51	0.54	0.54	0.54	0.56
	NH3	kt	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.04	0.03	0.03
	PM2.5	kt	0.53	0.37	0.27	0.34	0.18	0.17	0.16	0.16	0.19	0.19	0.18	0.19	0.17	0.18
	Pb	t	0.55	0.36	0.26	0.35	0.16	0.15	0.14	0.14	0.16	0.16	0.15	0.17	0.15	0.15
	Cd	t	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01
	Hg	t	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1A4b Residential	NOx	kt	7.32	5.86	5.84	6.56	6.87	7.02	6.10	5.78	5.76	5.08	5.33	5.30	5.23	5.73
	SO2	kt	26.76	17.46	15.62	12.95	9.60	9.23	8.47	8.18	8.83	7.74	7.54	7.41	7.80	8.23
	NMVOC	kt	28.52	18.05	12.35	11.00	11.39	10.76	9.97	9.88	10.73	9.53	9.38	8.67	8.54	9.46
	NH3	kt	0.15	0.10	0.06	0.05	0.06	0.06	0.05	0.06	0.07	0.06	0.06	0.06	0.06	0.07
	PM2.5	kt	23.91	15.16	10.35	9.23	9.57	9.04	8.38	8.33	9.04	8.03	7.92	7.33	7.22	7.99
	Pb	t	7.40	4.67	3.20	2.84	2.96	2.79	2.59	2.55	2.78	2.47	2.43	2.24	2.20	2.44
	Cd	t	0.11	0.07	0.05	0.04	0.05	0.05	0.04	0.04	0.05	0.04	0.05	0.04	0.04	0.04
	Hg	t	0.29	0.19	0.13	0.12	0.13	0.12	0.11	0.11	0.12	0.10	0.10	0.10	0.09	0.10
1A4c Agriculture/Forestry/Fishing	NOx	kt	8.76	14.31	12.91	12.76	8.57	7.43	6.56	6.19	5.55	4.84	4.27	4.05	4.21	4.50
	SO2	kt	1.41	1.34	0.94	0.86	0.42	0.37	0.06	0.09	0.08	0.05	0.04	0.04	0.05	0.03
	NMVOC	kt	1.38	1.71	1.35	1.09	0.69	0.60	0.53	0.48	0.40	0.34	0.30	0.29	0.29	0.30
	NH3	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PM2.5	kt	0.93	1.05	0.76	0.60	0.37	0.32	0.28	0.25	0.21	0.17	0.15	0.14	0.14	0.14
	Pb	t	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
	Cd	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hg	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

% Change in Emissions	Pollutant		1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1A4a Commercial/Institutional	NOx	%	-5.9%	-4.9%	-18.5%	-22.7%	-31.0%	-27.7%	-24.6%	-21.1%	-11.5%	-8.4%	-5.8%	-8.6%	-16.7%	-17.7%
	SO2	%	-2.2%	-3.1%	-22.6%	-31.3%	-51.3%	-47.0%	-49.6%	-54.6%	-39.9%	-20.9%	-12.1%	33.4%	-28.1%	-42.9%
	NMVOC	%	-3.9%	-1.2%	-7.1%	-7.4%	-20.9%	-17.7%	-7.8%	-5.8%	-2.5%	-4.5%	-2.9%	-8.0%	-13.8%	-15.5%
	NH3	%				0.0%	0.0%	0.1%	-10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.5%
	PM2.5	%	-5.3%	-7.4%	-29.0%	-30.3%	-43.5%	-41.8%	-45.9%	-42.0%	-24.4%	-13.5%	-10.5%	-7.4%	-20.2%	-20.2%
	Pb	%	-5%	-7%	-30%	-29%	-45%	-44%	-49%	-45%	-27%	-15%	-11%	-7%	-21%	-21%
	Cd	%	-5%	-8%	-30%	-31%	-19%	-20%	-25%	-15%	-6%	-3%	-3%	-2%	-5%	-6%
	Hg	%	-1%	-3%	-12%	-4%	-23%	-22%	-15%	-11%	-4%	-3%	-1%	-2%	-10%	-11%
1A4b Residential	NOx	%	0.0%	1.4%	7.5%	10.9%	11.8%	10.6%	12.5%	11.9%	7.8%	6.7%	7.2%	7.1%	12.3%	14.5%
	SO2	%	0.0%	0.8%	3.6%	6.0%	4.9%	4.8%	5.2%	7.4%	6.5%	10.6%	12.7%	11.1%	26.6%	37.9%
	NMVOC	%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	1.5%	2.6%	6.7%	8.1%	7.6%	17.9%	25.3%
	NH3	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	2.0%	5.0%	5.8%	4.8%	11.2%	18.2%
	PM2.5	%	0.0%	0.0%	0.1%	0.2%	0.2%	0.2%	0.2%	1.6%	2.7%	6.7%	8.1%	7.6%	17.8%	25.2%
	Pb	%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	1.5%	2.6%	6.7%	8.1%	7.6%	18.1%	25.4%
	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	2.2%	5.6%	6.1%	5.6%	13.7%	19.2%
	Hg	%	0.0%	0.1%	0.7%	1.3%	1.3%	1.3%	1.4%	2.7%	3.2%	6.8%	8.0%	7.6%	17.4%	24.0%
1A4c Agriculture/Forestry/Fishing	NOx	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	SO2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	NH3	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	PM2.5	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pb	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Hg	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

3.12 Quality Assurance/Quality Control

The time series spreadsheet system developed for individual categories, together with direct linking to the energy balance, allows for simple and efficient checking of activity data, emission factors, annual emissions and aggregated totals. Year-on-year changes immediately highlight any omissions, anomalies or internal errors. Initial checks are conducted by the inventory compiler as part of the calculation process, which is followed by a second check and completion of the QA/QC sheets which are integral to the calculation workbooks by another member of the inventories team. Cross-checks are performed for fuel data against the available supplementary sources for categories, such as 1A1a Public Electricity and Heat Production and some industrial processes, while maintaining consistency with fuel-use application in the estimation of GHG emissions. When new versions of the COPERT model are introduced for calculations in 1A3b, the previous year's activity data is run in the new model to compare with the current year, and the current year's activity data is run in the old version of the model to compare with the previous year. This allows firstly for identification of changes due to the model, and secondly for identification of changes due to the activity data.

3.13 Planned Improvements

The nature of the substances covered in transboundary emission inventories and the diverse range of sources involved, many of which are unintentional or uncontrolled releases, inevitably result in estimates that can be highly uncertain. There is heavy reliance on default emission factors made available through the Inventory Guidebook or other references, which are often based on limited information or which can only be applied in a limited or aggregated way because the necessary detailed activity data are not available. For some substances and categories, the emissions must be estimated in an indirect way, such as on a per-capita basis, which adds further to level of uncertainty.

This submission included checks on emission factors based on the latest Inventory Guidebook and this work will continue in future submissions with changes made where appropriate. The inventory agency plans to account more completely for technological improvements over time by attempting to apply Tier 2 emission factors that refer to different types of stationary combustion appliance for the fuels in common usage, especially in sub-categories 1A4a Commercial/Institutional combustion and 1A4b(i) Residential combustion. Ireland has investigated the use of Tier 2 method for 1A4bi Residential emissions of PAHs, PCBs, Cd, Hg, Pb and PCDD/F following a review recommendation (IE-1A4bi-2018-0002). The EU 28 average fuel use and technology type is not reflective of Irish conditions and technologies and the fuel use/technology type split are not available so Tier 1 must be used in Ireland's inventory for this category.

All emissions associated with the category 1A2g are reported in 1A2gviii, and mobile emissions, 1A2gvii, are reported as "included elsewhere" (IE) in 1A2gviii. Currently all fuel is assumed to be stationary as the energy balance does not provide an estimate for fuels used in mobile machinery. The inventory agency has tendered research to be undertaken to quantify the extent and amounts of fuel used by mobile combustion in mobile machinery and this research is currently being carried out and was due to finish by the end of 2020. Due to unprecedented circumstances surrounding remote working and subsequent issues collecting data the outcomes of this project will not now be ready until

August 2021. The outcomes may be implemented for the inventory submission in 2022 for 1990-2020 data or if delayed in 2023.

For category 1A3dii National navigation (shipping) Ireland uses a Tier 1 method to estimate NOx emissions. Ireland will investigate the feasibility of using a higher Tier approach for this category in its next submission.

For fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other) (NFR 1B2b) flaring has occurred at offshore gas facilities in the years 1999 and 2001 only, during commissioning of new wells. Only GHG emissions are reported in Ireland's inventories. It is planned to review information on fugitive emissions from natural gas flaring and report emissions of air pollutants where appropriate in the next submission. Ireland has 1 on-shore gas refinery (offshore wells are on the seabed) which commenced operation in late December 2015, which had flaring episodes in 2015 and in 2017. The emissions associated with these flaring episodes will be included in the next submission.

Ireland carried out a review of emission factors and updated all air pollutant, heavy metals and POPs to those in the latest version of the Inventory guidebook (EMEP/EEA, 2019) where possible. This review of emission factors highlighted some changes which Ireland plans to make to align emission factors for the next submission. The inventory agency will also endeavour to reduce the remaining instances of the use of notation key "NE" by providing an estimate or concluding that the source category does not occur "NO" in future submissions.

Review recommendations and responses are included in this report as Annex H.

3.14 Memo Items

The memo items of the NFR reporting format refer to activities for which the emissions are excluded from national totals. The use of fuels in domestic and international aviation (cruise phase) and marine bunkers are the most important of these activities. Some of the associated emissions, particularly from international aviation, are increasing very rapidly and it is therefore important that they are closely monitored for comparison with other sources and for the benefit of the international organisations that will have to develop control strategies for them in the future. The estimation of emissions for memo items is described here because they are calculated as part of the general estimation procedures for the Energy sector.

The national energy balance sheets include marine bunkers as a specific item and the emissions may be calculated directly. The approach used to for the cruise element of aviation is explained in Section 3.6.1 and this data is provided to SEAI for inclusion in the national energy balance.

Emission factors for international cruise aviation and navigation are documented in Tables C.19 and C.29 of Annex C.

Chapter Four

Industrial Processes and Product Use

4.1 Overview of the Industrial Processes and Product Use (NFR 2) Sector

The Industrial Processes sector has historically not been a large source of emissions in Ireland. Indeed, major industrial processes within the chemical sector and metal production that are common to many other developed countries have never been part of the economy in Ireland. Hence, many of the production processes within this sector are not relevant to the inventories of air pollutants in Ireland. Also, of note is the fact that for a number of pollutants, it has not been possible to separate emissions from the combustion of fuel within industry and those associated with production processes. For all industries, fuel-based estimates of emissions have been collated and are reported under NFR Sector 1A2 (Manufacturing Industries and Construction). Where specific information is available in relation to process emissions as distinct from those associated with fuel combustion, they are reported under NFR Sector 2 (Industrial Processes and Product Use) and are discussed in this chapter. In most of these cases, process-specific information is sourced from Annual Environmental Reports, which form part of the reporting obligations under IPPC/IED permits in Ireland. In some cases, production data (estimated and/or calculated) are also used where available.

Relevant subcategories under Mineral Products (2A), Chemical Industry (2B), Metal Production (2C), Solvent and other product use (2D-2H) and Other Production Processes (2L) for which process emissions of various pollutants are reported under Industrial Processes and Product Use in Ireland are described in the following sections.

4.2 Mineral Products (NFR 2A)

The industrial processes for which estimates are included in Ireland's air pollution inventory under NFR 2.A are as follows:

2.A.1   Cement Production
2.A.2   Lime Production
2.A.3   Glass Production
2.A.5.a Quarrying and mining of minerals other than coal
2.A.5.b Construction and demolition
2.A.5.c Storage, handling and transport of mineral products
2.A.6   Other mineral products

4.2.1 Cement Production (NFR 2A1)

Cement manufacture is a major mineral industry. During cement manufacture, raw materials, such as limestone, are finely ground and then transformed in a kiln at high temperatures (calcination) to produce clinker. Gypsum is then blended with clinker to produce cement. The combustion process in the cement kiln is an integral part of the production process, where the fuel ash becomes part of the cement clinker. It is therefore not possible in most cases to distinguish the process and combustion

emissions from one another. As a result, because most of the pollutants originate from the fuels used, emissions are generally reported under NFR Category 1A2f (Non-metallic minerals) and notation keys IE and NA are reported under 2A1 for these pollutants.

There are at present four cement plants in Ireland, all of which use the dry kiln process, and they are currently fuelled by coal, petroleum coke and fuel oil, with meat and bone-meal, solid recovered fuels (SRF) and tyre derived fuels co-incinerated at three of the four plants. Literature sources, in particular, the EMEP/EEA Guidebook (2019), provide some POP emission factors on an overall grams of pollutant per tonne of clinker produced basis. The guidebook states that these emissions are allocated to combustion in cement manufacture and so emissions of POPs are reported as NA for category 2A1. These emission factors have been used to determine the total emissions from cement plants. Fuel-use data are available from plant operators as part of their reporting requirements under the EU ETS (Directive 2003/87/EC) since 2005. Residual fuel not used in the cement manufacture sector but in other manufacturing industry in 1A2f is calculated and emissions from fuel use are calculated using combustion emission factors in 1A2f, while the fuel use data from cement manufacture is removed to ensure there is no double counting.

4.2.2 Lime Production (NFR 2A2)

The lime production process involves the grinding and "burning" of limestone ($CaCO_3$) to produce what is commonly termed "quicklime" (CaO). It can then be further treated by the addition of water, a process called slaking, to produce slaked lime (CaOH), which generates large amounts of heat and steam. The finished product can then be packaged and distributed for use. Currently, there are two lime plants in Ireland and a third that operated until 1999. It is understood that all three utilised limestone quarries and kilns to burn the limestone raw material. The nature of the fuel used and the abatement in place varies from plant to plant.

Process emissions from lime production are obtained as the difference between total emissions on a "per unit production" basis and those estimated from fuel combustion. In this case, it was found that fuel combustion estimates of emissions were generally larger than those estimated on a "per unit production" basis and therefore all emissions from lime production are assumed to be included in those reported within Sector 1A2f and the notation key IE (Include elsewhere) is used for 2A2.

4.2.3 Glass Production (NFR 2A3)

The manufacture of glass was not a predominant industry in Ireland, being limited to three sub-sectors: lead crystal, container glass, and glass wool. The only container glass plant closed in 2002, one of the lead crystal plants closed in early 2006, the glass wool plant closed in 2008 and the last one, (second of the two) lead crystal plant closed in 2009. Therefore, after this period, emissions of all pollutants are reported as 'NO' (not occurring). The pollutants for which process emission estimates have been made are particulate matter (TSP, PM_{10}, $PM_{2.5}$, BC) priority metals (Pb, Cd and Hg), other metals (As, Cr, Cu, Ni, Se and Zn), and PCDD/F. In addition, fuel-derived emissions from the glass industry for 1990-2009 are already accounted for within the Manufacturing Industries and Construction (1A2) sector.

Metal emissions can occur from glass processes from the metals contained in fossil fuels burnt to melt the glass and from metal additives to the glass. Metal emissions from industry fossil fuel use are accounted for within NFR Sector 1A2g (Other Manufacturing Industries). The metals emitted from glass production processes depend on the type of glass produced. Lead oxide and sometimes arsenic trioxide are used in the production of lead crystal glass and both metals can be emitted to air. Selenium and chromium compounds are used as colouring agents for container glass. Metal compounds are not believed to be used to any great extent in the production of glass wool. Of the glass processes outlined, all the plants were regulated under Integrated Pollution Prevention Control IPPC licences. Therefore, there is some information available from their AERs until they closed. Other licence information includes some details of plant design and operation, including capacities, fuel types and operating hours. In addition, confidential information in relation to production statistics has also been supplied to the inventory team.

Emission data for individual metals reported in AERs are limited to Pb emissions from the two lead crystal installations. These data have been used to estimate emissions of Pb from lead crystal production, while emission factors are used for the other glass processes. Literature emission factors are used from the Inventory Guidebook (EMEP/EEA, 2019) and, where deemed more appropriate, emission factors from the UK National Atmospheric Emissions Inventory (NAEI) database. The emission factors used are presented in Table D.1, Annex D. Total emissions for each metal from glass production are presented in Table 4.2.

Ireland includes process emissions for $PM_{2.5}$ from 2A3 Glass production using confidential production data and the Tier 2 emission factors presented in Tables 3.3, 3.5 and 3.6 from Chapter 2A3 of the 2019 EMEP/EEA Inventory guidebook (EMEP/EEA 2019). However, the Guidebook (chapter 1.A.2) notes that, Tier 1 emission factors from combustion in the industrial sector (NFR 1A2) would overlap at least partly with the estimate from process emissions in NFR 2A3. Therefore, Ireland estimates the emissions from category NFR 2A3 and subtracts those estimates from the total emissions calculated for category NFR 1A2f to avoid double counting of these emissions. The emission factors used are presented in Table D.1, Annex D.

The potential for PCDD/F emissions from glass production is generally low because of the long residence times in high-temperature conditions, although chlorine can be introduced via fuels and raw materials, and therefore there is some potential for PCDD/F emissions. However, in the plants in Ireland, the main energy sources used were gas and electricity, and therefore PCDD/F emissions from fuel combustion were likely to be low. The information on abatement technology is uncertain for the glass manufacturing plants in Ireland. The URS Dames & Moore (2000) PCDD/F inventory report implies that one furnace would be fitted with abatement by 2005, but it is assumed that this is the large facility that closed in 2002. IPPC licence information implies that the environmental performance at the glass wool plant was improved in 1999, but the nature of the improvements is not clear.

Emission factors for PCDD/F are provided in the UNEP Toolkit (2013) for two different classes of facility: 0.2 µg I-TEQ/t of glass produced for a facility with no dust control, and 0.015 µg I-TEQ/t of glass produced for a facility with abatement. However, there have been improvements in environmental performance; therefore, the emission factor of 0.2 µg I-TEQ/t is used to estimate emissions in 1990, with a linear decrease to 0.11 µg I-TEQ/t in 2000 (URS Dames & Moore, 2000) and with a subsequent decrease to 0.015 µg I-TEQ/t by 2003 (when the container plant had closed) and

remaining at this level up to 2009 when the last plant ceased its operation. Dioxin and furan emission estimates for glass production are presented in Table 4.1.

Table 4.1. Emission Time Series from Glass Production

Year	1990	1994	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2019
TSP (t)	22.56	22.56	22.56	21.88	22.20	14.04	5.62	5.44	6.01	6.21	6.07	5.08	0.01	NO	NO
PM$_{10}$ (t)	20.08	20.08	20.08	19.48	19.76	12.47	4.95	4.79	5.30	5.47	5.35	4.47	0.01	NO	NO
PM$_{2.5}$ (t)	17.68	17.68	17.68	17.15	17.40	10.98	4.37	4.23	4.67	4.82	4.71	3.94	0.01	NO	NO
BC (t)	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.09	0.10	0.09	0.08	0.00	NO	NO
As (kg)	17.57	17.57	17.57	17.55	17.56	8.87	0.17	0.16	0.18	0.18	0.18	0.15	NA	NO	NO
Cd (kg)	7.44	7.44	7.44	7.41	7.42	3.83	0.23	0.22	0.25	0.26	0.25	0.21	NA	NO	NO
Cr (kg)	23.90	23.90	23.90	23.69	23.79	12.76	1.65	1.60	1.77	1.85	1.80	1.50	NA	NO	NO
Cu (kg)	1.70	1.70	1.70	1.49	1.59	1.66	1.65	1.60	1.77	1.85	1.80	1.50	NA	NO	NO
Pb (Mg)	311	311	311	311	311	224	137	137	129	88.52	96.78	96.46	7.91	NO	NO
Hg (kg)	0.58	0.58	0.58	0.51	0.54	0.57	0.56	0.55	0.60	0.63	0.61	0.51	NA	NO	NO
Ni (kg)	18.46	18.46	18.46	18.25	18.35	11.22	4.02	3.96	4.00	3.36	3.46	3.16	0.14	NO	NO
Se (kg)	90.11	90.11	90.11	90.10	90.11	45.11	0.11	0.11	0.12	0.12	0.12	0.10	NA	NO	NO
Zn (kg)	33.47	33.47	33.47	31.07	32.21	33.03	32.97	32.34	33.57	30.32	30.63	27.13	0.80	NO	NO
PCDD/F (g I-TEQ)	0.54	0.46	0.39	0.26	0.17	0.11	0.01	0.02	0.01	0.01	0.01	0.01	0.00	NO	NO

4.2.4 Quarrying and Mining of Minerals Other than Coal (NFR 2A5a)

Emissions of PM$_{2.5}$, TSP and PM$_{10}$ have been estimated for all years of the time series 1990- 2019. Activity data was taken from national statistics from the CSO and emission factors from Chapter 2.A.5.a, Table 3.1 of the Inventory Guidebook (EMEP/EEA, 2019). Activity data and emissions are presented in Table 4.2.

Table 4.2 Quarrying and mining of minerals other than coal (2.A.5.a)

Activity Data		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Metallic minerals	Mt	2.68	2.60	3.49	4.65	4.28	4.18	4.21	3.82	3.66	3.40	2.60	2.31	2.20	2.27
Non-metallic minerals	Mt	28.82	26.81	63.10	94.46	37.96	25.85	30.41	29.03	29.47	33.63	42.08	45.09	45.09	46.58
Emissions factors															
TSP	g/t	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00	102.00
PM10	g/t	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
PM2.5	g/t	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Emissions															
TSP	kt	3.21	3.000	6.792	10.110	4.309	3.063	3.531	3.350	3.379	3.777	4.558	4.835	4.824	4.983
PM10	kt	1.58	1.470	3.330	4.956	2.112	1.501	1.731	1.642	1.656	1.852	2.234	2.370	2.365	2.443
PM2.5	kt	0.158	0.147	0.333	0.496	0.211	0.150	0.173	0.164	0.166	0.185	0.223	0.237	0.236	0.244

4.2.5 Construction and Demolition (NFR 2A5b)

Emissions of PM$_{2.5}$, TSP and PM$_{10}$ have been estimated for all years of the time series 1990- 2019. Activity data was taken from national statistics from the CSO and the US EPA Tier 1 methodology and emission factors from Chapter 2.A.5.b section 3.2 of the guidebook (EMEP/EEA, 2019). Ireland checked for sources of required data to implement a Tier 2 method and determined it is not possible to source any of the required data. The methodologies provided by US EPA with AP-42 require very detailed local data as mentioned e.g. material silt content, road surface silt content, material moisture content,

medium wind speed, mean vehicle weight, mean vehicle speed, vehicle kilometre travelled (VKT)etc. The 2019 EEA/EMEP guidebook states that collection of such data is likely to be possible only for individual large point sources. Ireland does not have this data available for any construction and demolition sites and will continue to use the Tier 1 method to estimate emissions from this source. The emissions are presented in Table 4.3.

Table 4.3 Construction and Demolition (2.A.5.b)

Emissions		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TSP	kt	1.74	1.93	1.55	6.25	12.49	0.53	0.74	1.85	1.17	1.38	1.15	3.27	0.97	2.94
PM_{10}	kt	0.52	0.58	0.47	1.87	3.73	0.16	0.22	0.55	0.35	0.41	0.34	0.98	0.29	0.88
$PM_{2.5}$	kt	0.052	0.058	0.047	0.187	0.373	0.016	0.022	0.055	0.035	0.041	0.034	0.098	0.029	0.088

4.2.6 Storage, Handling and Transport of Mineral Products (NFR 2A5c)

Emissions of $PM_{2.5}$ have been estimated for all years of the time series 1990- 2019. Activity data was taken from national statistics from the Central statistics office and emission factors from Table 3.4 Chapter 2.A.5.a of the guidebook (EMEP/EEA, 2019). Activity data and emissions are presented in Table 4.4.

Table 4.4 Storage, handling and transport of mineral products (2.A.5.c)

Activity Data		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Metallic minerals	Mt	2.68	2.60	3.49	4.65	4.28	4.18	4.21	3.82	3.66	3.40	2.60	2.31	2.20	2.27
Non-metallic minerals	Mt	28.82	26.81	63.10	94.46	37.96	25.85	30.41	29.03	29.47	33.63	42.08	45.09	45.09	46.57
Emissions factors															
PM2.5-handling	g/t	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Emissions															
PM2.5-handling	kg	0.019	0.018	0.040	0.059	0.025	0.018	0.021	0.020	0.020	0.022	0.027	0.028	0.028	0.029

4.2.7 Other (NFR 2A6)

The industrial processes included within NFR Sector 2A6 are Bricks and Ceramics Production and Asphalt Production. Each of these subcategories is described in the following sections in terms of the pollutants for which emission estimates are made.

4.2.7.1 Bricks and Ceramics Production

The production of bricks and ceramics is a small sector in Ireland with a total of four IPPC-licensed facilities in operation. Emission estimates are only made for PCDD/F as there are no data available in relation to process emissions of other pollutants and, furthermore, they are expected to be negligible (AEA/CTC, 2008). Direct production information in relation to the bricks and ceramics sector is not available; however, raw material input data are provided by the companies under the EU ETS. For the purposes of inventory estimates, as a worst-case scenario it is assumed that raw material input equals product output. Emission factors are sourced from the UNEP Toolkit (2013) in which two classes of facility are suggested: 0.2 µg I-TEQ/t of brick produced for a facility with no dust control and 0.02 µg I-TEQ/t of brick produced for a facility with abatement. The URS Dames & Moore (2000) report suggests an emission factor of 0.11 µg I-TEQ/t, which is the average of the two emission factors, and

this value, has been used across the time series. The UNEP Toolkit (2013) does not include emission factors for ceramics production and therefore the emission factor for bricks is also applied to ceramics production. Dioxin and furan emission estimates for bricks and ceramics production are presented in Table 4.5.

Table 4.5 Dioxin and Furan Emission Time Series from Bricks and Ceramics Production

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Bricks production														
PCDD/F (mg I-TEQ) **Ceramics production**	12.14	13.02	15.38	15.34	1.74	2.48	0.08	0.07	NO	1.62	2.84	3.32	3.55	3.34
PCDD/F (mg I-TEQ)	NO	NO	NO	0.032	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

4.2.7.2 Asphalt Production

In the context of this inventory, the term "asphalt" is used to describe a bituminous product that may contain varying amounts of aggregate, used to build and maintain roads, whilst "bitumen" is assumed to be a heavy oil tar product which is used at elevated temperatures particularly in roofing materials for some buildings. Currently, only PCDD/F emission estimates from asphalt are included in Ireland's air pollution inventory.

Information in relation to the production of asphalt in Ireland is sourced from the European Asphalt Pavement Association (EAPA, 2001,2007, 2012, 2016, 2018), which generates an annual report outlining the quantity and end use of asphalt produced in European countries. Production data are available from 1994 onwards, with pre-1994 production estimates assumed to be equal to those in 1994. The production levels until 2006 show an upward year-on-year trend due to increased road building in Ireland, from 2007 to 2014 the trend was decreasing but a slight increase is seen from 2015 to 2019

In Ireland, bag filters were fitted to most asphalt production facilities prior to 2000 and it was suggested that all facilities would have bag filters by 2001 (URS Dames & Moore, 2000). The UNEP Toolkit (2013) gives a range in emission factors of 0.007 to 0.07 µg I-TEQ/t asphalt produced. Given the above information, the emission factor for PCDD/F from asphalt production of 0.07 µg I-TEQ/t is adopted for 1990. A linear decrease in the emission factor is then assumed to 0.039 µg I-TEQ/t by 2000, and a further linear decrease is assumed to 0.007 µg I-TEQ/t by the end of 2002. The emission factor is assumed to be 0.007 µg I-TEQ/t from 2003 and onwards. Dioxin and furan emission estimates for asphalt production are presented in Table 4.6.

Table 4.6 Dioxin and Furan Emission Time Series from Asphalt Production

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PCDD/F (mg I-TEQ)	154	92.2	112	23.8	16.1	12.6	13.3	16.1	12.6	13.3	13.3	14.7	14.4	14.0

4.3 Chemical Industry (NFR 2B)

The chemical industry is not a dominant industry in Ireland in relation to industrial processes and is not an important source of emissions. The only source of emissions for which estimates are collated are NO_x emissions from Nitric Acid Production for the years 1990-2002.

4.3.1 Nitric Acid Production (NFR 2B2)

Nitric acid is used as a raw material mainly in the manufacture of nitrogen-based fertiliser. It may also be used in the production of adipic acid and explosives, for metal etching, and in the processing of ferrous metals. In the manufacture of nitrogenous fertilisers, the Haber Bosch process is utilised in which NH_3 is made by combining nitrogen from the air with hydrogen from natural gas and water, using the energy from the gas and a catalyst. Nitric acid is produced by burning (oxidising) the NH_3 over a catalyst. The nitric acid is combined with more NH_3 to produce ammonium nitrate, which is solidified into granules or bead-like prills for application to land using a fertiliser spreader. Up to its closure in 2002, there was one such plant in Ireland, which utilised the above process to produce calcium ammonium nitrate and other nitrogenous fertiliser blends. The inventory agency received direct correspondence from the plant in relation to the quantities of nitric acid produced and the measured emissions of NO_X. Emission estimates and associated activity data for NO_X emissions from nitric acid production are presented in Table 4.7. Abatement measures were installed at the plant in the mid-1990s and they are reflected in emission estimates from 1995.

Table 4.7 Nitrogen Oxides Emission Time Series from Nitric Acid Production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Nitric acid (kt)	338.8	260	260	260	260	260	260	260	260	260	260	260	130
NO_x (kt)	1.680	1.672	1.823	0.960	0.280	0.280	0.280	0.280	0.280	0.280	0.303	0.374	0.187

4.4 Metal Production (NFR 2C)

This category includes a wide range of processes such as primary and secondary iron and steel production, aluminium production and other non-ferrous production. In this category, emissions are estimated for the following subcategories and pollutants:

2C1   Iron and Steel Production – As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn, PCDD/F;
2C2   Ferroalloys Production – As, Cd, Cr, Ni, Pb, Zn, HCB;
2C3   Aluminium Production – Zn;
2C5   Lead production – Pb;
2C7   Other metal production – Cd, Cr, Cu, Ni, Pb, Zn;

Ireland is a major European producer of Zn and Pb ores. The preparation of Pb and Zn concentrates does not produce emissions and the concentrates are exported for further processing.

4.4.1 Iron and Steel Production (NFR 2C1)

This sector covers the manufacture of iron and steel, an energy-intensive process likely to generate high emissions to air from the use of furnaces and sintering processes, as well as the manual handling of the raw material to finished goods, which can include hot and cold rolling, and turning, temping and cutting of metal to reach a desired end product. Steel production in Ireland has been limited to a

single large electric arc furnace installation, which closed in 2001 but was operational throughout the period 1990–2001. One small foundry remained in operation contributing a negligible amount of emissions after the large plant's closure. The main plant produced up to 360 kt of steel per annum mainly from recycled scrap steel. It received an IPPC licence to operate just months before its closure, therefore no AERs were filed by the plant. However, some emission testing was carried out with respect to heavy metal emissions as part of its licence application.

Heavy metal emission estimates have been calculated using the aforementioned emission testing results for Cd, Cr, Pb, Ni and Zn, whilst for the remaining pollutants (i.e. As, Cu, Hg, and Se) Inventory Guidebook (EMEP/EEA, 2019) emission factors have been used, assuming no abatement at the plant. The emission factors used are presented in Table D.3, Annex D. Emission estimates for the 1990–2001 time series are shown in Table 4.8. Metal production data are available from the site for the period 1994–2001, with pre-1994 production assumed to be equal to that in 1994. Emission estimates are calculated by multiplying the production data by the relevant pollutant emission factor and assume that no abatement was in place at the plant.

Table 4.8 Emission Time Series from Iron and Steel Production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
As (Mg)	0.13	0.12	0.10	0.13	0.11	0.12	0.14	0.13	0.14	0.13	0.14	0.06	NO
Cd (Mg)	0.22	0.19	0.17	0.22	0.18	0.21	0.23	0.22	0.24	0.22	0.24	0.10	NO
Cr (Mg)	1.43	1.28	1.13	1.43	1.17	1.36	1.49	1.48	1.57	1.47	1.58	0.66	NO
Cu (Mg)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.01	NO
Pb (Mg)	1.75	1.58	1.38	1.75	1.43	1.67	1.83	1.81	1.93	1.80	1.94	0.81	NO
Hg (kg)	32.60	29.30	25.70	32.60	26.60	31.00	34.10	33.70	35.80	33.50	36.00	15.00	NO
Ni (Mg)	2.69	2.42	2.12	2.69	2.20	2.56	2.82	2.78	2.96	2.77	2.98	1.24	NO
Se (Mg)	0.007	0.006	0.005	0.007	0.005	0.006	0.007	0.007	0.007	0.007	0.007	0.003	NO
Zn (Mg)	27.75	24.94	21.87	27.75	22.64	26.38	29.02	28.68	30.47	28.51	30.64	12.77	NO
PCDD/F (g I-TEQ)	0.743	0.891	0.783	0.990	0.810	0.942	1.035	1.023	1.086	1.017	1.092	0.462	0.012
PCBs (kg)	0.619	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
B[a]p (Mg)	0.009	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

Electric arc furnaces are significant sources of POPs. The overall approach to report emissions of POPs from the iron and steel category has been to account for emissions from fuel combustion within Sector 1A2a, with the process emissions reported (where possible) under Sector 2C1, which have been estimated using the approach described with respect to Cement Production (2A1). Emission factors based on per unit production were used to calculate initial estimates of total emissions. These factors are sourced from the Inventory Guidebook (EMEP/EEA, 2019). The difference between estimates determined on this basis and those reported for fuel combustion sector 1A2a is then reported in sector 2C. Emission estimates for the sector are presented in Table 4.8 for PCDD/F. The notation key 'IE' (included elsewhere) is used for HCB emissions for years 1990-2002 and the notation key NO is used for the years 2003-2019. Emissions of HCB are reported and accounted for under NFR 1A2a as it has not been possible to separate process and fuel combustion related HCB emissions for the period 1990-2002 for which there was an iron and steel industry in Ireland.

4.4.2 Ferroalloys Production (NFR 2C2)

This sector covers several secondary sites engaged in iron and steel manufacture. Two types of installation are distinguished. The first type covers installations involved in the manufacture of ductile iron for use in street furniture, public benches, waste bins and manhole covers, and the second is the manufacture of cast iron for appliances. The process of creating ductile iron utilises electric arc furnaces to smelt the raw materials, iron and magnesium. In the manufacture of cast iron, ferrous and non-ferrous metals, including scrap metal, are used within the process. Since 1990, there have been three relevant facilities in Ireland. Due to a change in operations, one of these plants reported negligible emission estimates from 2003 onwards; one facility closed in 2014 leaving a single operating facility from 2014 onwards.

A number of the larger metal processing sites are regulated under IPPC. Some metal emission estimates and particulate emission estimates have been reported in AERs; however, not all installations report emissions in all years. In some cases, only production data and emissions of TSP are available. Where production data only were provided by the plant operator, they were used to calculate emissions of TSP using USEPA factors for dust emissions from abated/unabated iron foundry cupola processes. Estimates for metal emissions were then obtained from the TSP estimates based on Inventory Guidebook (EMEP/EEA, 2019) dust composition data for foundry dust. Abatement techniques are also taken into account in emission calculations at a plant-specific level, where this applies. Emission estimates of HCB for the time series 1990-1996 are presented in Table 4.9. The only source of HCB is the secondary manufacture of aluminium, for which the Inventory Guidebook (EMEP/EEA, 2019) indicates a factor of 5 g/t of aluminium. This factor has been used to estimate HCB emissions across the time series until use of the HCE-based cover gas was banned in 1996 and emissions are reported using the notation key NO for years after 1996.

Estimates for TSP, PM_{10}, $PM_{2.5}$ and BC have also been made for this category. Total Particulate Matter data reported in AERs were used to estimate emissions from TSP. Fractionation profiles based on the emission factors within the Inventory Guidebook (EMEP/EEA, 2019) were used to estimate PM_{10}, $PM_{2.5}$ and BC emissions.

Where production data are not available, TSP estimates have been used to estimate metal production across the time series using the BiPRO waste report (2005), other POPs like PCDD/F, PCB and PAHs are reported under fuel combustion sector 1A2b. The HCB emission factor used is presented in Table D.3, Annex D, and process emission estimates for the 1990-1996 time series are presented in Table 4.9.

Table 4.9 Emission Time Series from Ferroalloys Production

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TSP (Mg)	70.57	70.57	5.57	1.32	1.28	0.66	0.29	0.64	NO	NO	0.0002	0.0002	0.0002	0.0002
PM$_{10}$ (Mg)	59.99	59.99	4.74	1.12	1.09	0.56	0.24	0.54	NO	NO	0.0002	0.0002	0.0001	0.0001
PM$_{2.5}$ (Mg)	42.34	42.34	3.34	0.79	0.77	0.39	0.17	0.38	NO	NO	0.0001	0.0001	0.0001	0.0001
Cr (Mg)	0.252	0.252	0.019	0.005	0.004	0.002	0.001	0.002	NO	NO	NO	NO	NO	NO
As (Mg)	0.069	0.069	0.005	0.001	0.001	0.001	0.000	0.001	NO	NO	NO	NO	NO	NO
Cd (Mg)	0.0325	0.0325	0.0028	0.0006	0.0076	0.0004	0.0002	0.0004	0.0001	0.0001	NO	0.0001	0.0001	0.0001
Ni (Mg)	0.115	0.115	0.008	0.002	0.002	0.001	0.000	0.001	NO	NO	NO	NO	NO	NO
Pb (Mg)	1.712	1.712	0.183	0.031	0.035	0.016	0.007	0.015	0.0001	0.0001	NO	0.0001	0.0000	0.0001
Zn (Mg)	1.407	1.407	0.345	0.022	0.041	0.011	0.005	0.011	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
PCDD/F (g I-TEQ)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
HCB (kg)	40.000	40.000	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PCBs (kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B[a]p (Mg)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

4.4.3 Aluminium Production (NFR 2C3)

Ireland is an important producer of alumina at one large plant using the Bayer process (extraction of AlO$_3$ using NaOH). The production of alumina using the Bayer process does not give rise to significant metal emissions and therefore process emissions are not estimated for this source. Ireland has some secondary aluminium processing for which estimates of Zn have been made following reports from the plant involved. The plant closed in late 2006 and therefore estimates are only provided for the 1990–2006 time series as presented in Table 4.11. Production data for the plant are not available and therefore estimates were made using PM as an indicator. The UK NAEI emission factor of 2.725 g/t is then applied (Table D.3, Annex D).

Table 4.10 Emission Time Series for Zinc from Aluminium Production

Year	1990	1995	2000	2001	2002	2003	2004	2005	2006
Zn (t)	0.029	0.029	0.029	0.029	0.043	0.019	0.026	0.011	0.011

4.4.4 Lead Production (NFR 2C5)

A significant quantity of Lead is mined in Ireland, but such mining is assumed not to be a significant source of emissions to air. Estimates at facility level of Lead emissions have been obtained from AERs. Emission estimates for the time series are presented in Table 4.11 and are reported as not occurring since 2009.

Table 4.11 Emission Time Series for Lead Production

Pollutant (unit)	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Pb (kg)	7.845	7.845	7.845	7.845	0.018	0.008	0.013	0.006	0.025	0.034	0.030	NO

4.4.5 Other Metal Production (NFR 2C7)

This category covers all other metal manufacture and manipulation, including any emissions from the mining of raw materials. A significant quantity of Zn is mined in Ireland, but such mining is assumed not to be a significant source of emissions to air. Ireland has a number of small aluminium casting companies in addition to facilities for wire manufacture and the manufacture of refined or secondary Pb and Cu products, as well as a number of Zn galvanising plants.

Estimates at facility level of the heavy metals Cd, Cr, Cu, Ni, Pb and Zn have been obtained from AERs with respect to these secondary metal operations. Emission estimates for the time series are presented in Table 4.12. Emissions arise from 3 plants in the latter parts of the time series and are therefore very sensitive to changes in activity of individual plants.

Table 4.12 Emission Time Series for Non-Ferrous Metal Production

Pollutant	Units	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cd (kg)	kg	0.02	0.02	0.02	0.02	NO	0.20	0.20	0.20	0.20	0.10	NO	0.10	0.10	0.10
Cr (kg)	kg	15.0	211.0	211.0	256.3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Cu (kg)	kg	3.18	3.18	3.18	22.27	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Pb (kg)	kg	0.15	0.15	0.15	9.85	NO	0.30	0.30	0.40	0.41	0.30	0.20	0.30	0.17	0.30
Ni (kg)	kg	82.00	82.00	82.00	4.97	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Zn (kg)	kg	233.0	233.0	233.0	121.3	3.10	0.30	0.30	22.35	1.50	0.30	0.30	0.30	0.21	0.21

Process emissions of POPs (where applicable) are included in combustion emissions and reported as included elsewhere (IE) for category 2C7.

4.5 Overview of NMVOC emissions from Solvent and Other Product Use (NFR 2D-2L) Sector

The emission estimates presented in Solvent and Other Product Use (NFR 2D-2H) include Domestic solvent use including fungicides (2D3a), Road Paving with asphalt (2D3b), Coating Applications (2D3d), Degreasing and surface cleaning (2D3e), Dry Cleaning (2D3f), Chemical Products, Manufacture and Processing (2D3g), Printing (2D3h), Other Solvent Use (Fat, Edible and non-edible oil extraction) (2D3i), Other Product use (Use of Tobacco products and Fireworks) (2G) and Food and Beverages industry (2H2). Emissions are the result of continuing improvement of NMVOC emission estimates for Ireland through the outsourcing of tendered projects by the EPA. For 2D3c Asphalt roofing it has been determined that the production of asphalt roofing materials does not occur in Ireland. This category is reported as NO.

In 2012, the inventory agency commissioned a research project to update the NMVOC emission inventory for 2006-2013. This was a follow-on project to CTC/AEA (2005) and Finn et al. (2001) and resulted in a revised dataset where new data and methodologies had become available. This approach was taken in accordance with the Inventory Guidebook (EMEP/EEA 2016) methodology for NMVOC emissions for Solvent and Other Product Use (NFR 2D-2L). The results of this project were provided in the 2016 submission. This project continued into 2016 and resulted in further improvements to the NMVOC emission inventory from Solvent Usage.

Emissions data were gathered using a similar methodology to previous approaches. Bottom-up data was mainly obtained from submissions of Annual Environmental reports (AERs) which detail emissions in a variety of reporting formats ranging from the Solvent Mass Balance Summary, Solvent Management Plan (SMP), Pollution Release and Transfer Register (PRTR), or the Annual Environmental Report returns Workbook. In addition, new data sources were used from legislation designed to limit and report solvent usage (Solvent Directive 1999/13/EC). In conjunction with these data, the number of operators within each category was estimated using NACE codes provided by the Central Statistics Office (CSO) or from expert opinion.

Top–down methods were used for activities not covered by the IPPC licensing system nor under the Solvent Directive (1999/13/EC). The most significant included the use of non-industrial paints, metal degreasing and the use of domestic solvents. Input in the form of activity data, solvent usage or VOC emissions data for each individual activity were collated into spreadsheets. Emissions were estimated by applying the Inventory Guidebook (EMEP/EEA 2016) methods, default emission factors and general guidance as appropriate. Scaling up to national level was applied where necessary. The emission factors used are presented in Table D.4, Annex D

Emissions reported in NFR 2019 format are aggregated from the Selected Nomenclature for Air Pollutants (SNAP) categories. SNAP codes are used in the Inventory Guidebook (EMEP/EEA 2016) where sectoral emission sources and emission factors are provided in this system. Therefore, SNAP codes are adopted in these categories as it ensures that reporting of emissions is consistent with the guidebook and therefore other Parties submissions. Additionally, the use of SNAP codes facilitates a sub-sectoral analysis of drivers and trends.

For a number of sources, it was not possible to obtain reliable country-specific data (SNAP 060107: Paint Application: Wood, SNAP 060109: Non-Industrial Paint Application, SNAP 060408: Domestic Solvent Use). As a consequence of this, UK and other Parties' emission factors, and in some cases activity data (scaled by surrogate data), were used in the estimation methodology.

Obtaining country-specific data has been identified as an important issue in the past (Barry, S. and Regan, B., 2014). While new activity data were obtained for sectors that previously relied upon proxy sources, a number of sectors are still estimated using proxy information sources. Further reducing the dependence of these would require substantial investment, and the improvement that this would bring over using proxy-based data is thought to be relatively small due to the similarity in lifestyle behaviour between the countries operating within the EU (an in particular the United Kingdom) and therefore a common market place.

The main drivers associated with trends in implied emission factors relate to reduced solvent content of products, and paints. The trends in activity data reflect the fact that Ireland experienced rapid economic growth from the late 1990s to 2007. As a result, there was a substantial increase in the number of vehicles, growth in the number of individual households, and generally a higher per capita consumption of paints, cosmetics, toiletries, and other solvent containing products. Since 2007, there has been a rapid economic downturn, which has had a marked impact on consumption, and therefore emissions of NMVOC. As economic conditions began to improve emissions have also increased from 2012 to 2018.

Figure 4.1 illustrates the overall trend and shows a 46 per cent increase in total emissions between 1990 (33.0 kt of NMVOC) and 2019 (48.2 kt of NMVOC). The main contributor to the trend is sector 2H2 Food and Beverages industry, with 204 per cent increase between 1990 and 2019 and was responsible for 60.7 per cent share of emissions from solvent and other product use in 2019. The second largest contributor is sector 2D3a (Domestic Solvent Use including fungicides) with a contribution of 23.1 per cent of emissions from solvent and other product use (having increased by 40.4 per cent since 1990). Sector 2D3d (Coating Applications) accounted for 5.0 per cent in 2019 showing a decrease of 64.0 per cent between 1990 and 2019.
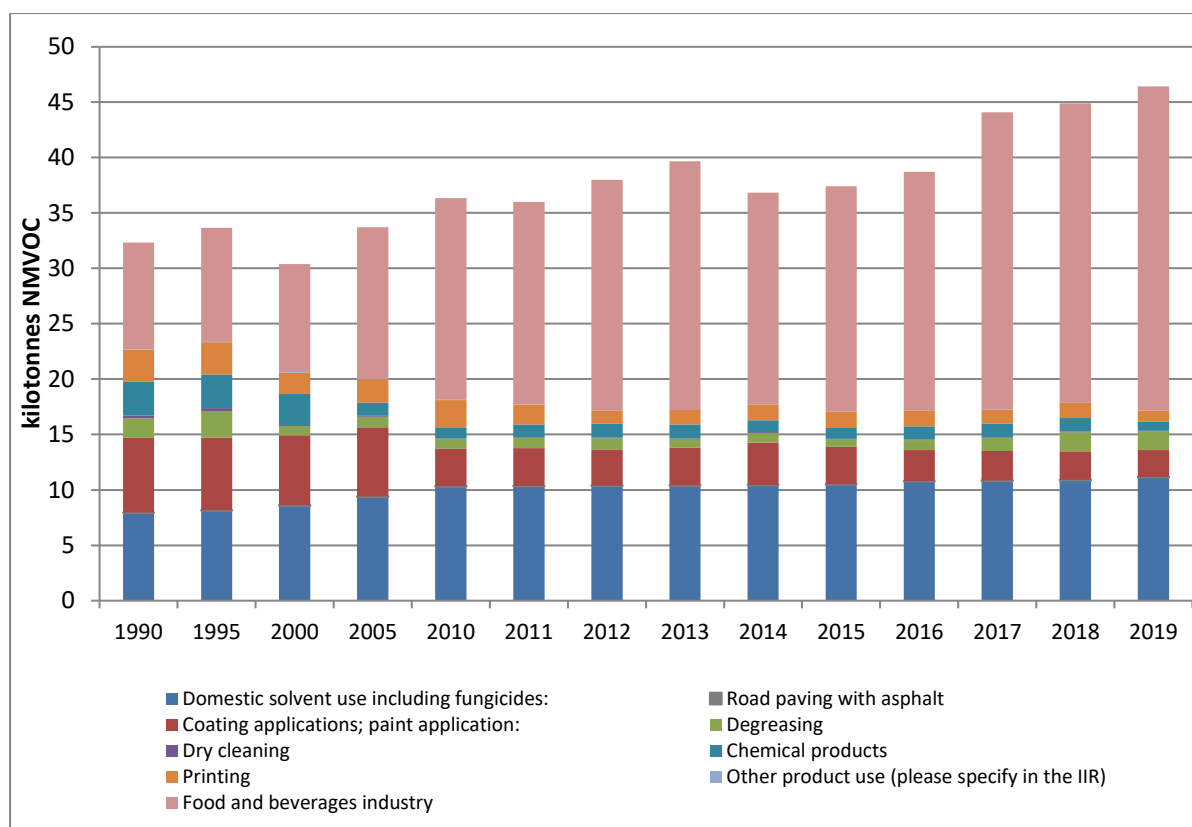
Figure 4.1 NMVOC Emission Trend for 2D-2H Other Solvent and Product 1990–2019

Sector 2D3a, (Domestic Solvent Use including fungicides) is the second largest contributor to NMVOC emissions (Table 4.13). A Tier 2 method was implemented which uses population data obtained from the C.S.O and per capita emission factors for product use from the Inventory guidebook (EMEP/EEA, 2019). This approach was used as the statistics required for the use of Tier 2b approach were not complete in terms of the product types covered by domestic solvent use. For Hg no Tier 2 emission estimate is available for fluorescent tubes. The 2019 Inventory Guidebook does not contain an emission factor for this source and states "Due to the uncertainty around these releases, this source is currently not considered in the Guidebook." Therefore, this emission is not applicable.

Sector 2D3b (Road paving with asphalt) emissions contribute less than 0.1 per cent of 2019 emissions. Emissions from the sector have decreased by 9.1 per cent since 1990.

Emissions from Coating applications (2D3d) decreased between 2007 and 2012 before increasing in 2013 and 2014 and decreasing again from 2015 to 2018 and reaching their lowest level in 2019 (24.3 kt). The main driver of NMVOC emissions from this emission category is the application of decorative paint (SNAP codes:060103/060104). A number of factors contributed to the ongoing decrease in emissions including; the substantial reduction in the solvent content of paint in recent years to comply with the Deco-Paints Directive (EP and CEU, 2004b), a greater awareness of environmental issues from the general public in addition to the economic downturn in Ireland. From discussions with industry, pressure from some of the larger retailers is noted to be one of the key drivers for the decrease in solvent use in architectural paint. The sales of water-based paints have decreased by 28.0 per cent

between 1990 and 2019 whereas solvent-based paint sales have decreased by 56.9 per cent over the same period.

Emissions from 2D3e (Degreasing) decreased by 3.92 per cent between 1990 and 2019. Emissions peaked in 1996 at 2.5 kt. The methodology is based on net consumption of solvents (imports minus exports) provided by the CSO. The analysis showed that the main solvent used in this sector is Dichloromethane. The reductions are assumed to be driven by improved management practices and abatement technologies (open-top tanks have been phased out in the European Union as a result of the Solvents Emissions Directive 1999/13/EC). Emissions from this emission source accounted for 3.5 per cent of the total emissions from solvent and other product use in 2019.

Data obtained under the reporting requirements of the Solvent Directive (1999/13/EC) was used to estimate emissions from 2D3f (Dry Cleaning). Solvent usage, emissions data and national statistics were used to estimate emissions from this emission source. Emissions decreased by 79.6 per cent over the 1990-2019 period. Emissions from 2D3f accounted for 0.12 per cent of the total emissions from solvent and other product use in 2019.

2D3g (Chemical products) accounts for 1.7 per cent of emissions in solvent and other product use in 2019. In 1990, this sector accounted for 9.2 per cent. This emission category consists of fourteen emission sources, however, the majority of the emissions sources contribute very little to the overall emissions from the Chemical products sector. The diversity within these sectors is very large in terms of the type of process, the products made and the scale involved. The main driver of emissions from this emission source is Pharmaceutical Production (SNAP code 060306). Emissions from pharmaceutical production accounted for 69.0 per cent of emissions in the 2D3g in 2019. Emissions from 2D3g decreased by 59.3 per cent between 1990 and 2019. Emissions decreased as a result of the introduction of new management practices or through the use of abatement technology (CTC/AEA, 2005 and Barry S. and O'Regan B., 2014). This indicates that current policy strategies are having an impact on solvent use and emissions. In addition, large reductions in emissions were found in several emission sources between 1990 and 2019. For instance, emissions reduced significantly from SNAP code 060303 (Polyureathane Processing), SNAP code 060305 (Rubber Processing). This was mainly a result of plant closures with the last rubber processing facility closing in 2016. 2D3h (Printing) emissions decreased 66.1 per cent over the 1990 to 2019. In 2019, the sector accounted for 2.1 per cent of total emissions from solvent and other product use. Emissions from this sector decreased by 28 per cent in 2019. It is important to note that the print industry is included under the Solvent Directive (1999/13/EC) and is subject to IPPC licencing where applicable which is most likely responsible for the decrease in emissions.

2D3i (Other Solvent use) emissions increased 149.3 per cent over the 1990 to 2019 timeseries. In 2019, the sector accounted for 3.6 per cent of total emissions from solvent and other product use. This emission category consists of 8 sources which include SNAP codes; 060401 (Glass Wool Enduction), 060402 (Mineral Wool Induction), 060404 (Fat, edible and non-edible oil extraction), 060405 (Application of Adhesives and Glues), 060406 (Preservation of Wood), 060407 (Underseal Treatment and Conservation of Vehicles), 060409 (Vehicle Dewaxing) and 060412 (Other). Application of Glues and Adhesives contribute 86.7 percent of total emissions from solvent and other product use in 2019. Emissions from this sub-category have increased 180.5 per cent between 1990 and 2019 due to

increased consumption of glue products. The methodology for reporting 060404 (Fat, edible and non-edible oil extraction) includes emissions from 1990 to 2019, the methodology is a Tier 2 method based on Oilseed rape crop yield data provided by the CSO and emission factor from the Inventory guidebook (EMEP/EEA 2019).

Emission sources from 2G4 include 060602 (Use of tobacco) and 060303 (Use of shoes). Emissions from SNAP code 060602 (Use of tobacco) has been included in this submission using Tier 2 emission factor from Inventory guidebook (EMEP/EEA 2019) and excise volumes data obtained from The Revenue Commissioners. Emissions from category 2G4 accounted for 0.04 per cent of emissions from solvent and other product use in 2019 and have decreased by 49.1 per cent between 1990 and 2019 as a large decrease in tobacco consumption was noted in 2018 with a recovery in consumption seen in 2019.

Sector 2H2 (Food and Beverage industry) is the largest contributor (60.76 per cent in 2019) to NMVOC emissions (Table 4.39-4.44). Tier 2 methodologies were applied to SNAP codes 040605 Bread, 040607 Production of Beer and 040608 Production of spirits, 040627 Meat frying and meat rendering, coffee roasting and feedstock, using activity data from C.S.O and Eurostat.

4.5.1 Domestic Solvent Use including fungicides (NFR 2D3a)

This subcategory covers SNAP sector 060408. This category addresses NMVOC emissions from the general use of products containing solvents by members of the public in their homes but does not include the use of decorative paints. Many domestic products are also used in industry and commerce and in many cases, it is difficult or impossible to separate total sales into domestic and industrial components. Products that contain VOCs can be divided into a number of categories such as Cosmetic and Personal Care Products, Household Products, DIY products, Car Care Products, Varnish remover, Sealant and filling agents, Pharmaceutical Products Use and Pesticides. In this submission, a Tier 2 methodology was used with per-capita emission factors. This is the recommended approach to use where product statistics for the use of the Tier 2b approach are not complete in terms of the product types covered by domestic solvent use. Further study is planned to source appropriate product statistics. Estimates of NMVOC emissions from domestic solvent use are provided in Table 4.13.

Table 4.13 Non-Methane Volatile Organic Compound Emissions from Domestic Solvent Use

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
kt	7.93	8.14	8.57	9.35	10.30	10.34	10.37	10.38	10.42	10.48	10.77	10.82	10.87	11.13

4.5.2 Road Paving with asphalt (NFR 2D3b)

This sector covers the use of asphalt for road paving and covers SNAP sector 040611. This source is estimated using a Tier 2 methodology using annual weight of warm and hot mix asphalt used in Ireland for years 1993-2019 and the Tier 2 emission factor from the Inventory guidebook (EMEP/EEA 2019). $PM_{2.5,}$ PM10, TSP and BC are estimated for all years 1990-2019. Estimates of NMVOC, PM_{10}, TSP, $PM_{2.5}$ and BC emissions from Road Paving with asphalt are provided in Table 4.14.

Table 4.14 Emissions from Road Paving with Asphalt (NFR 2D3b)

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

| kt | 7.93 | 8.14 | 8.57 | 9.35 | 10.30 | 10.34 | 10.37 | 10.38 | 10.42 | 10.48 | 10.77 | 10.82 | 10.87 | 11.13 |

4.5.3 Coating Application (NFR 2D3d)

This sector covers the use of paints within the industrial, trade and domestic sectors. The term paint includes pigmented coatings and clear coatings such as lacquers and varnishes, with the exception of glues, adhesives and inks. Unless captured on release and either recovered or destroyed, the solvent content of paint can be considered to be emitted to the atmosphere. The subcategories covered in this source category are presented below, with the relevant SNAP code in parentheses. SNAP codes not included below are deemed not to occur in Ireland.

Paint Application – Car Repairing (060102)
Paint Application – Construction and Buildings (060103)
Paint Application – Domestic Use (060104)
Paint Application – Boat Building (060106)
Paint Application – Wood (060107)
Paint Application – Other Industrial Paint Application (060108)
Paint Application – Other Non-Industrial Paint Application (060109)

Dependent on the SNAP code of interest, both bottom–up and top–down approaches have been used in emission estimates. Where there is an absence of country-specific data, per-capita emission factors derived from a number of EU member states national inventories were used to estimate emissions in Ireland using population statistics as a proxy. Further details of the methodological choices for this source category are provided in Barry and O'Regan. (2014), CTC/AEA (2005) and in Finn et al. (2001).

4.5.3.1 Paint Application: Car Repairing (SNAP 060102)

Activity data was obtained from a number of sources. From 2006-2019, sales data was obtained from a large supplier and data was scaled up based on market share and expert opinion. Data used in 1998 was calculated by Finn et al. (2001), data for 2000 and 2001 was provided by the British Coating Federation. Data was extrapolated and interpolated for the intervening years using passenger car numbers reported by the Department of Transport, Tourism and Sport each year (DTTAS, 2020). Emission factors were obtained using survey data from AEA/CTC (2005) and Barry and O'Regan (2014), default emission factors provided by the Inventory Guidebook (EMEP/EEA 2016) and where necessary, emission factors were calculated based on the average decrease in VOC content in known coating applications. The emission estimate includes thinners (EF 1000-835g/L), body fillers (EF 249-175g/L), top coat (720-420g/L) and primers (720-540g/L). This is considered a Tier 2 method. Emission estimates are provided in Table 4.15.

Table 4.15 Non-Methane Volatile Organic Compound Emissions from Paint Application: Car Repairing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.19	0.21	0.31	0.43	0.38	0.36	0.26	0.24	0.25	0.22	0.19	0.16	0.16	0.16

4.5.3.2 Paint Application: Construction and Building (SNAP 060103) and Domestic Use (SNAP 060104)

Activity data was obtained from the Irish Decorative Surface Coating Association (IDSCA) for the period 2006-2019. The Irish Business and Employers' Confederation (IBEC) collated the total product sales for both water-based and solvent-based paints and provided the information to the inventory agency for the period 2000-2004. Following the experience in the UK (CTC/AEA, 2005), total product sales are proportioned between trade (Construction and Buildings) and retail (Domestic Use) use, assuming a 44:56 split in 1998, reaching 40:60 in 2003, and 30:70 in 2013. The split in 2019 is assumed to be the same as 2013. Estimates of paint sales prior to 1998 were extrapolated using GDP (R=0.70).

A number of emission factors were used to calculate NMVOC emissions from decorative coating applications. A survey of products found in popular retail chain stores was completed to establish a realistic emission factor for decorative surface coating products for recent years:

- Interior matt walls and ceiling paint was found to be 30g of VOC/l for solvent based paints and 22.5g of VOC/l for water based paints.
- Interior glossy walls and ceilings were found to have 76g of VOC/l for solvent based paint and 50g of VOC/l for water based paints.
- Exterior walls of mineral substrate were found to have 126g of VOC/l of solvent based paints and 9g of VOC/l for water based paints.
- Interior/exterior trim and cladding paints for wood and metal have an average solvent content of 324g of VOC/l of solvent based paints and 43g of VOC/l of water based paints.
- Primers were found to have an average solvent based paints of 201g of VOC/l and 45g of VOC/l for water based paints.

These emission factors were used for 2010-2019 while emission factors prior to this were assumed to be similar to 2007 limits outlined in the decorative paints directive. This is considered a Tier 2 method. Emission estimates for this category are provided in Table 4.16.

Table 4.16 Non-Methane Volatile Organic Compound Emissions from Paint Application: Construction and Building (060103) and Domestic use (060104)

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
060104 kt	1.510	1.572	1.577	1.440	0.590	0.562	0.500	0.509	0.556	0.403	0.286	0.248	0.232	0.229
060103 kt	1.922	2.000	2.090	2.350	1.197	1.195	1.114	1.188	1.298	0.939	0.668	0.579	0.542	0.535

4.5.3.3 Paint Application: Boat Building (SNAP 060106)

Paint application in the Marine Sector includes a diverse range of products designed to prevent corrosion and protect ships hulls against damage from fouling. The formulation varies depending on the area being coated and application techniques also vary ranging from spraying to brushing and application by roller.

Activity data were obtained from a major marine coating supplier from 2010-2019 and was upscaled based upon the company's market share. Previous annual emissions were assumed to be the same as 2010. The supplier also provided an estimated industry product breakdown. Emission factors between products are relatively similar with Top coats, primers and anti-corrosion products having an estimated VOC content of 400g of VOC per kg of product while anti-fouling products are estimated to contain 440g of VOC per kg of product.

Paint Application in the Marine Sector in Ireland can be divided into domestic sector, cargo or freight sector and the fishery sector. Larger vessels which require more product application are unable to dry dock in Ireland due to a lack of facilities to handle larger vessels. Therefore, sales data are adjusted based upon expert opinion to account for this (50 per cent of paint sales are applied elsewhere). This sector is a minor emission source for this reason. The methodology is considered a Tier 1 method. Estimates of NMVOC emissions from this source category are provided in Table 4.17.

Table 4.17 Non-Methane Volatile Organic Compound Emissions from Paint Application: Boat Building

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.090	0.090	0.090	0.090	0.090	0.102	0.089	0.103	0.111	0.115	0.144	0.132	0.146	0.146

4.5.3.4 Paint Application: Wood (SNAP 060107)

This subcategory refers to all paints used for the wood and wooden products sector but excludes the use of wood preservatives and creosote. Some activity data were available; however, no indication of the number of operators or market size was obtainable. Therefore, the emissions estimate was downscaled from UK data where consumption patterns and product range were considered to be comparable to Ireland. This involved using UK emissions data from the UK National Atmospheric Emissions Inventory (NAEI) and calculating per capita emissions (kg/per person) and applying this to Ireland using national population statistics. The methodology is considered a Tier 1 method. Estimates of NMVOC emissions from this source sector are provided in Table 4.18.

Table 4.18 Non-Methane Volatile Organic Compound Emissions from Paint Application: Wood

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	1.11	0.97	0.76	0.60	0.42	0.43	0.41	0.37	0.32	0.24	0.25	0.24	0.24	0.24

4.5.3.5 Paint Application: Other Industrial Sources (SNAP 060108)

The methodology for this source category involves the use of IPPC emissions data and scaling up to account for emissions in the non-IPPC sector based on information obtained from reporting under the Solvent Directive 1999/13/EC. This category covers paints applied in industrial activities other than those already described in previous sections. Products painted include agricultural, construction and earth-moving equipment, aircraft, cans and drums, domestic appliances, electrical components, freight containers, machine tools, military vehicles, motor-vehicle components, office equipment, paper and plastics, and toys.

The scale of operation varies considerably from large operations employing automated roller coating to small-scale spraying painting. Processes may be enclosed or open air, and both air-dried and stove coatings are used. The emission estimate was up-scaled based on information obtained as a result of

Solvents Directive 1999/13/EC. Estimates of NMVOC emissions from this source category are provided in Table 4.19. This methodology is considered a Tier 3 method

Table 4.19 Non-Methane Volatile Organic Compound Emissions from Paint Application: Other Industrial Sources

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	1.425	1.321	1.019	0.996	0.461	0.483	0.587	0.671	0.828	0.950	0.771	0.789	0.729	0.567

4.5.3.6 Paint Application: Other Non-Industrial Sources (SNAP 060109)

This category refers to the use of high performance protective and/or anti corrosive paints applied to structural steel, concrete and other substrates and any other non-industrial coatings. The sector includes coatings for offshore drilling rigs, production platforms and similar structures as well as road marking paints and non-decorative floor paints. Finn et al. (2001) obtained the activity data for this category as the difference between total paint sales in Ireland according to CSO data on paint sales and that used in other SNAP sectors under SNAP 0601. However, as no other data are available, emissions have been calculated following the advice of CTC/AEA (2005) using extrapolation from UK per capita estimates.

In order to establish whether the use of UK data is appropriate, per capita emissions were compared to other reporting parties. It was found that per capita emissions from this category range from 0.08 to 0.45 kg/person. The UK's per capita estimate is calculated at 0.14 kg per person. This is considered to be a realistic estimate for Irish emissions and was used to estimate emissions. This involved calculating UK per capita emissions (kg/per person) and applying this to Ireland using national population statistics Estimates of NMVOC emissions from this source category are provided in Table 4.20. The methodology is considered a Tier 1 method

Table 4.20 Non-Methane Volatile Organic Compound Emissions from Paint Application: Other Non-Industrial Sources

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.490	0.401	0.466	0.337	0.234	0.268	0.298	0.317	0.443	0.502	0.507	0.511	0.533	0.542

4.5.4 Degreasing and Dry Cleaning (NFR 2D3e and 2D3f)

Degreasing and Dry Cleaning (2D3e and 2D3f) covers the four subcategories that constitute SNAP Sector 0602. The subcategories for which emission estimates have been made are as follows with the relevant SNAP code in parentheses:

Metal Degreasing (060201)
Dry Cleaning (060202)
Electronic Components (060203)
Other Industrial Cleaning (060204)

Activity data were obtained in the form of net consumption statistics (import minus exports) supplied by the CSO. Solvents included in the emissions estimate include perchloroethylene, dichloromethane, trichloroethylene and hydrocarbons from 1992-2019 before which time data are not available. The methodologies outlined in the Inventory Guidebook (EMEP/EEA 2019) and emissions data collected

under the Solvents Directive 1999/13/EC are used to derive emission estimates. Further details of the methodological choices for this source category are provided in Barry, S. and O'Regan B. (2014).

4.5.4.1 Metal Degreasing (SNAP 060201), Electronics Manufacture (SNAP 060203) and Other Industrial Cleaning (SNAP 060204)

Degreasing is a process for cleaning water-insoluble substances, such as grease, fats, oils, waxes, carbon deposits, fluxes and tars, primarily from various metal products, but plastic, fibreglass, printed circuit boards and other products may also be treated by the same process. Therefore, a wide range of activities is covered.

The metalworking industries are the major users of solvent degreasing. Many manufacturers of electronic components also employ degreasing, but it is difficult to differentiate between the emissions emanating from degreasing and those from other sources. As a result, for the purposes of inventory estimates, emissions from Other Industrial Cleaning (060204) and Electronic Manufacture (060203) are included with Metal Degreasing (060201) as national statistics do not facilitate disaggregation of individual sectors.

The Inventory Guidebook (EMEP/EEA 2019) Tier 1 methodology is used for inventory estimates, and solvent consumption statistics (import minus exports) are used as the activity data. The default emission factor of 460g of VOC per kg of cleaning product is used. As data are not available for 1990-1991, the annual emission estimates for these years are assumed to be the same as 1992. Estimates of NMVOC emissions from this source category are provided in Table 4.21.

Table 4.21 Non-Methane Volatile Organic Compound Emissions from Metal Degreasing, Electronics Manufacture and Other Industrial Cleaning

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	1.743	2.388	0.847	0.953	0.885	0.925	1.004	0.795	0.885	0.686	0.885	1.189	1.708	1.675

4.5.4.2 Dry Cleaning (SNAP 060202)

Dry cleaning refers to any process to remove contamination from furs, leather, down leathers, textiles or other objects made of fibres, using organic solvents. Dry cleaning can be defined as the use of chlorinated organic solvents, principally perchloroethylene, to clean clothes and other textiles.

Emissions and usage data were obtained from the Solvents Directive 1999/13/EC for the years 2008-2010. In addition, the CSO provides information directly to the inventory agency in relation to perchloroethylene imports and exports. It is assumed that the net consumption (imports minus exports) in any year are used in that year for inventory estimates, even if there is some carryover of stock between years. Data are available for the years 1992 to 2019. Based on the percentage of perchloroethylene used in Dry Cleaning compared to national consumption in 2008-2010 and 2012, emissions were calculated for 1990-2007, 2011 and for 2013-2019. Estimates of NMVOC emissions from this source sector are provided in Table 4.22. The methodology is considered a Tier 3 methodology.

Table 4.22 Non-Methane Volatile Organic Compound Emissions from Dry Cleaning

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.282	0.270	0.090	0.085	0.053	0.058	0.075	0.057	0.069	0.044	0.062	0.064	0.072	0.058

4.5.5 Chemical Products, Manufacture and Processing (NFR 2D3g)

The mapping of Chemical Products, Manufacture and Processing (2D3g) to SNAP covers 14 subcategories in SNAP Code 0603. These subcategories are all industrial applications and, similar to Coating Application (2D3d), emission sources not included including Asphalt blowing and Leather tanning activities do not occur in Ireland and the notation key "NO" is used for emissions from these categories. The 9 subcategories for which emission estimates are made are as follows with the relevant SNAP code in parentheses:

PVC Processing (060302)
Polyurethane Processing (060303)
Rubber Processing (060305)
Pharmaceutical Products Manufacturing (060306)
Paints Manufacturing (060307)
Inks Manufacturing (060308)
Adhesives Manufacturing (060309)
Adhesive and Magnetic Tapes, Films and Photographs Manufacturing (060311)
Textile Finishing (060312)

Information pertaining to these sectors has been obtained from IPPC licenced companies with the exclusion of PVC processing (060302) which is based upon expert opinion from Finn et al. (2001). Estimates were up-scaled to reflect national emissions using the number of companies for each sector classified under European industrial activity classifications (NACE Rev.2) provided by the CSO. Emissions from Adhesive and Magnetic Tapes, Films and Photographs Manufacturing (060311) are included under SNAP code (060405) Industrial adhesive usage in section 4.5.7.3 Other Use of Solvents and Related Activities (2D3i-2G). Further details as to the exact methodological choices and the use of Inventory Guidebook (EMEP/EEA 2019) methodologies applied in estimating emissions can be found in Finn et al. (2001), CTC/AEA (2005), and Barry and O'Regan (2014).

4.5.5.1 Polyvinyl Chloride (PVC) Processing (SNAP 060302)

The manufacture of polyvinyl chloride plastic involves an enclosed reaction or polymerisation step using the basic monomer to produce the resin, a drying step, and a final treating and forming step. Plastics are polymerised in completely enclosed vessels. Treatment of the resin after polymerisation varies with the proposed use. The major sources of air emission in plastics manufacture are the raw materials or monomers, solvents, or other volatile liquids emitted during the reaction, sublimed solids such as phthalic anhydride emitted in alkyd production, and solvents lost during storage and handling of thinned resins. Processing of PVC is not significant in Ireland. Emission data have been sourced from the installations involved which suggest an emission of 5 t/annum (Finn et al., 2001). The methodology is considered a Tier 1 method.

4.5.5.2 Polyurethane Processing (SNAP 060303)

This category deals with the application and subsequent discharge of organic compounds as blowing agents for creating polyurethane foams. Emissions are from the release of these blowing agents during foaming, or subsequently by the long-term release over several years. Polyurethane is used in building construction, for heat insulation, and for packaging material. For soft polyurethane foams, water may be used. Hard polyurethane foams utilise organic liquids as blowing agents.

Emission data have been sourced from IPPC-licensed companies involved in the manufacture of polyurethane and other foams. Estimates of NMVOC emissions from this category are provided in Table 4.23. The methodology is considered a Tier 1 method.

Table 4.23 Non-Methane Volatile Organic Compound Emissions from Polyurethane Processing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.162	0.162	0.080	0.044	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

4.5.5.3 Rubber Processing (SNAP 060305)

No detailed information for rubber processing is available within the Inventory Guidebook (EMEP/EEA 2019). Therefore, it is assumed in inventory estimates that this category includes processes such as moulding and mixing of natural and synthetic rubbers. Operations involving trimming and cutting are ignored since NMVOC emissions would not be associated with such operations.

Emission data have been sourced from IPPC-licensed companies involved in rubber processing that utilise organic solvents. Estimates of NMVOC emissions from this category sector are provided in Table 4.24. Emissions from this sector were dominated by the manufacture of tennis balls from two companies both of which have ceased operation and account for the steep decline in emissions. The last rubber processing facility closed in 2016 and emissions thereafter are reported using the notation key NO. The methodology is considered a Tier 2 method.

Table 4.24 Non-Methane Volatile Organic Compound Emissions from Rubber Processing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.423	0.424	0.422	0.199	0.001	0.001	0.001	0.001	0.001	0.001	NO	NO	NO	NO

4.5.5.4 Pharmaceutical Products Manufacturing (SNAP 060306)

Depending on the nature of the pharmaceutical manufacturing facility, organic chemicals are used in the synthesis, extraction, fermentation and purification of Active Pharmaceutical Ingredients. Solvents are also used in the dilution of liquids, granulation, packaging and film coating. Thousands of individual products are categorised as pharmaceuticals. These products are usually produced in modest quantities in relatively small plants using batch processes. A typical pharmaceutical plant will use the same equipment to make several different products at different times.

The pharmaceutical industry is well established in Ireland and subject to IPPC licence requirements. Emission estimates have been made for 1998 and 2004 using an emission factor of 2 per cent of usage data (Finn et al. 2001, CTC/AEA, 2005) and for 2006-2019 using reported fugitive emissions data

supplied by IPPC licenced facilities to the EPA. Other years (1990-1997 and 2005 emissions estimates) are interpolated or extrapolated from these estimates. The methodology is considered a Tier 3 method. Estimates of NMVOC emissions from this source category are provided in Table 4.25.

Table 4.25 Non-Methane Volatile Organic Compound Emissions from Pharmaceutical Products Manufacturing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	2.124	2.124	2.072	0.769	0.873	1.029	1.129	1.121	0.969	0.767	0.802	0.757	0.637	0.572

4.5.5.5 Coating Manufacture: Paint (SNAP 060307)

The manufacture of paint involves the dispersion of coloured oil or pigments in a vehicle, usually an oil or resin, followed by the addition of an organic solvent for viscosity adjustment. Only the physical processes of weighing, mixing, grinding, tinting, thinning and packaging take place. No chemical reactions are involved.

Input and usage data have been sourced from a number of installations for 1998 and 2004 and from 2007 to 2019 emissions data was obtained from AERs. Emissions data were upscaled based on national statistics to reflect national emissions. Emissions were assumed to remain at 1998 levels for the period 1990-1997 as no emissions data was available. Other years in the time series are estimated by interpolation and extrapolation. This methodology is considered a Tier 3 method. Emission estimates for NMVOC are provided in Table 4.26

Table 4.26 Non-Methane Volatile Organic Compound Emissions from Paint Manufacture

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.162	0.162	0.117	0.083	0.043	0.027	0.039	0.051	0.052	0.152	0.300	0.415	0.534	0.218

4.5.5.6 Inks Manufacturing (SNAP 060308)

There are four major classes of printing ink: letterpress and lithographic inks, commonly called oil or paste inks, and flexographic and rotogravure inks, which are referred to as solvent inks. These inks vary considerably in physical appearance, composition, method of application, and drying mechanism. Flexographic and rotogravure inks have many elements in common with the paste inks but differ in that they are of very low viscosity, and they almost always dry by evaporation of highly volatile solvents.

Emissions data were obtained from IPPC licensed facilities for 2008-2019. Where emissions estimates are based on usage data they are calculated based on an assumed emission factor of 2.5 per cent, which is the UK NAEI emission factor for this category (CTC/AEA, 2005). Emissions were assumed to remain at 1998 levels for the period 1990-1997 as no emissions data were available. Gaps in the time series were then filled by interpolation and extrapolation. The methodology is considered a Tier 2 method. Estimates of NMVOC emissions from this source category are provided in Table 4.27.

Table 4.27 Non-Methane Volatile Organic Compound Emissions from Inks Manufacturing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (t)	1.844	1.844	0.630	0.436	0.131	0.141	0.136	0.073	0.021	0.005	0.005	0.002	0.006	0.006

4.5.5.7 Adhesives Manufacturing (SNAP 060309)

This category includes the manufacture of glues and adhesives as it was difficult to derive separate activity data for glues and adhesives from those obtained from IPPC-licensed installations.

Emissions and usage data were supplied for a number of years in the time series (1998, 2006-2019). Emissions were assumed to remain at 1998 levels for the period 1990-1997 as no emissions data were available for that period. The methodology is considered a Tier 3 method. Estimates of NMVOC emissions from this source category are provided in Table 4.28.

Table 4.28 Non-Methane Volatile Organic Compound Emissions from Adhesives Manufacturing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.051	0.051	0.034	0.051	0.041	0.051	0.016	0.036	0.022	0.027	0.057	0.062	0.050	0.030

4.5.5.8 Textile Finishing (SNAP 060312)

Textile fabric finishing is part of the textile finishing industry. In fabric printing, a decorative pattern or design is applied to constructed fabric by roller, flat-screen or rotary-screen methods. Pollutants of interest in fabric printing are VOCs from mineral spirit solvents in print pastes or inks. Solvent use in this sector is usually associated with dry processing rather than wet processing of textiles.

Very little information is available for this activity. Two IPPC-regulated companies provided information to allow estimates to be made for a limited number of years (1998, 2004 and 2006-2015). Emissions were assumed to remain at 1998 levels for the period 1990-1997 as no emissions data were available. The remaining years were extrapolated. This is considered a Tier 1 method. The last company closed in 2016 and emissions are reported using the notation key NO for 2016 -2019. Estimates of NMVOC emissions from textile finishing are provided in Table 4.29.

Table 4.29 Non-Methane Volatile Organic Compound Emissions from Textile Finishing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.078	0.078	0.049	0.033	0.030	0.030	0.028	0.028	0.028	0.028	NO	NO	NO	NO

4.5.6 Printing (2D3h)

Printing involves the use of various types of inks, which may contain a proportion of organic solvents which may be diluted before use. Different inks have different proportions of organic solvents and require dilution to different extents. Printing can also require the use of cleaning solvents and organic dampeners. The main printing techniques identified include offset, cold-set web offset, heat-set web offset, sheet-fed offset, rotogravure, flexography, letterpress, and screen-printing.

Usage and emission data are sourced from IPPC-regulated companies and scaled for those not regulated by IPPC based on national statistics and average emissions. Estimates of NMVOC emissions

from printing are provided in Table 4.30. The large decrease in emissions is due to abatement measures introduced by the companies operating in Ireland due to the Solvent Directive (1999/13/EC) and a general greater awareness of environmental issues by the print industry. While the printing industry was affected by the economic recession from 2008 in Ireland and resulted in a decreasing emission trend, emissions increased in 2009 and 2010 due to emissions from two IPPC licenced facilities. An overall decrease in emissions has been seen since then. The methodology is considered a Tier 3 method.

Table 4.30 Non-Methane Volatile Organic Compound Emissions from Printing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	2.912	2.912	1.946	2.126	2.474	1.788	1.217	1.283	1.400	1.462	1.468	1.206	1.368	0.986

4.5.7 Other Use of Solvents and Related Activities (2D3i-2G)

This sector consists of 11 subcategories, which are a mixture of industrial and non-industrial activities, only 8 of which are applicable to Ireland. In NFR 2D3i (Other solvent use) the categories; Mineral wool enduction (060402) and Other (060412) are not considered to occur in Ireland. In NFR 2G4 Other product use the category Use of shoes (060602) is not estimated for Ireland. The 8 subcategories for which emission estimates are made are as follows with the relevant SNAP code in parentheses:

NFR 2D3i;
- Glass Wool Blowing/Enduction (060401)
- Fat, edible and non-edible oil extraction (060404)
- Application of Glues and Adhesives (060405)
- Preservation of Wood (060406)
- Underseal Treatment and Conservation of Vehicles (060407)
- Vehicle Dewaxing (060409)
- 4-stroke engine oil burning

NFR 2G4;
- Use of Fireworks (060601)
- Use of Tobacco (060602)

Both bottom–up and top–down approaches are used in the estimation of emissions from the subcategories outlined, depending on the availability of data for each subcategory. Similar to the other categories, further information in relation to subcategory estimation methodologies can be found in Finn et al. (2001), CTC/AEA (2005) and Barry and O'Regan (2014).

4.5.7.1 Glass Wool Blowing/Enduction (SNAP 060401)

Glass fibre manufacturing is the high-temperature conversion of various raw materials into a homogeneous melt, followed by the fabrication of this melt into glass fibres. The two basic types of glass fibre products, textile and wool, are manufactured by similar processes. Within the category in Ireland, formaldehyde and phenol are used. Usage and emission data have been sourced from one IPPC-regulated company which ceased operation in 2009. Estimates of NMVOC emissions from this source category are provided in Table 4.31.

Table 4.31 Non-Methane Volatile Organic Compound Emissions from Glass Wool Blowing/Enduction

Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008
NMVOC (kt)	0.003	0.003	0.003	0.003	0.003	0.003	0.005	0.005	0.005	0.005	0.001

4.5.7.2 Fat, edible and non-edible oil extraction (SNAP 060404)

This sector covers solvent extraction of edible oils from oilseeds and drying of leftover seeds before resale as animal feed. The extraction of oil from oil seeds is performed either mechanically or through the use of solvents, or both. Where solvent is used, it is generally recovered and cleaned for reuse. The seed may be subjected to solvent treatment many times before all the oil is extracted. The remaining seed residue is then dried and may be used as an animal feed. Emissions of NMVOC, TSP, PM_{10} and $PM_{2.5}$ for this sector were estimated using statistics obtained from the C.S.O on the national yield of oilseed. The Inventory Guidebook (EMEP/EEA, 2019) Tier 2 emission factors from Table 3-4 were applied. Estimates of NMVOC, TSP, PM_{10} and $PM_{2.5}$ are given in Table 4.32.

Table 4.32 Emissions from Fat, edible and non-edible oil extraction

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.031	0.020	0.014	0.022	0.044	0.088	0.092	0.077	0.054	0.063	0.054	0.065	0.064	0.060
TSP (kt)	0.022	0.014	0.009	0.016	0.031	0.061	0.065	0.054	0.038	0.044	0.038	0.046	0.045	0.042
PM10 (kt)	0.018	0.012	0.008	0.013	0.025	0.050	0.053	0.044	0.031	0.036	0.031	0.038	0.037	0.035
PM2.5 (kt)	0.012	0.008	0.005	0.009	0.017	0.034	0.035	0.030	0.021	0.024	0.020	0.025	0.025	0.023

4.5.7.3 Application of Glues and Adhesives (SNAP 060405)

This sector covers the use of all adhesives excluding domestic adhesive usage and includes adhesive and magnetic tape production (SNAP 060311). These data include adhesives used for publications and packaging, footwear, construction, transport equipment, rubber and plastic products, abrasives, engineering, laminating and other sectors.

This estimate is based upon net consumption statistics (import minus export data) and the Inventory Guidebook (EMEP/EEA, 2019) default emission factor of 522 g/kg of adhesive. The methodology is considered a Tier 2 method. Estimates of NMVOC emissions from the application of glues and adhesives are provided in Table 4.33.

Table 4.33 Non-Methane Volatile Organic Compound Emissions from Application of Glues and Adhesives

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.540	0.313	0.755	2.986	1.121	1.293	0.872	0.701	0.972	1.123	1.064	1.122	1.388	1.516

4.5.7.4 Preservation of Wood (SNAP 060406)

This section refers to emissions from the industrial use of wood preservatives. It does not include emissions from the surface coating of timber with paints, varnishes or lacquer (which are covered under SNAP 060107), and it does not cover the use of wood preservatives by the public at large (which is covered under SNAP 060408). Wood preservation is carried out using solvent-based preservatives, water-based preservatives or creosote. Creosote is an oil product, prepared from coal tar distillation,

and contains a high proportion of aromatic compounds such as PAHs. Regulations banning the sale of creosote took effect from June 2003. However, creosote may still be used for industrial applications, e.g. railway sleepers, telegraph poles and fencing, but with tougher restrictions on its composition and how it is applied. Creosote is gradually being replaced by water-borne preservatives. Preservatives based on organic solvents have a wide-ranging content of organic solvent, usually white spirit or other petroleum-based hydrocarbons. Water-borne preservatives consist of solutions of inorganic salts in water, with Cu, Cr and As (CCA)-based preservatives being the most widely used. Water-borne preservatives are not of concern to this inventory, as they do not contain VOCs.

In addition to bottom–up IPPC-licensed data, usage data was provided by the sole Creosote using company in Ireland. The Inventory Guidebook (EMEP/EEA, 2019) emission factor of 105 g/litre creosote applied is used. The methodology is considered a Tier 3 method. Estimates of NMVOC emissions from wood preservation are provided in Table 4.34.

Table 4.34 Non-Methane Volatile Organic Compound Emissions from Preservation of Wood

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.092	0.122	0.216	0.090	0.292	0.239	0.536	0.342	0.354	0.236	0.252	0.241	0.254	0.172

4.5.7.5 Underseal Treatment and Conservation of Vehicles (SNAP 060407)

The application of coatings to the underside of car bodies is conducted for protection from stone chips and for sound deadening. In the aftermarket sector, coatings are applied to the underside of cars only during repair of damaged bodywork. Finn et al. (2001) stated that sources within the trade suggested that application of underseal in Ireland was zero or minimal. However, further contact with suppliers revealed that a market of 650 l/annum existed at the time (1998). It is assumed that this market existed for all years prior to 1998. However, CTC/AEA (2005) suggested that this market no longer exists in Ireland and that emissions decreased in a linear fashion up to 2003, after which emissions from the activity no longer occur. The approach uses an average solvent content of 20 per cent, a density of 1,000 kg/m^3, and assumes that 100 per cent of the solvent is emitted. Estimates of NMVOC emissions from this source category are provided in Table 4.35.

Table 4.35 Non-Methane Volatile Organic Compound Emissions from Underseal Treatment and Conservation of Vehicles

Year	1990	1995	2000	2001	2002	2003
NMVOC (Kg)	130	130	87	65	43	22

4.5.7.6 Vehicle Dewaxing (SNAP 060409)

In the past, some manufacturers of new cars applied a protective covering to parts of the car body after painting to provide protection during transport. Removal of this coating was carried out at the import centres using solvents. However, car manufacturers now invariably use either water-soluble wax that can be removed using hot water or self-adhesive film instead of wax. Consequently, it is assumed that emissions from this activity are now zero. Discussion with car distributors suggested that, historically, 20 per cent of new cars in Ireland were dewaxed and that the practice was discontinued after 2003. An emission factor of 1 kg/car is applied to estimate emissions using vehicle statistics provided by the CSO (Finn et al., 2001). Estimates of NMVOC emissions from vehicle dewaxing are provided in Table 4.36.

Table 4.36 Non-Methane Volatile Organic Compound Emissions from Vehicle Dewaxing

Year	1990	1995	2000	2001	2002	2003
NMVOC (kt)	0.035	0.035	0.023	0.017	0.012	0.006

4.5.7.7 Use of Tobacco (SNAP 060602)

This category comprises NMVOC, NO_x, CO, NH_3, TSP, PM_{10}, $PM_{2.5}$ and BC emissions from the combustion (smoking) of tobacco products. Activity data was obtained from The Office of the Revenue Commissioners regarding the excise volumes of tobacco and includes an estimation of Illegal tobacco imported to Ireland from an illegal products research report produced by the Office of the Revenue Commissioners (Office of the Revenue Commissioners, 2017). A significant decrease in tobacco products was noted in 2018 and an increase was seen in 2019. The Inventory guidebook (EMEP/EEA, 2019) Tier 2 emission factors in table 3-15 are applied. Estimates of emissions from Use of Tobacco are provided in Table 4.37.

Table 4.37 Emissions from Use of Tobacco

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.034	0.037	0.039	0.032	0.024	0.025	0.023	0.020	0.019	0.020	0.017	0.022	0.011	0.017
NOx (kt)	0.013	0.014	0.015	0.012	0.009	0.009	0.008	0.007	0.007	0.008	0.006	0.008	0.004	0.006
CO (kt)	0.386	0.419	0.449	0.360	0.278	0.280	0.257	0.224	0.213	0.230	0.194	0.250	0.127	0.196
NH3 (kt)	0.029	0.032	0.034	0.027	0.021	0.021	0.019	0.017	0.016	0.017	0.015	0.019	0.010	0.015
TSP (kt)	0.189	0.205	0.220	0.176	0.136	0.137	0.126	0.110	0.104	0.113	0.095	0.123	0.062	0.096
PM10 (kt)	0.189	0.205	0.220	0.176	0.136	0.137	0.126	0.110	0.104	0.113	0.095	0.123	0.062	0.096
PM2.5 (kt)	0.189	0.205	0.220	0.176	0.136	0.137	0.126	0.110	0.104	0.113	0.095	0.123	0.062	0.096
BC (kt)	0.076	0.082	0.088	0.070	0.054	0.055	0.050	0.044	0.042	0.045	0.038	0.049	0.025	0.038

4.5.7.8 Use of Fireworks (SNAP 060601)

This category comprises NO_x, CO, SO_2, TSP, PM_{10} and $PM_{2.5}$ emissions from the use of fireworks. Activity data was obtained from The Department of Justice and Equality and relates to the professional use of fireworks in displays. The Inventory guidebook (EMEP/EEA, 2019) Tier 2 emission factors in Table 3-14 are applied. Estimates of emissions from Use of Fireworks are provided in Table 4.38.

Table 4.38 Emissions from Use of Fireworks

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NOx (t)	0.011	0.012	0.012	0.012	0.012	0.011	0.011	0.010	0.010	0.008	0.007	0.009	0.009	0.010
CO (t)	0.315	0.331	0.340	0.335	0.326	0.307	0.293	0.283	0.262	0.208	0.199	0.240	0.252	0.272
SO2 (t)	0.133	0.140	0.143	0.141	0.138	0.130	0.124	0.119	0.111	0.088	0.084	0.101	0.106	0.115
TSP (t)	4.835	5.091	5.218	5.145	5.011	4.717	4.505	4.340	4.021	3.193	3.059	3.687	3.865	4.174
PM10 (t)	4.399	4.632	4.747	4.681	4.559	4.291	4.098	3.949	3.659	2.905	2.783	3.354	3.516	3.798
PM2.5 (t)	2.287	2.408	2.468	2.433	2.370	2.231	2.130	2.053	1.902	1.510	1.447	1.744	1.828	1.974

4.5.7.9 4-stroke engine lubricant consumption

The COPERT model used for estimating emissions of air pollutants from road transport includes heavy metal emissions from lubricant oil. These metals are assumed to be emitted to the atmosphere when oil burning occurs in the engine combustion chamber. Lubricant consumption in 2-stroke engines is considered intentional, therefore emissions must be reported under 1A3b. On the other hand 4-stroke

engine lubricant consumption is undesirable and should not take place. However small amounts are consumed in the combustion chamber and their emissions are reported in 2D3i. Emissions of heavy metals are shown in Table 4.51.

Table 4.51 Emissions from 4-stroke oil combustion in road transport

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Pb (t)	0.0001	0.0001	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Cd (t)	0.0147	0.0178	0.0299	0.0364	0.0341	0.0338	0.0328	0.0337	0.0346	0.0358	0.0363	0.0357	0.0359	0.0364
Cr (t)	0.0617	0.0751	0.1261	0.1531	0.1438	0.1421	0.1380	0.1417	0.1458	0.1506	0.1527	0.1503	0.1510	0.1534
Cu (t)	2.4995	3.0436	5.1088	6.2031	5.8255	5.7585	5.5933	5.7420	5.9078	6.1015	6.1895	6.0896	6.1170	6.2177
Ni (t)	0.1025	0.1248	0.2094	0.2543	0.2388	0.2360	0.2293	0.2354	0.2422	0.2501	0.2537	0.2496	0.2507	0.2549
Se (t)	0.0146	0.0178	0.0298	0.0362	0.0340	0.0336	0.0326	0.0335	0.0345	0.0356	0.0361	0.0355	0.0357	0.0363
Zn (t)	1.4464	1.7612	2.9563	3.5895	3.3710	3.3322	3.2366	3.3227	3.4186	3.5307	3.5816	3.5238	3.5397	3.5980

4.5.8 Food and Beverage Industry (NFR 2H2)

According to the EMEP/EEA Guidebook (EMEP/EEA, 2019) this sector includes emissions from all processes in the food production chain which occur after the slaughtering of animals and the harvesting of crops as well as drink manufacturing including production of alcoholic beverages. For Ireland, Wine production (040606) is not occurring, Sugar production (040625) has not occurred since 2005, when the last sugar factory was closed (no activity data available), and Flour production (040626) does not occur on a large scale (no activity data available), margarine and fats production is not thought to occur (no activity data available). Emissions include Spirit production, Animal feed production and Bread production which are the most significant source of emissions in the Food and Beverage industry in Ireland. The 6 subcategories for which emission estimates are made for Ireland are as follows with the relevant SNAP code in parentheses, where applicable:

Bread (SNAP 040605)

Beer (SNAP 040607)

Spirits (SNAP 040608)

Meat fish etc. frying/curing (SNAP 040627)

Coffee Roasting

Feedstock

4.5.8.1 Bread (SNAP 040605)

This sector includes bread, cakes and baking products. Activity data on white bread and bread products production was obtained from EUROSTAT for years 1995 to 2019. The data for years 1990-1994 was taken to be the same as 1995 as no data was available for these years. Emissions from cakes are not included in this estimate as no activity data is available. Tier 2 emission factors from the Inventory guidebook (EMEP/EEA, 2019) were used for bread and cakes, biscuits and breakfast cereals i.e. baking goods. The NMVOC emissions from Bread is given in table 4.39.

Table 4.39 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Bread

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

NMVOC (kt)	1.707	1.707	1.006	1.374	2.577	1.707	1.593	1.838	1.714	1.696	1.643	1.749	2.848	1.922

4.5.8.2 Beer (SNAP 040607)

This includes mainstream beer production and craft beer production which has seen a steady increase since 2005 and a significant increase in Ireland since 2010. Activity data was obtained from a variety of sources including the Irish Brewers Association reports (ABFI,2013, 2014, 2015, 2017 & 2018) and Independent Craft Brewers of Ireland and Bord Bia Report (Feeney, 2015). The Inventory Guidebook (EMEP/EEA, 2019) Tier 2 emission factor of 0.035 kg/hL was used. The NMVOC emissions from Beer production is given in table 4.40.

Table 4.40 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Beer

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.194	0.207	0.225	0.250	0.274	0.274	0.288	0.282	0.258	0.276	0.274	0.286	0.297	0.294

4.5.8.3 Spirits (SNAP 040608)

Spirit production is a significant source of NMVOC emissions within the Food and Beverage industry due to the growth of the Whiskey production industry in Ireland. In the current submission activity data is based on national statistics for the years 1999-2019. Other years were extrapolated using this data. A Tier 2 emission factor of 15kg/hl alcohol was used from the Inventory Guidebook (EMEP/EEA, 2019). NMVOC emissions from Spirit production in Ireland in given in table 4.41.

Table 4.41 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Spirits

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	3.97	4.68	4.90	8.53	12.29	13.31	14.69	16.29	13.56	14.38	15.50	20.44	19.28	22.29

4.5.8.4 Meat, fish etc., frying/curing (SNAP 040627)

Emissions mainly occur from the cooking of meat, fish and poultry, releasing fats and oils and their degradation products. Emissions from fish frying and curing were not estimated due to absence of accurate activity data. Activity data for fish frying is under investigation and included in the planned improvement section 4.10. Activity data was obtained from the CSO on tonnes of animal slaughterings in Ireland which is taken to be the equivalent of meat rendered in Ireland the Inventory guidebook (EMEP/EEA, 2019) emission factor of 0.33 kg/Mg of meat rendered was used. Activity data on human consumption of meat from the CSO was taken to equate to meat frying and using the Inventory Guidebook (EMEP/EEA, 2019) emission factor of 0.3 kg/Mg product was used this is considered a Tier 2 method. The NMVOC emissions from meat frying/curing is given in table 4.42.

Table 4.42 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Meat, fish etc. frying/curing

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.398	0.402	0.450	0.438	0.425	0.426	0.415	0.424	0.457	0.457	0.481	0.500	0.510	0.515

4.5.8.5 Coffee Roasting

The roasting of coffee beans is a source of NMVOC emissions. This activity does not have a relevant SNAP code. Activity data for unroasted coffee imports was obtained from the UN Comtrade Database and the Tier 2 emission factor from the Inventory Guidebook (EMEP/EEA, 2019) was used to estimate emissions as can be seen in table 4.43.

Table 4.43 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Coffee roasting

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.001	0.001	0.002	0.003	0.001	0.003	0.003	0.003	0.003	0.005	0.006	0.007	0.007	0.006

4.5.8.6 Feedstock

The processing of by-products to produce animal feeds is a source of NMVOC emissions in Ireland. The tonnage of animal feed produced was sourced from the CSO and the Inventory Guidebook (EMEP/EEA, 2019) emission factor of 1 kg/Mg feed was used to estimate emissions from this source as can be seen in table 4.44.

Table 4.44 Non-Methane Volatile Organic Compound Emissions from Food and Beverage Industry; Feedstock

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	3.351	3.291	3.168	3.090	2.636	2.563	3.801	3.621	3.142	3.529	3.611	3.856	4.070	4.246

4.6 Other production, consumption, storage, transportation or handling of bulk product (NFR 2L)

The Other production, consumption, storage, transportation or handling of bulk product category in Ireland's air pollutant inventory includes emissions of PCDD/F and PCBs from leakage from electrical equipment and emissions of PCBs from fragmentisers and shredders. The main use of PCBs since the 1970s, when open uses were banned, has been as dielectric fluids in electrical equipment such as transformers and capacitors. However, the production and use of dielectric fluid containing PCBs has been highly regulated since 1986. Releases to the environment have decreased since 1990 as older PCB-containing equipment is taken out of service and is replaced by PCB-free equipment, which reduces the stocks that may lead to PCB emissions. It is also taken into consideration that, in some cases, trace PCDD/F may be present in PCB dielectric fluid. These arise from the original PCB synthesis process and from oxidation during dielectric breakdown events.

Electrical equipment, including white goods and electronic equipment, is partly recycled by breaking down the products in fragmentisers and shredders. Fragments are separated into ferrous scrap, a fraction containing non-ferrous scrap (which would then be processed separately), and a waste fraction that is typically disposed to landfill. Polychlorinated biphenyls are present in the capacitors of

old electrical equipment. Hence, there is potential for PCBs to be released to air during fragmentiser operations.

4.6.1 Leakage from Electrical Equipment (NFR 2L)

The release of PCBs to the environment from electrical equipment is very difficult to estimate with any accuracy due to the large number of components potentially containing PCBs, the range of lifetime and replacement rates for PCB components, and the difficulties for users in identifying such components. Polychlorinated biphenyls have never been manufactured in Ireland. Production ceased in the UK in 1977 and in the rest of Europe and North America in 1986. Manufacturers of electrical equipment were then supplied with alternative dielectric media and replacement products entered the market. However, some countries outside the EU and North America continued to produce these substances until recently. Hence, products from those countries may have continued to contain PCBs until the mid-1990s. Current releases to the environment arise principally from the closed electrical appliances that still exist, as their useful life could be up to 40 years.

Activity data are very difficult to obtain on quantities of PCBs in existing transformers and associated leakage rates. A National Inventory of PCB Holdings for Ireland was originally prepared in 2001. This inventory has been updated a number of times, the most recent data corresponding to 2019. The report for this inventory provides an estimate of the total volume of PCB oil (confirmed and suspected) for 2019 of 12.98 m^3. This estimate includes both inventoried (confirmed) large and small holdings and estimated non-inventoried (suspected) holdings. Indications are that this is an overestimate and that many of the suspected holdings do not contain any PCBs. The estimate of holdings for 2019 represents a substantial decrease on the peak value in 2009 (522.06 m^3) following a large decrease in 2008 (114.29 m^3). This is partly due to methodological changes in the inventory compilation, which has given rise to a step change in the emission estimates. This issue requires further investigation to determine the level of inconsistency that may have been introduced across the current time series. The European Union's Chemical Legislation European Enforcement Network (CLEEN) initiated a project to compare inventories of PCBs in Member States of the EU. The CLEEN project documents summarise a large amount of information held within the EU offices (on PCB stocks) that have been reported by Member States to the EC but have not to date been published or synthesised by the Commission itself. Analysis of the CLEEN data indicates that Ireland has a lower than average PCB per-capita stock when compared with other Member States. All of this qualitative information points towards a lower than average prevalence of PCB-containing materials within electrical equipment in Ireland and this has been taken into consideration in the estimation method used for category 2L.

The derivation of activity data outlined above provides a time series of estimates of PCB-containing oil stocks in Ireland, based on a worst-case assumption that all of the as yet unreported transformer stocks do contain PCBs. The estimates range from 417,620 dm^3 of oil in 1990 to 12,983 dm^3 of oil (as reported by the EPA) in 2019. Data from the UK NAEI indicate that annual emissions of PCBs derived from dielectric fluid stocks can be estimated as 0.5 g PCBs/kg fluid, of which emissions to air comprise 0.06 g PCBs/kg emitted, with the remainder emitted to land. In the absence of source activity and monitoring data, these factors have been used to estimate Ireland's PCB emission estimates. The time series of PCB emissions from leakage of electrical equipment is presented in Table 4.45. As noted above, the current data gives rise to a sharp increase in emissions for 2009 to decrease again in 2010

and further in each consecutive year, caused by a change in the methodology used for estimating the volume of dielectric fluid containing PCBs. Total quantity of PCB containing oil contained in equipment in-situ at start of year for 2018 is substantially lower than previous years, resulting in decreased emissions.

The data on PCDD/F concentrations in dielectric PCB fluid from Dyke (1997) give a concentration in PCB dielectric fluid of 83.5 µg I-TEQ/kg of PCBs. It is assumed that the evaporation rate is the same for PCBs and PCDD/F so that for every kilogram of PCBs that is emitted to air, 83.5 µg I-TEQ of PCDD/F are emitted. Using this factor, estimates for PCDD/F emissions to air from dielectric fluid stocks in Ireland have been made. The time series of PCDD/F emissions from leakage from electrical equipment is presented in Table 4.45.

Table 4.45 Time Series of Polychlorinated Biphenyls and Dioxin and Furan Emissions from Leakage from Electrical Equipment

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PCDD/F (µg I-TEQ)	1.034	1.034	0.842	0.790	0.625	0.546	0.172	0.061	0.055	0.036	0.032	0.032	0.032	0.032
PCBs (kg)	0.0124	0.0124	0.0101	0.0095	0.0075	0.0065	0.0021	0.0007	0.0007	0.0004	0.0004	0.0004	0.0004	0.0004

4.6.2 Fragmentisers and Shredders (NFR 2L)

The practice of fragmenting or shredding electrical equipment currently occurs in a small number of IPPC-licensed facilities, where any suspected POP-containing components (e.g. capacitors) are removed and the residual material is then exported. White goods are also exported for recovery or treatment. The recycling of electrical and electronic goods has also been improved since the introduction of the WEEE Regulations in 2005. However, prior to the commencement of the WEEE Regulations and the All Island Fridge & Freezer Collection and Export Scheme in 2004, it is possible that white goods may have been shredded within Ireland, although there is little evidence that such practice was widespread. To provide a worst-case estimate for this potential emission, the UK NAEI activity data have been scaled on a per-capita basis to prepare estimates for Ireland for 1990–2005.

The shredding of End-of-Life Vehicles (ELVs) is another operation that may result in the possible emissions of POPs, and it has been found to be a relatively significant source in other European countries. Currently, two companies operate ELV shredders at three locations. The larger company operates two shredders but undertakes no monitoring of POPs on incoming vehicles or auto residue post-shredding. However, due to the ELV regulations all vehicles are "de-polluted" either on-site or prior to receipt from dismantlers, with all suspected contaminated materials being removed. In addition, the de-polluting process is expected to further improve in future years. Approximately 30,000 tonnes of auto residue (de-polluted vehicles) are shredded annually. Prior to the implementation of the ELV regulations the entire intact vehicle was shredded. Therefore, it can be assumed that for earlier years the shredding of ELVs would have resulted in larger quantities of shredded auto residue, with a higher potential for release of POPs.

Very limited data are available on emissions of POPs to air from fragmentisers, especially for the early part of the time series. Emission estimates for POPs are based on the Inventory Guidebook (2000) factor of 0.004 g/capita/year for PCB emissions from fragmentisers, which is considered to apply in the early part of the time series, around the time of the banning of PCBs (1985). The starting point for the time series of estimates of emissions from fragmentisers in Ireland is the estimated emissions in

1986 using population data and the factor of 0.004 g/capita/year, and this leads to an initial estimate of 14 kg PCBs emitted to air in Ireland in 1986. Assuming a 20-year lifespan of electronic equipment, it is reasonable to assume that 5 per cent of the 1986 emissions are removed each year, as old PCB-containing equipment is disposed of and new PCB-free equipment is used as replacements. This assumption leads to an estimated time series of PCB emissions to air of 11.9 kg in 1990, falling to zero emissions by 2006 and are reported using the notation key "NO" for the period 2006 to 2019. Although this is a very broad "top–down" approach and is subject to significant uncertainty, there are very little additional data available to inform more accurate estimates. Emission estimates for the time series are presented in Table 4.46.

Table 4.46 Emission Time Series for Polychlorinated Biphenyls from Fragmentisers and Shredders

Year	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2018	2019
PCBs (kg)	11.920	8.643	5.305	4.617	3.917	3.184	2.427	1.654	NO	NO	NO	NO

4.7 Recalculations in the Industrial Processes Sector

4.7.1 Heavy Metals recalculations

There were minor recalculations to emission estimates for 1990–2018 in sector 2D3i Other solvent use. This was a result of emissions calculated in COPERT (Computer programme to calculate emissions from road transport) from lubricant oil which contains a number of heavy metals which is assumed to be emitted to the atmosphere when oil burning occurs in the combustion chamber. These recalculations were as a result of improvements to the stock inputs to the COPERT model. Recalculations averaged 6 to 9 per cent across the time series. In 2C metal production there was a recalculation for Pb and Cd for 2017 and 2018 due to an omission in the 2020 submission which was corrected in this submission Recalculations are as shown in Table 4.48.

4.7.2 Particulate matter recalculations

There was a recalculation for 2011 in 2.A.5.a Quarrying and mining of minerals and 2.A.5.c Storage and transport of mineral products due to an update to activity data on domestic extraction of non-metallic minerals by the national statistics provider C.S.O. This resulted in a reduction of 22.4 per cent for TSP, PM $_{2.5}$ and PM$_{10}$ for 2011.

4.7.3 Nitrogen Oxides (NOx) recalculations

There were no recalculations to emission estimates for 1990-2018 as can be seen in table 4.50.

4.7.4 Non- Methane Volatile Organic Compounds (NMVOC) recalculations

Recalculations occurred in this reporting round due to updates to activity data in category 2H2 Food and Beverages industry. Revisions were made to activity data by the CSO which resulted in a change in the emissions estimates as can be seen in Table 4.50. 2D2d Coating applications also had a recalculation of 44.5 per cent in 2018 due to correction in reported emissions which were omitted in the 2020 submission.

4.8 Quality Assurance/Quality Control

Section 4.7 outlines the recalculations which were undertaken in the Industrial Processes sector in this reporting round. The inventory agency will continue to implement QA/QC procedures with respect to the estimates from the Industrial Processes sector in future submissions. The time series spreadsheet system developed for individual categories as described in Section 1.3.5 now allows for simple and efficient checking of activity data, emission factors, annual emissions and aggregated totals. Year-on-year changes immediately highlight any omissions, anomalies or internal errors. Initial checks are conducted by the inventory compiler as part of the calculation process, which is followed by a second check by another member of the inventories team and completion of the QA/QC sheets in calculation workbooks.

4.9 Overview of Notation Keys

Table 4.47 describes the notation keys used in the 2018 NMVOC emission inventory for Other Solvent and Product Use (2D-2L).

Table 4.47 Notation keys used in 2018 NMVOC inventory

NFR	Snap	Description	Notation Key	Reason
2D3a	060411	Domestic use of pharmaceutical products	IE	Included in 060408
2D3e	060203	Electronic components manufacturing	IE	Included under metal degreasing
2D3e	060204	Other industrial cleaning	IE	Included under metal degreasing
2D3g	060311	Adhesive, magnetic tapes, films and photographs manufacturing	IE	Included under 060405

4.10 Planned Improvements

The inventory team will continue to review emission estimates for this sector in light of any new information that may become available for future submissions. In addition, the inventory team also plans to continue to outsource contracts on a periodic basis to re-examine and extend the inventory time series with respect to emissions of heavy metals and POPs.

Ireland is aware of the EFs for Hg in the 2016 Guidebook for NFR sector 2D3c Asphalt roofing. Data was requested from the Irish Asphalt Producers association (IAPA), the PRODCOM data was requested from the national statistics agency (CSO) however, neither of these organizations could provide a suitable data source. It has been determined that the production of asphalt roofing materials does not occur in Ireland. This category is thus reported using the notation key "NO". In relation to emissions of Hg from NFR 2K, Ireland notes that a Tier 1 approach is available in the 2019 EMEP/EEA Inventory Guidebook and continue to investigate whether mercury containing button cell batteries data is available in Ireland. Latest efforts to source activity data on button cell batteries included contacting the national statistics agency (CSO), Producer Register Ireland and Waste Electrical and Electronic Equipment Ireland (WEEE) as well as metal recyclers in Ireland, however a reliable source of this data has not yet been found. Ireland is attempting to find suitable activity data on mercury containing

batteries sold and recovered in the country. To date we have received limited information on the amount of all batteries placed on the market and waste batteries collected for recycling (exported) however, we do not have information on what proportion of these batteries contain mercury. As we do not have suitable activity data we cannot determine whether this category is above or below the threshold of significance. As stated in the 2019 Inventory guidebook (EMEP/EEA, 2019) the Tier 1 emission factors need to be used with some caution as they are based on old studies with a very large uncertainty and may overestimate this sector. Current estimates of Hg are approximately 300 kg per annum in 2018. Ireland does not consider adding another 49 kg of Hg emissions (0.01g/capita) to the national total without an explanation of the source to the inventory as good practice.

The levels of solvent use and the emissions from solvents are changing substantially in response to product replacement and reformulation and emission controls being implemented under IPPC and the Solvents Directive (1999/13/EC). The reduction of solvent content has been captured in the methodologies, but this has relied on a number of assumptions, and the collection of real data is required to determine emissions with improved confidence.

In addition, liaison with industry will allow refinement of the estimates for activities subject to licensed controls and to reflect abatement measures in the time series. However, the per capita approach to estimating NMVOC emissions will remain the only option in several important categories, such as SNAP code 060107 (Paint Application: Wood). For category 2D3a Domestic Solvent Use including fungicides) The 2019 Guidebook (EMEP/EEA, 2019) does not have an emission factor for this source and states "Due to the uncertainty around these releases, this source is currently not considered in the Guidebook." and so it is reported as NA.

Review recommendations and responses are included in this report as Annex H.

Table 4.48 Recalculations for Industrial Processes 1990−2018 (Heavy Metals)

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
2A3 Glass Production	Pb	t	0.311	0.311	0.311	0.129	0.008	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	Cd	t	0.007	0.007	0.007	0.000	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	Hg	t	0.001	0.001	0.001	0.001	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C Metal Production	Pb	t	3.473	3.387	2.127	0.041	0.047	0.035	0.016	0.007	0.016	0.001	0.000	0.000	0.000	0.000
2C Metal Production	Cd	t	0.249	0.238	0.241	0.001	0.001	0.008	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
2C Metal Production	Hg	t	0.033	0.031	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Submission 2021																
2A3 Glass Production	Pb	t	0.311	0.311	0.311	0.129	0.008	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	Cd	t	0.007	0.007	0.007	0.000	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	Hg	t	0.001	0.001	0.001	0.001	NA	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C Metal Production	Pb	t	3.473	3.387	2.127	0.041	0.047	0.035	0.016	0.007	0.016	0.001	0.000	0.000	0.000	0.000
2C Metal Production	Cd	t	0.249	0.238	0.241	0.001	0.001	0.008	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
2C Metal Production	Hg	t	0.033	0.031	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% Change in Emissions																
2A3 Glass Production	Pb	%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-
2A3 Glass Production	Cd	%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-	-
2A3 Glass Production	Hg	%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-	-
2C Metal Production	Pb	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%	11.8%
2C Metal Production	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	0.0%	100.0%
2C Metal Production	Hg	%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-	-	-

Table 4.49 Recalculations for Industrial Processes 1990−2018 (Particulates and NOx)

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
2A3 Glass Production	TSP	kt	0.023	0.023	0.022	0.006	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	PM$_{10}$	kt	0.020	0.020	0.019	0.005	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	PM$_{2.5}$	kt	0.018	0.018	0.017	0.005	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A5a Quarrying and mining of minerals other than coal	TSP	kt	3.213	3.000	6.792	10.110	6.344	4.310	3.947	3.569	3.704	3.605	3.777	4.558	4.835	4.835
2A5a Quarrying and mining of minerals other than coal	PM$_{10}$	kt	1.575	1.470	3.330	4.956	3.110	2.113	1.935	1.749	1.816	1.767	1.852	2.234	2.370	2.370
2A5a Quarrying and mining of minerals other than coal	PM$_{2.5}$	kt	0.158	0.147	0.333	0.496	0.311	0.211	0.193	0.175	0.182	0.177	0.185	0.223	0.237	0.237
2A5b Construction and Demolition	TSP	kt	1.739	1.928	1.552	6.247	7.968	12.493	0.527	0.744	1.852	1.171	1.377	1.145	3.270	0.968
2A5b Construction and Demolition	PM$_{10}$	kt	0.522	0.578	0.465	1.871	2.384	3.733	0.159	0.224	0.555	0.351	0.414	0.345	0.979	0.292
2A5b Construction and Demolition	PM$_{2.5}$	kt	0.052	0.058	0.047	0.187	0.238	0.373	0.016	0.022	0.055	0.035	0.041	0.034	0.098	0.029
2A5c Storage and Handling of mineral products	PM$_{2.5}$	kt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10b Storage, handling and transport of chemical products	TSP	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2B10b Storage, handling and transport of chemical products	PM$_{10}$	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2B10b Storage, handling and transport of chemical products	PM$_{2.5}$	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2C Metal Production	TSP	kt	0.071	0.071	0.006	0.001	0.002	0.001	0.001	0.000	0.001	NO	NO	0.000	0.000	0.000
2C Metal Production	PM$_{10}$	kt	0.060	0.060	0.005	0.001	0.002	0.001	0.001	0.000	0.001	NO	NO	0.000	0.000	0.000
2C Metal Production	PM$_{2.5}$	kt	0.042	0.042	0.003	0.001	0.001	0.001	0.000	0.000	0.000	NO	NO	0.000	0.000	0.000
2D3b Road Paving	TSP	kt	33.000	25.500	43.500	51.000	49.500	34.500	27.000	28.500	27.000	27.000	28.500	28.500	31.500	30.750
2D3b Road Paving	PM$_{10}$	kt	4.400	3.400	5.800	6.800	6.600	4.600	3.600	3.800	3.600	3.600	3.800	3.800	4.200	4.100
2D3b Road Paving	PM$_{2.5}$	kt	0.220	0.170	0.290	0.340	0.330	0.230	0.180	0.190	0.180	0.180	0.190	0.190	0.210	0.205
2D3i Other solvent use	TSP	kt	0.022	0.014	0.009	0.016	0.026	0.031	0.061	0.065	0.054	0.038	0.044	0.038	0.046	0.045
2D3i Other solvent use	PM$_{10}$	kt	0.018	0.012	0.008	0.013	0.021	0.025	0.050	0.053	0.044	0.031	0.036	0.031	0.038	0.037
2D3i Other solvent use	PM$_{2.5}$	kt	0.012	0.008	0.005	0.009	0.014	0.017	0.034	0.035	0.030	0.021	0.024	0.020	0.025	0.025
Submission 2021																
2A3 Glass Production	TSP	kt	0.023	0.023	0.022	0.006	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	PM$_{10}$	kt	0.020	0.020	0.019	0.005	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A3 Glass Production	PM$_{2.5}$	kt	0.018	0.018	0.017	0.005	0.000	NO	NO	NO	NO	NO	NO	NO	NO	NO
2A5a Quarrying and mining of minerals other than coal	TSP	kt	3.213	3.000	6.792	10.110	6.284	4.309	3.063	3.531	3.350	3.379	3.777	4.558	4.835	4.824
2A5a Quarrying and mining of minerals other than coal	PM$_{10}$	kt	1.575	1.470	3.330	4.956	3.080	2.112	1.501	1.731	1.642	1.656	1.852	2.234	2.370	2.365
2A5a Quarrying and mining of minerals other than coal	PM$_{2.5}$	kt	0.158	0.147	0.333	0.496	0.308	0.211	0.150	0.173	0.164	0.166	0.185	0.223	0.237	0.236
2A5b Construction and Demolition	TSP	kt	1.739	1.928	1.552	6.247	7.968	12.493	0.527	0.744	1.852	1.171	1.377	1.145	3.269	0.967
2A5b Construction and Demolition	PM$_{10}$	kt	0.522	0.578	0.465	1.871	2.384	3.733	0.159	0.224	0.555	0.351	0.414	0.345	0.979	0.291
2A5b Construction and Demolition	PM$_{2.5}$	kt	0.052	0.058	0.047	0.187	0.238	0.373	0.016	0.022	0.055	0.035	0.041	0.034	0.098	0.029
2A5c Storage and Handling of mineral products	PM$_{2.5}$	kt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2B10b Storage, handling and transport of chemical products	TSP	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2B10b Storage, handling and transport of chemical products	PM$_{10}$	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2B10b Storage, handling and transport of chemical products	PM$_{2.5}$	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2C Metal Production	TSP	kt	0.071	0.071	0.006	0.001	0.002	0.001	0.001	0.000	0.001	NO	NO	0.000	0.000	0.000
2C Metal Production	PM$_{10}$	kt	0.060	0.060	0.005	0.001	0.002	0.001	0.001	0.000	0.001	NO	NO	0.000	0.000	0.000
2C Metal Production	PM$_{2.5}$	kt	0.042	0.042	0.003	0.001	0.001	0.001	0.000	0.000	0.000	NO	NO	0.000	0.000	0.000
2D3b Road Paving	TSP	kt	33.000	25.500	43.500	51.000	49.500	34.500	27.000	28.500	27.000	27.000	28.500	28.500	31.500	30.750
2D3b Road Paving	PM$_{10}$	kt	4.400	3.400	5.800	6.800	6.600	4.600	3.600	3.800	3.600	3.600	3.800	3.800	4.200	4.100
2D3b Road Paving	PM$_{2.5}$	kt	0.220	0.170	0.290	0.340	0.330	0.230	0.180	0.190	0.180	0.180	0.190	0.190	0.210	0.205
2D3i Other solvent use	TSP	kt	0.022	0.014	0.009	0.016	0.026	0.031	0.061	0.065	0.054	0.038	0.044	0.038	0.046	0.045
2D3i Other solvent use	PM$_{10}$	kt	0.018	0.012	0.008	0.013	0.021	0.025	0.050	0.053	0.044	0.031	0.036	0.031	0.038	0.037
2D3i Other solvent use	PM$_{2.5}$	kt	0.012	0.008	0.005	0.009	0.014	0.017	0.034	0.035	0.030	0.021	0.024	0.020	0.025	0.025
% Change in Emissions																
2A3 Glass Production	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-
2A3 Glass Production	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-
2A3 Glass Production	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-
2A5a Quarrying and mining of minerals other than coal	TSP	%	0.0%	0.0%	0.0%	0.0%	-1.0%	0.0%	-22.4%	-1.1%	-9.5%	-6.3%	0.0%	0.0%	0.0%	-0.2%
2A5a Quarrying and mining of minerals other than coal	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	-1.0%	0.0%	-22.4%	-1.1%	-9.5%	-6.3%	0.0%	0.0%	0.0%	-0.2%
2A5a Quarrying and mining of minerals other than coal	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	-1.0%	0.0%	-22.4%	-1.1%	-9.5%	-6.3%	0.0%	0.0%	0.0%	-0.2%
2A5b Construction and Demolition	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
2A5b Construction and Demolition	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
2A5b Construction and Demolition	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
2A5c Storage and Handling of mineral products	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	-1.0%	0.0%	-22.4%	-1.1%	-9.5%	-6.3%	0.0%	0.0%	0.0%	-0.2%
2B10b Storage, handling and transport of chemical products	TSP	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2B10b Storage, handling and transport of chemical products	PM$_{10}$	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2B10b Storage, handling and transport of chemical products	PM$_{2.5}$	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2C Metal Production	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	0.0%	0.0%	0.0%
2C Metal Production	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	0.0%	0.0%	0.0%
2C Metal Production	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	0.0%	0.0%	0.0%
2D3b Road Paving	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3b Road Paving	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3b Road Paving	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3i Other solvent use	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.7%	0.0%
2D3i Other solvent use	PM$_{10}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.7%	0.0%
2D3i Other solvent use	PM$_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.7%	0.0%

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
2B2 Nitric Acid Production	NOx	kt	0.960	0.280	0.302	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Submission 2021																
2B2 Nitric Acid Production	NOx	kt	0.960	0.280	0.302	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
% Change in Emissions																
2B2 Nitric Acid Production	NOx	%	0.0%	0.0%	0.0%	-	-	-	-	-	-	-	-	-	-	-

Table 4.50 Recalculations for Industrial Processes 1990−2018 (NMVOC)

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
2D3a Domestic solvent use including fungicides	NMVOC	kt	7.927	8.143	8.568	9.347	10.250	10.298	10.344	10.368	10.385	10.422	10.481	10.767	10.818	10.869
2D3b Road Paving	NMVOC	kt	0.035	0.027	0.046	0.054	0.053	0.037	0.029	0.030	0.029	0.029	0.030	0.030	0.034	0.033
2D3c Asphalt Roofing	NMVOC	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D3d Coating Applications	NMVOC	kt	6.742	6.560	6.315	6.238	4.259	3.373	3.394	3.259	3.402	3.800	3.369	2.811	2.661	1.787
2D3e Degreasing	NMVOC	kt	1.743	2.388	0.847	0.953	0.789	0.885	0.925	1.004	0.795	0.885	0.686	0.885	1.187	1.707
2D3f Dry Cleaning	NMVOC	kt	0.282	0.270	0.090	0.085	0.063	0.053	0.058	0.075	0.057	0.069	0.044	0.062	0.064	0.071
2D3g Chemical products manufacturing or processing	NMVOC	kt	3.023	3.024	2.786	1.189	1.888	0.999	1.149	1.224	1.248	1.082	0.986	1.168	1.243	1.230
2D3h Printing	NMVOC	kt	2.912	2.912	1.946	2.126	2.360	2.474	1.788	1.217	1.283	1.400	1.462	1.468	1.206	1.368
2D3i Other solvent use	NMVOC	kt	0.701	0.493	1.011	3.103	2.198	1.457	1.620	1.501	1.121	1.379	1.422	1.370	1.423	1.714
2G Other product use	NMVOC	kt	0.034	0.037	0.039	0.032	0.027	0.024	0.025	0.023	0.020	0.019	0.020	0.017	0.022	0.011
2H2 Food and Beverages Indsutry	NMVOC	kt	9.617	10.216	9.683	13.296	15.540	18.052	18.184	20.412	22.492	19.031	20.041	21.241	26.575	26.802
Submission 2021																
2D3a Domestic solvent use including fungicides	NMVOC	kt	7.927	8.143	8.568	9.347	10.250	10.298	10.344	10.368	10.385	10.422	10.481	10.767	10.818	10.869
2D3b Road Paving	NMVOC	kt	0.035	0.027	0.046	0.054	0.053	0.037	0.029	0.030	0.029	0.029	0.030	0.030	0.034	0.033
2D3c Asphalt Roofing	NMVOC	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D3d Coating Applications	NMVOC	kt	6.742	6.560	6.315	6.238	4.259	3.373	3.394	3.259	3.402	3.800	3.369	2.811	2.663	2.583
2D3e Degreasing	NMVOC	kt	1.743	2.388	0.847	0.953	0.789	0.885	0.925	1.004	0.795	0.885	0.686	0.885	1.189	1.708
2D3f Dry Cleaning	NMVOC	kt	0.282	0.270	0.090	0.085	0.063	0.053	0.058	0.075	0.057	0.069	0.044	0.062	0.064	0.072
2D3g Chemical products manufacturing or processing	NMVOC	kt	3.023	3.024	2.786	1.189	1.888	0.999	1.149	1.224	1.248	1.082	0.986	1.168	1.243	1.230
2D3h Printing	NMVOC	kt	2.912	2.912	1.946	2.126	2.360	2.474	1.788	1.217	1.283	1.400	1.462	1.468	1.206	1.368
2D3i Other solvent use	NMVOC	kt	0.701	0.493	1.011	3.103	2.198	1.457	1.620	1.501	1.120	1.379	1.422	1.370	1.428	1.706
2G Other product use	NMVOC	kt	0.034	0.037	0.039	0.032	0.027	0.024	0.025	0.023	0.020	0.019	0.020	0.017	0.022	0.011
2H2 Food and Beverages Indsutry	NMVOC	kt	9.617	10.285	9.751	13.686	15.646	18.198	18.281	20.788	22.457	19.133	20.342	21.514	26.836	27.017

% Change in Emissions																
2D3a Domestic solvent use including fungicides	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3b Road Paving	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3c Asphalt Roofing	NMVOC	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2D3d Coating Applications	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	44.5%
2D3e Degreasing	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
2D3f Dry Cleaning	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
2D3g Chemical products manufacturing or processing	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3h Printing	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2D3i Other solvent use	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.4%	-0.5%
2G Other product use	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2H2 Food and Beverages Industry	NMVOC	%	0.0%	0.7%	0.7%	2.9%	0.7%	0.8%	0.5%	1.8%	-0.2%	0.5%	1.5%	1.3%	1.0%	0.8%

Chapter Five

Agriculture

5.1 Overview of the Agriculture (NFR 3) Sector

The Agriculture sector is the largest source of NH_3 in Ireland and at 124.6 kt accounted for 99.4 per cent of national total NH_3 emissions (125.4 kt) in 2019. The majority of the remainder of national total emissions is attributable to Road Transport (1A3b) and smaller fractions to combustion in the Manufacturing Industry and Construction (1A2), Commercial (1A4a) and Residential (1A4b), Agriculture/Forestry/Fishing: Off-road vehicles and other machinery (1A4cii) sectors, Other product Use (2G) and Biological treatment of waste – Composting (5B1).

Emissions of NH_3 from agriculture in Ireland's inventory are calculated using a Tier 2 approach developed by a member of the inventory team. The methodologies employed follow those utilised by Misselbrook et al. (2004, 2010, 2016), Misselbrrok and Gilhespy (2020), and the Inventory Guidebook (EMEP/EEA, 2019) and are described in the following sections. The methodology is based largely on the UK National Ammonia Reduction Strategy Evaluation System (NARSES) model for emissions from livestock and where required the Inventory Guidebook (EMEP/EEA, 2019) is also used (poultry and minor livestock species). For the calculation of NH_3 emissions from nitrogen fertilizer application the Tier 2 approach provided in the Inventory Guidebook (EMEP/EEA, 2019) is adopted.

The trend in emissions of NH_3 from agricultural sources is shown in Figure 5.1. Management of animal manures (3B) produced 47.7 per cent of NH_3 emissions from agriculture in 2019, with the application of inorganic fertiliser, sewage sludge and animal manures deposited and applied to soils (52.3%) accounting for the remainder. The NH_3 emission trend is largely determined by the cattle population and shows a steady increase up to 126.2 kt in 1998 (an increase by 15.5 per cent from 1990). There has been some decline in the populations of cattle and sheep since 1999, as well as a decrease in fertiliser use, which contributed to a downturn in NH_3 emissions in the 1999–2014 period. Emissions for the period 2015 onwards are on an upward trajectory in response to growth plans for the agricultural sector in Ireland and the removal of milk quotas in 2005. Emissions peaked in 2018 at 134.3 kt. The NH_3 emissions from the agriculture sector in 2019 were 14.0 per cent higher than the emission levels in 1990 (109.3 kt) and 7.2 per cent lower than the peak levels in 2018 and 1.3 per cent lower than the previous peak in emission levels in 1998.

NMVOCs from agriculture are estimated to be 45.46 kt in 2019, accounting for 39.9 per cent of the NMVOC inventory total (113.81 kt). Emissions from manure management (3B) make up 89.7 per cent of agriculture related NMVOC in 2019, with the remaining 10.3 per cent from cultivated crops (3De). For the calculation of NMVOC emissions, a Tier 2 methodology is adopted for cultivated crops (3De) included Chapter 3D Table 3.4 of the 2019 Inventory Guidebook (EMEP/EEA, 2019) which exist in Ireland (namely Wheat, Rape and Grass). The Inventory Guidebook (EMEP/EEA, 2019) Tier 1 approach is adopted for cultivated crops (3De) not included in Table 3.4. A Tier 2 approach is utilised for NMVOC emissions from manure management (3B). The trend in NMVOC emissions from agriculture is shown in Figure 5.2.

NO_x emissions form agriculture are estimated to be 33.75 kt in 2019, accounting for 41.7 per cent of the national total (98.03 kt). Emissions from manure management (3B) make up 2.9 per cent of the agriculture related NO_x with Inorganic N-fertilizers (3Da1), Animal manure applied to soils (3Da2a), Sewage sludge applied to soils (3Da2b), and Urine and dung deposited by grazing animals (3Da3) accounting for 41.7 per cent, 21.1 per cent, 0.3 per cent and 34.0 per cent of total agriculture emissions, respectively. Emissions in 2019 were 4.2 per cent above those in 1990 (32.38 kt). Estimates from manure management (3B) are derived from the Tier 2 mass flow approach to estimate NH_3 emissions, whilst emissions from agricultural soils (3D) utilise the Tier 1 emission factor presented in the Inventory Guidebook. The trend in NO_x emissions from agriculture is shown in Figure 5.3.

Estimates for agriculture emissions of TSP, PM_{10} and $PM_{2.5}$ contribute significantly to national totals for these pollutants, accounting for 19.0 per cent, 31.8 per cent and 7.8 per cent of national totals respectively. For these calculations, Tier 1 and 2 approaches provided in the Inventory Guidebook (EMEP/EEA, 2019) are adopted. For $PM_{2.5}$ Dairy cattle (3B1a) and Non-dairy cattle (3B1b) are the main drivers of the trend accounting for 59.4 per cent of emissions in 2018. For PM_{10} the main driver of the trend in emissions from agriculture is Inorganic N-fertilizers (3Da1) which accounted for 80.0 per cent of emissions in 2019. The second and third largest sources are Non-dairy cattle (3B1b) and Dairy cattle (3B1a) accounting for 5.4 per cent and 3.9 per cent, respectively of the agricultural total in 2019. A similar trend is evident for TSP with Inorganic N-fertilizers (3Da1), Non-dairy cattle (3B1b) and Dairy cattle (3B1a) accounting for 58.6 per cent, 8.7 per cent and 6.3 per cent, respectively of the agriculture sector total in 2019. The trend in $PM_{2.5}$ is presented in Figure 5.4.

The use of some pesticides for arable farming can be a source of POP emissions, notably due to the trace content of HCB within some pesticides as a contaminant from the manufacturing process. Emissions of HCB from NFR Sector 3Df (Use of pesticides) are a key category in 2019, accounting for 87.0 per cent of national total HCB emissions.
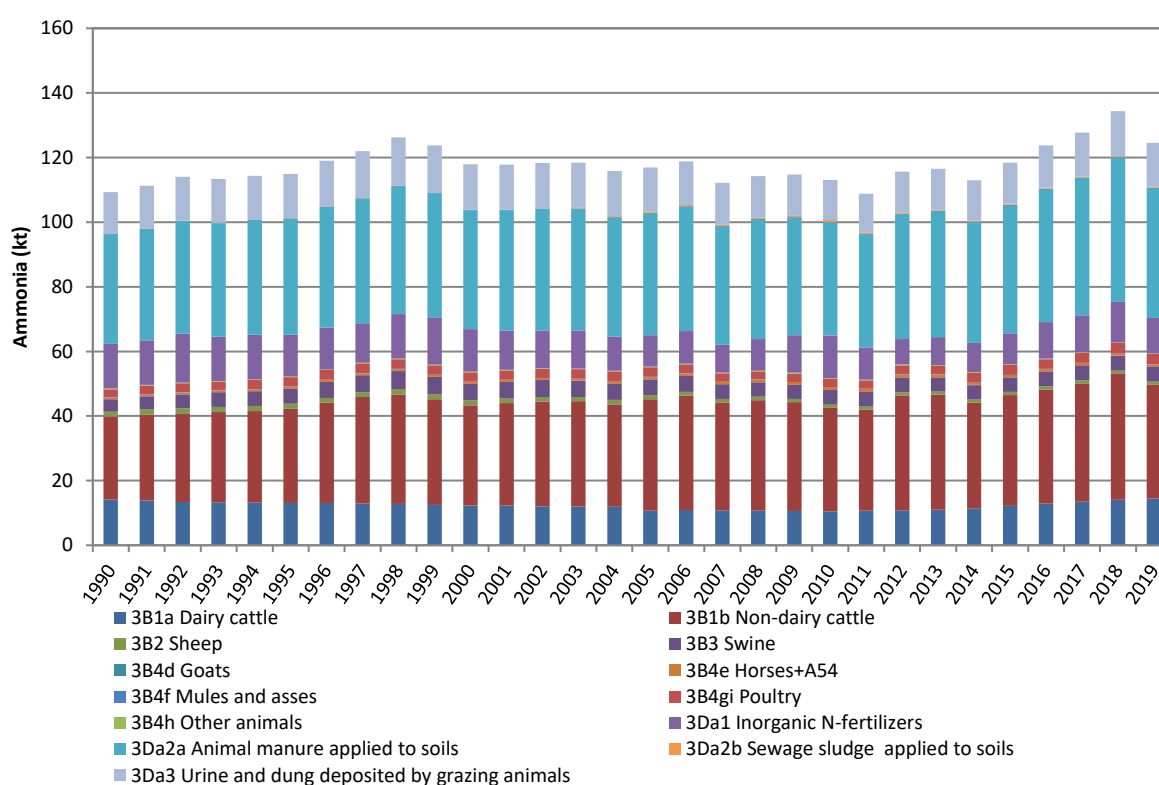
Figure 5.1. Emission Trend for Ammonia from Agriculture 1990−2019

Legend:
- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Poultry
- 3B4h Other animals
- 3Da1 Inorganic N-fertilizers
- 3De Cultivated crops
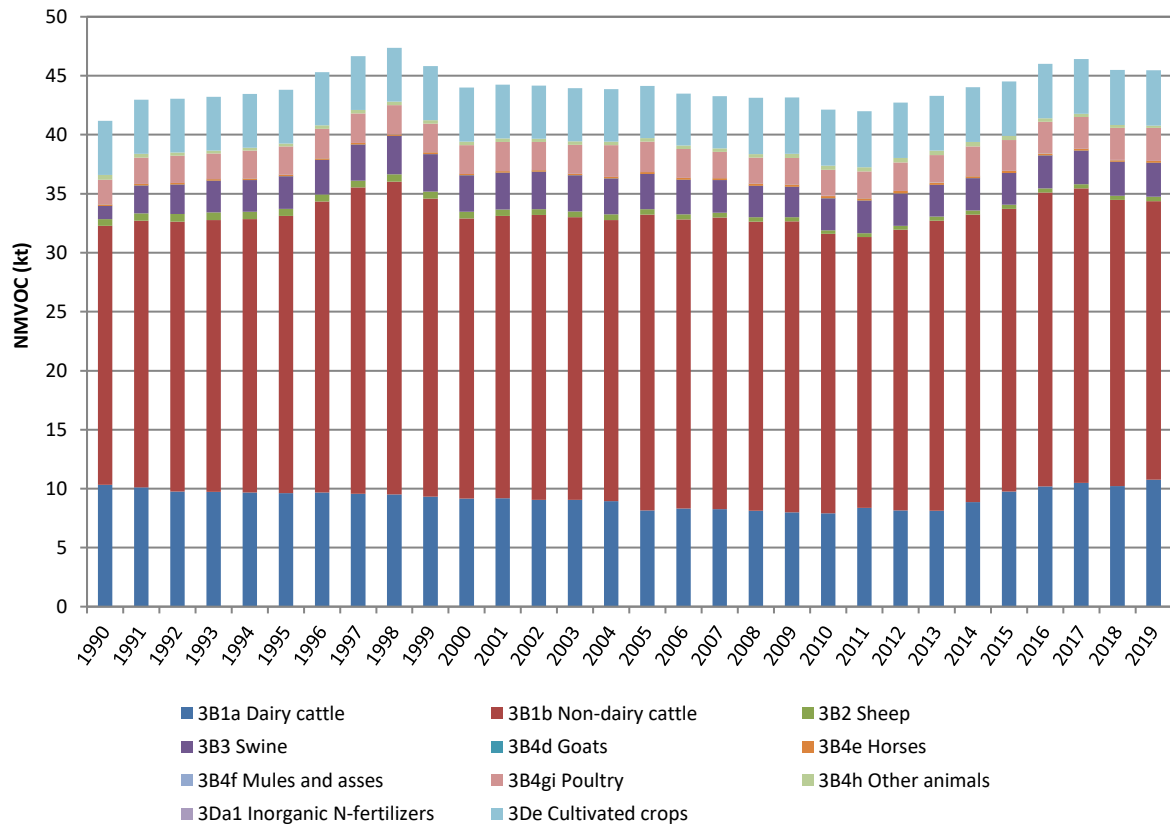
Figure 5.2. Emission Trend for NMVOC from Agriculture 1990−2019

Legend:
- 3B Manure management
- 3Da1 Inorganic N-fertilizers
- 3Da2a Animal manure applied to soils
- 3Da2b Sewage sludge applied to soils
- 3Da3 Urine and dung deposited by grazing animals
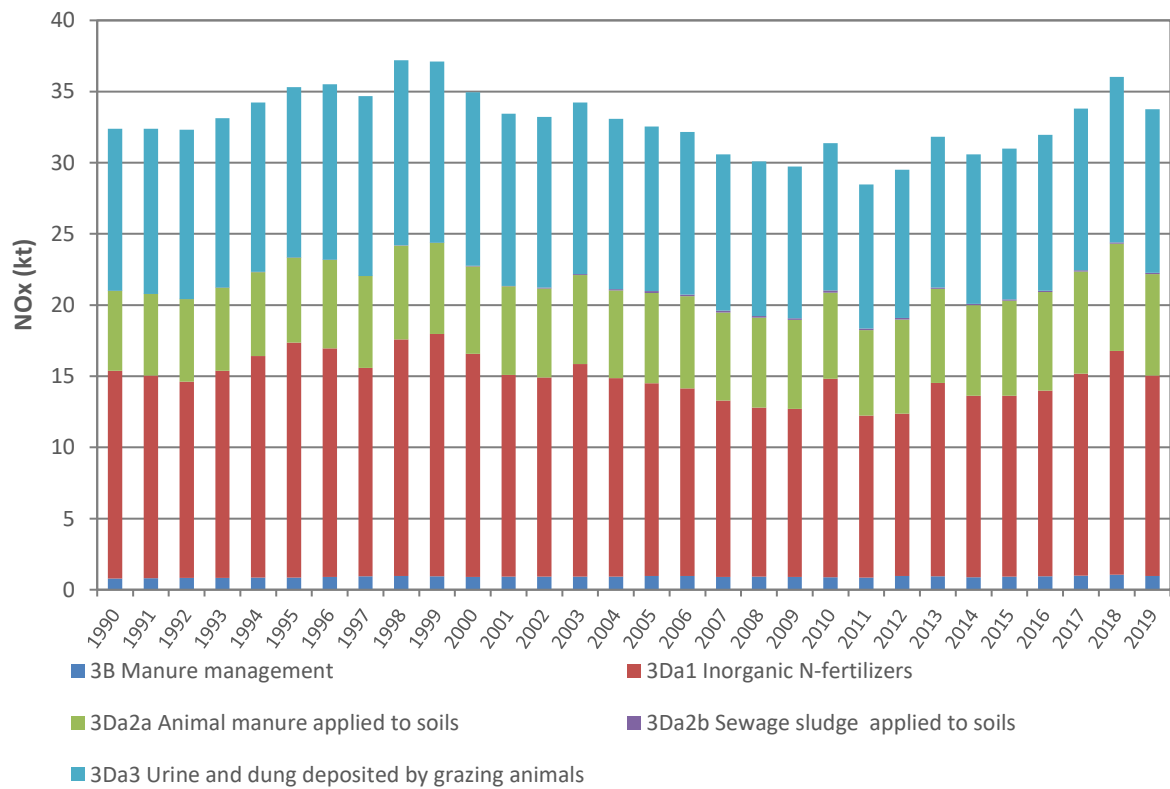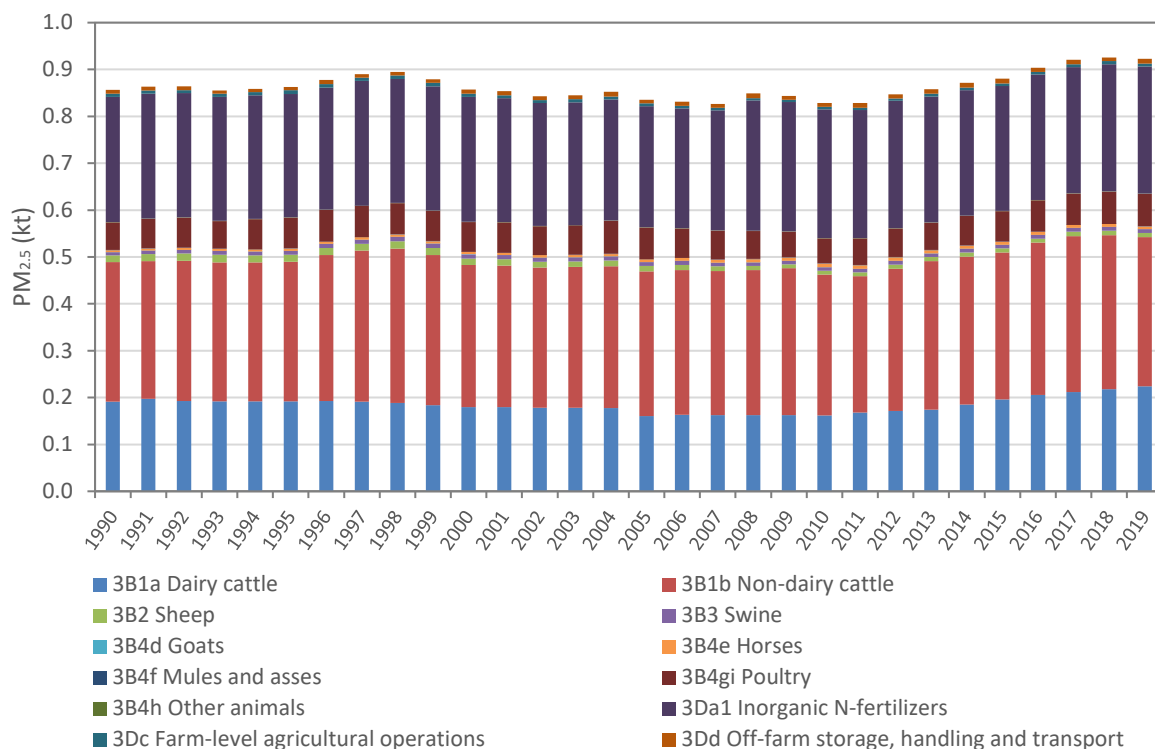
Figure 5.4. Emission Trend for PM$_{2.5}$ from Agriculture 1990−2019

5.2 Manure Management (NFR 3B)

The following sections outline the activity data, assumptions and calculations utilised in estimating NH$_3$, NMVOC, NO$_x$, TSP, PM$_{10}$ and PM$_{2.5}$ emissions from agriculture in Ireland. For NH$_3$ and NO$_x$, the Tier 2 methodology uses a mass flow approach based on the concept of the flow of Total Ammoniacal Nitrogen (TAN) through the manure management system. Emissions are calculated for the same animal sub-categories as those utilised in Ireland's national greenhouse gas inventory (Table E.1 Annex E). The first step in the mass flow approach is the estimation of total annual nitrogen excretion by the animals. For dairy cows and other cattle, Ireland utilises the method described in IPCC (2006), chapter 10, further enhanced by country-specific data on feeding practices and milk production (O'Mara, 2007, Duffy et al., 2021) to estimate N excretion. For all other categories of livestock, national values are utilised. Total nitrogen excretion is then apportioned to that which is deposited in buildings, collection yards (only applicable to dairy cows during lactation) and grazing. See Table E.3 Annex E for animal nitrogen excretion.

The method used to estimate NMVOC emissions is the tier 2 approach based on emission factors from Table 3.11 and Table 3.12 of the Inventory Guidebook (EMEP/EEA, 2019) for all livestock categories. The tier 2 approach considers NMVOC emissions from the following; silage stores, silage for feeding, housing, outdoor manure stores, manure application and from grazing animals as outlined in section 3.4 of the Inventory Guidebook (EMEP/EEA, 2019).

For TSP, PM_{10} and $PM_{2.5}$ emissions are estimated based upon animal numbers using the Tier 1 method and emission factors from the Inventory Guidebook (EMEP/EEA, 2019). See Table E.7 of Annex E for additional information of the EFs used for NH_3, NMVOC, TSP, PM_{10} and $PM_{2.5}$ emission estimation.

5.2.1 Cattle (NFR 3B1)

A Farm Facilities Survey conducted in 2003 (Hyde et al., 2008) and recent analysis by Teagasc (Teagasc, 2020) provides the basis for the calculation of the number of days housed and the number of days spent grazing by cattle on farms in Ireland across the timeseries. National averages are used for the purpose of inventory calculations. Data for the number of days housed and proportion of manure and therefore nitrogen deposited in the manure in housing systems are presented in Table E.2.1. The number of days spent grazing and the proportion of nitrogen excreted at pasture is then calculated by subtracting these values from the total number of days in the year and the total nitrogen excreted.

Two housing types are distinguished for cattle production systems in Ireland – liquid (slurry-based) and solid manure-based housing. As a result of differing management practices on farms, a proportion of each of the cattle subdivisions is not housed (out-wintered) and therefore graze pasture for the full year, however this proportion has reduced across the timeseries. The proportion of each sub-category of cattle that is managed in this manner is accounted for in Table E.2.1. For liquid manure-based housing an emission factor of 27.7 per cent of the TAN available in liquid-based housing is applied (Misselbrook and Gilhespy, 2020). The TAN in cattle manure is assumed to be 60 per cent. For solid manure-based housing, emission factors of 16.8 per cent and 4.2 per cent of the TAN available in solid manure-based housing are applied to cattle housed on straw and calves housed on straw, respectively (Misselbrook and Gilhespy, 2020).

In addition to animal housing, emissions are estimated for cow collecting yards used during milking utilising an emission factor of 22.5 per cent of the TAN available (Misselbrook and Gilhespy, 2020).

The storage of both liquid and solid manure is considered. Liquid manure is stored either below the animals in slatted floor housing or removed from the house to outdoor storage. Emissions are calculated separately for indoor and outdoor storage. It is assumed that a crust will form in the indoor under slat storage. In addition, a fraction of the organic nitrogen in liquid manure is mineralised to TAN before emissions are calculated. A value of 0.1 (Dammgen et al., 2007) is applied as suggested in the Inventory Guidebook (EMEP/EEA, 2019). To fully account for all losses of N from liquid manure during storage, estimates are made of N_2O, NO and N_2 losses during storage utilising the emission factors provided in the Inventory Guidebook (EMEP/EEA, 2019). An emission factor of 5 per cent of the TAN available in liquid manure stores is applied to estimate NH_3 emissions from liquid manure storage in covered stores and 10 per cent of the TAN available in liquid manure stored in uncovered stores (Misselbrook and Gilhespy, 2020).

Solid manure is generally stored in the shed or outside in heaps. The contribution of the nitrogen content of straw used for bedding is accounted for based on national data on straw used for bedding and the length of the housing period (Hyde et al., 2008, Teagasc, 2020). Where manures are managed as solid, a fraction of the TAN is immobilised in organic matter. Immobilisation of nitrogen reduces the potential for NH_3 emissions from solid manures during storage and after landspreading. The value proposed in the Inventory Guidebook (EMEP/EEA, 2019) of 0.0067 kg kg^{-1} (Kirchmann and Winter, 1989) is applied. To fully account for all losses of N from solid manure during storage, estimates are

made of N_2O, NO and N_2 losses during storage utilising the emission factors provided in the Inventory Guidebook (EMEP/EEA, 2019). An emission factor of 26.3 per cent of the TAN available in solid manure stores is utilised (Misselbrook and Gilhespy, 2020).

Landspreading emissions are calculated by estimating the quantity of TAN available post storage of the manure (both liquid and solid) and accounting for the period of the year in which it is spread (i.e. spring, summer, autumn and winter) as outlined in Table E.5 Annex E. In this submission new information on the use of low emission spreading techniques (Teagasc, 2020) is included in emission estimates for the first time. Data on broadcast spreading (splashplate), trailing hose application, trailing shoe application and injection are included. For liquid manure, a dry matter value of 6 per cent is assumed and two emission factors are applied for the proportion that is broadcast spread, 48.4 per cent of the TAN available for the proportion applied in summer and 26.1 per cent for proportion applied in spring, autumn and winter (Misselbrook and Gilhespy, 2020). With respect to low emission spreading techniques the values presented in the UNECE Guidance document on preventing and abating ammonia emissions from agricultural sources (UNECE, 2014) with a 30 per cent, 60 per cent and 70 per cent reduction in emission levels with the use of trailing hose, trailing shoe and injection, respectively. For solid manure, an emission factor of 68.3 per cent of the TAN available is applied regardless of the period of the year in which it is spread (Misselbrook and Gilhespy, 2020). The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from manure (solid and liquid) application to soil.

For cattle (both dairy and non-dairy catte) grazing an emission factor of 6 per cent of the TAN available at grazing is applied for all cattle categories (Misselbrook and Gilhespy, 2020). The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from excreta deposited during grazing.

NMVOC emissions are estimated using Tier 2 emission factors from the Inventory Guidebook (EMEP/EEA, 2019). Estimates are made for housed cattle, silage feeding, silage store, manure storage, manure application and grazing. The emission factors for silage feeding and silage storage, housing and grazing are combined with the feed intake values (MJ feed intake) from Ireland's Tier 2 approach to the estimation of CH_4 emissions from enteric fermentation and manure management. The feed intake values for silage and grass are presented in Table E.6, Annex E with the emission factors used presented in Table E.7. Emissions of NMVOC from manure storage and manure application use the Inventory Guidebook (EMEP/EEA, 2019) approach whereby the NMVOC emissions from livestock buildings are coupled with the ratio of NH_3 emissions from storage and application with those in livestock buildings, respectively.

Emissions of TSP, PM_{10} and $PM_{2.5}$ are estimated using Tier 1 emission factors split by cattle type and housing category (slurry/solid housing). The emission factors used are presented in Table E.7, Annex E.

5.2.2 Sheep (3B2)

Sheep in Ireland are categorised into those on upland and those on lowland areas. Four subcategories exist within both upland and lowland areas, namely ewes, rams, lambs and other sheep more than 1 year old. The CSO publishes sheep population statistics on an annual basis and, to derive the number of heads on both lowland and upland areas, several assumptions are made as follows based on expert

opinion. Total ewe and ram numbers are taken as the mean of the June and December CSO censuses. On this basis, the number of ewes and rams are subdivided using the ratio 55:45 (lowland/upland) for years up to and including 1997. For 1998 to 2004 inclusive, a ratio of 70:30 is used, reflecting the destocking of upland areas. For 2005 onwards, a ratio of 80:20 is used. The total number of lambs slaughtered in any 1-year period is used as the activity data for lambs. Monthly lamb slaughtering figures are available from the CSO. From 2001 onwards, these numbers are adjusted for the number of lambs that originate in Northern Ireland and that are slaughtered in the Republic of Ireland and for the number of lambs that are reared in the Republic but slaughtered in Northern Ireland. National totals are then subdivided similarly to the other categories of sheep. The numbers of other sheep over 1 year old are calculated from unpublished CSO data. Population statistics for each subcategory of sheep are presented in Table E.1, Annex E. Input data with respect to manure management practices are presented in Table E2.2 Annex E. Nitrogen excretion coefficients for all sub categories of sheep are provided in Table E.3 Annex E.

Similar to cattle, the proportion of TAN in the nitrogen excreted by sheep is assumed to be 60 per cent. An emission factor of 21.6 per cent of the TAN available in sheep housing (Misselbrook and Gilhespy, 2020) is applied. Information on the number of days that sheep are housed during the winter period is derived from the Farm Facilities Survey (Hyde et al., 2008), which suggests sub-category specific housing period lengths (Table E.2.2 Annex E). More specifically, lowland and upland ewes are assumed to be housed for 84 and 85 days/year. No differentiation is made for upland and lowland rams, lambs and other sheep >1 year old - being housed for 56, 28 and 67 days/year respectively. In Ireland, sheep are generally housed in solid-manure-based housing systems.

The NH_3 emission factors used for the storage and landspreading of solid manure used for Cattle (3B1) are also considered appropriate for sheep manure (Misselbrook and Gilhespy, 2020). For storage of solid manure and subsequent landspreading the emission factors for solid manure from cattle are used (26.3 per cent of TAN available in the manure store and 68.3 per cent of TAN available at landspreading). Account is also taken of the nitrogen added from straw used for bedding and the immobilisation of TAN in organic matter when solid manures are managed following the approach adopted for solid manure from cattle. The emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019) are used to estimate NO, N_2O and N_2 emissions from manure management. The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from excreta deposited during grazing and the application of solid manure to soil. For sheep grazing, the emission factor applied for cattle of 6 per cent of the TAN available at grazing is utilised to estimate NH_3 emissions from grazing sheep (Misselbrook and Gilhespy, 2020).

NMVOC emissions are estimated using Tier 2 emission factors from the Inventory Guidebook (EMEP/EEA, 2019) based on volatile solid (VS) excretion data as estimated in the national greenhouse gas inventory for agriculture. Estimates are made for housed sheep, manure storage, manure application and grazing sheep. The emission factors used are presented in Table E.7, Annex E.

Emissions of TSP, PM_{10} and $PM_{2.5}$ are estimated using Tier 1 emission factors in the Inventory Guidebook (EMEP/EEA, 2019) The emission factors used are presented in Table E.7, Annex E.

5.2.3 Swine (NFR 3B3)

Detailed population statistics are available for seven subcategories of pigs in Ireland using national statistics published by the CSO as follows: sows in pig, gilts in pig, other breeding sows, boars, gilts not yet served and two categories of fattening pigs (<20 kg and >20 kg live weight). The CSO undertakes and publishes two censuses per year, one in June and one in December. The average of the two census values is used in deriving the pig populations in the seven subcategories, thus providing an appropriate measure of the number of pigs on farms for the purposes of the annual NH_3 emission inventory.

For the NH_3 inventory, it is assumed that all pigs are housed and that the housing systems are liquid/slurry-based. Furthermore, it is assumed that the proportion of TAN in nitrogen excreted is 70 per cent. An emission factor of 29.4 per cent of the TAN in slurry produced by gilts in pig, gilts not yet served and pigs greater than 20 kgs is applied. For sows in pig, other sows for breeding and boars, an emission factor of 30.8 per cent of the TAN produced in the slurry of these pig sub-categories is used and an emission factor of 7.9 per cent of the TAN in slurry produced by pigs under 20 kg (Misselbrook and Gilhespy, 2020).

For slurry storage, emissions of NH_3 are calculated separately for covered and uncovered stores based on the proportion of slurry stored in covered and uncovered storage (Hyde et al., 2008). Emission factors of 13.0 per cent of the TAN available in covered storage and 52.0 per cent of the TAN available in uncovered slurry stores are applied (Misselbrook and Gilhespy, 2020). As is the case with cattle slurry, account is taken of the losses of N_2O, NO and N_2 using the emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019) and the mineralisation of organic nitrogen in the liquid manure is also accounted for (Dammgen et al., 2007). It is assumed that all pig slurry is applied using the splashplate method as no information is currently available on the use of low emission spreading techniques for pig slurry. An emission factor of 19.2 per cent (Misselbrook and Gilhespy, 2020) of the TAN available post storage is applied on the basis that pig slurry contains less than 4 per cent DM.

The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO emissions from the application of liquid manure to soil.

NMVOC emissions are estimated using Tier 2 emission factors from the Inventory Guidebook (EMEP/EEA, 2019) based on volatile solid (VS) excretion data as estimated in the national greenhouse gas inventory for agriculture. Estimates are made for housed pigs, manure storage and manure application. The emission factors used are presented in Table E.7, Annex E.

Emissions of TSP, PM_{10} and $PM_{2.5}$ are estimated using Tier 1 emission factors from the Inventory Guidebook (EMEP/EEA, 2019). The emission factors used are presented in Table E.7, Annex E.

5.2.4 Poultry (NFR 3B4g)

Detailed population statistics are available for eight subcategories of poultry in Ireland using national statistics collated by the Department of Agriculture and the CSO as follows: layers, broilers, layer breeders, broiler breeders, turkeys, turkey breeders, geese and ducks. The population statistics are provided in Table E.1, Annex E. The estimation of NH_3 emissions from poultry production utilises bird places as opposed to bird numbers so that production cycles are considered. The number of bird places is estimated from the annual bird population assuming that all bird places are full throughout the year after rest periods have been taken into account (rest periods are those periods after a production cycle in which the housing systems are emptied of all manure and bedding, thoroughly

washed and prepared for the next batch of birds). In the case of broilers, there are 5.5 production cycles per year, with a 3- to 4-week rest period between production cycles. In the case of turkeys, there are 2.5 production cycles per year of approximately 120 days in length, with a 3- to 4-week rest period also applied. All other poultry subcategories have production cycles of over 1 year, and therefore no adjustments to population statistics are made.

It is assumed that all poultry are housed in some form of solid manure housing system and that the proportion of TAN in nitrogen excreted by poultry is 70 per cent. For a proportion of laying birds, free-range systems are in use, which consist of an area of grassland beside the bird house which the birds are allowed onto for a period of hours during the day. The percentage of laying birds that are housed in this type of system is based on statistics supplied by the Department of Agriculture, Food and Marine. An emission factor of 35 per cent of TAN is applied to the quantity of TAN which is deposited outdoors. Emission factors for housing of 20.0 per cent, 21.0 per cent, and 35.0 per cent, 57.0 per cent and 24.0 per cent of TAN are applied to layer, broiler, turkey, geese and duck housing, respectively (EMEP/EEA, 2019). The storage of poultry manure is separated into two classes, litter and layer manure. An emission factor of 30.0 per cent of TAN is applied to broiler manure, 8.0 per cent for layer manure, 24.0 per cent for turkey manure, 16.0 per cent for geese manure and 24.0 per cent for duck manure (EMEP/EEA, 2019). To account for the loss of other nitrogen compounds, account is taken of the losses of N_2O, NO and N_2 using the emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019). It is assumed that all poultry manure is broadcast spread and emission factors of 45.0 per cent, 38.0 per cent, 54.0 per cent, 45 per cent and 54.0 per cent of the TAN available post storage, are adopted for layers, broilers, turkeys, geese and ducks respectively (EMEP/EEA, 2019). The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO emissions from excreta deposited during grazing and the application of manure to soil.

NMVOC, TSP, PM_{10} and $PM_{2.5}$ emissions are estimated using Tier 1 emission factors from the Inventory Guidebook (EMEP/EEA, 2019). The emission factors used are presented in Table E.7, Annex E.

5.2.5 Other livestock – Goats (NFR 3B4d), Horses (3B4e), Mules and Asses (NFR 3B4f) and Other Animals (3B4h)

The remaining livestock categories include goats, horses, mules and asses, deer, mink and foxes and estimates are made for emissions of NH_3, NO, NMVOC, TSP, PM_{10} and $PM_{2.5}$.

For NH_3 emissions the emission factors used are the default Tier 2 factors presented in the Inventory guidebook (EMEP/EEA, 2019) for each step in the manure management chain. As part of the mass flow approach, inventory guidebook emission factors for NO, N_2O and N_2 emissions from manure management are also estimated. The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from excreta deposited during grazing and the application of manure to soil.

NMVOC emissions are estimated for goats (3B4d), Horses (3B4e) and Mules and asses (3B4f) using the Tier 2 emission factors from the Inventory Guidebook (EMEP/EEA, 2019). In the case of other animals (3B4h) the Tier 1 emission factors presented in the inventory guidebook (EMEP/EEA, 2019) are used. The emission factors applied are presented in Table E.7, Annex E.

Tier 1 emission factors from the Inventory Guidebook (EMEP/EEA, 2019) are applied to estimate emissions of TSP, PM$_{10}$ and PM$_{2.5}$ from the livestock categories described except for deer for which no emission factor is supplied in the Inventory Guidebook (EMEP/EEA, 2019).

In the period 2010 to 2011 there was a change in the Agricultural Waste Management System (AWMS) for mink (3B4h) production from 100% solid manure-based in the period 1990-2010 to 52% liquid/slurry-based and 48% solid manure-based AWMS resulting in a decrease in associated NH$_3$ emissions for category 3B4h.

5.2.6 Uncertainties

There is extensive and up-to-date statistical data on all aspects of the agriculture sector in Ireland. Most of this data is compiled and published by the Central Statistics Office and is the official source of the basic data for inventory purposes. The exception is for statistics on synthetic fertiliser use and the poultry population which are obtained from the Department of Agriculture Food and the Marine (DAFM). The CSO and DAFM are key data providers whose annual statistical inputs to the inventory agency are covered by Memorandum of Understanding (MOU) in Ireland's national inventory system. As a result, the uncertainty associated with animal population statistics is low, at 1 per cent. The emission factor uncertainty associated with NH$_3$ emission factors for dairy and other cattle is 50 per cent, and for all other livestock categories 100 per cent. Much of NH$_3$ emission research is aimed at dairy cattle and other cattle therefore emissions from these categories are relatively well quantified in comparison to the other livestock categories. In comparison, the uncertainties associated with NMVOC and PM$_{10}$ emissions in agriculture are largely due to the uncertainty (300 per cent) associated with the emission factors for both pollutants as discussed in the Inventory Guidebook (EMEP/EEA, 2019).

5.3 Agricultural Soils (NFR 3D)

5.3.1 Direct Soil Emissions - Inorganic N-fertilizers (NFR 3Da1)

The calculation of NH$_3$ emissions from nitrogen fertilizer application to agricultural soils utilises the Tier 2 approach outlined in the Inventory Guidebook (EMEP/EEA, 2019). Total fertilizer sales and emission estimates for each year of the time series 1990-2019 (Table E.4, Annex E) are apportioned into the categories, Ammonium sulphate, CAN, NK mixtures, NPK mixtures, NP mixtures, Other straight N compounds, Urea, and protected urea products, according to the known sales of these compounds in each year as supplied to the inventory agency by the DAFM. Table E.8 of Annex E includes additional information on the methodological approach, quantities of individual fertilizer types, the emission factors used and resultant emissions. The emission factor presented in the Inventory Guidebook (EMEP/EEA, 2019) of 0.04 kg NO per kg of nitrogen is applied to calculate NO$_x$ emissions from the application of inorganic N-fertilizers to soil. Ireland, in previous submissions, reported emissions of PM$_{10}$, PM$_{2.5}$ and TSP from farm-level agricultural operations under 3Da1, to separate these emissions from those previously reported under 2B10b. These are now reported under 3Dc following a recommendation in the NECD expert review of Ireland's 2019 submission. The default emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019) are applied (Table E.8, Annex E) coupled with the total utilisable agricultural area (Table E.9, Annex E).

5.3.2 Direct Soil Emissions – Livestock manure applied to soils (NFR 3Da2a)

The calculation of NH_3 emissions from livestock manure applied to soil is discussed in sections 5.2.1 to 5.2.5 inclusive. Emissions for each of the livestock species are summed and reported under 3Da2a. The default emission factor of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from the application of livestock manure to soils.

5.3.3 Direct Soil Emissions – Sewage sludge applied to soils (NFR 3Da2b)

Estimates of NH_3 were estimated from the application of sewage sludge (3Da2b) for the first time in Ireland's 2015 submission. The quantity of sewage sludge applied to land is estimated as part of the calculations for emissions of CH_4 and N_2O from wastewater in Ireland's Greenhouse Gas Inventory. The fraction of nitrogen volatilised is 0.13 kg NH_3 per kg N applied (EMEP/EEA, 2019). With respect to NO emissions, the default Tier 1 emission factor of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from the application of sewage sludge to soils.

5.3.4 Direct Soil Emissions – Other organic fertilizers applied to soils (NFR 3Da2c)

Emissions of NH_3 and NO from this source category are currently reported as NE. Information on the quantities of other organic fertilizers applied to agricultural soils does not exist in Ireland and is considered negligible compared to the total quantity of nitrogen applied in manures or deposited during grazing.

5.3.5 Direct Soil Emissions – Urine and dung deposited during grazing (NFR 3Da3)

The calculation of NH_3 emissions from urine and dung deposited on soil during grazing is discussed in sections 5.2.1 to 5.2.5 inclusive. Emissions for each of the livestock species are summed and reported under 3Da3. The default emission factor of 0.04 kg NO per kg of nitrogen is applied to calculate NO_x emissions from urine and dung deposited on soil during grazing.

5.3.6 Farm-level agricultural operations (NFR 3Dc)

Emissions of PM_{10}, $PM_{2.5}$ and TSP are reported under NFR 3Dc. Previously the emission reported in this category were reported under 2B10b, however in response to the 2017 NECD expert review, these emissions have now been reallocated to 3Dc. Emissions are estimated using the total quantity of fertilizers (by weight) applied to soils in Ireland. The emission factors applied are those provided in CEPMEIP (2001) and are presented in Table E.8 Annex E. The total quantity of fertilizers (by weight) applied to agricultural soils is presented in Table E.9, Annex E. In addition, Ireland also reports emissions of PM_{10}, $PM_{2.5}$ and TSP from farm level agricultural operations under 3Dc in this submission following a recommendation from the NECD review in 2018. These emissions were reported in previous submissions under 3Da1 to separate these emissions from those previously reported under 2B10b.

5.3.7 Off-farm storage, handling and transport (NFR 3Dd)

In this category, fugitive PM emissions in the form of TSP, PM_{10} and $PM_{2.5}$ are estimated from the bulk handling of cereal grains. The general method for estimating fugitive PM emissions involves multiplying the amount of material, which in this case is cereal grain (barley, wheat and oats), by an emission factor. Given the importance of agriculture to Ireland's economy, production statistics are freely available (Table E.9, Annex E). Data in relation to the production of cereal grains are collated and provided by the Central Statistics Office (CSO). Emission factors of 100 g/t, 25 g/t and 4 g/t from CEPMEIP (2001) are utilised in the calculation of emissions of TSP, PM_{10} and $PM_{2.5}$, respectively.

5.3.8 Cultivated crops (NFR 3De)

Emissions of NMVOCs are estimated using the default emission factor of 0.86 kg/ha for those crops not listed in Table 3.3 Chapter 3.D of the inventory guidebook (EMEP/EEA, 2019) and the crop areas presented in Table E.9, Annex E. For wheat, rape and grass (15°C), the Tier 2 emission factors presented in Table 3.4 Chapter 3.D of the inventory guidebook (EMEP/EEA, 2019) are used. The areas of these crops and grassland area are presented in Table E.9, Annex E.

5.3.9 Use of Pesticides (NFR 3Df)

The main source of POPs from pesticides is HCB contamination of currently used pesticides. Where available, annual pesticides usage data have been used. Pesticide usage surveys are available for 2003, 2004, 2011, 2012, 2013 and 2014, 2015, 2016 and 2017 from the DAFM. Interpolation and extrapolation are used for the remaining years up to the date at which usage stopped for particular pesticides as described in Table 4 annex to chapter 3.D.f-3.I of the inventory guidebook (EMEP/EEA, 2019). Both the activity data used and impurity factors for each active ingredient are presented in Table E.10 of Annex E.

Table 5.1 Emission Estimates for Hexachlorobenzene Emissions from Pesticide Use

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
HCB (kg)	7.163	7.247	7.299	2.030	2.151	2.175	2.200	2.172	2.152	2.124	2.090	2.089	2.041	2.039

5.4 Field burning of agricultural residues (NFR 3F)

Field burning of agricultural residues is the practice whereby crop residues are burnt as a means of clearing land to allow tillage operations to proceed. As stated in chapter 3F of the EMEP/EEA Guidebook 2019 the practice is largely outlawed. Prescribed burning of agricultural residues in Ireland may only be allowed in the case of disease or maintenance of soil organic matter as detailed in GAEC 6 page 52 of the cross-compliance handbook (DAFM, 2015). In addition, the inventory agency has undertaken some analysis on this issue (Zimmerman, 2014) which suggests that fires on agricultural land are in general fires that have occurred due to fires in adjoining forestry or peatland, for example, and are not the anthropogenic burning of agricultural residues. The inventory agency continues to discuss with relevant agencies with respect to the identification of fires due to its importance in the estimation of non-CO_2 gases within the Land Use, Land Use Change and Forestry sector.

5.5 Uncertainties associated with Synthetic Fertilizer (3Da1), Organic fertilizers (3Da2c) and urine and dung deposited by grazing animals (3Da3).

Although losses of NH_3 from N-fertilisers applied to grass grazed by livestock are difficult to distinguish from subsequent NH_3 emissions from urine patches produced by grazing animals, those two emissions are calculated separately with emissions from grazing reported in 3Da3. The sources making the largest contributions to the overall uncertainty are ammonia losses from synthetic fertiliser use and animal manures deposited to pasture, range and paddock. The emission factors for these sources are

currently assigned an uncertainty of ±200%, and they contribute to 95.6 per cent of the overall uncertainty.

5.6 Recalculations in the Agriculture Sector

In this submission the inventory agency has undertaken a major revision to NH_3 emission estimates based on the publication in 2020 of updated information on the crude protein of concentrate feeds to livestock and new data on manure management practices. In conjunction with the aforementioned publications the inventory agency also undertook a revision to the Tier 2 CH_4 emission factor models used for the cattle which are used to derive nitrogen excretion values for the national cattle herd. Finally minor revisions to emission factors used in NARSES model (Misselbrook and Gilhespy, 2020) have also been taken on board. Emissions of NH_3 have increased by 5.2 per cent on average per annum across the timeseries. The largest recalculations for cattle are evident in the category *3B1b Manure management – Non-dairy cattle* with a 7.3 per cent on average annual increase in emissions levels and in *3Da2a Animal manure applied to soils*, where a 12.9 per cent annual average increase in emission is evident. Revised emission factors for NH_3 emissions from solid manure (deep bedding) and litter based housing systems in the NARSES model (Misselbrook and Gilhespy, 2020) result in substantial recalculations for categories *3B2 Sheep, 3B4gi Laying Hens, 3B4gii Broilers* and *3B4h Other animals* as shown in Table 5.2. Activity data for the population of mink reported in *3B4h Other animals* has also been revised in this submission. There is also minor recalculations to the *3B3 Swine* as a result of updated emissions factors for pig housing in the NARSES model (Misselbrook and Gilhespy, 2020).

The above mentioned changes in national NH_3 emission estimates are partially responsible for the recalculations in emissions of NMVOC emissions from manure management from Dairy cattle, Non-dairy cattle, whereby the emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019) are presented in terms of ratios of emissions of NH_3 between the different stages of the manure management chain are used to derive NMVOC emissions. In addition feed intake has been revised as part of revisions to Ireland's Tier 2 approach to estimating CH_4 emissions from cattle and this also contributes to the recalculations presented in Table 5.3.

For the calculation of NMVOC emissions, a Tier 2 methodology was adopted for cultivated crops (3De) included in 2019 EMEP/EEA Guidebook 3D Table 3.4 which exist in Ireland (namely Wheat, Rape and Grass). The Inventory Guidebook (EMEP/EEA, 2019) Tier 1 approach was adopted for cultivated crops (3De) not included in Table 3.4. However during the 2020 NECD review it became evident that the guidance provided in the 2019 Inventory Guidebook (EMEP/EEA, 2019) was erroneous with respect to the units used in Table 3.3 and Table 3.4 (kg NMVOC per kg dm per hour and kg NMVOC per dm per ha). This has led a large recalculation in emissions from this category of 592.4 per cent on average per annum across the timeseries. Activity data for the population of mink reported in *3B4h Other animals* has also been revised in this submission and is responsible for the recalculations evident in the years 2016, 2017 and 2018 for that category.

With respect to emission of particulate matter ($PM_{2.5}$, PM_{10} and TSP), revisions to manure management practices for the national cattle herd as described for NH_3 emission estimates result in revised emissions estimates for all three pollutants as shown in Tables 5.4, 5.5 and 5.6 for categories *3B1a* and *3B1b*. Activity data for the population of mink reported in *3B4h Other animals* has also been revised in this submission and is responsible for the recalculations evident in the years 2016, 2017 and 2018 for that category evident in Tables 5.4, 5.5 and 5.6.

5.7 Quality Assurance/Quality Control

The general QA/QC procedures set down in Ireland's QA/QC plan have been undertaken for the Agriculture sector. The spreadsheets incorporate transparent linking between input data statistics and calculations, as well as internal checks on the calculations and the outputs. The inventory experts are actively involved in assessing the outcomes of NH_3 emission research in Ireland and continually re-examine the underlying assumptions in inventory estimates with sector-specific experts in the Department of Agriculture and other related bodies. This is evident in the recalculations that are present in this chapter for NH_3 emissions whereby new information on manure management practices was recently published and is now used in NH_3 emission estimates.

5.8 Planned Improvements

A large number of input variables determine emissions in the Agriculture sector and the final results are very sensitive to changes in many of these variables. Assumptions relating to some parameters have an important bearing on the outcome. Whilst 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 involved. 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, manure management systems and other influencing factors in a robust and justifiable manner when applying these methodologies. This requires detailed data from research programmes, and large amounts of statistical data. Nevertheless, the inventory agency is continually developing emission estimates so that they fully reflect national circumstances within the availability of reliable statistics and research studies.

The inventory agency will consider revising the ammonia emission factors, if necessary, based on any updates in the Inventory Guidebook and the NARSES model and following the publication of any relevant country-specific research for the next annual submission.

Review recommendations and responses are included in this report as Annex H.

Table 5.2. NH₃ Recalculations for Agriculture 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																	
3B1a Manure management - Dairy cattle	NH3	kt	12.70	11.95	11.45	10.38	10.57	10.45	10.50	10.90	10.97	11.20	11.68	12.71	13.44	14.10	14.54
3B1b Manure management - Non-dairy cattle	NH3	kt	27.41	29.46	29.80	31.61	30.57	30.16	28.73	28.15	30.04	30.49	29.91	29.86	31.02	31.26	30.68
3B2 Manure management - Sheep	NH3	kt	1.72	1.75	1.75	1.51	1.18	1.11	1.09	1.11	1.16	1.16	1.14	1.13	1.13	1.21	1.18
3B3 Manure management - Swine	NH3	kt	3.85	4.79	5.20	5.03	4.57	4.47	4.65	4.70	4.64	4.53	4.60	4.54	4.72	4.83	4.82
3B4d Manure management - Goats	NH3	kt	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3B4e Manure management - Horses	NH3	kt	0.53	0.58	0.60	0.68	0.82	0.84	0.91	0.91	0.95	0.87	0.81	0.80	0.79	0.73	0.72
3B4f Manure management - Mules and asses	NH3	kt	0.05	0.04	0.03	0.03	0.05	0.05	0.04	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.05
3B4gi Manure management - Laying hens	NH3	kt	0.64	0.45	0.43	0.49	0.46	0.54	0.54	0.54	0.66	0.72	0.74	0.83	0.84	0.88	0.91
3B4gii Manure management - Broilers	NH3	kt	0.97	1.35	1.51	1.55	1.18	1.44	1.44	1.40	1.40	1.31	1.47	1.48	1.49	1.48	1.46
3B4giii Manure management - Turkeys	NH3	kt	1.00	1.07	0.87	0.84	0.88	0.58	0.58	0.71	0.81	0.74	0.79	0.81	0.84	0.84	0.91
3B4giv Manure management - Other poultry	NH3	kt	0.11	0.11	0.11	0.16	0.12	0.10	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.10
3B4h Manure management - Other animals (please specify in IIR)	NH3	kt	0.46	0.27	0.30	0.29	0.28	0.35	0.33	0.27	0.29	0.29	0.29	0.29	0.29	0.29	0.29
3Da1 Inorganic N-fertilizers (includes also urea application)	NH3	kt	13.69	13.01	13.17	9.76	9.75	11.58	13.16	9.96	7.84	8.69	9.03	9.68	11.23	11.46	12.57
3Da2a Animal manure applied to soils	NH3	kt	32.38	33.49	33.41	33.79	32.80	32.50	30.44	30.46	31.89	32.24	32.33	33.15	34.58	35.29	35.27
3Da2b Sewage sludge applied to soils	NH3	kt	0.02	0.02	0.10	0.39	0.41	0.43	0.54	0.38	0.44	0.34	0.28	0.30	0.29	0.30	0.29
3Da3 Urine and dung deposited by grazing animals	NH3	kt	13.92	14.34	14.44	13.96	13.56	13.43	13.15	12.99	13.43	13.63	13.69	13.70	14.14	14.51	14.50
Total	**NH3**	**kt**	**109.48**	**112.71**	**113.17**	**110.49**	**107.21**	**108.07**	**106.21**	**102.62**	**104.68**	**106.34**	**106.91**	**109.44**	**114.97**	**117.33**	**118.31**
Submission 2021																	
3B1a Manure management - Dairy cattle	NH₃	kt	14.20	13.08	12.26	10.74	10.73	10.60	10.46	10.76	10.85	10.98	11.32	12.23	12.90	13.47	14.10
3B1b Manure management - Non-dairy cattle	NH₃	kt	25.68	29.19	31.10	34.41	34.19	33.75	32.06	31.16	35.54	35.56	32.81	34.28	35.25	36.51	38.92
3B2 Manure management - Sheep	NH3	kt	1.48	1.51	1.51	1.30	1.02	0.95	0.94	0.96	1.00	1.00	0.98	0.97	0.97	1.04	1.01
3B3 Manure management - Swine	NH3	kt	3.80	4.70	5.10	4.92	4.47	4.37	4.55	4.58	4.51	4.41	4.48	4.42	4.59	4.69	4.68
3B4d Manure management - Goats	NH3	kt	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3B4e Manure management - Horses	NH3	kt	0.53	0.58	0.60	0.68	0.82	0.84	0.91	0.91	0.95	0.87	0.81	0.80	0.79	0.73	0.72
3B4f Manure management - Mules and asses	NH3	kt	0.05	0.04	0.03	0.03	0.05	0.05	0.04	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.05
3B4gi Manure management - Laying hens	NH3	kt	0.34	0.24	0.23	0.26	0.25	0.29	0.29	0.29	0.35	0.38	0.40	0.44	0.45	0.47	0.49
3B4gii Manure management - Broilers	NH3	kt	1.08	1.49	1.67	1.73	1.31	1.60	1.60	1.55	1.55	1.45	1.63	1.65	1.66	1.64	1.62
3B4giii Manure management - Turkeys	NH3	kt	1.00	1.07	0.87	0.84	0.88	0.58	0.58	0.71	0.81	0.74	0.79	0.81	0.84	0.84	0.91
3B4giv Manure management - Other poultry	NH3	kt	0.11	0.11	0.11	0.16	0.12	0.10	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.10
3B4h Manure management - Other animals (please specify in IIR)	NH3	kt	0.30	0.18	0.19	0.19	0.18	0.23	0.21	0.21	0.23	0.23	0.23	0.20	0.18	0.16	0.14
3Da1 Inorganic N-fertilizers (includes also urea application)	NH3	kt	13.69	13.01	13.17	9.76	9.75	11.58	13.16	9.96	7.84	8.69	9.03	9.68	11.23	11.46	12.57
3Da2a Animal manure applied to soils	NH3	kt	34.01	35.97	36.88	37.95	37.17	36.61	35.18	35.05	38.86	39.10	37.53	39.77	41.38	42.69	44.90

3Da2b Sewage sludge applied to soils	NH3	kt	0.02	0.02	0.10	0.39	0.41	0.43	0.54	0.38	0.44	0.34	0.28	0.30	0.29	0.30	0.29
3Da3 Urine and dung deposited by grazing animals	NH3	kt	12.98	13.71	14.09	13.56	12.93	12.71	12.42	12.16	12.55	12.68	12.58	12.68	13.07	13.51	13.82
Total	**NH3**	**kt**	**109.30**	**114.93**	**117.92**	**116.95**	**114.29**	**114.71**	**113.05**	**108.83**	**115.64**	**116.58**	**113.01**	**118.40**	**123.77**	**127.68**	**134.33**
% Change in Emissions																	
3B1a Manure management - Dairy cattle	NH$_3$	%	11.8%	9.5%	7.1%	3.5%	1.6%	1.4%	-0.4%	-1.2%	-1.1%	-2.0%	-3.1%	-3.8%	-4.0%	-4.4%	-3.1%
3B1b Manure management - Non-dairy cattle	NH$_3$	%	-6.3%	-0.9%	4.4%	8.9%	11.8%	11.9%	11.6%	10.7%	18.3%	16.6%	9.7%	14.8%	13.6%	16.8%	26.9%
3B2 Manure management - Sheep	NH$_3$	%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-13.9%	-14.1%
3B3 Manure management - Swine	NH$_3$	%	-1.2%	-1.8%	-2.0%	-2.2%	-2.3%	-2.2%	-2.2%	-2.5%	-2.8%	-2.6%	-2.6%	-2.7%	-2.7%	-2.9%	-2.9%
3B4d Manure management - Goats	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4e Manure management - Horses	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4f Manure management - Mules and asses	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gi Manure management - Laying hens	NH$_3$	%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%	-46.4%
3B4gii Manure management - Broilers	NH$_3$	%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%	11.1%
3B4giii Manure management - Turkeys	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giv Manure management - Other poultry	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4h Manure management - Other animals	NH$_3$	%	-35.0%	-33.7%	-34.4%	-34.6%	-34.6%	-34.9%	-35.4%	-20.9%	-21.0%	-21.0%	-21.0%	-28.7%	-36.4%	-44.1%	-51.8%
3Da1 Inorganic N-fertilizers (includes urea application)	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Da2a Animal manure applied to soils	NH$_3$	%	5.0%	7.4%	10.4%	12.3%	13.3%	12.6%	15.6%	15.1%	21.8%	21.3%	16.1%	20.0%	19.7%	21.0%	27.3%
3Da2b Sewage sludge applied to soils	NH$_3$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Da3 Urine and dung deposited by grazing animals	NH$_3$	%	-6.8%	-4.4%	-2.5%	-2.8%	-4.6%	-5.4%	-5.6%	-6.4%	-6.5%	-7.0%	-8.1%	-7.4%	-7.6%	-6.9%	-4.7%
Total	**NH3**	**%**	**-0.2%**	**2.0%**	**4.2%**	**5.8%**	**6.6%**	**6.1%**	**6.4%**	**6.1%**	**10.5%**	**9.6%**	**5.7%**	**8.2%**	**7.6%**	**8.8%**	**13.5%**

Table 5.3. NMVOC Recalculations for Agriculture 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																	
3B1a Manure management - Dairy cattle	NMVOC	kt	9.23	8.45	7.87	7.01	7.18	7.14	7.16	7.43	7.48	7.69	8.05	8.80	9.31	9.75	10.06
3B1b Manure management - Non-dairy cattle	NMVOC	kt	22.56	24.81	25.39	26.67	26.09	26.15	25.04	24.46	25.59	26.41	25.87	25.41	26.46	26.65	26.30
3B2 Manure management - Sheep	NMVOC	kt	0.59	0.62	0.59	0.48	0.38	0.35	0.32	0.33	0.36	0.36	0.37	0.36	0.36	0.39	0.38
3B3 Manure management - Swine	NMVOC	kt	1.02	2.50	2.74	2.66	2.39	2.33	2.43	2.47	2.44	2.39	2.43	2.39	2.48	2.54	2.54
3B4d Manure management - Goats	NMVOC	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	NMVOC	kt	0.11	0.13	0.13	0.15	0.18	0.18	0.20	0.20	0.20	0.19	0.18	0.17	0.17	0.16	0.16
3B4f Manure management - Mules and asses	NMVOC	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4gi Manure management - Laying hens	NMVOC	kt	0.31	0.23	0.26	0.32	0.30	0.35	0.35	0.35	0.43	0.47	0.48	0.54	0.55	0.57	0.59
3B4gii Manure management - Broilers	NMVOC	kt	0.87	1.20	1.34	1.38	1.05	1.29	1.29	1.24	1.24	1.16	1.31	1.32	1.33	1.31	1.30
3B4giii Manure management - Turkeys	NMVOC	kt	0.74	0.79	0.65	0.62	0.65	0.43	0.43	0.53	0.60	0.55	0.58	0.60	0.62	0.62	0.67
3B4giv Manure management - Other poultry	NMVOC	kt	0.18	0.18	0.18	0.26	0.21	0.17	0.14	0.14	0.14	0.13	0.14	0.15	0.16	0.16	0.16
3B4h Manure management - Other animals	NMVOC	kt	0.41	0.25	0.29	0.29	0.29	0.37	0.36	0.36	0.38	0.38	0.38	0.38	0.38	0.38	0.38
3Da1 Inorganic N-fertilizers (includes urea application)	NMVOC	kt	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3De Cultivated crops	NMVOC	kt	0.73	0.60	0.71	0.67	0.66	0.66	0.61	0.61	0.64	0.67	0.67	0.68	0.71	0.70	0.70
Total	**NMVOC**	**kt**	**36.76**	**39.76**	**40.16**	**40.52**	**39.38**	**39.43**	**38.33**	**38.12**	**39.53**	**40.42**	**40.47**	**40.82**	**42.54**	**43.23**	**43.25**
Submission 2021																	
3B1a Manure management - Dairy cattle	NMVOC	kt	10.32	9.63	9.16	8.16	8.12	8.00	7.92	8.38	8.16	8.13	8.85	9.75	10.20	10.49	10.22
3B1b Manure management - Non-dairy cattle	NMVOC	kt	21.96	23.48	23.76	25.08	24.52	24.66	23.67	22.95	23.79	24.59	24.38	23.98	24.91	24.95	24.26
3B2 Manure management - Sheep	NMVOC	kt	0.57	0.60	0.57	0.46	0.37	0.34	0.31	0.32	0.35	0.35	0.36	0.35	0.35	0.37	0.37
3B3 Manure management - Swine	NMVOC	kt	1.11	2.77	3.07	2.99	2.66	2.59	2.71	2.77	2.74	2.69	2.73	2.69	2.79	2.84	2.85
3B4d Manure management - Goats	NMVOC	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	NMVOC	kt	0.11	0.13	0.13	0.15	0.18	0.18	0.20	0.20	0.20	0.19	0.18	0.17	0.17	0.16	0.16
3B4f Manure management - Mules and asses	NMVOC	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4gi Manure management - Laying hens	NMVOC	kt	0.31	0.23	0.26	0.32	0.30	0.35	0.35	0.35	0.43	0.47	0.48	0.54	0.55	0.57	0.59
3B4gii Manure management - Broilers	NMVOC	kt	0.87	1.20	1.34	1.38	1.05	1.29	1.29	1.24	1.24	1.16	1.31	1.32	1.33	1.31	1.30
3B4giii Manure management - Turkeys	NMVOC	kt	0.74	0.79	0.65	0.62	0.65	0.43	0.43	0.53	0.60	0.55	0.58	0.60	0.62	0.62	0.67
3B4giv Manure management - Other poultry	NMVOC	kt	0.18	0.18	0.18	0.26	0.21	0.17	0.14	0.14	0.14	0.13	0.14	0.15	0.16	0.16	0.16
3B4h Manure management - Other animals	NMVOC	kt	0.41	0.25	0.29	0.29	0.29	0.37	0.36	0.36	0.38	0.38	0.38	0.35	0.31	0.27	0.23
3Da1 Inorganic N-fertilizers (includes urea application)	NMVOC	kt	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3De Cultivated crops	NMVOC	kt	4.58	4.56	4.59	4.43	4.78	4.76	4.75	4.74	4.69	4.65	4.63	4.60	4.62	4.66	4.68
Total	**NMVOC**	**kt**	**41.18**	**43.82**	**43.99**	**44.15**	**43.13**	**43.15**	**42.13**	**41.99**	**42.72**	**43.31**	**44.03**	**44.50**	**46.01**	**46.42**	**45.50**
% Change in Emissions																	
3B1a Manure management - Dairy cattle	NMVOC	%	11.8%	14.0%	16.3%	16.3%	13.0%	12.2%	10.6%	12.9%	9.0%	5.6%	10.0%	10.7%	9.6%	7.6%	1.6%
3B1b Manure management - Non-dairy cattle	NMVOC	%	-2.7%	-5.4%	-6.4%	-6.0%	-6.0%	-5.7%	-5.5%	-6.2%	-7.1%	-6.9%	-5.8%	-5.6%	-5.8%	-6.4%	-7.8%

3B2 Manure management - Sheep	NMVOC	%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.1%	-3.2%
3B3 Manure management - Swine	NMVOC	%	9.2%	11.0%	12.0%	12.3%	11.5%	11.2%	11.3%	12.1%	12.3%	12.5%	12.4%	12.4%	12.3%	12.1%	12.4%
3B4d Manure management - Goats	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4e Manure management - Horses	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4f Manure management - Mules and asses	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gi Manure management - Laying hens	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gii Manure management - Broilers	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giii Manure management - Turkeys	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giv Manure management - Other poultry	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4h Manure management - Other animals	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-9.8%	-19.6%	-29.4%	-39.2%
3Da1 Inorganic N-fertilizers (includes urea application)	NMVOC	%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3De Cultivated crops	NMVOC	%	524.9%	660.0%	544.7%	565.8%	622.9%	617.3%	682.6%	680.3%	628.2%	596.1%	589.4%	577.8%	554.2%	569.4%	570.0%
Total	**NMVOC**	**%**	**12.0%**	**10.2%**	**9.6%**	**9.0%**	**9.5%**	**9.4%**	**9.9%**	**10.1%**	**8.1%**	**7.2%**	**8.8%**	**9.0%**	**8.2%**	**7.4%**	**5.2%**

Table 5.4. TSP Recalculations for Agriculture 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																	
3B1a Manure management - Dairy cattle	TSP	kt	0.59	0.59	0.55	0.49	0.50	0.50	0.50	0.52	0.53	0.54	0.57	0.61	0.65	0.66	0.68
3B1b Manure management - Non-dairy cattle	TSP	kt	0.95	0.97	0.99	1.06	1.03	1.02	0.97	0.94	1.00	1.01	0.98	0.99	1.03	1.03	1.01
3B2 Manure management - Sheep	TSP	kt	0.10	0.11	0.10	0.08	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06
3B3 Manure management - Swine	TSP	kt	0.98	1.24	1.36	1.32	1.20	1.17	1.22	1.24	1.23	1.20	1.22	1.20	1.25	1.28	1.28
3B4d Manure management - Goats	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	TSP	kt	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
3B4f Manure management - Mules and asses	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	TSP	kt	0.35	0.26	0.30	0.37	0.34	0.41	0.41	0.41	0.49	0.54	0.55	0.62	0.63	0.66	0.68
3B4gii Manure management - Broilers	TSP	kt	0.32	0.44	0.50	0.51	0.39	0.48	0.48	0.46	0.46	0.43	0.49	0.49	0.49	0.49	0.48
3B4giii Manure management - Turkeys	TSP	kt	0.17	0.18	0.15	0.14	0.15	0.10	0.10	0.12	0.13	0.12	0.13	0.14	0.14	0.14	0.15
3B4giv Manure management - Other poultry	TSP	kt	0.05	0.05	0.05	0.08	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
3B4h Manure management - Other animals	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	TSP	kt	6.93	6.85	6.93	6.71	7.22	7.17	7.13	7.11	7.07	6.99	6.97	6.91	6.96	7.00	7.05
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	TSP	kt	0.18	0.19	0.17	0.15	0.12	0.12	0.14	0.12	0.12	0.15	0.14	0.14	0.14	0.16	0.17
3Dd Off-farm storage, handling and transport of bulk agricultural products	TSP	kt	0.20	0.18	0.22	0.19	0.25	0.21	0.20	0.25	0.21	0.24	0.26	0.26	0.23	0.24	0.19
Submission 2021																	
3B1a Manure management - Dairy cattle	TSP	kt	0.64	0.64	0.60	0.54	0.55	0.55	0.54	0.56	0.58	0.59	0.62	0.66	0.69	0.71	0.73
3B1b Manure management - Non-dairy cattle	TSP	kt	0.99	0.98	1.00	1.02	1.02	1.04	0.99	0.96	1.00	1.05	1.04	1.04	1.08	1.10	1.09
3B2 Manure management - Sheep	TSP	kt	0.10	0.11	0.10	0.08	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06
3B3 Manure management - Swine	TSP	kt	0.98	1.24	1.36	1.32	1.20	1.17	1.22	1.24	1.23	1.20	1.22	1.20	1.25	1.28	1.28
3B4d Manure management - Goats	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	TSP	kt	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
3B4f Manure management - Mules and asses	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	TSP	kt	0.35	0.26	0.30	0.37	0.34	0.41	0.41	0.41	0.49	0.54	0.55	0.62	0.63	0.66	0.68
3B4gii Manure management - Broilers	TSP	kt	0.32	0.44	0.50	0.51	0.39	0.48	0.48	0.46	0.46	0.43	0.49	0.49	0.49	0.49	0.48
3B4giii Manure management - Turkeys	TSP	kt	0.17	0.18	0.15	0.14	0.15	0.10	0.10	0.12	0.13	0.12	0.13	0.14	0.14	0.14	0.15
3B4giv Manure management - Other poultry	TSP	kt	0.05	0.05	0.05	0.08	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
3B4h Manure management - Other animals	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	TSP	kt	6.93	6.85	6.93	6.71	7.22	7.17	7.13	7.11	7.07	6.99	6.97	6.91	6.96	7.00	7.05
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	TSP	kt	0.18	0.19	0.17	0.15	0.12	0.12	0.14	0.12	0.12	0.15	0.14	0.14	0.14	0.16	0.17
3Dd Off-farm storage, handling and transport of bulk agricultural products	TSP	kt	0.20	0.18	0.22	0.19	0.25	0.21	0.20	0.25	0.21	0.24	0.26	0.26	0.23	0.24	0.19

% Change in Emissions																	
3B1a Manure management - Dairy cattle	TSP	%	9.9%	10.1%	10.0%	9.9%	9.2%	8.9%	8.9%	8.8%	8.2%	8.0%	8.0%	7.5%	6.8%	6.9%	6.9%
3B1b Manure management - Non-dairy cattle	TSP	%	3.5%	1.3%	1.1%	-3.4%	-0.7%	1.3%	2.6%	2.7%	0.9%	3.3%	6.1%	4.9%	4.8%	6.8%	7.6%
3B2 Manure management - Sheep	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
3B3 Manure management - Swine	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4d Manure management - Goats	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4e Manure management - Horses	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4f Manure management - Mules and asses	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gi Manure management - Laying hens	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gii Manure management - Broilers	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giii Manure management - Turkeys	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giv Manure management - Other poultry	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4h Manure management - Other animals	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-9.8%	-19.6%	-29.4%	-39.2%
3Da1 Inorganic N-fertilizers (includes urea application)	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dd Off-farm storage, handling and transport of bulk agricultural products	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5.5. PM₁₀ Recalculations for Agriculture 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																	
3B1a Manure management - Dairy cattle	PM$_{10}$	kt	0.27	0.27	0.25	0.22	0.23	0.23	0.23	0.24	0.24	0.25	0.26	0.28	0.29	0.30	0.31
3B1b Manure management - Non-dairy cattle	PM$_{10}$	kt	0.43	0.44	0.45	0.48	0.47	0.46	0.44	0.43	0.45	0.46	0.45	0.45	0.47	0.47	0.46
3B2 Manure management - Sheep	PM$_{10}$	kt	0.04	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
3B3 Manure management - Swine	PM$_{10}$	kt	0.15	0.18	0.20	0.19	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19
3B4d Manure management - Goats	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	PM$_{10}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4f Manure management - Mules and asses	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	PM$_{10}$	kt	0.07	0.05	0.06	0.08	0.07	0.09	0.09	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.14
3B4gii Manure management - Broilers	PM$_{10}$	kt	0.16	0.22	0.25	0.26	0.19	0.24	0.24	0.23	0.23	0.22	0.24	0.24	0.25	0.24	0.24
3B4giii Manure management - Turkeys	PM$_{10}$	kt	0.17	0.18	0.15	0.14	0.15	0.10	0.10	0.12	0.13	0.12	0.13	0.14	0.14	0.14	0.15
3B4giv Manure management - Other poultry	PM$_{10}$	kt	0.05	0.05	0.05	0.08	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
3B4h Manure management - Other animals	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	PM$_{10}$	kt	6.93	6.85	6.93	6.71	7.22	7.17	7.13	7.11	7.07	6.99	6.97	6.91	6.96	7.00	7.05
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	PM$_{10}$	kt	0.06	0.06	0.06	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.05
3Dd Off-farm storage, handling and transport of bulk agricultural products	PM$_{10}$	kt	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.05
Submission 2021																	
3B1a Manure management - Dairy cattle	PM$_{10}$	kt	0.29	0.29	0.27	0.24	0.25	0.25	0.25	0.26	0.26	0.27	0.28	0.30	0.31	0.32	0.33
3B1b Manure management - Non-dairy cattle	PM$_{10}$	kt	0.44	0.44	0.45	0.46	0.46	0.47	0.45	0.44	0.46	0.47	0.47	0.47	0.49	0.50	0.50
3B2 Manure management - Sheep	PM$_{10}$	kt	0.04	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
3B3 Manure management - Swine	PM$_{10}$	kt	0.15	0.18	0.20	0.19	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19
3B4d Manure management - Goats	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	PM$_{10}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4f Manure management - Mules and asses	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	PM$_{10}$	kt	0.07	0.05	0.06	0.08	0.07	0.09	0.09	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.14
3B4gii Manure management - Broilers	PM$_{10}$	kt	0.16	0.22	0.25	0.26	0.19	0.24	0.24	0.23	0.23	0.22	0.24	0.24	0.25	0.24	0.24
3B4giii Manure management - Turkeys	PM$_{10}$	kt	0.17	0.18	0.15	0.14	0.15	0.10	0.10	0.12	0.13	0.12	0.13	0.14	0.14	0.14	0.15
3B4giv Manure management - Other poultry	PM$_{10}$	kt	0.05	0.05	0.05	0.08	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
3B4h Manure management - Other animals	PM$_{10}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	PM$_{10}$	kt	6.93	6.85	6.93	6.71	7.22	7.17	7.13	7.11	7.07	6.99	6.97	6.91	6.96	7.00	7.05
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	PM$_{10}$	kt	0.06	0.06	0.06	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.05
3Dd Off-farm storage, handling and transport of bulk agricultural products	PM$_{10}$	kt	0.05	0.04	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.05

% Change in Emissions

3B1a Manure management - Dairy cattle	PM10	%	9.9%	9.8%	9.8%	9.7%	9.1%	8.8%	8.8%	8.7%	8.2%	8.0%	8.0%	7.6%	6.9%	6.9%	7.0%
3B1b Manure management - Non-dairy cattle	PM10	%	2.2%	0.2%	0.0%	-4.2%	-1.4%	0.8%	2.1%	2.2%	0.5%	3.0%	5.8%	4.7%	4.7%	6.6%	7.5%
3B2 Manure management - Sheep	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
3B3 Manure management - Swine	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4d Manure management - Goats	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4e Manure management - Horses	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4f Manure management - Mules and asses	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gi Manure management - Laying hens	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gii Manure management - Broilers	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giii Manure management - Turkeys	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giv Manure management - Other poultry	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4h Manure management - Other animals	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-9.8%	-19.6%	-29.4%	-39.2%
3Da1 Inorganic N-fertilizers (includes urea application)	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dd Off-farm storage, handling and transport of bulk agricultural products	PM10	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5.6. PM$_{2.5}$ Recalculations for Agriculture 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																	
3B1a Manure management - Dairy cattle	PM$_{2.5}$	kt	0.17	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.18	0.19	0.20	0.20
3B1b Manure management - Non-dairy cattle	PM$_{2.5}$	kt	0.29	0.29	0.30	0.32	0.31	0.31	0.29	0.28	0.30	0.30	0.30	0.30	0.31	0.31	0.30
3B2 Manure management - Sheep	PM$_{2.5}$	kt	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B3 Manure management - Swine	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4d Manure management - Goats	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	PM$_{2.5}$	kt	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4f Manure management - Mules and asses	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	PM$_{2.5}$	kt	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4gii Manure management - Broilers	PM$_{2.5}$	kt	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3B4giii Manure management - Turkeys	PM$_{2.5}$	kt	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
3B4giv Manure management - Other poultry	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4h Manure management - Other animals	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	PM$_{2.5}$	kt	0.27	0.26	0.27	0.26	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
3Dd Off-farm storage, handling and transport of bulk agricultural products	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Submission 2021																	
3B1a Manure management - Dairy cattle	PM$_{2.5}$	kt	0.19	0.19	0.18	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.19	0.20	0.21	0.21	0.22
3B1b Manure management - Non-dairy cattle	PM$_{2.5}$	kt	0.30	0.30	0.30	0.31	0.31	0.31	0.30	0.29	0.30	0.32	0.32	0.31	0.33	0.33	0.33
3B2 Manure management - Sheep	PM$_{2.5}$	kt	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B3 Manure management - Swine	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4d Manure management - Goats	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4e Manure management - Horses	PM$_{2.5}$	kt	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4f Manure management - Mules and asses	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3B4gi Manure management - Laying hens	PM$_{2.5}$	kt	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4gii Manure management - Broilers	PM$_{2.5}$	kt	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3B4giii Manure management - Turkeys	PM$_{2.5}$	kt	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
3B4giv Manure management - Other poultry	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3B4h Manure management - Other animals	PM$_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3Da1 Inorganic N-fertilizers (includes urea application)	PM$_{2.5}$	kt	0.27	0.26	0.27	0.26	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
3Dd Off-farm storage, handling and transport of bulk agricultural products	PM$_{2.5}$	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

% Change in Emissions

3B1a Manure management - Dairy cattle	$PM_{2.5}$	%	9.9%	10.1%	10.0%	9.9%	9.2%	8.9%	8.9%	8.8%	8.2%	8.0%	8.0%	7.6%	6.9%	6.9%	7.0%
3B1b Manure management - Non-dairy cattle	$PM_{2.5}$	%	4.0%	1.8%	1.5%	-3.0%	-0.3%	1.8%	3.1%	3.2%	1.4%	3.8%	6.6%	5.5%	5.3%	7.3%	8.2%
3B2 Manure management - Sheep	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
3B3 Manure management - Swine	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4d Manure management - Goats	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4e Manure management - Horses	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4f Manure management - Mules and asses	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gi Manure management - Laying hens	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4gii Manure management - Broilers	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giii Manure management - Turkeys	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4giv Manure management - Other poultry	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3B4h Manure management - Other animals	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-9.8%	-19.6%	-29.4%	-39.2%	
3Da1 Inorganic N-fertilizers (includes urea application)	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3Dd Off-farm storage, handling and transport of bulk agricultural products	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Chapter Six

Waste

6.1 Overview of the Waste (NFR 5) Sector

Emissions from the Waste sector cover a number of different source categories and pollutants. These are detailed below in Table 6.1. All sources are considered in detail in this chapter.

Table 6.1 Pollutant Emissions by Waste Source Category

NFR Source Category	Pollutants
5A Biological treatment of waste - Solid waste disposal on land	NMVOC, Hg, PCDD/F, PCB, TSP, PM_{10}, $PM_{2.5}$
5B1 Biological treatment of waste - Composting	NH_3, CO
5B2 Biological treatment of waste - Anaerobic digestion at biogas facilities	NO, NA, NE
5C1a Municipal waste incineration	NO
5C1bi Industrial waste incineration	NOx, SO_2, NMVOC, CO, TSP, $PM_{2.5}$, PM_{10}, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, PCDD/F, B[a]P, B[b]F, B[k]F, HCB, PCB
5C1bii Hazardous waste incineration	IE (5C1bi)
5C1biii Clinical waste incineration	NOx, SO_2, NMVOC, CO, TSP, $PM_{2.5}$, PM_{10}, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, PCDD/F, B[a]P, B[b]F, B[k]F, HCB, PCB
5C1biv Sewage sludge incineration	NO, NA, IE
5C1bv Cremation	NOx, SO_2, NMVOC, CO, TSP, $PM_{2.5}$, PM_{10}, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, PCDD/F, B[a]P, B[b]F, B[k]F, HCB, PCB
5C1bvi Other waste incineration	NO, NA, NE
5C2 Open burning of waste	PCDD/F, B[a]P, B[b]F, B[k]F, PCB
5D Waste-water handling	NA, NE
5E Other waste	$PM_{2.5}$, PM_{10}, TSP, PCDD/F, B[a]P, B[b]F, B[k]F, I[123-cd]P, PCB

The Waste sector contains four key categories for six pollutants. Category Industrial waste incineration (5C1bi) is a key category for two pollutants: As and Cr, accounting for 58.0 per cent and 27.7 per cent of national total emissions, respectively. This category is the largest source of As and Cr in Ireland's 2019 inventory. The second key category in the waste sector is Other waste (5E) for two pollutants: PCDD/F and PCBs. The category accounts for 39.6 per cent of national total PCB emissions in Ireland's 2019 inventory. The category also accounts for 16.4 per cent of national total PCDD/F emissions. Other waste (5E) is also a key category for $PM_{2.5}$ accounting for 2.1 per cent of emissions. Open burning of waste (5C2) is a key category for PCBs accounting for 18.0 per cent of emissions. Solid waste disposal on land (5A) is a key category for Mercury (Hg) accounting for 6.5 per cent of the national total in 2019.

6.2 Biological treatment of waste - Solid waste disposal on land (NFR 5A)

6.2.1 Main Pollutants

Landfill gas generated at solid waste disposal sites is a source of NMVOC emissions. In Ireland sector 5A has been responsible on average for 0.5 per cent of national total emissions across the time series 1990-2019, showing a decrease of 48.6 per cent from 0.83 kt in 1990 to 0.43 kt in 2019. Emission factors for NMVOC were sourced from the Inventory Guidebook (EMEP/EEA, 2019) and are listed in Table F1 of Annex F. The activity data used is the net fugitive methane emissions from SWDS (kt) as calculated in the national greenhouse gas inventory, which are converted to landfill gas data (Gm^3) using standard temperature and pressure (STP) molar conversion factors.

Emission of TSP, PM_{10} and $PM_{2.5}$ are also estimated. Emission factors from the Inventory Guidebook (EMEP/EEA, 2019) are applied to annual MSW data. Resulting emission estimates are included in Table 6.2 below.

Table 6.2 Emission Time Series for NMVOC TSP, PM_{10} and $PM_{2.5}$ from Solid Waste Disposal on Land

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NMVOC (kt)	0.83	1.01	0.80	0.64	0.18	0.24	0.19	0.29	0.41	0.46	0.47	0.45	0.44	0.43
TSP (t)	0.89	0.90	1.01	0.88	0.69	0.62	0.51	0.36	0.29	0.30	0.37	0.31	0.21	0.19
PM_{10} (t)	0.42	0.43	0.48	0.42	0.33	0.30	0.24	0.17	0.13	0.14	0.18	0.15	0.10	0.09
$PM_{2.5}$ (t)	0.06	0.06	0.07	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.03	0.02	0.02	0.01

6.2.2 Heavy Metals

The relevant emissions in the Category 5A Solid Waste Disposal on Land sector in Ireland's air pollutant inventory include emissions of Hg from the disposal of batteries, electrical equipment, fluorescent lighting tubes, and measurement and control equipment in solid waste disposal sites (landfills). There is no direct estimate of the scale of disposal of the items mentioned at landfills in Ireland. However, Netcen/CTC (2006) provides a methodology to estimate emissions in Ireland using UK emission estimates, scaling by population for batteries and by household numbers for electrical equipment, fluorescent lighting and measurement and control equipment. Emission estimates for the above sources of Hg are presented in Table 6.3.

Table 6.3 Emission Time Series for Mercury from Solid Waste Disposal on Land

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hg (kg)	28.96	18.27	18.68	20.08	21.71	22.35	22.06	21.88	21.72	21.42	21.54	21.37	21.03	21.17

No data are available on emissions of POPs to air from municipal solid waste (MSW) disposal, although the emissions are likely to be negligible. There is potential for POP emissions to air from landfill gas (LFG) as described in the following section.

6.2.3 Landfill Gas and Persistent Organic Pollutants

There is potential for releases of POPs in landfill gas (LFG) through the transfer of POPs present in solid waste to the LFG that is generated by the waste. A proportion of this LFG escapes to air, with the remainder captured for flaring or utilisation for energy recovery. The proportion of LFG that is utilised

for electricity generation is not considered in this chapter as it is accounted for in NFR Category 1A1a Public Energy and Heat Production (Chapter Three), from which POP emissions are negligible. There is currently no information in Ireland on the release of POPs from LFG and therefore emission estimates are based on the UK inventory.

Activity data on the quantity of LFG flared and LFG that escapes to the atmosphere have been obtained from Ireland's GHG emission inventory for the 1990–2019 time series. Emission factors have been taken from the UK NAEI (2006) for PCDD/F as 0.953 µg I-TEQ/t of escaping LFG and 0.614 µg I-TEQ/t of flared LFG (Table F.1 of Annex F). The emission factor for PCBs is 0.0008 kg/t of escaping gas (UK NAEI). Emission estimates and activity data for PCDD/F and PCBs are presented in Table 6.4.

Table 6.4 Time Series of Activity Data and Emissions of Dioxins and Furans and Polychlorinated Biphenyls from Landfill Gas

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
LFG emitted (kt)	105.4	127.4	101.5	80.6	22.3	30.5	24.2	36.9	51.8	58.2	60.0	57.4	55.4	54.2
LFG flared (kt)	NO	NO	50.7	40.3	11.1	15.3	12.1	18.4	25.9	29.1	30.0	28.7	27.7	27.1
PCDD/F (g I-TEQ)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
PCBs (kg)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

6.3 Biological treatment of waste - Composting (NFR 5B1)

Composting of organic waste, such as food waste, garden and park waste has taken place in Ireland since 2001. It consists of organic waste collected at kerbside and brought to civic amenity/temporary collections sites, as well as organic material composted at households. Activity data is sourced from National Waste Database Reports published by the EPA on a regular basis. Composting is a source of emissions of NH_3 and CO and the Tier 2 emission factors in the Inventory Guidebook (EMEP/EEA, 2019) of 0.66 kg/Mg waste and 0.56 kg/Mg waste are used, respectively. Emission estimates and activity data are presented in Table 6.5.

Table 6.5 Time Series of Activity Data and Emissions of NH3 and CO from Composting

Year	2001	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Waste composted (kt)	22.2	80.3	122	133.6	130.7	132.5	112.5	120.5	116	149.5	157.5	157.5
NH3 (kt)	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04
CO (kt)	0.01	0.04	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.08	0.09	0.09

6.4 Waste Incineration (NFR 5C)

Ireland carries out relatively little waste incineration compared with some European countries and there is currently no incineration, without energy recovery, of MSW. The Waste Incineration (5C) category includes estimates of air pollutant emissions from the incineration of clinical waste (5C1biii), industrial waste (5C1bi), including hazardous waste (5C1bii), emissions from crematoria (5C1bv), and the open burning/combustion of waste materials such as farm plastics (5C2).

There is incineration of municipal wastes in Ireland following the commissioning of one incinerator in 2011 and a further one in 2017. However, these are waste-to-energy facilities, and as such emissions are reported under Public electricity and heat production (1A1a). Approximately 50 per cent of health-care waste was incinerated during the 1990s, with a total of 150 incinerators in operation. By 1999, only two of these remained in operation and both closed the following year. Most of the industrial installations that incinerate hazardous industrial wastes are in the pharmaceutical sector. The practice of cremation is also less common in Ireland than in other countries but has increased in recent years due to the decrease in available burial plots, particularly in larger cities and towns in Ireland.

All the above are sources of heavy metals, POPs and combustion pollutants (NO_X, SO_2, NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$ and BC) in Ireland and are discussed in detail in the following sections.

6.4.1 Clinical Waste (5C1biii)

The incineration of Clinical Waste is no longer carried out in Ireland. The bulk of hazardous clinical waste in Ireland is now treated using non-incineration technologies (namely sterilisation and shredding), with the remaining waste disposed of through landfilling, exported for incineration or used as a fuel in cement kilns. In the early 1990s, most hospitals operated on-site incinerator units where hazardous clinical waste was incinerated. A number of hospitals operated the practice of incinerating both hazardous and non-hazardous waste. Due to the implementation of stricter standards on incineration and the requirement for facilities to be licensed by the EPA, all incinerators were closed by the mid- to late-1990s. Prior to the closure of these facilities, a number of applications were made to the EPA in respect of IPPC licences. National reports and Government records contain some information on the quantity of health-care waste incinerated during the period of operation of the incinerators. From these sources, it was determined that an estimated 4,000 t of health-care waste was incinerated per annum. This value was used across the time series for the period 1990–1997, after which negligible quantities of health-care waste were incinerated up until the closure of the two remaining incinerators in 2000.

Emission estimates were derived for heavy metals using the quantity of health-care waste determined to be incinerated and Inventory Guidebook (EMEP/EEA, 2019) emission factors for As, Cd, Cr, Cu, Pb, Hg and Ni, assuming controlled air flow with no abatement. The emission factor for Zn was sourced from the UK NAEI. Emission factors are provided in Table F.1 of Annex F. Emission estimates for heavy metals are presented in Table 6.6.

Emissions of POPs from clinical wastes have been estimated using emission factors sourced from the UK NAEI. Dioxin and furan emission estimates are made utilising an emission factor of 372.1 μg I-TEQ/t health-care waste incinerated. This emission factor is used in the inventory for the period 1990–1997 until closure of all major plants. The PCB emission factor of 3.15 kg/Mt in 1990 reduces to 2.87 kg/Mt by 1995 and 2.36 kg/Mt by 1997, the last year of clinical waste incineration on the basis that environmental performance at the plants would have improved as in the UK. The emission factors for HCB from health-care waste incinerators have been estimated by taking the UK NAEI factor of 0.5 kg/Mt for 2006 and estimating the historical emission factors for 1990 and 1995 in proportion to those for PCBs in order to take account of the improvements in environmental performance that would have been introduced at some incinerators. Emission factors for intervening years are interpolated.

Emission factors for 2006 are also available from the UK NAEI for benzo[a]pyrene, benzo[b]fluoranthene and benzo[k]fluoranthene, but there are no data for indeno[1,2,3-cd]pyrene. The emission factors for 2006 have been used to estimate emission factors for 1990 and 1995, scaling back in proportion to the emission factors for PCBs similar to that undertaken for HCB emission factors. Emission factors are given in Table F.1 of Annex F and the estimates for POPs are presented in Table 6.6.

Emission factors for: NO_X, CO, NMVOC, SO_X, TSP, PM_{10} and $PM_{2.5}$ were sourced from the Inventory guidebook (EMEP/EEA, 2019), using a Tier 1 approach, and are listed in Table F1 of Annex F. Resulting emission estimates 1990-1997 are included in Table 6.6.

Table 6.6 Time Series of Emissions from the Incineration of Clinical Waste

Year	1990	1991	1992	1993	1994	1995	1996	1997
NO_X (kt)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO (t)	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
NMVOC (t)	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
SO_X (t)	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
TSP (kt)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
PM_{10} (kt)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
$PM_{2.5}$ (kt)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
As (kg)	0.40	0.40	0.40	0.40	0.40	0.40	NO	NO
Cd (t)	0.01	0.01	0.01	0.01	0.01	0.01	NO	NO
Cr (kg)	1.60	1.60	1.60	1.60	1.60	1.60	NO	NO
Cu (kg)	24.00	24.00	24.00	24.00	24.00	24.00	NO	NO
Pb (t)	0.14	0.14	0.14	0.14	0.14	0.14	NO	NO
Hg (t)	0.22	0.22	0.22	0.22	0.22	0.22	NO	NO
Ni (kg)	1.20	1.20	1.20	1.20	1.20	1.20	NO	NO
Zn (t)	0.07	0.07	0.07	0.07	0.07	0.07	NO	NO
PCDD/F (g-I-TEQ)	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
PCBs (kg)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
HCB (kg)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B[a]p (kg)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B[b]F (kg)	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
B[k}F (kg)	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04

6.4.2 Industrial Waste (5C1bi), Hazardous Waste (5C1bii) and Sewage Sludge (5C1biv)

The category Hazardous Waste Incineration (5C1bii) is reported in Industrial Waste Incineration (5C1bi) and reported as IE under the latter category. EU Directives on waste management have set the basis for strict regulatory control on the environmental performance of hazardous industrial waste incinerators. The incineration of Industrial Waste (5C1bi) (including hazardous waste) is now highly regulated in Ireland. There are currently only a small number of facilities based in the pharmaceutical and chemical sectors that operate incinerators for the treatment of hazardous waste. The facilities that operate these units report emissions to the atmosphere to the EPA as part of IPPC licensing requirements. The disposal of CCA treated wood (CCA being a preservative containing copper, chromium and arsenic) by burning is also included as a source in this sector.

Estimates of the quantity of hazardous waste incinerated at the relevant facilities, determined from returns to the National Waste Database (Carey et al, 1996; Crowe et al, 2000; Meaney et al, 2003; Collins et al, 2004a; Collins et al, 2004b; Collins et al, 2005; Le Bolloch et al, 2006; Le Bolloch et al, 2007; Le Bolloch et al, 2009; McCoole et al, 2009; McCoole et al, 2011; McCoole et al, 2012; McCoole et al, 2013, http://www.epa.ie/nationalwastestatistics/), and information supplied by the facilities involved allows for the calculation of heavy metal emission estimates. Emission factors sourced from the Inventory Guidebook (EMEP/EEA 2019) for As, Cd, Pb, Hg, Ni and the UK NAEI for Cr and Cu are used to estimate emissions. Emission estimates are presented in Table 6.7, while the emission factors used are presented in Table F.1 of Annex F.

Table 6.7 Time Series of Emissions from the Incineration of Industrial (incl. Hazardous & Sludge) Waste

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NO_x (kt)	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO (t)	1.90	1.90	1.40	2.54	1.28	0.88	1.06	1.01	0.92	0.93	0.52	0.58	0.48	0.65
NMVOC (kt)	0.20	0.20	0.15	0.27	0.13	0.09	0.11	0.11	0.10	0.10	0.06	0.06	0.05	0.07
SO_x (t)	1.27	1.27	0.94	1.70	0.86	0.59	0.71	0.68	0.62	0.62	0.35	0.39	0.32	0.44
TSP (t)	0.27	0.27	0.20	0.36	0.18	0.13	0.15	0.14	0.13	0.13	0.07	0.08	0.07	0.09
PM_{10} (t)	0.19	0.19	0.14	0.25	0.13	0.09	0.11	0.10	0.09	0.09	0.05	0.06	0.05	0.07
$PM_{2.5}$ (t)	0.11	0.11	0.08	0.14	0.07	0.05	0.06	0.06	0.05	0.05	0.03	0.03	0.03	0.04
As (t)	0.55	0.56	0.58	0.62	0.65	0.65	0.65	0.65	0.64	0.64	0.65	0.65	0.65	0.66
Cd (kg)	2.71	2.71	2.00	3.62	1.82	1.26	1.51	1.44	1.31	1.33	0.75	0.82	0.68	0.93
Cr (t)	0.53	0.54	0.56	0.60	0.63	0.63	0.63	0.62	0.62	0.62	0.63	0.63	0.63	0.64
Cu (t)	0.29	0.30	0.31	0.33	0.35	0.35	0.35	0.34	0.34	0.34	0.35	0.35	0.35	0.35
Pb (t)	0.04	0.04	0.03	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Hg (kg)	1.52	1.52	1.12	2.03	1.02	0.71	0.85	0.81	0.73	0.74	0.42	0.46	0.38	0.52
Ni (kg)	0.38	0.38	0.28	0.51	0.26	0.18	0.21	0.20	0.18	0.19	0.10	0.12	0.10	0.13
Zn (t)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
PCDD/F (g-I-TEQ)	0.03	0.03	0.08	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.61	1.31	0.35
PCBs (kg)	0.09	0.08	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
HCB (kg)	0.05	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
B[a]p (kg)	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B[b]F (kg)	0.07	0.05	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01
B[k}F (kg)	0.07	0.05	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01

The hazardous waste incinerators currently in use in Ireland are relatively modern units designed to optimise the burning process, with wet scrubber abatement systems in place to reduce the emissions of POPs to air. Further to the use of incinerators, there are also a number of facilities that use thermal oxidisers, which are subject to emission limit values. Annual Environmental Reports and IPPC Licence Applications provide adequate information in relation to the monitoring of PCDD/F emissions to air with limited information on the other relevant POPs. With respect to emissions of PAHs, emission factors sourced from the UK NAEI were applied to the tonnage of waste incinerated for each year. Pollutant-specific emission factors are presented in Table F.1 of Annex F. Emission estimates for POPs are presented in Table 6.7.

Emission factors for: NOₓ, CO, NMVOC, SOₓ, TSP, PM$_{10}$ and PM$_{2.5}$ were sourced from the Inventory Guidebook (EMEP/EEA, 2019), using a Tier 1 approach, and are listed in Table F.1 of Annex F. Resulting emission estimates are included in Table 6.7.

6.4.3 Crematoria (5C1bv)

The practice of cremation is less popular in Ireland than in other countries. However, due to the decrease in the number of burial plots available, particularly in larger cities and towns, the number of cremations in Ireland has been steadily increasing. There are currently seven crematoria operating in Ireland. Cremation has been in operation in Ireland for over a decade, with one of the crematoria open since the early 1990s. A pet crematorium is also currently operating in Ireland; however, emissions from this source are regarded as negligible. Data on the number of cremations in Ireland have been obtained via correspondence with crematoria operators.

Heavy metals emissions are estimated using Inventory Guidebook (EMEP/EEA, 2019) emission factors for As, Cd, Pb, Cr, Hg, Ni, Cu Se and Zn and are presented in Table F.1 of Annex F. Emissions of POPs from crematoria include PCDD/F, HCB and benzo[a]pyrene. Inventory Guidebook (EMEP/EEA, 2019) emission factors are used to derive emission estimates for the years 1990–2019 (Table F.1 of Annex F). Emission factors for: NOₓ, CO, NMVOC, SOₓ, TSP, PM$_{10}$ and PM$_{2.5}$ were sourced from the Inventory guidebook (EMEP/EEA, 2019), using a Tier 1 approach, and are listed in Table F.1 of Annex F. Resulting emission estimates are included in Table 6.8.

Table 6.8 Time Series of Emissions from Crematoria

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NOₓ (t)	1.24	1.24	1.82	2.03	2.54	2.75	3.07	3.37	3.73	4.11	4.52	4.92	5.34	5.81
CO (t)	0.21	0.21	0.31	0.34	0.43	0.47	0.52	0.57	0.63	0.70	0.77	0.84	0.91	0.99
NMVOC (t)	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.09
SOₓ (t)	0.17	0.17	0.25	0.28	0.35	0.38	0.42	0.46	0.51	0.56	0.62	0.67	0.73	0.80
TSP (t)	0.06	0.06	0.08	0.09	0.12	0.13	0.14	0.16	0.17	0.19	0.21	0.23	0.25	0.27
PM$_{10}$ (t)	0.05	0.05	0.08	0.09	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.21	0.22	0.24
PM$_{2.5}$ (t)	0.05	0.05	0.08	0.09	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.21	0.22	0.24
As (g)	20.42	20.42	29.94	33.45	41.96	45.38	50.62	55.54	61.48	67.85	74.49	81.18	95.88	95.88
Cd (g)	7.55	7.55	11.07	12.36	15.51	16.77	18.71	20.53	22.72	25.07	27.53	30.00	35.44	35.44
Cr (g)	20.34	20.34	29.83	33.32	41.81	45.21	50.43	55.34	61.25	67.60	74.21	80.89	95.53	95.53
Cu (g)	18.65	18.65	27.35	30.55	38.32	41.44	46.23	50.73	56.15	61.96	68.03	74.14	87.57	87.57
Pb (g)	45.05	45.05	66.07	73.80	92.58	100.1	111.7	122.6	135.6	149.7	164.4	179.1	211.6	211.6
Hg (kg)	2.24	2.24	3.28	3.66	4.59	4.97	5.54	6.08	6.73	7.43	8.15	8.89	10.50	10.50
Ni (kg)	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.09	0.10	0.12	0.12
PCDD/F (g-I-TEQ)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCBs (g)	0.23	0.23	0.33	0.37	0.46	0.50	0.56	0.61	0.68	0.75	0.82	0.89	0.97	1.06
B[a]p (g)	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.09	0.09

6.4.4 Open Burning of Agricultural Wastes (5C2)

Open Burning of Agricultural Wastes, which includes the burning of crop residues, animal carcasses and poultry litter is a practice generally not undertaken in Ireland. Therefore, emission estimates from these sources are reported as "NO" (not occurring) for Heavy Metals.

Emissions from the open burning of farm plastics are the only source of emissions from agricultural wastes for which estimates are made. Information on the quantity of waste farm plastics that are burned in open fires is difficult to obtain. One of the largest sources of waste farm plastic, is waste plastic silage wrap and to a lesser extent synthetic fertiliser bags. The increased replacement of conventional silage with plastic wrapped silage bales, which use substantially more plastic, has seen an increase in the quantity of this waste stream. A number of different sources of information were utilised in the derivation of emission estimates. Information on the quantities of silage plastic on the market was obtained from the Irish Farm Film Producers Group (IFFPG), and national agricultural statistics were provided by the CSO and the National Farm Survey. Using the area of land utilised for silage for each year of the time series, an estimate of the plastic used for conventional (pit) silage and baled silage is made. Account is taken of plastic recovery under the silage plastics collection service operated by both the IFFPG and the Farm Relief Services. The plastic collected is recycled and used to make products such as park benches, plastic bags, garden furniture and plastic piping. The remaining plastic is assumed to be burned. In the period 2006 to 2007, there were separate silage plastic collections organised by the then Department of Environment. These were subsequently discontinued. As a result the IFFPG in the period to 2011, increased the quantity collected significantly which is the reason emissions decreased significantly in 2011.

Dioxin and furan emissions from the open burning of farm plastics are determined using estimates of the quantities of material burned and the UNEP Toolkit (2013) emission factor of 300 μg I-TEQ/t burned for the open burning of municipal wastes. The UK NAEI provides an emission factor of 510 kg/Mt burned for the estimation of PCB emissions. There is minimal data available on emission factors for PAHs; however, the emission factors from the UK NAEI for small-scale waste burning are used as a best estimate. Emission factors of 89.5 kg/Mt for benzo[a]pyrene, 405 kg/Mt for benzo[b]fluoranthene and 405 kg/Mt for benzo[k]fluoranthene are applied. No data is available for indeno[1,2,3-cd] pyrene. Emission factors are compiled in Table F.2 of Annex F and the emission estimates are presented in Table 6.9.

Emissions of NO_x, SO_2, NMVOC, CO and particles from this small source are not estimated, and are therefore reported as "NE".

Table 6.9 Time Series of Emissions from the Open Burning of Farm Plastics

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PCDD/F (g-I-TEQ)	0.94	1.10	0.65	0.23	1.15	0.30	0.39	0.28	0.45	0.49	0.46	0.50	0.59	0.83
PCBs (kg)	1.59	1.86	1.11	0.39	1.96	0.50	0.67	0.48	0.77	0.84	0.78	0.84	1.01	1.41
B[a]p (kg)	0.28	0.33	0.20	0.07	0.34	0.09	0.12	0.08	0.13	0.15	0.14	0.15	0.18	0.25
B[b]F (kg)	1.26	1.48	0.88	0.31	1.55	0.40	0.53	0.38	0.61	0.67	0.62	0.67	0.80	1.12
B[k]F (kg)	1.26	1.48	0.88	0.31	1.55	0.40	0.53	0.38	0.61	0.67	0.62	0.67	0.80	1.12

6.5 Wastewater handling (NFR 5D)

Emissions of NMVOC from wastewater treatment plants may in some cases be significant in urban areas and may contribute at a national level. In Ireland's case, based on the use of the emission factor of 15mg/m3 of wastewater handled from EMEP/EEA 2019 guidebook and wastewater quantities handled in Ireland the emissions were estimated to be 0.004 per cent of national NMVOC emissions. Therefore, Ireland considers emissions from this source as negligible and NE is reported for this source.

6.6 Other Waste (NFR 5E)

This NFR category includes emissions from accidental vehicle and building fires and other burning, which constitutes bonfires, domestic burning of MSW and burning of construction wastes. These are all sources of POPs, TSP, PM_{10} and $PM_{2.5}$. Each of these combustion sources is described in the following sections. The activity data associated with each type of fire is shown in Table 6.10.

6.6.1 Accidental Fires

Accidental fires are poorly controlled combustion events that can release large quantities of POPs and particulates into the environment. These include accidental fires of houses, other buildings and cars. A variety of materials can be burned in accidental fires, which can lead to some difficulty in obtaining detailed activity data and applying emission factors correctly. However, there are some data available in Ireland in relation to accidental building and vehicle fires from the Fire Services Department (Table 6.10).

Table 6.10 Time Series of activity data from Accidental Fires from Vehicles and Buildings

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Vehicle fires	4130	4130	7749	4907	4534	3541	2937	1609	1637	2681	1607	2137	2667	2316
Building fires-detached	1344	1344	1344	1263	1671	1462	1306	800	770	1392	621	860	1099	946
Building fires-undetached	2015	2015	2015	1894	2506	2194	1959	1200	1155	2088	931	1290	1649	1420
Apartment fires	426	426	426	470	245	271	246	242	214	240	192	211	229	209
Industrial fires	508	508	508	433	453	391	343	270	288	458	234	317	400	386

Vehicle fire statistics are only available since 2000, with the number of fires ranging from 1,600 to 7,700 per annum. With respect to earlier years, the URS Dames & Moore (2000) report suggests that the number of vehicle fires in 1998 was 4,130. It is assumed that, in the absence of any information, the number of vehicle fires per year in the period 1990–1997 is equal to that in 1998. Dioxin and furan emissions from vehicle fires are estimated using the UNEP Toolkit 2013 emission factor of 100 µg I-TEQ/vehicle fire. An emission factor of 25.5 mg/vehicle fire based on the NAEI emission factor of 510 kg/Mt burned for small scale domestic waste burning (UK NAEI) for PCB emissions from the open burning of MSW is used for accidental vehicle fires, assuming that on average 50 kg of material are burnt per fire (Dyke, 1997), while those in relation to PAHs, also based on the mass of material burnt, sourced from the UK NAEI, suggest values for benzo[a]pyrene of 0.06 mg/vehicle fire, for benzo[b]fluoranthene of 0.095 mg/vehicle fire, for benzo[k]fluoranthene of 0.03 mg/vehicle fire, and for indeno[1,2,3-cd]pyrene of 0.065 mg/vehicle fire. With respect to TSP, PM_{10} and $PM_{2.5}$, the Tier 2 emission factors presented in the EMEP/EEA 2019 Guidebook are adopted.

The Fire Services Department also provides information in relation to building fires, which is disaggregated into the type of building and the number of fires that are chimney fires. Information is only available for the years 2000–2018 at this level of disaggregation. For data prior to 2000, no differentiation was made between chimney fires and other types of building fires. The proportion of chimney fires to the total number of building fires post-2000 is therefore used to estimate the number of chimney fires annually prior to 2000. Limited information is available on the quantity of material burnt in accidental fires both in Ireland and internationally. The assumed quantity of material burnt in each building fire is 2.28 t per fire (Lorenz et al., 1996) and approximately 10 kg in each chimney fire. Dioxin and furan emissions are estimated using an emission factor of 400 µg I-TEQ/t of material burned (UNEP Toolkit, 2013). For PCB emissions, the emission factor of 510 kg/Mt burned (UK NAEI) for the open burning of MSW is applied, while, for PAH emissions (UK NAEI), the emission factors equate to 1.2 kg/Mt for benzo[a]pyrene, 1.9 kg/Mt for benzo[b]fluoranthene, 0.67 kg/Mt for benzo[k]fluoranthene and 1.3 kg/Mt for indeno[1,2,3-cd]pyrene. Accidental vehicle fires and building fires emission estimates are summed to provide an estimate of the total emissions from accidental fires. Emission estimates for the 1990–2019 time series are presented in Table 6.11. Emission factors are compiled in Table F.2 of Annex F. Ireland has included estimates of TSP, PM_{10} and $PM_{2.5}$ emissions in this using the emission factors from the Inventory Guidebook (EMEP/EEA, 2019).

Table 6.11 Time Series of Emissions from Accidental Fires from Vehicles and Buildings

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PCDD/F (g-I-TEQ)	5.13	5.13	3.87	3.39	4.28	3.71	3.29	2.00	1.93	3.46	1.59	2.19	2.78	2.40
PCBs (kg)	6.12	6.12	4.14	3.82	5.00	4.37	3.89	2.39	2.30	4.13	1.86	2.57	3.28	2.82
B[a]p (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B[b]F (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B[k]F (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I(123-cd)P (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TSP (kt)	0.36	0.36	0.37	0.34	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29	0.25
PM10 (kt)	0.36	0.36	0.37	0.34	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29	0.25
PM2.5 (kt)	0.36	0.36	0.37	0.34	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29	0.25

6.6.2 Other Burning

This section includes the emission of POPs from domestic bonfires, the burning of domestic waste both indoors and outdoors and the open burning of construction waste. Domestic bonfires normally include a variety of garden wastes (e.g. wood, leaves, etc.), and their importance with respect to POP emissions is greatly increased in cases where other wastes are added to the bonfires (e.g. plastics). Some households are not covered, or opt not to be covered, by waste collection systems and may burn household waste. Combustion of treated wood that has been used for construction, fencing and furniture can be a particularly significant source of POP emissions. For example, where wood is pre-treated with chlorinated fungicides, such as lindane or pentachlorophenol, its combustion can be a potentially significant source of PCDD/F emissions to air, whilst wood pre-treatment with creosote is a potential source for PAH emissions. However, the use of these chemicals has been significantly reduced in Ireland since the early 1990s.

For domestic bonfires, activity data are determined on a per-capita basis using the UK inventory as the reference, as no information is available in Ireland. For the burning of household waste, estimates for uncollected household waste were obtained for each of the years 2001 through to 2013, as well as for 1998 and 1995 from National Waste Reports (Carey et al., 1996; Crowe et al., 2000; Collins et al., 2004a, 2004b; Le Bolloch et al., 2006, 2007, 2009, McCoole et al, 2009; McCoole et al, 2011; McCoole et al, 2012; McCoole et al, 2013, http://www.epa.ie/nationalwastestatistics), with data calculated for other years using waste statistical data. "Uncollected waste" refers to the waste produced by the portion of the population not provided with, or not availing of, a waste collection service, corrected to take account of local conditions. This is calculated according to a standard methodology at the local authority level, based on total numbers of households, numbers of households served with waste collection, and quantities of waste collected per household in each local authority area. In addition, a proportion of households share waste collections services. Only the fraction of household waste that is combustible is burned. Compositional statistics at a national level are applied to estimate the quantities of combustible materials burnt.

Information on construction and demolition waste is available from National Waste Reports. The proportion of wood within this waste stream is estimated using data collected but not published in the National Waste Reports for the years 2004 and 2006, based on estimates of both authorised and unauthorised construction and demolition waste disposal. These values have been used for all other years in the absence of any other information. The URS Dames & Moore study (2000) suggests that 5 per cent of construction and demolition waste wood arising is burned on construction sites, whereas the UK NAEI suggests a value of 0.1 per cent. The value of 5 per cent is applied for the years 1990–1998, linearly decreasing for the years 1999-2003, with the value of 0.1 per cent applied for the period 2004–2019, based on correspondence with representatives from the National Construction and Demolition Waste Council who indicate that they would expect virtually no uncontrolled burning in urban areas.

The UNEP toolkit for open burning of construction and demolition waste wood (60 µg-I-TEQ/t burned) is applied to estimate PCDD/F emissions from bonfires on the basis that bonfires contain mainly wood and garden waste. Domestic burning of MSW contains material that varies and that often includes plastics and sometimes specific chemicals that potentially affect PCDD/F emissions. The UNEP 2013 toolkit emission factor of 40 µg-I-TEQ/t burned is used for burning of household waste. This emission factor not only takes into account the wide range of materials in household waste but also other materials such as treated and untreated wood. In relation to PCDD/F emissions from wood burning, an emission factor of 60 µg I-TEQ/t is applied.

The estimated emission factor of 1.14 kg/Mt burned for PCBs from bonfires has been taken as the average of the UK NAEI emission factors for domestic wood combustion (e.g. fireplaces) (1.99 kg/Mt burned) and open burning of crop residues (0.29 kg/Mt). For the open burning of domestic wastes, the UK NAEI emission factor of 510 kg/Mt burned has been adopted for PCBs. There are no specific data on PCB emissions from the open burning of construction wood, but emission factors from the NAEI for industrial combustion of wood indicate no difference for treated and untreated wood. Emission factors for domestic wood combustion from the NAEI and the Inventory Guidebook range from 1.99 to 6 kg/Mt burned. The emission factor of 1.99 kg/Mt has been adopted for open burning of construction waste wood in Ireland.

Emission factors with respect to PAH emission estimates are also sourced from the UK NAEI. For bonfires, the emission factors are 1,300 kg/Mt for benzo[a]pyrene, 1,500 kg/Mt for benzo[b]fluoranthene, 500 kg/Mt for benzo[k]fluoranthene and 90 kg/Mt for indeno[1,2,3-cd] pyrene. For the open burning of domestic wastes, emission factors for small-scale waste burning are applied as follows: 89.5 kg/Mt for benzo[a]pyrene, 405 kg/Mt for both benzo[b]fluoranthene and benzo[k]fluoranthene. No data are available for indeno[1,2,3-cd] pyrene. These emission factors are also used to estimate emissions from the open burning of wood at construction sites.

The three sources of emissions described in previous paragraphs are summed to provide total emission estimates for Category 5.E Other Waste. Emission factors are compiled in Table F.2 of Annex F. Emission estimates for the 1990–2019 time series are presented in Table 6.12.

Table 6.12 Time Series of Emissions from Other Waste Burning

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PCDD/F (g-I-TEQ)	1.15	1.29	1.72	2.24	0.72	0.73	0.70	0.66	0.62	0.62	0.63	0.63	0.63	0.64
PCBs (kg)	7.73	9.46	14.75	21.21	1.43	1.48	1.15	0.70	0.24	0.24	0.25	0.25	0.26	0.26
B[a]p (t)	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
B[b]F (t)	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
B[k]F (t)	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
I(123-cd)P (kg)	0.82	0.83	0.85	0.87	0.92	0.92	0.91	0.91	0.91	0.90	0.92	0.92	0.92	0.93

6.7 Recalculations in the Waste Sector

Recalculations in the waste sector (Table 6.13) in this submission are limited to estimates from:

Solid Waste Disposal to Land (5A)

There was an update to activity data concerning the number of households for years 2011-2017 in the previous submission. Extrapolation of the number of households for 2018 results in a minor recalculation of activity data for 2018. Household surveys are undertaken on a four yearly basis with data extrapolated until the result of the next survey is available.

Composting (5B1)

Recalculations to emissions estimates of NH_3 and CO from composting is a result of an update to activity data, on the quantities of household organic waste collected at kerbside and brought to civic amenity/temporary collection sites. This applies to the year 2018 with an increase of 5.4 per cent in NH_3 emissions and a decrease of 62.2 per cent in CO emissions as a result.

Waste Incineration (5C)

Revised activity data for the quantity of hazardous waste incinerated for the year 2018 has led to a recalculation of emissions of all reported pollutants from this source category as shown in Table 6.13.

Other waste (5E)

Revised estimates of the quantities of household waste produced in 2018 and subsequently may be burnt are responsible for the minor (< 1 per cent) recalculations in emissions of PCB, B[a]P, B[b]F, B[k]F and I[123-cd]P evident in Table 6.13.

6.8 Quality Assurance/Quality Control

As identified in section 6.7 the implementation of QA/QC activities ensures that the estimates in the Waste sector are now fully consistent with estimates of greenhouse gas emissions from the sector.

6.9 Planned Improvements

The inventory team will continue to review emission estimates for this sector in light of any new information that may become available for future submissions.

Review recommendations and responses are included in this report as Annex H.

Table 6.13 Recalculations for Waste 1990−2018

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2012																
5A Solid waste disposal on land	NMVOC	kt	0.83	1.01	0.80	0.64	0.18	0.18	0.24	0.19	0.29	0.41	0.46	0.47	0.45	0.44
5A Solid waste disposal on land	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	PM_{10}	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	$PM_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	Hg	t	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5A Solid waste disposal on land	PCDD/F	g-I-TEQ	0.10	0.12	0.10	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07
5A Solid waste disposal on land	PCBs	kg	0.08	0.10	0.08	0.06	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.05	0.05	0.04
Submission 2021																
5A Solid waste disposal on land	NMVOC	kt	0.83	1.01	0.80	0.64	0.18	0.18	0.24	0.19	0.29	0.41	0.46	0.47	0.45	0.44
5A Solid waste disposal on land	TSP	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	PM_{10}	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	$PM_{2.5}$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5A Solid waste disposal on land	Hg	t	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5A Solid waste disposal on land	PCDD/F	g-I-TEQ	0.10	0.12	0.10	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07
5A Solid waste disposal on land	PCBs	kg	0.08	0.10	0.08	0.06	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.05	0.05	0.04
% Change in Emission																
5A Solid waste disposal on land	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5A Solid waste disposal on land	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5A Solid waste disposal on land	PM_{10}	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5A Solid waste disposal on land	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5A Solid waste disposal on land	Hg	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
5A Solid waste disposal on land	PCDD/F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5A Solid waste disposal on land	PCBs	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2019																
5B Biological treatment of waste - Composting	NH3	kt	NO	NO	NO	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
5B Biological treatment of waste - Composting	CO	kt	NO	NO	NO	0.04	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.08	0.23
Submission 2020																
5B Biological treatment of waste - Composting	NH3	kt	NO	NO	NO	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
5B Biological treatment of waste - Composting	CO	kt	NO	NO	NO	0.04	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.08	0.09
% Change in Emission																
5B Biological treatment of waste - Composting	NH3	%				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.4%
5B Biological treatment of waste - Composting	CO	%				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-62.2%

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2020																
5C Waste Incineration	NO$_x$	kt	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01
5C Waste Incineration	NMVOC	kt	0.20	0.20	0.15	0.27	0.16	0.13	0.09	0.11	0.11	0.10	0.10	0.06	0.06	0.06
5C Waste Incineration	SO$_2$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	TSP	kt	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	PM$_{10}$	kt	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	PM$_{2.5}$	kt	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	Cd	t	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	Pb	t	0.18	0.18	0.03	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
5C Waste Incineration	Hg	t	0.22	0.22	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5C Waste Incineration	PCDD/F	g-I-TEQ	2.46	2.62	0.73	0.25	1.56	1.16	0.31	0.40	0.29	0.46	0.51	0.48	1.10	1.90
5C Waste Incineration	PCBs	kg	1.69	1.95	1.15	0.42	1.97	1.97	0.51	0.68	0.49	0.78	0.85	0.79	0.85	1.02
5C Waste Incineration	HCB	t	0.06	0.05	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
5C Waste Incineration	B[a]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	B[b]F	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	B[k]F	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	I[123-cd]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Submission 2021																
5C Waste Incineration	NO$_x$	kt	0.03	0.03	0.02	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01
5C Waste Incineration	NMVOC	kt	0.20	0.20	0.15	0.27	0.16	0.13	0.09	0.11	0.11	0.10	0.10	0.06	0.06	0.05
5C Waste Incineration	SO$_2$	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	TSP	kt	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	PM$_{10}$	kt	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	PM$_{2.5}$	kt	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	Cd	t	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	Pb	t	0.18	0.18	0.03	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
5C Waste Incineration	Hg	t	0.22	0.22	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5C Waste Incineration	PCDD/F	g-I-TEQ	2.46	2.62	0.73	0.25	1.56	1.16	0.31	0.40	0.29	0.46	0.51	0.48	1.10	1.90
5C Waste Incineration	PCBs	kg	1.69	1.95	1.15	0.42	1.97	1.97	0.51	0.68	0.49	0.78	0.85	0.79	0.85	1.02
5C Waste Incineration	HCB	t	0.06	0.05	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00
5C Waste Incineration	B[a]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	B[b]F	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	B[k]F	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5C Waste Incineration	I[123-cd]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

% Change in Emission																	
5C Waste Incineration	NO_x	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-9.7%
5C Waste Incineration	NMVOC	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-16.9%
5C Waste Incineration	SO_2	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-5.8%
5C Waste Incineration	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-4.2%
5C Waste Incineration	PM_{10}	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-3.5%
5C Waste Incineration	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-2.2%
5C Waste Incineration	Cd	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-15.9%
5C Waste Incineration	Pb	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-16.4%
5C Waste Incineration	Hg	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.6%
5C Waste Incineration	PCDD/F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5C Waste Incineration	PCBs	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
5C Waste Incineration	HCB	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-13.7%
5C Waste Incineration	B[a]P	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
5C Waste Incineration	B[b]F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
5C Waste Incineration	B[k]F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
5C Waste Incineration	I[123-cd]P	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

NFR Category	Pollutant	Unit	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Submission 2019																
5E Other Waste	TSP		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	PM_{10}		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	$PM_{2.5}$		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	PCDD/F	g-I-TEQ	6.19	6.33	5.59	5.63	5.12	5.01	4.43	3.99	2.66	2.55	4.08	2.22	2.82	3.42
5E Other Waste	PCBs	kg	13.73	15.46	18.89	25.04	5.75	6.43	5.85	5.04	3.09	2.54	4.38	2.11	2.82	3.53
5E Other Waste	B[a]P	t	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5E Other Waste	B[b]F	t	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5E Other Waste	B[k]F	t	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5E Other Waste	I[123-cd]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Submission 2020																
5E Other Waste	TSP		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	PM_{10}		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	$PM_{2.5}$		0.36	0.36	0.37	0.34	0.43	0.43	0.38	0.34	0.21	0.20	0.36	0.17	0.23	0.29
5E Other Waste	PCDD/F	g-I-TEQ	6.28	6.43	5.59	5.63	5.12	5.01	4.43	3.99	2.66	2.55	4.08	2.22	2.82	3.42
5E Other Waste	PCBs	kg	13.85	15.58	18.89	25.04	5.75	6.43	5.85	5.04	3.09	2.54	4.38	2.11	2.82	3.54
5E Other Waste	B[a]P	t	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5E Other Waste	B[b]F	t	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5E Other Waste	B[k]F	t	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5E Other Waste	I[123-cd]P	t	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% Change in Emission																
5E Other Waste	TSP	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5E Other Waste	PM_{10}	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5E Other Waste	$PM_{2.5}$	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5E Other Waste	PCDD/F	%	1.5%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5E Other Waste	PCBs	%	0.9%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.4%
5E Other Waste	B[a]P	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5E Other Waste	B[b]F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
5E Other Waste	B[k]F	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%
5E Other Waste	I[123-cd]P	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

*Prior to 1998, emissions were only reported for the sub-category 5Cbiii (Clinical waste incineration). For the years 1998-2015 this sub-category is NO. Other sub-categories of 5C are reported as NO, NA, IE, and NE.

Chapter Seven

Gridded and LPS data

7.1 Overview of Gridded and LPS data reporting

It is mandatory to report gridded emissions and emissions from large point sources every four years both under the Convention on Long-Range Transboundary Air Pollution and under Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants (the revised National Emission Ceilings Directive).

The Guidelines for Reporting Emissions and Projections Data under the Convention on Long-Range Transboundary Air Pollution (ECE/EB.AIR/125), adopted in 2014, specify the scope, methodologies, formats and deadlines for annual inventory submissions by Parties to the Convention. The guidelines specify that at four yearly intervals, starting in 2017, Parties shall report updated aggregated sectoral (GNFR) gridded emissions and LPS emissions. The EMEP grid is defined in paragraph 14 of the reporting guidelines and refers to a 0.1°x0.1° latitude-longitude projection in the geographic coordinate World Geodetic System (WGS) latest revision, WGS 84. The EMEP domain covers the geographic domain between 30°N-82°N latitude and 30°W-90°E longitude.

The reporting guidelines under the Convention refers to the EMEP/EEA Guidebook for technical guidance on the spatial distribution of emissions. Directive (EU) 2016/2284 refers to the reporting guidelines under the Convention and as such the requirements under the two reporting requirements are identical.

The development of a high-resolution model for distribution of emissions was part of a research project funded by the EPA ("National mapping of GHG and non-GHG emissions sources". Ref: 2015-CCRP-MS.26). The project has developed a model for distributing emissions at a resolution of 1 km x 1 km covering all sectors and pollutants included in the official Irish emission inventory. The generated spatial emissions data (GNFR) is fully consistent with the reported emission inventories (NFR) under the LRTAP Convention. A list of GNFR categories is presented in Table 7.1 and the relationship between NFR and GNFR is presented in Table 7.2.

Table 7.1. List of GNFR categories

GNFR
A_PublicPower
B_Industry
C_OtherStationaryComb
D_Fugitive
E_Solvents
F_RoadTransport
G_Shipping
H_Aviation
I_Offroad
J_Waste
K_AgriLivestock
L_AgriOther
M_Other
'MEMO' ITEMS - NOT TO BE INCLUDED IN NATIONAL TOTALS
O_AviCruise
P_IntShipping
z_Memo
N_Natural

Table 7.2. Correspondence list for GNFR and NFR categories

NFR	NFR name	GNFR
1A1a	Public electricity and heat production	A_PublicPower
1A1b	Petroleum refining	B_Industry
1A1c	Manufacture of solid fuels and other energy industries	B_Industry
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	B_Industry
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	B_Industry
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	B_Industry
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	B_Industry
1A2e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	B_Industry
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	B_Industry
1A2gvii	Mobile Combustion in manufacturing industries and construction	I_Offroad
1A2gviii	Stationary combustion in manufacturing industries and construction: Other	B_Industry
1A3ai(i)	International aviation LTO (civil)	H_Aviation
1A3aii(i)	Domestic aviation LTO (civil)	H_Aviation
1A3bi	Road transport: Passenger cars	F_RoadTransport
1A3bii	Road transport: Light duty vehicles	F_RoadTransport
1A3biii	Road transport: Heavy duty vehicles and buses	F_RoadTransport
1A3biv	Road transport: Mopeds & motorcycles	F_RoadTransport
1A3bv	Road transport: Gasoline evaporation	F_RoadTransport
1A3bvi	Road transport: Automobile tyre and brake wear	F_RoadTransport
1A3bvii	Road transport: Automobile road abrasion	F_RoadTransport
1A3c	Railways	I_Offroad
1A3di(ii)	International inland waterways	G_Shipping

NFR	NFR name	GNFR
1A3dii	National navigation (shipping)	G_Shipping
1A3ei	Pipeline transport	I_Offroad
1A3eii	Other (please specify in the IIR)	I_Offroad
1A4ai	Commercial/institutional: Stationary	C_OtherStationaryComb
1A4aii	Commercial/institutional: Mobile	I_Offroad
1A4bi	Residential: Stationary	C_OtherStationaryComb
1A4bii	Residential: Household and gardening (mobile)	I_Offroad
1A4ci	Agriculture/Forestry/Fishing: Stationary	C_OtherStationaryComb
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	I_Offroad
1A4ciii	Agriculture/Forestry/Fishing: National fishing	I_Offroad
1A5a	Other stationary (including military)	C_OtherStationaryComb
1A5b	Other, Mobile (including military, land based and recreational boats)	I_Offroad
1B1a	Fugitive emission from solid fuels: Coal mining and handling	D_Fugitive
1B1b	Fugitive emission from solid fuels: Solid fuel transformation	D_Fugitive
1B1c	Other fugitive emissions from solid fuels	D_Fugitive
1B2ai	Fugitive emissions oil: Exploration, production, transport	D_Fugitive
1B2aiv	Fugitive emissions oil: Refining / storage	D_Fugitive
1B2av	Distribution of oil products	D_Fugitive
1B2b	Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)	D_Fugitive
1B2c	Venting and flaring (oil, gas, combined oil and gas)	D_Fugitive
1B2d	Other fugitive emissions from energy production	D_Fugitive
2A1	Cement production	B_Industry
2A2	Lime production	B_Industry
2A3	Glass production	B_Industry
2A5a	Quarrying and mining of minerals other than coal	B_Industry
2A5b	Construction and demolition	B_Industry
2A5c	Storage, handling and transport of mineral products	B_Industry
2A6	Other mineral products	B_Industry
2B1	Ammonia production	B_Industry
2B10a	Chemical industry: Other (please specify in the IIR)	B_Industry
2B10b	Storage, handling and transport of chemical products (please specify in the IIR)	B_Industry
2B2	Nitric acid production	B_Industry
2B3	Adipic acid production	B_Industry
2B5	Carbide production	B_Industry
2B6	Titanium dioxide production	B_Industry
2B7	Soda ash production	B_Industry
2C1	Iron and steel production	B_Industry
2C2	Ferroalloys production	B_Industry
2C3	Aluminium production	B_Industry
2C4	Magnesium production	B_Industry
2C5	Lead production	B_Industry
2C6	Zinc production	B_Industry
2C7a	Copper production	B_Industry
2C7b	Nickel production	B_Industry
2C7c	Other metal production	B_Industry
2C7d	Storage, handling and transport of metal products	B_Industry
2D3a	Domestic solvent use including fungicides	E_Solvents
2D3b	Road paving with asphalt	E_Solvents
2D3c	Asphalt roofing	B_Industry
2D3d	Coating applications	B_Industry
2D3e	Degreasing	E_Solvents
2D3f	Dry cleaning	E_Solvents
2D3g	Chemical products	E_Solvents
2D3h	Printing	E_Solvents
2D3i	Other solvent use	E_Solvents
2G	Other product use	E_Solvents
2H1	Pulp and paper industry	B_Industry
2H2	Food and beverages industry	B_Industry

NFR	NFR name	GNFR
2H3	Other industrial processes	B_Industry
2I	Wood processing	B_Industry
2J	Production of POPs	B_Industry
2K	Consumption of POPs and heavy metals (e.g. electrical and scientific equipment)	B_Industry
2L	Other production, consumption, storage, transportation or handling of bulk products	B_Industry
3B1a	Manure management - Dairy cattle	K_AgriLivestock
3B1b	Manure management - Non-dairy cattle	K_AgriLivestock
3B2	Manure management - Sheep	K_AgriLivestock
3B3	Manure management - Swine	K_AgriLivestock
3B4a	Manure management - Buffalo	K_AgriLivestock
3B4d	Manure management - Goats	K_AgriLivestock
3B4e	Manure management - Horses	K_AgriLivestock
3B4f	Manure management - Mules and asses	K_AgriLivestock
3B4gi	Manure management - Laying hens	K_AgriLivestock
3B4gii	Manure management - Broilers	K_AgriLivestock
3B4giii	Manure management - Turkeys	K_AgriLivestock
3B4giv	Manure management - Other poultry	K_AgriLivestock
3B4h	Manure management - Other animals	K_AgriLivestock
3Da1	Inorganic N-fertilizers (includes also urea application)	L_AgriOther
3Da2a	Animal manure applied to soils	L_AgriOther
3Da2b	Sewage sludge applied to soils	L_AgriOther
3Da2c	Other organic fertilisers applied to soils (including compost)	L_AgriOther
3Da3	Urine and dung deposited by grazing animals	L_AgriOther
3Da4	Crop residues applied to soils	L_AgriOther
3Db	Indirect emissions from managed soils	L_AgriOther
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	L_AgriOther
3Dd	Off-farm storage, handling and transport of bulk agricultural products	L_AgriOther
3De	Cultivated crops	L_AgriOther
3Df	Use of pesticides	L_AgriOther
3F	Field burning of agricultural residues	L_AgriOther
3I	Agriculture other	L_AgriOther
5A	Biological treatment of waste - Solid waste disposal on land	J_Waste
5B1	Biological treatment of waste - Composting	J_Waste
5B2	Biological treatment of waste - Anaerobic digestion at biogas facilities	J_Waste
5C1a	Municipal waste incineration	J_Waste
5C1bi	Industrial waste incineration	J_Waste
5C1bii	Hazardous waste incineration	J_Waste
5C1biii	Clinical waste incineration	J_Waste
5C1biv	Sewage sludge incineration	J_Waste
5C1bv	Cremation	J_Waste
5C1bvi	Other waste incineration	J_Waste
5C2	Open burning of waste	J_Waste
5D1	Domestic wastewater handling	J_Waste
5D2	Industrial wastewater handling	J_Waste
5D3	Other wastewater handling	J_Waste
5E	Other waste	J_Waste
6A	Other (included in national total for entire territory)	M_Other
'MEMO' ITEMS - NOT TO BE INCLUDED IN NATIONAL TOTALS		
1A3ai(ii)	International aviation cruise (civil)	O_AviCruise
1A3aii(ii)	Domestic aviation cruise (civil)	O_AviCruise
1A3di(i)	International maritime navigation	P_IntShipping
1A5c	Multilateral operations	z_Memo
1A3	Transport (fuel used)	z_Memo
6B	Other not included in national total of the entire territory	z_Memo
11A	Volcanoes	N_Natural
11B	Forest fires	N_Natural
11C	Other natural emissions	N_Natural

7.2 Mapping methodology

The methodology used in the emissions mapping follow the guidelines in the 2019 EMEP/EEA emission inventory guidebook. The overall approach aims to allocate the national total emissions to the geographical location where they occur as accurately as possible. A distinction is made between point sources and area sources. Point sources are sources that can be treated individually and have an exact location, e.g. industrial plants. Area sources cover a group of minor emission sources with similar characteristics that cannot be treated individually because of the number of sources, e.g. residential plants. Some sectors are covered only by point sources or only by area sources, but many sectors cover both point and area sources. In the latter case point and area sources are treated separately in the data processing and following they are combined on sectoral level in the spatial emission mapping.

Emissions from point sources can be allocated to an exact location, e.g. the location of a power plant or an industrial plant. Activity data and/or emissions are available for a number of large plants e.g. from PRTR/E-PRTR reporting. These data are used either directly (emissions) or indirectly (activity data) to allocate point source emissions. Both locations and emissions are generally very accurate for point sources.

The individual source contribution cannot be determined for area sources, and emissions allocations are based on a number of spatial data sets. For each area source related available spatial data are evaluated and the closest related are used for emission mapping, taking into account completeness (must cover the entire national area), spatial resolution, accuracy, update frequency etc.

The 2019 EMEP/EEA Guidebook describes a tiered approach for spatial distribution of emissions, depending on the data availability and level of detail for the individual emission sources/sectors. Furthermore, different methodological tiers can be used for different pollutants from a source, e.g. point source emission data are most often available only for some pollutants, while emission mapping for remaining pollutants follow a lower tier method.

The concept of tiered mapping is summarised as follows:

- **Tier 3 methods** are based on closely related spatial emission or activity data, e.g. data for regulated processes and industries, and road traffic flows by vehicle type derived from surveys.
- **Tier 2 methods** are based on the use of surrogate statistics relate to the sector, e.g. heat demand for the residential sector, agricultural animal statistics, and land parcel identification system data
- **Tier 1 methods** are based on loosely related surrogate statistics, e.g. building use, population density, and land use.

The tiered methodology is outlined in the decision tree in Figure 7.1
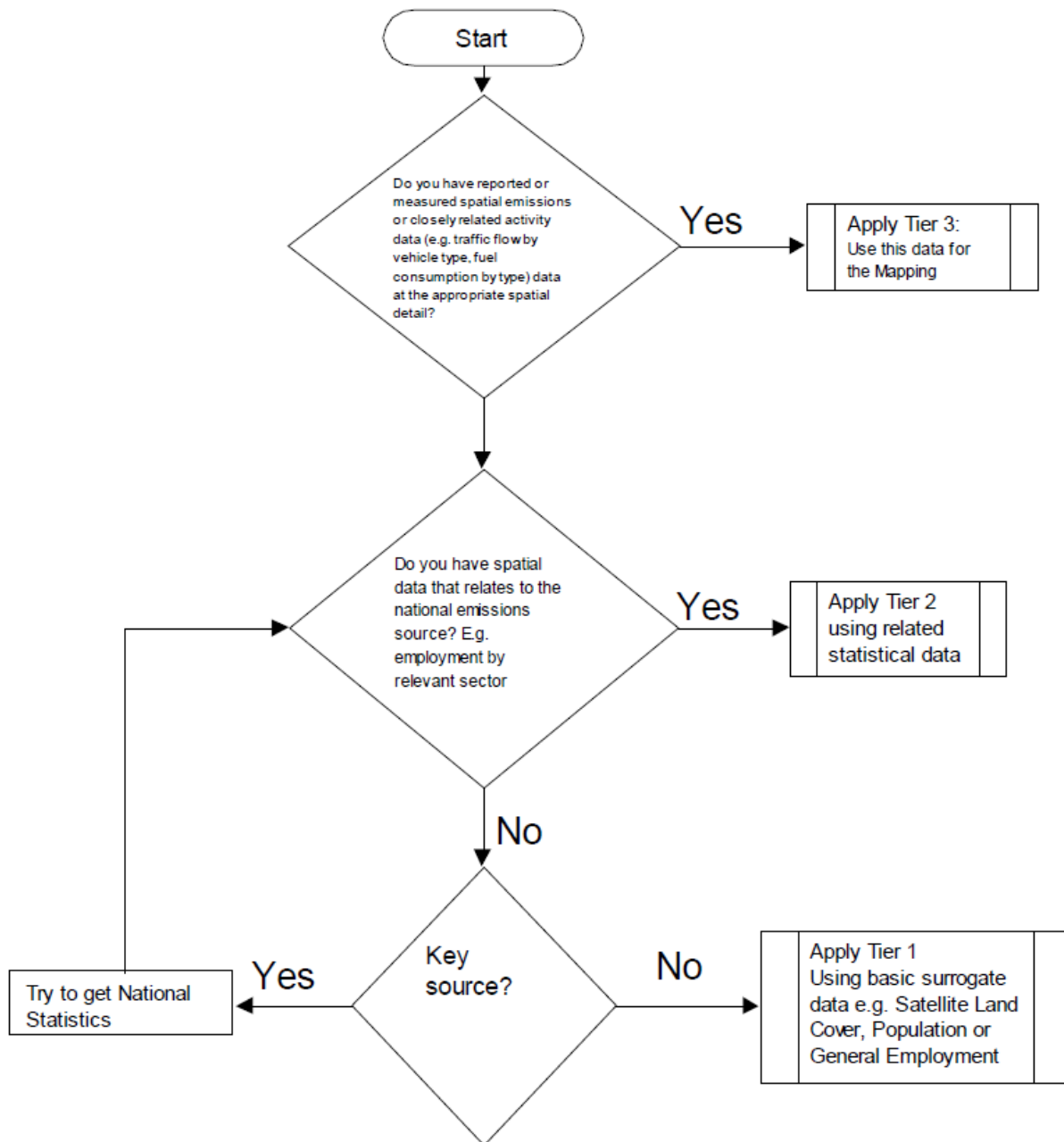
Figure 7.1 General decision tree for emissions mapping (EMEP/EEA 2019)

Mapping of Irelands emissions is done on a highly disaggregated level both regarding sectoral and spatial resolution. Spatial distribution keys (GeoKeys) are set up for each NFR category with a spatial resolution of 1 km x 1 km. GeoKeys are normalised tables including the share of an emission source that should be allocated to each grid cell. Some GeoKeys are used for all pollutants from a sector, while others are pollutant specific. Further, some sectors have been disaggregated into different sources and GeoKeys have been set up on source level and afterwards combined to create one overall GeoKey for the NFR sector. In this way, a high level of accuracy is ensured in the emission mapping as the highest tier level methodology is applied for all sources.

GeoKeys for the individual sectors/sources are built from a number of different spatial data. Some of the spatial data sets describe the emission allocation very accurate, e.g. E-PRTR reporting, while others

are proxies for activity level or other related parameters; some being good proxies, e.g. mileage data for emissions from road transport, others being less good proxies, e.g. population density for domestic solvent use.

The common methodological approach is to make an overlay analysis of one or more spatial layers and the 1 km x 1 km grid in a geographical information system (GIS).

Preparation of the GeoKey for railway transport is described here as an example, and related maps are shown in Figure 7.2. Railway transport is an area source, and the emissions are spatially allocated to the railway network. The railway network is available as a digital map including the network as lines (Figure 7.2 a), which allow the emissions to be distributed evenly to the railway network. Activity data based on railway statistics are added to the map's attribute data, and are used to improve the spatial distribution to allocate emissions according to the activity levels. An overlay of the railway network including activity data and the 1 km x 1 km grid is made in GIS (Figure 7.2 b), and the layers are intersected to cut the railway lines by the grid (Figure 7.2 c). The length of each line segment is calculated using standard GIS tools, and the share of each railway line in each grid cell is calculated. As more line segments can occur in the same grid cell, e.g. when two railway lines meet, the shares are summarised by grid cell to generate the GeoKey, which holds the share of the national emission by grid cell (Figure 7.2 d).

a)

b)

c)

d)
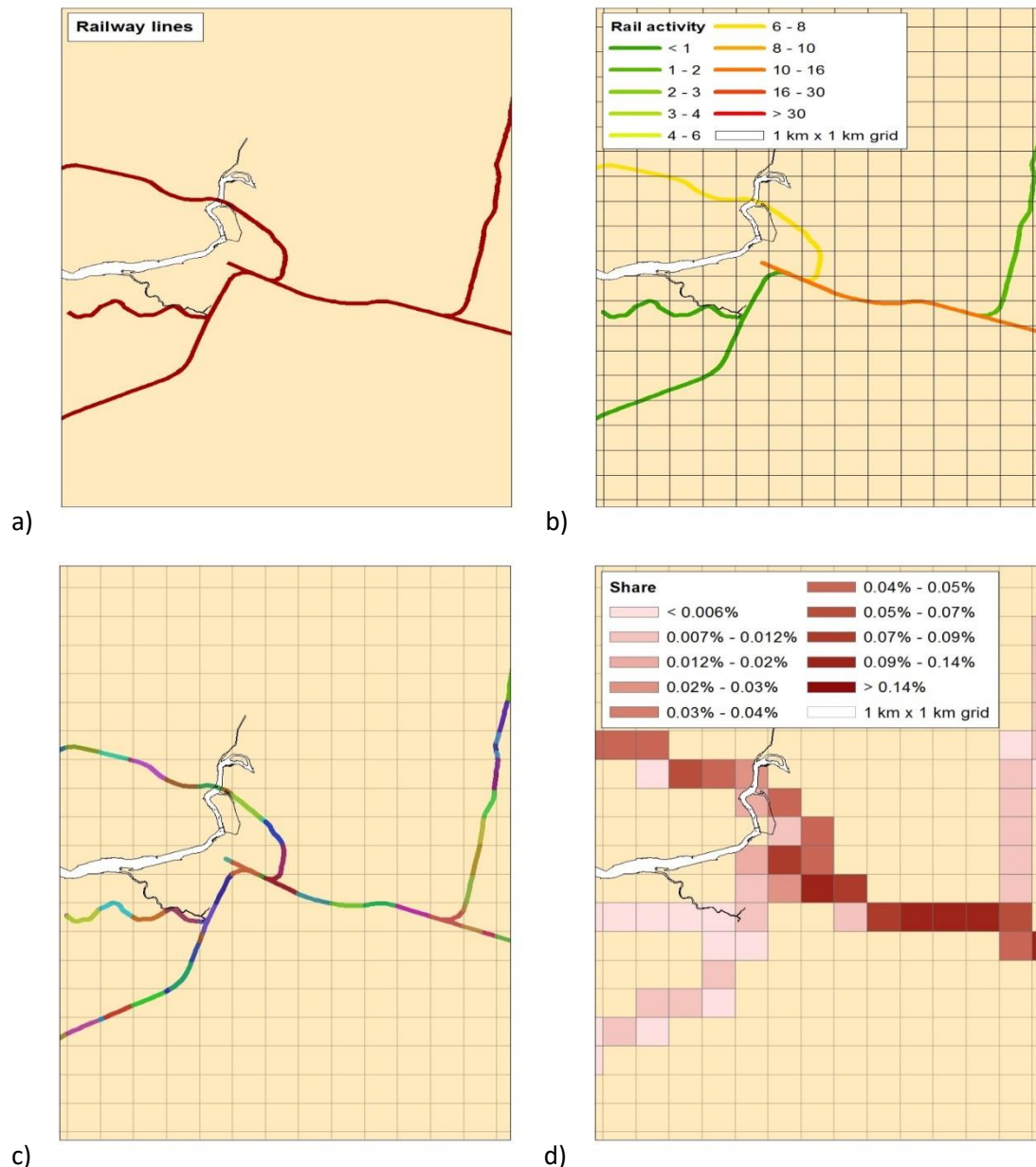
Figure 7.2 Example of GeoKey preparation

The emission mapping is made using an orthogonal grid with a resolution of 1 km x 1 km in the Irish projection TM65 (EPSG 29902). The spatial emissions are redistributed into the reporting grid, the EMEP/EEA grid with a spatial resolution of 0.1 degree x 0.1 degree, using the share of each 1 km x 1 km grid cell that intersects the individual 0.1 degree x 0.1 degree grid cells.

7.3 Mapping methods for each GNFR

A summary of the data and mapping approaches used in compilation of the spatial inventory for Ireland are outlined in the tables below by GNFR sector. An indication of the tier 1-3 categorisation has also been provided as a simple measure of uncertainty in the approach applied. A more detailed description of the methodologies applied is available in Plejdrup et al. (2017)

7.3.1 Public Power (GNFR A_PublicPower)

Detailed location information for this sector were available on the individual large point sources for the NFR sector 1A1a Public Power. The emissions for some pollutants were available for the individual point sources, and in these cases, the data were used directly. For the pollutants where plant specific data were not available, the distribution is based on the activity data. The use of plant specific data and exact location of the emissions corresponds to a tier 3 method.

7.3.2 Industry (GNFR B_Industry)

As shown in Table 7.1, this GNFR covers many different source categories and hence the available spatial data vary across sectors. The categories include both combustion related categories and categories where the emissions are related to the process.

Where detailed emissions and location information were available, e.g. from the E-PRTR or the EU ETS on the individual point source emissions for the NFR sectors in GNFR B Industrial Combustion sector, these were used to map emissions to the known location. This is the case for e.g. emissions from refining and other energy industries (NFR categories 1A1b and 1A1c respectively).

For other source categories, some data are available at point source level, but the coverage does not match the national total. In these cases the emissions covered by point sources are allocated to the relevant point sources and the residual emission is distributed according to a more general spatial distribution key, e.g. industrial heat demand. These two distributions are then combined to one GeoKey covering the total sectoral emission.

This approach is considered a tier 2 or tier 3 method.

7.3.3 Other stationary combustion (GNFR C_OtherStationaryComb)

This GNFR category covers combustion in three subsectors, i.e. commercial/institutional, residential and agriculture. The most important sector in terms of emission contribution is residential combustion.

For commercial/institutional plants, the distribution is based on heat demand for commercial and public buildings as calculated by the Irish Heat Map. The Heat Map is based on a study from 2015 commissioned by SEAI to fulfil Ireland's requirements under article 14 of the Energy Efficiency Directive (2012/27/EU). As part of this study a spatial representation of Ireland's heat demand was developed.

For residential plants, the distribution is based on information from the 2011 census on primary fuel types in households combined with an estimated unit consumption calibrated with the estimated national residential fuel consumption and the emission factors used in the emission inventory.

For the agricultural sector, the spatial data on farmyards and buildings from the Land Parcel Information System (LPIS) were used.

This is considered tier 2/3 methodologies.

7.3.4 Fugitive Emissions (GNFR D_Fugitive)

This sector covers both categories estimated as point sources (e.g. coal mining/handling, service stations and flaring) and area sources (e.g. natural gas distribution).

The point source data have been used to allocate emissions and, where available, activity data have been incorporated to further improve the distribution of emissions. Information on coal mining areas as well as coal consumers were provided by the EPA, while a list of service stations was provided by the CSO. For natural gas distribution, the spatial information included for gas use in the Heat Map was utilised to distribute emissions.

This is considered tier 2/3 methodologies.

7.3.5 Solvents (GNFR E_Solvents)

The national emissions from domestic solvent use were mapped across the country using population density as spatial proxy. This approach is a tier 2 method.

For the remaining solvent use categories, there was some spatial information available, e.g. location of dry cleaners. However, both population density and industrial heat demand were used as spatial proxies to map emissions from coating applications, chemical products and printing.

This is considered tier 1/2/3 methodologies.

7.3.6 Road transport (GNFR F_RoadTransport)

Spatial mileage data for national roads (NR) provided by TII for total mileage and % heavy vehicles are used to allocate emissions from road transport on NR. Road transport on other roads is estimated as the residual of the national total mileage used in the inventory, and emissions are allocated to roads other than NR. As mileage data is not available for other roads than NR a polygon map of the road network is applied for mapping, thereby using road area as a proxy for the activity level. Separate GeoKeys are prepared for passenger cars including vans and 2-wheelers (PC), heavy vehicles including busses (HV), and all vehicles (PC+HV).

The approaches used are tier 3 for NR and tier 2 for remaining roads.

7.3.7 National navigation (GNFR G_Shipping)

The estimates of the emissions from national navigation were mapped using a buffer zone of six nautical miles around the coast of Ireland. The buffer zone was adjusted to take into account the shortest path between headlands.

This approach is a tier 2 method.

7.3.8 Aviation (LTO) (GNFR H_Aviation)

National total emissions from aircraft operating on the ground and in the air over Ireland, up to an altitude of 1000 m (equating to the take offs and landing – LTO) were mapped at the locations of the airports including a five-kilometre buffer zone. The number of LTOs at each airport was used to further improve the distribution of emissions.

This approach is a tier 3 method.

7.3.9 Off road mobile sources (GNFR I_Offroad)

This GNFR category comprises several different activities such as railways, fishing and agricultural machinery.

For railways, the railway network and data for annual passages were provided by Irish Rail and this information has been used to develop a GeoKey for this sector.

For fishing, the emissions have been distributed based on data for fishing areas within the Irish exclusive economic zone and fishing statistics.

For agricultural machinery, data on the number of different types of machinery at county level were obtained from the CSO and this information was combined with the land information from LPIS on cropland and improved grassland.

This is considered tier 2/3 methodologies.

7.3.10 Waste handling and treatment (GNFR J_Waste)

The estimates of the emissions from solid waste disposal on land were mapped at the locations of landfill sites. For composting 75 % of the emission were allocated to the licensed facilities while the remaining 25 % where allocated to non-urban residential buildings.

Emissions from clinical waste incineration, industrial waste incineration and cremation were mapped at the locations of the known facilities. Activity and location data for industrial waste incinerators and crematoria were available and used to weight emissions to areas of known activity proportionally.

Estimates of the national emissions from other waste handling (e.g. accidental fires) were mapped according to population density.

This is considered tier 1/2/3 methodologies.

7.3.11 Agricultural livestock (GNFR K_AgriLivestock)

National emissions from pigs and poultry were distributed based on detailed data on farms and animal numbers from the 2010 agricultural census provided by UCD.

National emissions from mink were distributed based on farm locations and animal numbers provided by EPA.

National emissions from cattle, sheep and horses were distributed based on data from the 2010 agricultural census provided by CSO on the number of animals per electoral district combined with the Land Parcel Identification System (LPIS) data on location of farmyards and buildings.

National emissions from goats, mules and asses, and deer were distributed based on data from the 2010 agricultural census provided by CSO on the number of animals per county combined with the Land Parcel Identification System (LPIS) data on location of farmyards and buildings.

This approach is a tier 2/3 method.

7.3.12 Agricultural soils (Other emissions) (GNFR L_AgriOther)

National emissions from sources related to agricultural soils, e.g. application of fertiliser and manure as well as grazing animals were distributed on cropland and/or grassland from LPIS, taking into account the animal density when distributing emissions from animal manure.

This approach is a tier 1/2 method.

7.3.13 Aviation (Cruise) (GNFR O_AviCruise)

This category includes cruise emissions from both national and international aviation. For national cruise emissions, the distribution is based on information on the number of flights between the major Irish airports and emissions are allocated to great circle lines between these airports.

For international cruise emissions, the majority of emissions will occur outside the Irish territory, but for the purposes of the submission, emissions are allocated evenly across the entire Irish area outlined by the Irish Exclusive Economic Zone (EEZ).

This is considered tier 1/2 methodologies.

7.3.14 International navigation (GNFR P_IntShipping)

Emissions from international navigation will largely occur outside the Irish territory, but for the purposes of the submission, emissions are allocated evenly across the sea area outlined by the Irish Exclusive Economic Zone (EEZ).

This approach is a tier 1 method.

7.4 National total emission mapped by the EMEP 0.1 degree x 0.1 degree grid

Figure 7.3 a-e present the mapped national total emissions for NO_x, SO_2, NMVOC, NH_3, and $PM_{2.5}$ in Ireland by EMEP 0.1 x 0.1 degree grid.

NOx [ktonnes], 2019

	0.00 - 0.02
	0.03 - 0.04
	0.05 - 0.10
	0.11 - 0.15
	0.16 - 0.20
	0.21 - 0.40
	0.41 - 0.80
	0.81 - 1.30
	1.31 - 2.00
	2.01 - 1000.00

Kilometers
0   25   50   100

SO2 [ktonnes], 2019

	0.000 - 0.001
	0.002 - 0.005
	0.006 - 0.010
	0.011 - 0.020
	0.021 - 0.050
	0.051 - 0.100
	0.101 - 0.200
	0.201 - 0.500
	0.501 - 1.000
	> 1.000

Kilometers
0   25   50   100

NMVOC [ktonnes], 2019

- 0.00 - 0.02
- 0.03 - 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20
- 0.21 - 0.30
- 0.31 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- > 1.50

Kilometers
0   25   50   100

NH3 [ktonnes], 2019

	0.00 - 0.02
	0.03 - 0.04
	0.05 - 0.06
	0.07 - 0.09
	0.10 - 0.12
	0.13 - 0.16
	0.17 - 0.20
	0.21 - 0.25
	0.26 - 0.30
	> 0.30

Kilometers
0   25   50   100

PM2.5 [ktonnes], 2019

	0.000 - 0.002
	0.003 - 0.004
	0.005 - 0.007
	0.008 - 0.010
	0.011 - 0.150
	0.151 - 0.250
	0.251 - 0.500
	0.501 - 0.100
	0.101 - 0.150
	> 0.150

Figure 7.3 National Total Emissions in 2015 for a) NOₓ, b) SO₂, c) NMVOC, d) NH₃, and e) PM₂.₅

Chapter Eight

Projections

8.1 Overview of Emissions Projections

Ireland's Environmental Protection Agency (EPA) is responsible for developing, preparing and reporting periodic projections of air pollutants. The EPA is also the responsible body for preparing greenhouse gas emissions projections that are submitted under the Governance of the Energy Union and Climate Action Regulation (EU) 2018/1999. In this section an overview of the emission projections is discussed.

Section 8.2 describes emission ceilings for 2020 and 2030. Section 8.3 provides a short explanation of how energy projections are generated for both "*With Measures*" and "*With Additional Measures*" scenarios. Information on key assumptions and underlying data are also provided.

Section 8.4 presents the emission projections for each of the pollutants covered, and considers the key trends across the time series. Sections 8.5 to 8.13 present the key input assumptions and methodologies for the main sectors which include the impact of national policies and measures aimed at reducing greenhouse gas emissions and how these affect air pollutant emission levels.

Article 8 of Directive (2016/2284/EU) requires biennial reporting from 2017 of projected emissions for SO_2, NO_x, NH_3, NMVOC, $PM_{2.5}$ and, if available, Black Carbon (BC) covering projection years 2020, 2025, 2030 and, where available, 2040 and 2050. 2021 is a mandatory reporting year.

The CLRTAP guidelines for reporting emissions projections state that parties to the Gothenburg Protocol within the geographical scope of the EMEP shall regularly update their projections and report every four years from 2015 onwards their updated projections, for the years 2020, 2025 and 2030 and, where available, also for 2040 and 2050. Parties to the other protocols are encouraged to regularly update their projections and report every four years from 2015. In addition, parties should provide a "*With Measures*" (WM) and where relevant a "*With Additional Measures*" (WAM) projection estimate.

Projected emission estimates and supporting quantitative information are reported for SO_2, NO_x, NH_3, NMVOC, $PM_{2.5}$ and BC under Directive (2016/2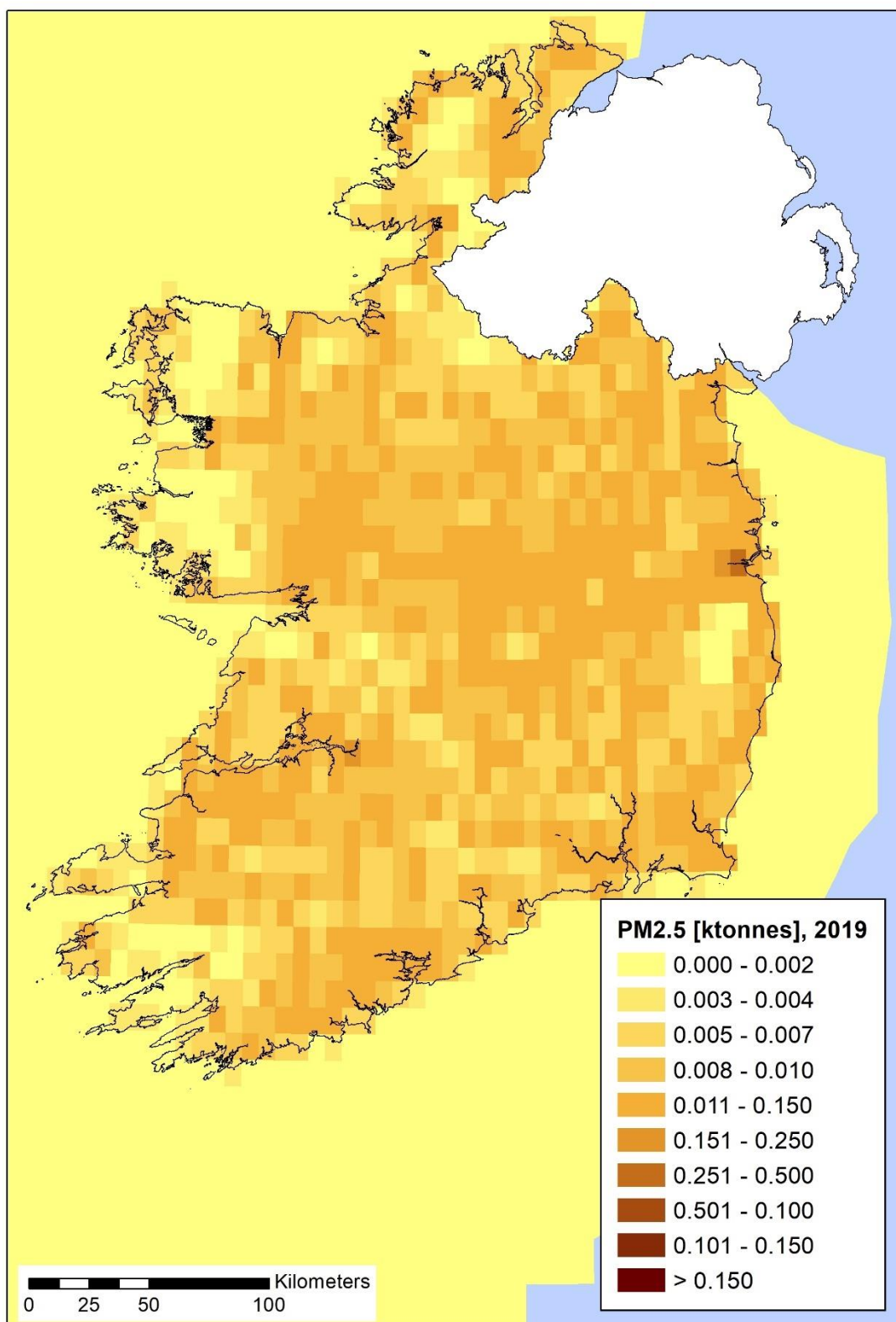284/EU) utilising the reporting template contained within annex IV of the Guidelines for Reporting Emissions and Projections Data under the CLRTAP[5].

This chapter details emission projections under both the *With Measures* scenario and *With Additional Measures* scenario for the following pollutants which are subject to emission ceilings for the period 2020-2030: NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$.

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[5] http://www.ceip.at/reporting_instructions/annexes_to_guidelines/

8.2 Emission Ceilings for 2020 and 2030

The National Emission Ceilings Directive (NECD, 2001/81/EC) was reviewed as part of the Clean Air Policy Package and a new Directive came into effect in December 2016[6]. Emission reduction commitments have been set for Ireland for 2020 and 2030 for NO_x, SO_x, NMVOC, NH_3, and $PM_{2.5}$. Table 8.1 details the emission ceilings in place for each pollutant for 2020 and 2030 for Ireland under the new National Emissions Ceilings Directive.

Table 8.1. Emission Reduction Commitments for 2020 and 2030 (expressed as a percentage reduction on 2005 levels)

Pollutant	SO_2	NO_X	NH_3	NMVOC	$PM_{2.5}$
2020	65%	49%	1%	25%	18%
2030	85%	69%	5%	32%	41%

8.3 With Measures and With Additional Measures Scenarios - Approach

This year's projections take into account updated projected activity data provided by a number of key data providers including:

- Energy projections underpinning the 2021 emissions projections were prepared by Sustainable Energy Authority of Ireland (SEAI) in conjunction with the Economic and Social Research Institute (ESRI). The ESRI produce energy demand projections using the I3E model (Ireland Environment, Energy and Economy model)[7].

- Agricultural projections provided by Teagasc (Agriculture and Food Development Authority) in March 2021 which consider the impact of Food Wise 2025[8] and the impacts of Brexit for the agriculture sector.

SEAI compile two energy projections scenarios, which are used in national emission projections:

- The *WEM* energy projections project forward Ireland's energy demand, incorporating the expected impacts of policies and measures that were in place (e.g. legislatively provided for) by the end of 2019. It includes progress in the implementation of polices and measures as set out in Ireland's National Renewable Energy Action Plan (NREAP), National Energy Efficiency Action Plan (NEEAP) and the National Development Plan 2018-2027. It represents a hypothetical future scenario in which no further policy actions or measures have been taken.

- The *WAM* energy projections present an alternative view of future energy demand that accounts for further implementation of the *With Measures* scenario in addition to the implementation of planned government policies and measures such as Ireland's 2019 Climate Action Plan[9] and in the case of agriculture an update Marginal Abatement Cost Curve (MACC) of NH_3 emissions in Ireland[10] and the recently published Roadmap to Climate Neutrality for

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[6] DIRECTIVE (EU) 2016/2284 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

[7] https://www.esri.ie/current-research/the-i3e-model

[8] http://www.agriculture.gov.ie/foodwise2025/

[9] https://www.dccae.gov.ie/en-ie/climate-action/publications/Pages/Climate-Action-Plan.aspx

[10] https://www.teagasc.ie/media/website/publications/2020/NH3-Ammonia-MACC.pdf

the Agriculture sector "AgClimatise" published by the Department of Agriculture Food and the Marine[11] .

The *Baseline* energy projection underpins the *With Measures* emission projection for the energy sector and the *Advanced* energy projection underpins the *With Additional Measures* projection for the energy sector.

For the energy demand projections, the Economic and Social Research Institute (ESRI) used the I3E model[12].

The I3E model is an intertemporal computable general equilibrium (CGE) model, which reproduces the structure of the Irish economy in its entirety, including productive sectors, households, and the government, among others. In the model the nature of all existing economic transactions among diverse economic agents is quantified. According to micro economic behaviour, producers and consumers maximise their profits/utility given their budget constraints. In other words, a CGE model examines how inputs and outputs flow between production sectors of the economy and finally result in goods and services being consumed by households. The model combines theory and data to examine energy use changes due to developments in the economy, labour market, policies and international prices.

The explicit modelling of sectoral inter-linkages makes it possible to investigate the wider economic impacts of a specific shock or policy through the different transmission channels in the economy. Therefore, CGE models have become a standard tool of empirical analysis, and are widely used to analyse the welfare and distributional impacts of policies whose effects may be transmitted through multiple markets. Because of its nature, CGE modelling is useful for policy design and evaluation, specifically when policy measures are expected to lead to indirect as well as direct effects, as in the case of energy-related policies. For example, the economic implications of an energy tax in the transport sector can be evaluated both for the transport sector and other sectors through inter-sectoral spill-overs.

The I3E model includes energy flows in addition to the standard monetary flows. Each production sector produces an economic commodity using labour, capital, material inputs, and energy inputs. The I3E model explicitly comprises a set of carbon commodities including peat, coal, natural gas, crude oil, fuel oil, LPG, gasoline, diesel, kerosene, and other petroleum products. Production activities produce in the cheapest way possible by using the optimal set of capital, labour, energy and other intermediate inputs based on both relative prices and substitution possibilities. When an energy policy is implemented (e.g. an increase in carbon tax) or in case of an external shock (e.g. an increase in international energy prices or ETS price), production sectors will where possible substitute energy inputs for other inputs and/or decrease the carbon content of their energy inputs by demanding cleaner energy. From the consumers' perspective, higher prices of goods with higher carbon content will encourage them to consume less carbon-intensive products.

I3E is a dynamic model, which incorporates economic growth over the modelling horizon. Economic growth originates from three sources; the growth of employment driven by population growth, the

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[11] https://www.gov.ie/en/press-release/a8823-publication-of-ag-climatise-national-climate-air-roadmap-for-the-agriculture-sector/

[12] https://www.esri.ie/current-research/the-i3e-model

growth in capital stock driven by investment, and the growth in total factor productivity or productivity of factors of production. It is assumed that the total population grows at a constant rate and the technology, i.e. the productivity of labour force grows at a constant rate. In the current version, the values of population growth and economic growth are retrieved from the medium-run estimates of the macro econometric forecast model of the ESRI, namely COSMO (COre Structural MOdel for Ireland).

Baseline Assumptions

In CGE modelling, a change in a policy variable/parameter or a set of policy variables/parameters is defined as a shock process or experiment. The effects of the experiment are given as the paths of variables that are solved within the model and are reported in terms of a percentage change with respect to the baseline. The baseline is a path such that there is no change in any policy variables/parameters, but an economy evolves according to its internal dynamics. For instance, since the internal dynamics of the I3E model are driven by the population and labour productivity growths, the Irish economy would grow at 3.3% per annum without any policy intervention. Since there are no external interventions in the economy, the base path is also called the business-as-usual path. This pathway now includes a carbon tax that increases to €80 per tonne by 2030.

Fossil Fuel Prices

Future international fossil fuel prices are given as input to the I3E model. For the energy related projections described in this document), the UK Department for Business, Energy and Industrial Strategy (BEIS) scenario is applied[13] (oil, gas and coal price projections). Furthermore, how other fuel prices (gasoline, diesel, kerosene, LPG, fuel oil and other petroleum products) fluctuate with the oil price are econometrically estimated. These estimated relationships are used to project future international prices of all fuel types.

Carbon prices

The recommended ETS carbon prices are based on the EU Reference Scenario. The I3E model implements two carbon prices, namely the Irish carbon tax and the EU ETS price. The EU ETS price projections are taken from the EU reference scenario. The Irish carbon tax currently stands at €20 a tonne. Two Irish carbon tax scenarios are run; one (*With Existing Measures* scenario) with a varying carbon tax that increases to €80 per tonne by 2030 and one (*With Additional Measures* scenario) with a varying carbon tax that increase by €7.50 per annum to 2020 and reaches €100 per tonne by 2030.

The software used for to model the Irish Electricity Market is PLEXOS which is a power systems modelling tool used for electricity market modelling and planning.

To produce the finalised *Baseline* energy projections, SEAI amends the output of the energy demand produced by ESRI to take account of the expected impact of energy efficiency measures put in place before the end of 2019 but which are considered too recent to be detectable in any time-series analysis. The *Advanced* energy projections builds on the *Baseline* projections with adjustments made

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[13]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/764342/BEIS_2018_Fossil_Fuel_Price_Assumptions.pdf

to account for implementation of additional policies and measures outlined in Ireland's 2019 Climate Action Plan.

The model input assumptions for the latest SEAI Energy Projections were finalised in quarter 1 of 2021. Determination of anticipated progress in the implementation of policies and measures was coordinated by the SEAI in discussion with the relevant Government Departments. Table 8.2 shows the key parameters underlying the macroeconomic outlook and therefore the *With Measures* and *With Additional Measures* emission projections scenarios.

Further details on the models used for preparing the energy projections (i.e. COSMO I3E, Plexos Integrated Energy Model, SEAI's National Energy Modelling Framework, SEAI BioHeat Model) are included in the 2021 submission made under made under Article 18 (4) of the Governance Regulation of the Energy Union and Climate Action (EU) 2018/1999. This is available in the relevant 2021 submission folder at the following link:

https://reportnet.europa.eu/public/dataflows

Table 8.2. Key assumptions underpinning the energy projections

	2020	2021-2025	2026-2030
Average Annual % Growth Rate			
GDP	-10.35	6.21	3.29
GNP	-14.10	7.11	3.29
Personal Consumption	-11.07	6.69	3.28
	2020	**2025**	**2030**
Housing Stock ('000)	2,071	2,196	2,322
Population ('000)	4,824	5,021	5,225
EUETS: Carbon €$_{2016}$/tCO$_2$	25	28	30
Carbon tax €/tCO$_2$ (WEM Scenario)	26	56	80
Coal €$_{2016}$/boe	6.68	6.70	6.73
Oil €$_{2016}$/boe	27.54	28.76	29.80
Gas €$_{2016}$/boe	18.30	19.44	20.40
Peat €/MWh	25	25	25

8.4 Key Trends

In the following sections, both *the With Measures* (WM) and *With Additional Measures* (WAM) scenarios are presented in the context of emission reduction targets set for 2020 and 2030. The WAM scenario is then considered in more detail. The 1990-2019 inventory was used as the baseline historic inventory for the emissions projections. Figures in the following sections include historic air pollutant

emission estimates from 2000-2019 or 2010-2019. Tables in the following sections present projected emission estimates up to and including 2030 under both the WM and WAM scenarios.

8.4.1 Sulphur Dioxide (SO$_2$)

Emission projections for SO$_2$ for the WM and WAM scenarios are presented in Figure 8.1. The emission reduction targets for 2020 and 2030 are also presented. The emission projections predict compliance with the 2020 and 2030 emission reduction target throughout the projected period. Key sources of SO$_2$ emissions in the projections include emissions from residential, commercial and industry. Emissions from electricity generation are projected to significantly reduce with the proposed closure of Ireland's only coal fired electricity generation plant in 2025.

Total SO$_2$ emissions under the WAM scenario are projected to be 11.0 kt in 2020. The emission projections predict compliance with the 2020 emission reduction target by 14.5 kt. Total SO$_2$ emissions are projected to be 5.6 kt in 2030 under the WAM scenario which is below the emission reduction target (10.9 kt) for that year.
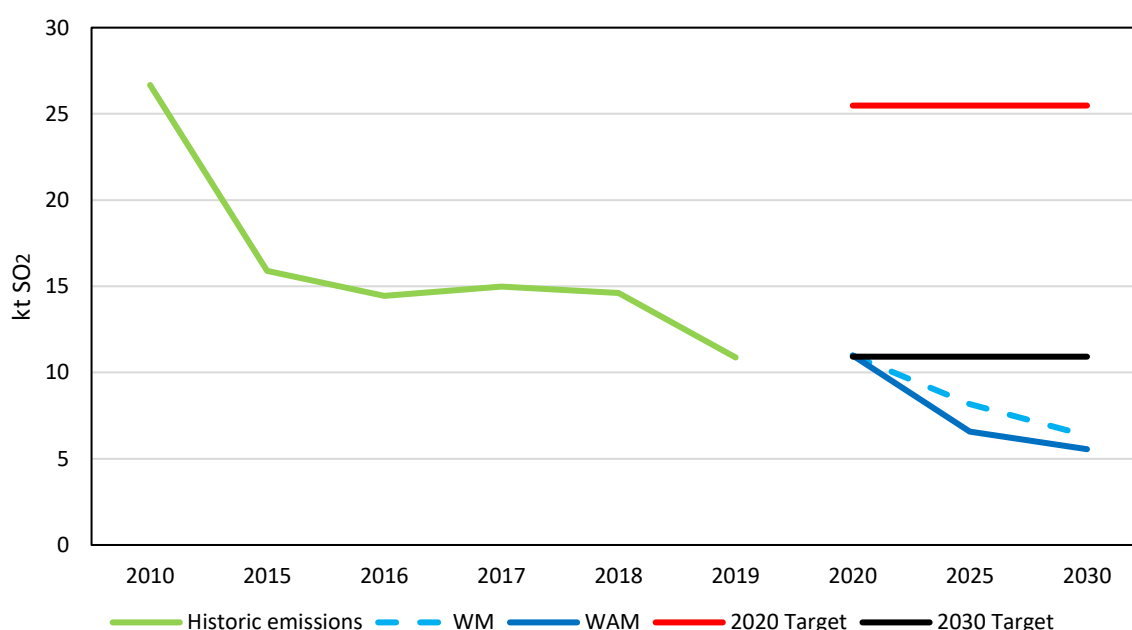
Figure 8.1 SO$_2$ Emission Projections for the With Measures and With Additional Measures Scenarios

SO$_2$ emissions under the WAM scenario by source sector are presented in Figure 8.2. Emissions from Public Electricity and Heat Production (1A1a) contribute approximately 19.9 per cent and 4.0 per cent of national total emissions of SO$_2$ in 2020 and 2030, respectively. The reduction in 2030 is largely attributed to coal and peat no longer being used for electricity generation. The combined Residential and Commercial sectors account for 66.9 per cent and 68.8 per cent of emissions in 2020 and 2030 respectively.

Table 8.3 presents the projected Emissions of SO$_2$ under the WM and WAM by sector over the period 2019 to 2030.

Figure 8.2 SO₂ Emission Projections for the With Additional Measures Scenario by Source Sector

Table 8.3. Projected Emissions of SO₂ under the With Measures and With Additional Measures Scenarios (kt)

With Measures scenario				
	2019	2020	2025	2030
Public Electricity and Heat Production	2.2	2.2	1.6	0.2
Manufacturing Industries and Construction	1.5	1.1	1.3	1.3
Residential & Commercial/Institutional	6.8	7.4	5.0	4.5
Agriculture/Forestry/Fishing	0.0	0.0	0.0	0.0
Transport	0.2	0.2	0.2	0.3
Other NFR Sectors	0.2	0.2	0.0	0.0
TOTAL	**10.9**	**11.0**	**8.2**	**6.3**
With Additional Measures scenario				
Public Electricity and Heat Production	2.2	2.2	0.3	0.2
Manufacturing Industries and Construction	1.5	1.1	1.3	1.2
Residential & Commercial/Institutional	6.8	7.4	4.7	3.8
Agriculture/Forestry/Fishing	0.0	0.0	0.0	0.0
Transport	0.2	0.2	0.2	0.3
Other NFR Sectors	0.2	0.2	0.0	0.0
TOTAL	**10.9**	**11.0**	**6.6**	**5.6**

8.4.2   Nitrogen Oxides (NO$_X$)

Emission projections for NO$_X$ for the WM and WAM scenarios are presented in Figure 8.3. The emission reduction targets for 2020 and 2030 are also presented.

Article 4 (3) of the National Emission Ceiling Directive provides that emissions of nitrogen oxides from categories 3B (manure management) and 3D (agricultural soils) are not accounted for the purpose of complying with 2020 and 2030 targets. The WM emissions and WAM emissions (in addition to 2020 and 2030 targets) displayed in Figure 8.3 excludes emissions from these categories (3B and 3D) for the

period 2020 to 2030 for the purposes of the reduction target compliance assessment. The historic NOx levels in the graph include the adjusted NOx inventory for the years 2010-2019.

Emission projections predict non-compliance with the 2020 emission reduction target under the WM and WAM scenarios. Emissions from transport is the largest contributor to NOx emissions. The projections predict compliance with both the 2020 and 2030 emission reduction target under the WAM scenarios.

Total NO_X emissions (excluding agricultural categories 3B and 3D) under the WAM scenario are projected to be 55.8 kt in 2020 which is compliant with the 2020 emission reduction target by 13.2 kt. Total NO_X emissions in 2030 are projected to be 33.5 kt, which is a compliance with the emission reduction target for that year by 8.5 kt.
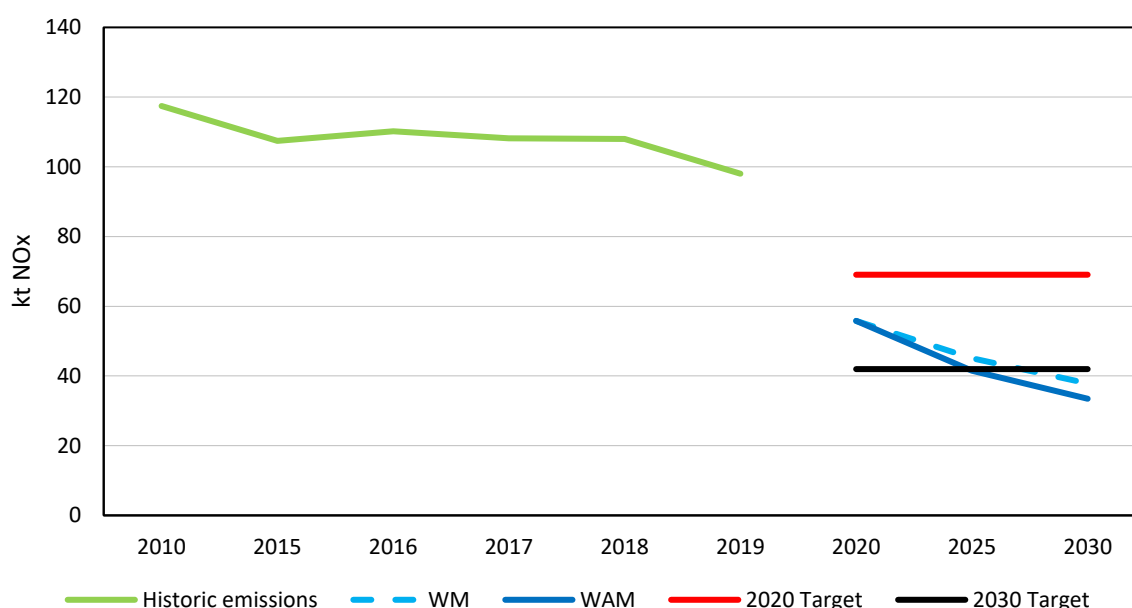
Figure 8.3 NO$_X$ Emission Projections for the With Measures and With Additional Measures Scenarios

Figure 8.4 presents the total NO_X emissions under the WAM scenario by source sector. The largest sectoral contribution is from agriculture and transport. In terms of compliance assessment (i.e. excluding agricultural categories 3B and 3D) transport accounts for 54.8 per cent and 42.7 per cent share of emissions in 2020 and 2030 respectively.

Table 8.4 presents the projected Emissions of NO_X under the WM and WAM by sector over the period 2019 to 2030.
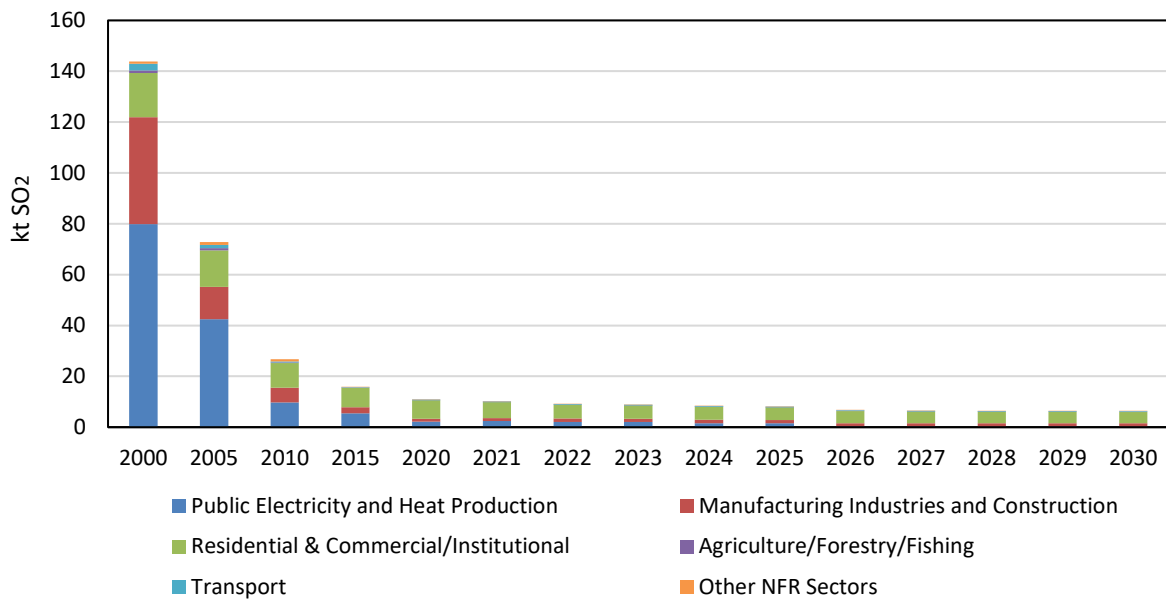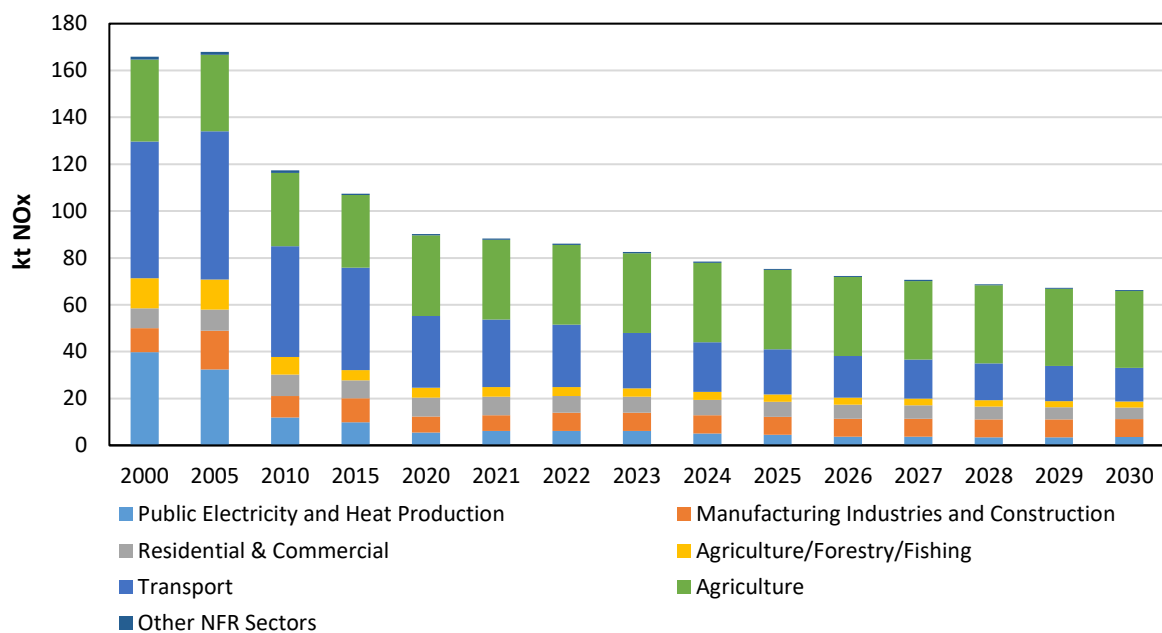
Figure 8.4 NOx Emission Projections for the With Additional Measures Scenario by Source Sector

Table 8.4. Projected Emissions of NOx under the With Measures and With Additional Measures Scenarios (kt)

With Measures scenario				
	2019	**2020**	**2025**	**2030**
Public Electricity and Heat Production	6.0	5.5	6.5	4.7
Manufacturing Industries and Construction	8.2	6.8	7.9	8.1
Residential & Commercial	7.6	8.1	7.0	6.8
Agriculture/Forestry/Fishing	4.0	4.3	3.3	2.7
Transport	37.9	30.6	19.9	15.1
Agriculture	33.7	34.4	35.2	35.1
Other NFR Sectors	0.5	0.6	0.4	0.4
TOTAL	**98.0**	**90.2**	**80.3**	**73.0**
With Additional Measures scenario				
Public Electricity and Heat Production	6.0	5.5	4.5	3.6
Manufacturing Industries and Construction	8.2	6.8	7.7	7.7
Residential & Commercial	7.6	8.1	6.3	4.9
Agriculture/Forestry/Fishing	4.0	4.3	3.2	2.6
Transport	37.9	30.6	19.3	14.3
Agriculture[14]	33.7	34.4	33.9	32.8
Other NFR Sectors	0.5	0.6	0.4	0.4
TOTAL	**98.0**	**90.2**	**75.3**	**66.3**

8.4.3 Ammonia (NH₃)

Figure 8.5 presents the emission projections for NH$_3$ for the WM and WAM scenarios. The emission reduction targets for 2020 and 2030 are also presented. Overall the Ammonia emission projections predict non-compliance with the 2020 and 2030 emission reduction target under the WM scenario. Under the WAM scenario, Under the WAM scenario, compliance is projected for the 2020 emission reduction target in 2022 and compliance with the 2030 emission reduction target is also projected. The majority of projected emissions come from agriculture sources (agriculture accounted for 99 per cent of emissions in 2019) and this is maintained throughout the projection period.

Total NH$_3$ emissions under the WAM scenario are projected to be 124.7 kt in 2020. As a result, an exceedance of the 2020 emission reduction target by 6.3 kt is projected. Post 2020, emissions are projected to decrease to 112.7 kt in 2030. Ireland's 2030 emission target of a 5 per cent reduction on 2005 levels results in compliance with the emission reduction target in 2030 of 0.8 kt under the WAM scenario. Compliance with emission reduction targets is a challenge for the agricultural sector, however there have been some encouraging signs of uptake of abatement measures in the sector which are further descried in Chapter 5.
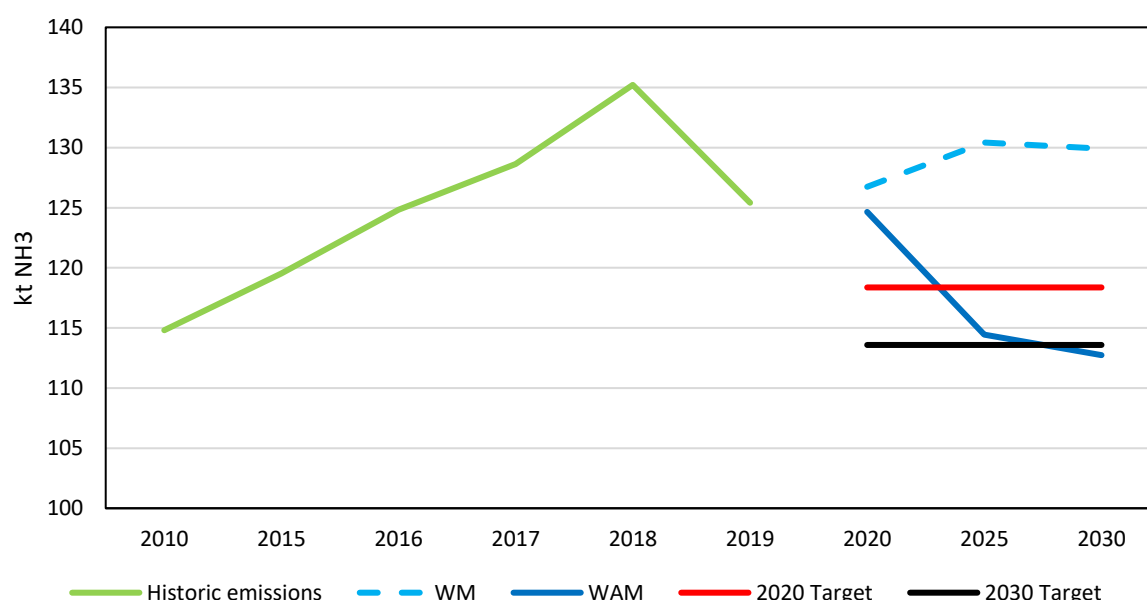
Figure 8.5 NH₃ Emission Projections for the With Measures and With Additional Measures Scenarios

The reduction in the WAM scenario compared to the WM scenario over the period 2021-2030 is attributable to measures that are included in the most recent Teagasc Marginal Abatement Cost Curve[14]), and the Department of Agriculture, Food and the Marine National Climate and Air Roadmap for the Agriculture Sector "AgClimatise"[15]. Key measures include, for example, low emission slurry spreading, use of inhibited urea fertiliser products, reduction of crude protein in dairy cow diets, and manure amendments.

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[14] https://www.teagasc.ie/news--events/news/2020/reduce-ammonia-emissions.php
https://www.teagasc.ie/media/website/publications/2018/An-Analysis-of-Abatement-Potential-of-Greenhouse-Gas-Emissions-in-Irish-Agriculture-2021-2030.pdf
[15] https://www.gov.ie/en/publication/07fbe-ag-climatise-a-roadmap-towards-climate-neutrality/
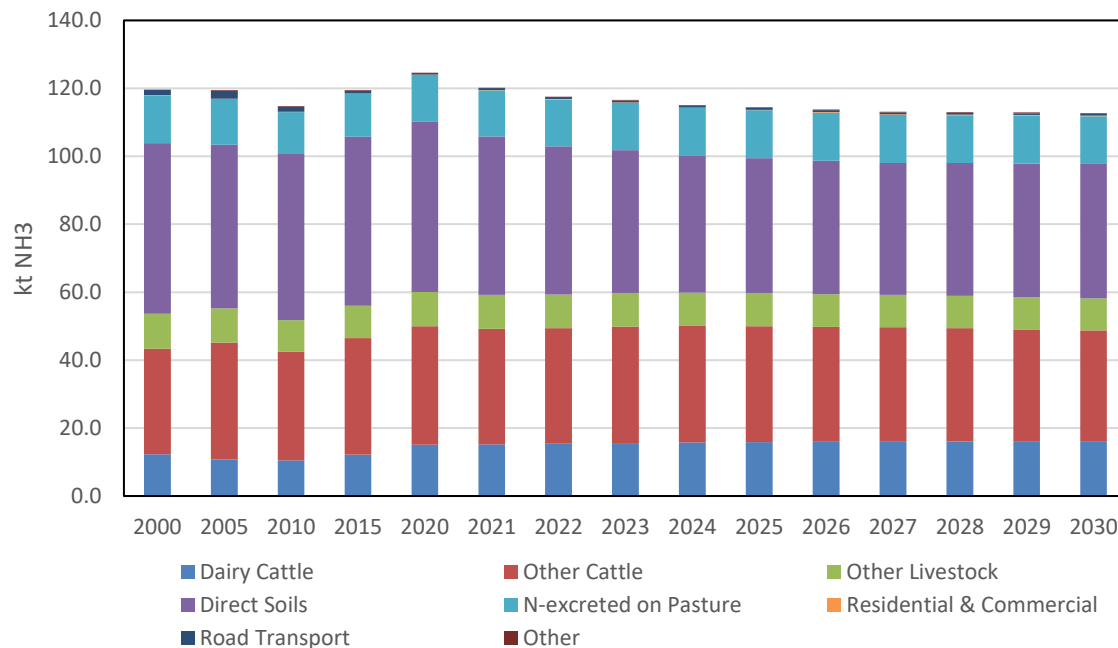
Figure 8.6 NH₃ Emission Projections for the With Additional Measures Scenario by Source Sector

Ammonia emissions by source sector under the WAM scenario are presented in Figure 8.6. Table 8.5 presents the projected ammonia emissions under the WM and WAM by sector over the period 2019 to 2030.

Table 8.5. Projected Emissions of NH₃ under the With Measures and With Additional Measures Scenarios (kt)

With Measures Scenario				
	2019	**2020**	**2025**	**2030**
Dairy Cattle	14.5	15.1	16.4	17.0
Other Cattle	35.1	34.9	34.7	33.5
Other Livestock	9.8	10.1	10.5	10.9
Direct Soils	51.6	52.3	53.6	53.3
N-excreted on Pasture	13.6	13.7	14.2	14.1
Residential & Commercial	0.1	0.1	0.1	0.2
Road Transport	0.5	0.5	0.6	0.6
Other	0.2	0.1	0.2	0.3
Total	**125.4**	**126.1**	**130.4**	**129.9**
With Additional Measures Scenario				
Dairy Cattle	14.5	15.1	15.9	16.2
Other Cattle	35.1	34.9	34.1	32.6
Other Livestock	9.8	10.1	9.7	9.5
Direct Soils	51.6	50.2	39.7	39.5
N-excreted on Pasture	13.6	13.7	14.1	14.1
Residential & Commercial	0.1	0.1	0.1	0.2
Road Transport	0.5	0.5	0.6	0.5
Other	0.2	0.1	0.2	0.2
Total	**125.4**	**124.7**	**114.4**	**112.7**

8.4.4 Non-Methane Volatile Organic Compounds (NMVOCs)

Figure 8.7 presents the emissions projections for NMVOCs for the WM and WAM scenarios. The emission reduction targets for 2020 and 2030 are also presented.

Overall NMVOC emission projections predict non-compliance with the 2020 and 2030 emission reduction target under both the WM and WAM scenarios. Large emission sources include solvents and other product use, and emissions from the food and beverages industry.

Article 4 (3) of the National Emission Ceiling Directive provides that emissions of non-methane volatile organic compounds from categories 3B (manure management) and 3D (agricultural soils) are not accounted for the purpose of complying with 2020 and 2030 targets. The WM and WAM emissions (in addition to 2020 and 2030 targets displayed) in Figure 8.7 exclude emissions from these categories (3B and 3D).

Total NMVOC emissions under the WAM scenario (excluding emissions from agricultural categories 3B and 3D) are projected to be 68.2 kt in 2020. The emission projections predict non-compliance with the 2020 target by approximately 11.3 kt. Emissions in 2030 are projected to be 69.2 kt which is 17.6 kt above the emission reduction target for 2030.
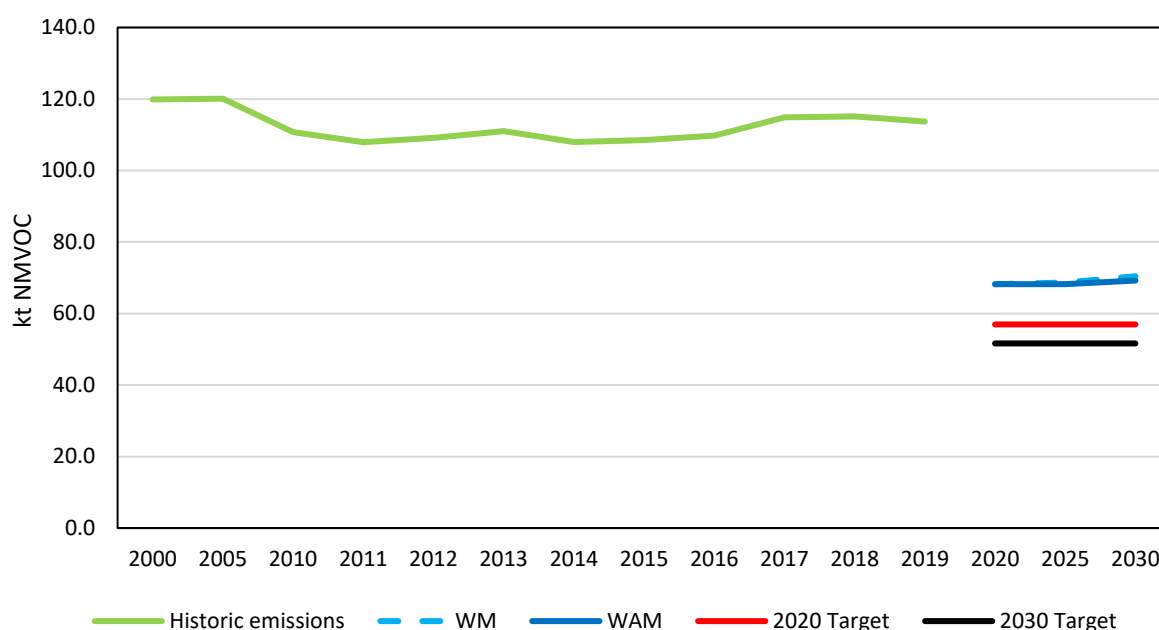
Figure 8.7 NMVOC Emission Projections for the With Measures and With Additional Measures Scenarios[16]

Figure 8.8 presents a scenario where projected adjustments to the national emission inventory in relation to emissions from spirit production are accepted for the compliance assessment. This is on the basis that NMVOCs from category 2.H (Spirits) were included in the 1990-2015 inventory for the February 2017 Inventory submission (after the 2016 NEC Directive came into effect). The historic NMVOC levels in the graph include the adjusted NMVOC inventory for the years 2010-2019. In the

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[16] Article 4 (3) of the National Emission Ceiling Directive provides that emissions of non-methane volatile organic compounds from categories 3B (manure management) and 3D (agricultural soils) are not accounted for the purpose of complying with 2020 and 2030 targets. The *With Measures* emissions and *With Additional Measures* emissions in addition to 2020 and 2030 targets displayed in this graph exclude emissions from these categories (3B and 3D)

WAM scenario that assumes adjustments for the category spirit production are accepted, the emission projections predict compliance with the 2020 target by approximately 1.9 kt. Emissions in 2030 are projected to be 48.0 kt which is 2.2 kt above emission reduction target for 2030.

Figure 8.8 NMVOC Emission Projections for the With Measures and With Additional Measures Scenarios[17]
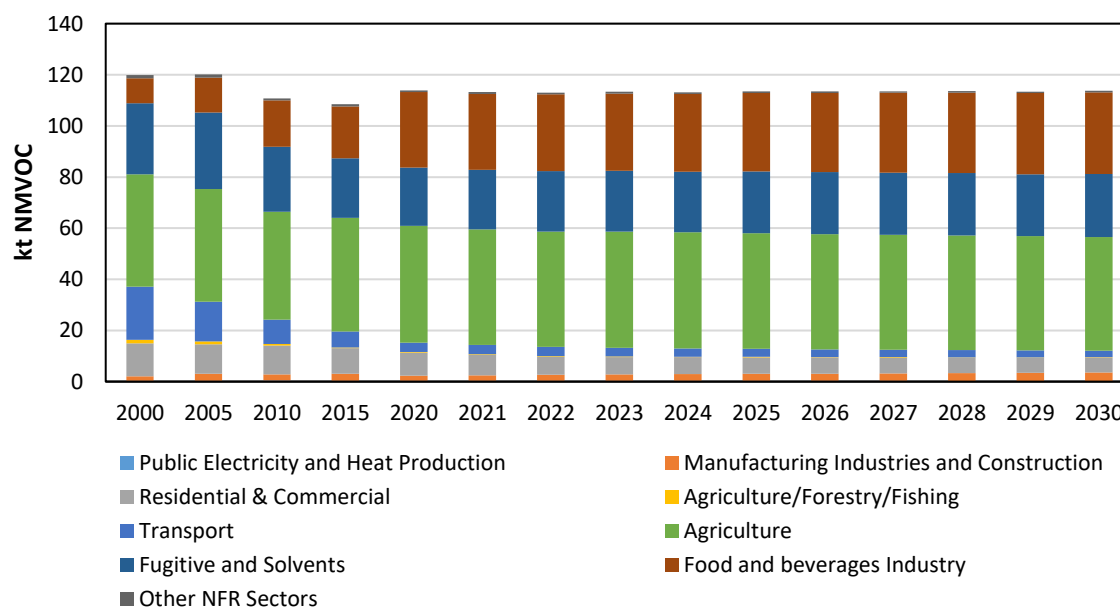
Figure 8.9 NMVOC Emission Projections for the With Additional Measures Scenario by Source Sector

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[17] The *With Measures* emissions and *With Additional Measures* emissions in addition to 2020 and 2030 targets displayed in this graph exclude emissions from NFR categories 3B (manure management) and 3D (agricultural soils), and category 2H (Spirits)

Projected total NMVOC emissions by source sector under the WAM scenario are presented in Figure 8.9. In terms of compliance assessment (which exclude agricultural categories 3B and 3D) projected emissions from Solvents and Fugitive emissions account for 33.5 per cent and 35.6 per cent in 2020 and 2030 respectively under the WAM scenario. Food and Beverage production accounts for 43.3 per cent and 46.2 per cent of emissions in 2020 and 2030 respectively.

Projected emissions across the time series show a slight increase in the WM scenario and a stabilisation of emissions under the WAM scenario over the projected period to 2030. The trend of reduced emissions in the Residential and Commercial and Transport sectors are counteracted by the increase in emissions from solvents and fugitive emissions and the food and beverages industry.

Table 8.6 presents the projected NMVOC emissions under the WM and WAM by sector over the period 2019 to 2030.

Table 8.6. Projected Emissions of NMVOC under the With Measures and With Additional Measures Scenarios (kt)

With Measures Scenario				
	2019	2020	2025	2030
Public Electricity and Heat Production	0.3	0.3	0.4	0.3
Manufacturing Industries and Construction	3.0	2.0	2.7	3.4
Residential & Commercial	8.3	9.0	6.7	6.5
Agriculture/Forestry/Fishing	0.3	0.3	0.2	0.1
Transport	4.0	3.6	3.1	2.7
Agriculture[11]	45.5	45.9	46.8	46.3
Fugitive and Solvents	22.4	22.8	24.2	24.8
Food and beverages Industry	29.3	29.5	30.7	32.0
Other NFR Sectors	0.7	0.7	0.7	0.6
Total	**113.7**	**114.1**	**115.5**	**116.7**
With Additional Measures Scenario				
Public Electricity and Heat Production	0.3	0.3	0.3	0.2
Manufacturing Industries and Construction	3.0	2.0	2.7	3.3
Residential & Commercial	8.3	9.0	6.5	5.8
Agriculture/Forestry/Fishing	0.3	0.3	0.2	0.1
Transport	4.0	3.6	3.1	2.5
Agriculture[11]	45.5	45.7	45.3	44.5
Fugitive and Solvents	22.4	22.8	24.1	24.6
Food and beverages Industry[12]	29.3	29.5	30.7	32.0
Other NFR Sectors	0.7	0.7	0.7	0.6
Total	**113.7**	**113.9**	**113.5**	**113.8**

8.4.5   Particulate Matter< 2.5 µm in diameter (PM$_{2.5}$)

Emissions projections for PM$_{2.5}$ for the WM and WAM scenarios are presented in Figure 8.10. The emission reduction targets for 2020 and 2030 are also presented. Overall the PM$_{2.5}$ emission projections predict compliance with the 2020 and 2030 emission reduction target under both the WM and WAM scenarios. Emissions from Residential and Commercial combined are the largest contribution to the projected emissions.

Total PM$_{2.5}$ emissions under the WAM scenario are projected to be 11.6 kt in 2020. The emission projections under the WAM scenario predict compliance with both the 2020 and 2030 emission reduction targets by a margin of 3.9 kt and 1.3 kt, respectively.

Table 8.7 presents the projected PM$_{2.5}$ emissions under the WM and WAM by sector over the period 2019 to 2030.
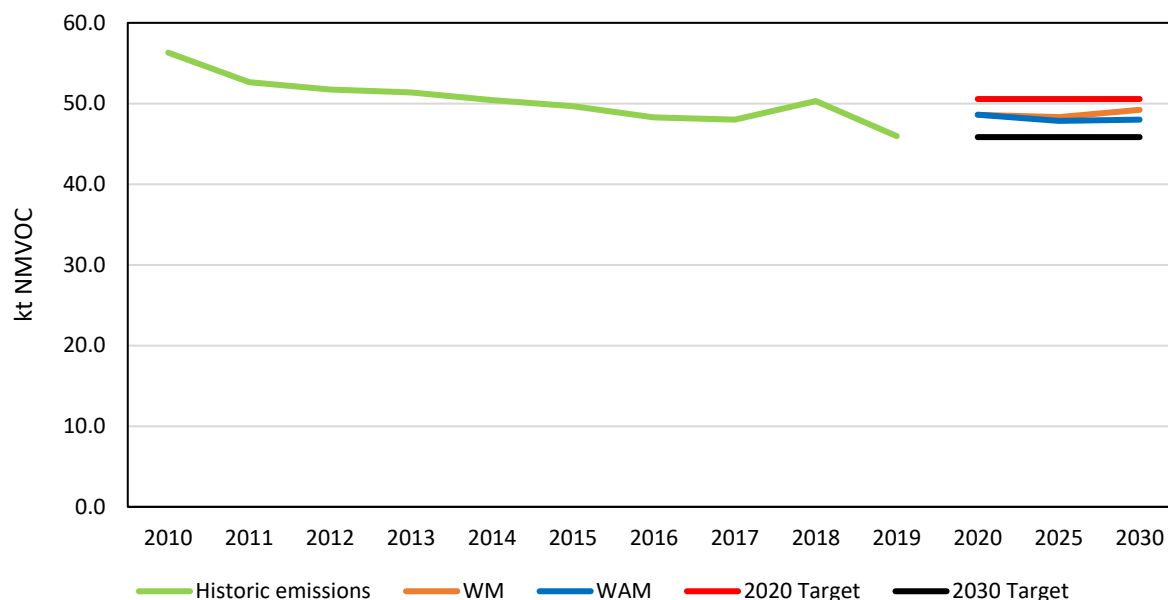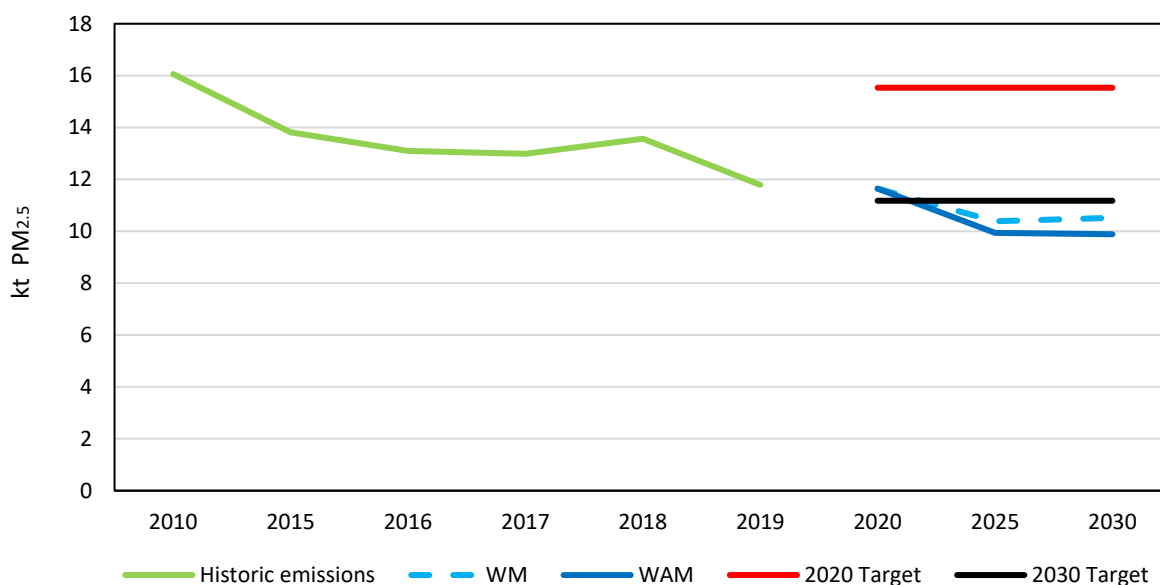

Figure 8.10 PM$_{2.5}$ Emission Projections for the With Measures and With Additional Measures Scenarios
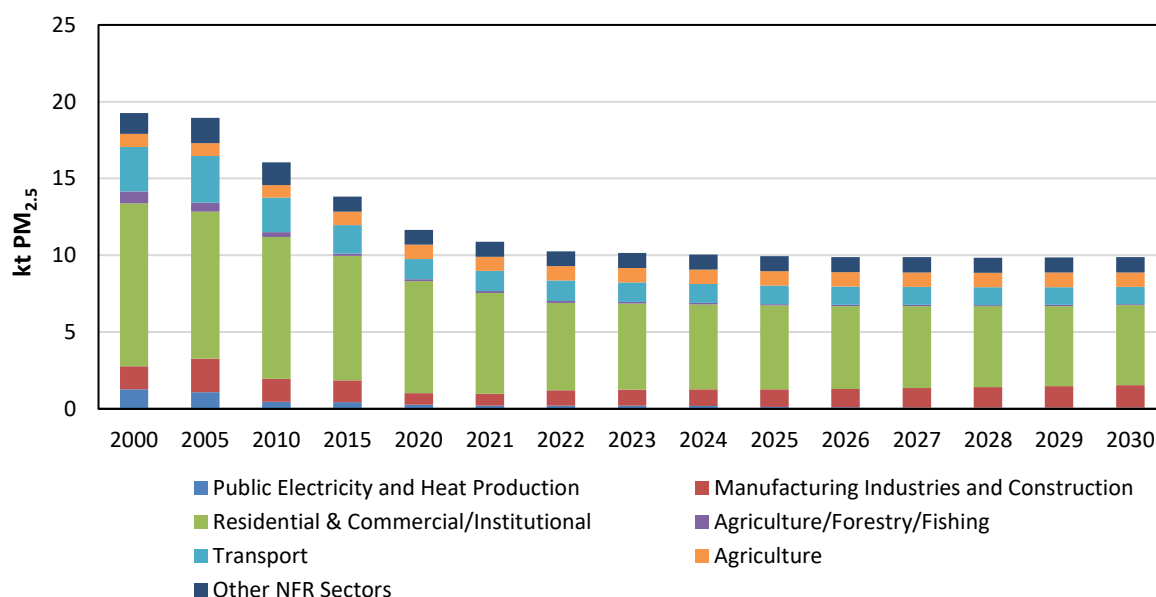
Figure 8.11 PM$_{2.5}$ Emission Projections for the With Additional Measures Scenario by Source Sector

Projected emissions across the time series show a decline for both the WM and WAM scenarios up to 2030 (Figure 8.11). This trend is largely the result of projected reductions in emissions in the combined Residential and Commercial sectors.

Table 8.7. Projected Emissions of PM$_{2.5}$ under the With Measures and With Additional Measures Scenarios (kt)

With Measures scenario				
	2019	**2020**	**2025**	**2030**
Public Electricity and Heat Production	0.2	0.3	0.3	0.1
Manufacturing Industries and Construction	1.4	0.8	1.2	1.5
Residential & Commercial/Institutional	6.7	7.3	5.6	5.6
Agriculture/Forestry/Fishing	0.1	0.1	0.1	0.1
Transport	1.5	1.3	1.3	1.2
Agriculture	0.9	0.9	0.9	0.9
Other NFR Sectors	1.0	1.0	1.0	1.0
TOTAL	**11.8**	**11.6**	**10.4**	**10.5**
With Additional Measures scenario				
Public Electricity and Heat Production	0.2	0.3	0.1	0.1
Manufacturing Industries and Construction	1.4	0.8	1.1	1.5
Residential & Commercial/Institutional	6.7	7.3	5.5	5.2
Agriculture/Forestry/Fishing	0.1	0.1	0.1	0.1
Transport	1.5	1.3	1.2	1.1
Agriculture	0.9	0.9	0.9	0.9
Other NFR Sectors	1.0	1.0	1.0	1.0
TOTAL	**11.8**	**11.6**	**9.9**	**9.9**

8.5 Energy Industries (NFR 1A1)

Public Electricity and Heat Production (1A1a) covers all electricity generation including electricity generated from renewable sources. The Plexos_Ireland model was used to model projected future electricity generation. As an electrical systems model, the core input data comprises technical details of generators, transmission lines and loads as well as fuel costs, operational costs and emission reduction rates and costs.

In the *Baseline* energy projection, the renewable energy generated shows Ireland reaching approximately 37.6 per cent of electricity consumption from renewable energy by 2020. Renewable electricity generation capacity is dominated by wind. In 2030 it is estimated that renewable energy generation increases to approximately 55 per cent of electricity consumption.

The use of peat/biomass in three peat stations is determined by the plants operation in the electricity market taking into account supports (Public Service Obligation (PSO)/REFIT3[18]) and maximum levels of peat likely to be permitted under planning permission.

In the assumptions underpinning both the baseline and advanced scenarios, one peat station is eligible for REFIT3 30 per cent biomass cofiring up to the end of 2030. However, it only has planning permission to the end of 2023 and therefore, only operates to the end of 2023 with 30% cofiring. The

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[18]https://www.dccae.gov.ie/en-ie/energy/topics/Renewable-Energy/electricity/renewable-electricity-supports/refit/Pages/REFIT-3.aspx

other two peat plants operate until the end of 2020 at up to 100 per cent peat and close at the end of 2020.

One coal plant is assumed to operate in the market up to end 2025 at which point it no longer generates electricity from coal.

It is assumed there will be a roll out of approximately 2.25 million smart meters by 2024, on a phased basis which started in 2019.

In the *Advanced* energy projection (and therefore the *With Additional Measures* emissions scenario) it is assumed that for 2020 there is a 36.3 per cent of per cent share of renewable energy in electricity generation. In 2030 it is estimated that renewable energy generation increases to approximately 70 per cent of electricity consumption. This is mainly a result of additional expansion in wind energy and Solar PV.

In terms of inter-connection, it is assumed that the Greenlink 500MW interconnector to the UK to come on stream in 2025 and the Celtic 700MW interconnector to France to come on stream in 2026.

Emission factors for NO_X and SO_2 predominantly are based on those used for the year 2019 in the national inventory (1990-2019). Based on available data the projections take into account emission limit values provided in the transitional national plan for large combustion plants (e.g. coal fired electricity generation plant).

There has been significant reduction in the use of oil in electricity generation due to the closure and decommissioning of oil fuelled generation plants. Oil is also used as a start-up fuel in coal and peat fired generation stations. The 2019 SO_2 inventory emission factor for oil is assumed for all future years.

NMVOC and $PM_{2.5}$ emission factors for most of the other relevant fuel types (i.e. coal, peat, biomass and non-renewable wastes) are assumed to remain constant at the 2019 value utilised in the national inventory (1990-2019).

8.5.1   Oil and Gas Refining and Solid Fuel Manufacturing (NFR 1A1b and 1A1c)

Projected NO_X, SO_2, NMVOC and $PM_{2.5}$ for oil refining and solid fuel manufacture are based on data provided by the relevant operators as energy demand from these sectors is not included in SEAI's energy projections. The oil refining sector (1.A.1.b) in Ireland consists of a single installation. Projections are based on the growth rate of projected greenhouse gas emissions, which are provided to the EPA by the relevant installation operators.

8.6   Manufacturing Industries and Construction (NFR 1A2)

Projected NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ emissions are based on SEAI's *Baseline* and *Advanced* energy projections and are therefore estimated for both the WM and WAM scenarios.

Energy projections are provided to the EPA at an aggregated level only (i.e. 1A2) and underpin the air pollutant projections for this sector. The projected emission factors for NO_X and SO_2 from the combustion of coal, natural gas and petroleum coke are based on the weighted average emission factor for all fuels across the sub sectors 1A2a – 1A2g from the values used in the inventory.

The following policies and measures relevant to the industry sector are included in the *Baseline* (WM) Projection:

- SEAI Large Industry Programme
- Accelerated Capital Allowances - Industry
- Combined Heat and Power
- Excellence in Energy Efficiency Design (EXEED) Industry

The *Advanced* (WAM) Projection includes an extension of the above polices and measures.

8.7 Transport (NFR 1A3)

Transport emissions cover Aviation (1A3a), Road Transportation (1A3b), Rail (1A3c), Navigation (1A3d) and Other transportation (Natural gas pipeline compressors, 1A3e). Projected emissions of NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ from road transport are based on SEAI's *Baseline* and *Advanced* energy projections and are therefore estimated for both the WM and WAM scenarios.

It is assumed that fuel use in rail and navigation will remain constant at 2019 levels for each year out to 2030.

Other Transportation (1A3e) refers to the use of natural gas for combustion in natural gas pipeline compressor stations. Emissions from this sector are inferred from projected gas demand in the residential, industrial and commercial and institutional services sectors from the energy projections provided by SEAI and are calculated for both the WM and WAM scenarios.

8.7.1 Domestic aviation (NFR 1A3a)

NO_X, SO_2, NMVOC and $PM_{2.5}$ emission projections from aviation are estimated using the 2019 inventory and also projected data, where available, related to aircraft movements as provided to the EPA by the relevant airport authorities. Emissions associated with all LTO (landing and take-off) cycles are calculated. It is assumed that NO_X, SO_2, NMVOC and $PM_{2.5}$ emission factors remain constant for all projected years based on the average of the previous 5 years (i.e. 2015-2019) used in the 1990-2019 national inventory.

8.7.2 Road transportation (NFR 1A3b)

The transport sector is a large energy using sector and is reliant on imported fossil fuels in the form of petroleum products and biofuels. Freight transport energy demand is strongly influenced by the level of commercial activity in the economy. Personal transport energy demand is influenced by both the level of employment as well as the oil price. Biofuel uptake in Ireland is driven primarily through the Biofuel Obligation Scheme[19], an obligation on fuel suppliers to blend an increasing percentage of biofuel with their fuel.

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[19]https://www.dccae.gov.ie/en-ie/energy/topics/RenewableEnergy/transport/biofuels/Pages/Biofuels.aspx

Energy projections provide future demand for petrol, diesel, renewables and electricity use in the road transport sector for both the WM and WAM scenarios.

Projected emissions (NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$) for road transport for the 2021 submission were produced using the COPERT model. A fleet model is produced in order to prepare data needed for the COPERT modelling. To produce the fleet model, an analysis was carried out on the inventory passenger car and light goods vehicles fleet data to ascertain the life cycle patterns for each of the vehicle Euro classes. This analysis was used to model future curves for each existing vehicle Euro class. Along with projected transport fuel projections, the EPA was also provided with projected total passenger car fleet data over the projected period which included projected electric vehicle uptake under both the WM and WAM scenarios. Gaps between the fleet model passenger car numbers and total projected fleet number were then populated with the latest Euro vehicles (e.g. Euro class 6 for passenger cars).

The same approach was applied to the heavy-duty trucks and buses, however the overall fleet data total for this section was based on a 2014 national research report[20] containing projected fleet numbers.

In terms of biofuels used in road transport fuel diesel blended fuel of B6.9 on average (i.e. fuel dispensed for diesel vehicles contains 6% biodiesel by volume), whilst Petrol remains at E5 on average (i.e. fuel dispensed for petrol vehicles contains 5% bioethanol by volume).

For the WAM scenario, it is assumed that the Biofuel Obligations Scheme is developed further. Incremental increases are assumed to occur with 10% blend for petrol (E10) and a 12% blend for diesel (B12) in place in 2030.

In terms of Electric Vehicles, the *baseline* energy projection assumes approximately 488,830 Electric Vehicles on the road by 2030 (includes 326,002 Passenger Battery Electric Vehicles, 148,183 Passenger Plug in Hybrid Electric Vehicles the *Advanced* Scenario assumes 935, 800 Electric Vehicles on the road by 2030 (includes 550,000 Passenger Battery Electric Vehicles, 288,000 Plug in Hybrid Electric Vehicles).

8.7.3 Rail (NFR 1A3c)

NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$ emission projections from rail transport are estimated. It is assumed that fuel use in the sector will remain constant at 2019 levels for each year out to 2030. It is also assumed that NO_x, NMVOC, NH_3 $PM_{2.5}$ emission factors remain the same as in the 2019 national inventory. Due to the variability in the sulphur content of gas oil in recent years an average SO_2 emission factor over the 2015-2019 period was used for projected years.

8.7.4 Navigation (NFR 1A3d)

NO_x, SO_2, NMVOC, NH_3 and $PM_{2.5}$ emission projections from navigation are estimated. Gasoil/diesel consumption in in-land navigation is assumed to remain constant at the 2019 level out to 2030. NO_x, NMVOC, NH_3 and $PM_{2.5}$ emission factors are assumed to remain constant at the 2019 level. Due to the

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[20] https://www.esri.ie/publications/demographic-and-economic-forecasting-report-national-transport-model-volume-3

variability in the sulphur content of gas oil in recent years an average SO_2 emission factor over the 2015-2019 period was used for projected years.

8.7.5 Gas Transmission (NFR 1A3e)

Emissions projections for NO_X, SO_2, NMVOC, and $PM_{2.5}$ from natural gas transmission in Ireland's natural gas pipeline network are estimated. Future gas demand for "own use and transformation" is inferred based on projected gas demand in the residential, commercial services and industrial sectors. Subtracting the amount of gas estimated to be lost from the distribution network allows "own use" gas demand and associated emissions to be estimated. It is assumed that NO_X, SO_2, NMVOC and $PM_{2.5}$ emission factors remain the same as in the 2018 national inventory.

8.8 Residential and Commercial/Institutional (NFR 1A4)

8.8.1 Commercial/Institutional (NFR 1A4a)

Projected NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ emissions are based on SEAI's *Baseline* and *Advanced* energy projections and are therefore estimated for both the WM and WAM scenarios. Oil and gas account for the majority of non-electricity energy demand in this sector. These fuels are used predominantly for space-heating purposes. Projected emissions of NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ are estimated.

It is assumed that NO_X, NMVOC, NH_3 and $PM_{2.5}$ emission factors remain the same as in the 2019 national inventory. SO_2 emission factors for oil-derived fuels for the projected period are based on an average of the last 5 years (i.e. 2015-2019).

The following policies and measures are included in the WM projection:

- ReHeat
- Public Sector Programme
- Public Sector Capital Exemplars
- Small and Medium Enterprises (SME) Programme
- Accelerated Capital Allowances - Services
- Supports for Exemplar Energy Efficiency Projects (SEEEP) and Energy Efficiency Retrofit Fund (EERF) and Better Energy Workplaces
- 2005/2008 Building Regulations - Buildings other than dwellings
- 2018 Building Regulations - Buildings other than dwellings
- Excellence in Energy Efficiency Design (EXEED) - Services
- Better Energy Communities - Services
- Supplier Obligation Non-Grant - Non-Residential
- Heat Pump Supports - Non-Domestic

The WAM Projection includes an extension of the following polices and measures:

- Public Sector Programme
- Public Sector Capital Exemplars
- SME Programme
- Accelerated Capital Allowances – Services

- EXEED - Services
- Better Energy Communities - Services
- Supplier Obligation Non-Grant - Non-Residential
- Heat Pump Supports - Non-Domestic

8.8.2 Residential (1A4b)

Projected NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ emissions are based on SEAI's *Baseline* and *Advanced* energy projections and are therefore estimated for both the WM and WAM scenarios.

Projected emissions of NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ are estimated. It is assumed that NO_X, NMVOC, NH_3 and $PM_{2.5}$ emission factors remain the same as in the 2019 national inventory. SO_2 emission factors for oil-derived fuels for the projected period are based on an average of the last 5 years (i.e. 2015-2019).

The following policies and measures are included in the WM energy projection:

- ReHeat
- 2002 Building Regulations -Dwellings
- 2008 Building Regulations -Dwellings
- 2011 Building Regulations -Dwellings
- 2019 Building Regulations - Dwellings
- Greener Homes Scheme
- Energy Efficient Boiler Regulation
- Domestic Lighting
- Warmer Homes Scheme
- Warmth and Wellbeing Pilot
- Deep Retrofit Pilot
- Better Energy Communities - Household
- Better Energy Homes
- Major Renovations - Dwellings
- Smart Meter Roll-Out - Household
- Supplier Obligation Non-Grant - Residential
- Heat Pump Supports – Domestic
- Other Domestic Retrofit
- Better Energy Finance
- Solar Pilot scheme

The WAM projection includes an extension of the following polices and measures:

- Warmer Homes Scheme
- Warmth and Wellbeing Pilot
- Deep Retrofit Pilot
- Better Energy Communities - Household
- Better Energy Homes
- Smart Meter Roll-Out – Household

- Heat Pump Supports – Domestic
- Other Domestic Retrofit
- Better Energy Finance
- Solar Pilot Scheme

8.9 Combustion in Agriculture and Fishing (NFR 1A4c)

Projected emissions of NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ are estimated for the combustion of diesel in the Agriculture sector and the combustion of diesel and fuel oil in the Fishing sector. Projected fuel use in the agriculture sector is included in the energy projections. For mobile combustion the same modelling approach is used as in the national inventory which takes into account the relevant Tier legislation as it affects the age structure mobile agricultural machinery. For stationary combustion in agriculture and combustion in fishing, NO_X, NMVOC, NH_3 and $PM_{2.5}$ emission factors remain the same as in the 2019 national inventory. SO_2 emission factors for oil-derived fuels for the projected period are based on an average of the last 5 years (i.e. 2015-2019).

Cross cutting measures impacting key energy sectors

There are cross cutting measures that have a significant impact across a number of sectors in terms of energy consumption and a reduction in emissions. These included carbon tax and supports for renewable heat which are described below.

- Carbon tax is a cross cutting measure that applies to industry, residential, commercial services, transport and agriculture fuel. Under the Baseline Scenario, the rate of carbon tax (€20 per tonne of CO2) increases to €80 per tonne by 2030. Under the Advanced scenario the carbon tax increases by €7.50 per tonne of CO2 to 2020 and reaches €100 per tonne by 2030.

- In terms of renewable heat, both the WM and WAM scenario assumes 1,600GWh of additional renewable heat (six year ramp up 2020 to 2025) supported under the Support Scheme for Renewable Heat (SSRH)[21].

- It is also assumed that 175,000 heat pumps replace residential oil boilers by 2030 under the WM scenario. Under the WAM scenario it is assumed that 385,000 existing residential oil boilers, gas boilers and electric heaters are replaced with heat pumps. District heating is also assumed to be deployed (additional 120 GWh by 2028 growing linearly from 2023).

- Under the WAM scenario, a total of 1,600GWh of biogas use across the heat and transport sectors by 2030 is assumed (linear increase from 2025 is assumed).

8.10 Fugitive emissions (NFR 1B)

Projected NMVOCs emissions from category 1B are estimated from three sources, Refining of oil products, Distribution of Oil Products and transmission and distribution of natural gas. Refinery NMVOC emissions are projected using the latest inventory year refinery NMVOC emissions and using the projected trend in CO_2 emissions from the refinery over the projected period as a proxy. Emissions from distribution of oil products are estimated by projecting the trend in imported petrol/gasoline

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[21] https://www.seai.ie/business-and-public-sector/business-grants-and-supports/support-scheme-renewable-heat/

using the latest inventory year imported petrol/gasoline and using the total projected transport petrol that is available from the energy forecasts for each of the scenarios (WEM and WAM).The total projected transport petrol that is available from the energy forecasts have been revised downwards since the previous projections submission. The latest inventory emission factors and abatement efficiencies are also used to produce the projected emission estimates. NMVOC from the transmission and distribution of natural gas is projected using the latest inventory year fugitive releases reported by Bord Gais Eireann and projected trend in CO_2 emissions from gas transmission and distribution over the projected period. The percentage NMVOC in natural gas is taken from gas analysis reports for the current inventory year and flatlined for the projected years. $PM_{2.5}$ emissions from category 1B are projected for coal storage and coal handling. Projections for coal storage are flatlined from the latest inventory year which is based on the area of coal storage and relevant emission factor that is used for the latest inventory year. Projections for coal handling is based on the projected coal used for electricity generation and applying the emission factor that is used in the latest inventory.

8.11 Mineral Products (NFR 2A), Chemical industry (NFR 2B), Metal Industry (NFR 2C)

Emission of air pollutants (e.g. NOx and SO_2 emissions) from Industrial Processes cannot usually be separated from the emissions from fuel combustion in industry. Emissions from industrial processes are therefore assumed to be included in projected estimates for the Manufacturing Industries and Construction (1.A.2) sector. 2.A.1 Cement Production, emissions are generally reported under NFR Category 1A2f (Non-metallic minerals) and notation keys IE and NA are reported under 2A1 for these pollutants.,2.A.2 Lime Production all emissions from lime production are assumed to be included in those reported within Sector 1A2f and the notation key IE (Include elsewhere) is used for 2A2, 2.A.3 Glass Production- the only container glass plant closed in 2002, one of the lead crystal plants closed in early 2006, the glass wool plant closed in 2008 and the last one, (second of the two) lead crystal plant closed in 2009. Therefore, after this period, emissions of all pollutants are projected as 'NO' (not occurring),2.A.5.a Quarrying and mining of minerals other than coal, 2.A.5.b Construction and demolition, 2.A.5.c Storage, handling and transport of mineral products and 2.A.6 Other mineral products (Bricks and ceramics and Asphalt production) do not have NOx, SO_2 or NH_3 emissions associated with them, only particulates are projected for these subcategories.

The chemical industry NFR category 2.B is not a dominant industry in Ireland in relation to industrial processes and is not an important source of emissions. The only source of emissions for which estimates are collated are NOx emissions from Nitric Acid Production for the years 1990-2002 after which the plant was closed therefore no emissions are reported for projected years.

2.C Metal production the following subcategories are reported; 2C1 Iron and Steel Production in Ireland has been limited to a single large electric arc furnace installation, which closed in 2001 but was operational throughout the period 1990–2001; 2C2 Ferroalloys Production –Ireland has a single operating facility from 2014 onwards no NOx, SO_2 or NH_3 emissions occur from this facility; 2C3 Aluminium Production – Ireland is an important producer of alumina at one large plant using the Bayer process (extraction of AlO_3 using NaOH). The production of alumina using the Bayer process does not give rise to significant emissions and therefore process emissions are not estimated for this source; 2C5 Lead production – A significant quantity of Lead is mined in Ireland, but such mining is assumed not to be a significant source of emissions to air. Estimates at facility level of Lead emissions have been

obtained from AERs and are reported as NO since 2009 therefore emissions from these categories are not projected.

8.12 Non-Energy Products from Fuels and Non-Energy Products from Fuels and Solvent Use (NFR 2D) and NFR 2H, I, J,K,L

Emissions projections of NMVOCs from solvent use and other products are estimated. Population growth is used to project emissions out to 2030 with the 2019 inventory used as a starting point.

Projected emissions for NFR category 2.H; The 6 subcategories for which emission estimates are made for Ireland are as follows with the relevant SNAP code in parentheses, where applicable: Bread (SNAP 040605), Beer (SNAP 040607), Spirits (SNAP 040608), Meat fish etc. frying/curing (SNAP 040627), Coffee Roasting,Feedstock. These activities do not have NOx, SO_2 or NH_3 emissions associated with them. Emissions projections of NMVOCs are reported for this category.

2.I Wood processing, as stated in the EMEP/EEA 2019 guidebook this source category is only important for particulate emissions.

2.J Production of POPs as stated in the EMEP/EEA 2019 guidebook this source category is not significant, since the contribution to the total national emissions is less than 1 % of the national emissions of any pollutant, these are not occurring in Ireland and projected emissions are not reported for this category.

2K Consumption of POPs and Heavy metals no emissions occur in this subcategory in Ireland and projected emissions are not reported.

2L Other production, consumption, storage, transportation or handling of bulk products category in Ireland's air pollutant inventory includes emissions of PCDD/F and PCBs from leakage from electrical equipment and emissions of PCBs from fragmentisers and shredders, therefore no NOx, SO_2 or NH_3 or $PM_{2.5}$ projected emissions are associated with these activities.

8.13 Agriculture (NFR 3)

The Agriculture sector is the largest source of NH_3 emissions in Ireland. Projected estimates of NH_3 from the Agriculture sector are undertaken using the same methodological approach as the current national inventory.

Two scenarios were developed for agricultural emission projections, a WM scenario and a WAM scenario. Projected activity data (animal numbers, crop areas and fertiliser use) are provided by Teagasc (The Irish Agriculture and Food Development Authority) to the EPA in Q1 2021 in order to prepare agricultural emission projections. This includes proposed national herd, crop areas and fertilizer use to meet the overarching objectives of Food Wise 2025 and more recently the likely impact of Brexit on agricultural output in Ireland.

The FAPRI-Ireland model was used for preparing agricultural forecast data to underpin the emissions projections. This model is linked to the FAPRI world modelling system and so takes account of and contributes to, the projections for prices obtained and quantities traded on the world markets. The activity data assumes that there is an expansion in the value of Irish agriculture over the period to

2025 to meet the targets set out in "Food Wise 2025"[22] published by the Department of Agriculture, Food and the Marine in 2015. The main growth projections set out in this document are as follows:

- Increasing the value of agri-food exports by 85 per cent to €19 billion.
- Increasing the value added in the agri-food, fisheries and wood products sector by 70 per cent to in excess of €13 billion.
- Increasing the value of Primary Production by 65 per cent to almost €10 billion.

The majority of the data supplied to the EPA is disaggregated at the level of that used in inventory estimates.

Under WM scenario dairy cow numbers are projected to increase reflecting the continuing profitability of dairy production in Ireland. Dairy cow numbers in 2030 reach 1.651 million. This represent a 13% increase relative to 2019. In contrast, the continuing low levels of profitability of beef cow production systems is reflected in a projected contraction of beef cow inventories. Beef cow numbers in 2030 are projected to decline to 0.78 million. This represent a 20% decrease relative to 2019. The total cattle herd in 2030 are projected to be 7.1 million. This represent a 3% decrease relative to 2019.

Even though the total cattle population are relatively stable over the projection period, projected growth in dairy cow numbers and contraction in beef cow numbers leads to a change in the composition of the Irish bovine inventory and in the intensity of grassland use. Dairy production systems operate at a higher stocking rate than beef production systems and this higher stocking rate is reflected in higher projected use of nitrogen fertiliser per hectare and in total aggregate nitrogen fertiliser use by the Irish agricultural sector.

Total nitrogen fertiliser use in 2030 is projected to be 384,050 tonnes. This represent a 5% increase relative to 2019.

Irish ewe and total sheep numbers are projected to increase over the period to 2030. By 2030 total Irish sheep numbers are projected to increase to 5.50 m. This represent an 8% increased relative to 2019. This increase reflects the increased profitability of sheep production over the period 2030. The Trade and Cooperation (Brexit) Agreement (TCA) means that while there will be no tariff barriers to UK exports of lamb to EU markets there will be new non-tariff barriers to UK lamb exports to the EU, which will be reflected in relatively buoyant Irish (and EU) lamb prices, due to the reduced competitiveness of UK lamb on the EU market. The total crop land area is projected to contract due to the higher level of profits per hectare in grassland farming (dairying) compared to tillage. By 2030, the total cereal area harvested in Ireland is projected to decrease to 230,000 hectares. This represent an 14% decrease relative to 2019.

The WAM scenario assumes mitigation over the period 2021-2030 attributable to measures that are included in the Teagasc Marginal Abatement Cost Curve[23], and the DAFM led National Climate and Air Roadmap for th Agriculrture Sector to 2030 and Beyond "AgClimatise"[24]. Some of the key measures

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[22] Food Wise 2025. A 10-year vision for Irish agri-industry. Department of Agriculture, Food and the Marine, 2015. https://www.agriculture.gov.ie/foodwise2025/

[23] https://www.teagasc.ie/media/website/publications/2020/NH3-Ammonia-MACC.pdf

[24] https://www.gov.ie/en/publication/07fbe-ag-climatise-a-roadmap-towards-climate-neutrality/

include low emission slurry spreading, use of inhibited urea fertiliser, reduction of crude protein in dairy cow and pig diets and the use of manure amendments.

Projected emissions of NMVOC and $PM_{2.5}$ from manure management are estimated using the same approaches and methodologies as the national inventory. Projected activity data that is utilized for NH_3 emission projections is also used to estimate projected emissions of NMVOC and $PM_{2.5}$ for the Agriculture sector.

8.14 Waste (NFR 5)

Air pollutant emission projections in the form of NO_X, SO_2, NMVOC, NH_3 and $PM_{2.5}$ are estimated for the waste sector. Non-methane volatile organic compounds are estimated from landfill gas production, whilst NO_X, SO_2 and $PM_{2.5}$ emissions are estimated from the incineration of industrial waste and from cremation. NH_3 emissions are estimated from composting. $PM_{2.5}$ emissions are estimated from Solid waste disposal to landfill (5A).

Solid waste disposal to landfill produces significant quantities of landfill gas. Projected landfill gas production is based on greenhouse gas emission estimates for the sector undertaken by the EPA and submitted to the European Commission under Regulation 525/2013. The emission factor utilized in the national inventory of 5.65 gm^{-3} NMVOC/m^3 landfill gas is used in projected emission estimates. Ireland has met all Landfill Directive[25] targets for diversion of biodegradable municipal waste from landfill to date.

The incineration of Industrial waste (5Cb) is highly regulated in Ireland. There are currently only a small number of facilities based in the pharmaceutical and chemical sectors that operate incinerators for the treatment of industrial waste. It is assumed that the quantity of industrial waste incinerated and the emissions of NO_X, SO_2, NMVOC and $PM_{2.5}$ at these facilities will remain constant at the 2019 level for each projected year to 2030.

The practice of Cremation (5C1bv) is less popular in Ireland than in other countries. However, due to the decrease in the number of burial plots available, particularly in larger cities and towns, the number of cremations in Ireland has increased. There are currently five crematoria operating in Ireland. It is assumed that the number of cremations will increase for each projected year to 2030 at the average of the 1999-2019 activity level.

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[25] Council Directive 1999/31/EC on the landfill of waste

Chapter Nine

Adjusted annual national emission inventories

9.1 Introduction

Ireland is a signatory to the Gothenburg Protocol but has not yet ratified it and so is not formally covered by its emission ceilings or the associated adjustment mechanism. However, Ireland had national emissions ceilings for sulphur dioxide (SO_2), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs) and ammonia (NH_3) under the Directive 2001/81/EC (National Emissions Ceilings Directive) for 2010. Furthermore, article 4 of the new National Emissions Ceilings Directive (2016/2284/EU) ensures that the commitments of Directive 2001/81/EC continue to apply until 31st December 2019.

Article 21(2) of Directive (EU) 2016/2284 indicates that Member States may apply Article 5(1) of the Directive in relation to the ceilings in Annex I to Directive 2001/81/EC. Article 5(1) allows Member States to establish adjusted annual national emission inventories where non-compliance with emission ceilings or reduction commitments occur due to applying improved emission inventory methods in accordance with best science. The information provided in this chapter follows the reporting requirements of the adjustment process presented in Article 5 and Part 4 of Annex IV of the Directive (EU) 2016/2284.

Ireland's latest inventory submission estimates emissions of NO_x and NMVOC as presented in Table 9.1. For both NO_x and NMVOC national emission ceilings are exceeded for all years since 2010 and the emission ceiling for NH_3 is exceeded in 2012, 2013, 2015, 2016, 2017, 2018 and 2019. Ireland considers that this has arisen due to several factors including;

- New sources that have been added to the inventory, which were either not known when the NECD (2001/81/EC) ceilings were set, or for which there was no available methodology at the time
- Emission factors and methodologies which have been improved in accordance with best practice, resulting in an increase to the estimated emissions. These revisions were not foreseen when the NECD (2001/81/EC) ceilings were set.

Table 9.1. Summary of National Emissions and the NECD Emission Ceilings

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NOx National Total (kt NO_2)	117.45	104.78	108.24	109.76	108.20	106.19	110.18	108.17	107.95	98.03
NO_x NECD 2010 Ceiling (kt of NO_2)	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
NMVOC (kt)	110.73	107.92	109.13	110.99	108.01	108.54	107.80	114.85	115.09	113.74
NMVOC NECD 2010 Ceiling (kt)	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00

Ireland has undertaken a detailed assessment of the new and revised sources within the national inventory in the context of the requirements outlined in Part 4 of Annex IV in Directive (EU) 2016/2284, and is of the view that several changes to the national inventory should be included in the adjusted annual national emission inventory. The proposed adjustments for NO_x and NMVOC are summarised in the Tables 9.2a and 9.2b below.

The resulting adjusted annual national emission inventories show Ireland to be in compliance with the NMVOC ceiling and the NOx emission ceiling from 2011 onwards.

The justification and quantification of each adjustment application is provided in detail in the following sections and is also summarised in the excel spreadsheet (Annex VII Adjustment summary) that was submitted with the national emission inventory. The established adjusted annual emission inventory outlined here will be subject to a review by the European Commission as outlined in Article 5(6) of Directive (EU) 2016/2284, to assess whether Member States have fulfilled the relevant conditions set out in Article 5(1) and Part 4 of Annex IV. These adjustments were approved in 2018 , 2019 and 2020.

Without the adjustments indicated above, it is estimated that under the With Additional Measures scenario (WAM), Ireland would not reach compliance with the NO_x and NMVOC ceiling before compliance requirements change to emission reduction commitments post 2020.

Table 9.2a. Summary of NOx Adjustments

NFR	Source Sector Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Comments
	NOx Adjustments (kt NO₂)	**-46.581**	**-43.283**	**-44.863**	**-48.328**	**-48.036**	**-47.186**	**-48.302**	**-48.250**	**-49.060**	**-44.289**	
1A3bi	Road transport - Passenger Cars	-2.630	-3.496	-4.259	-5.064	-5.928	-6.459	-7.065	-6.438	-5.802	-4.979	*Current (COPERT5) - Original (COPERT2 EFs x Current Fleet)*
1A3bii	Road transport - Light Duty Vehicles	-0.501	-0.472	-0.483	-0.529	-0.635	-0.647	-0.877	-0.980	-0.517	-0.072	
1A3biii	Road transport - Heavy Duty Vehicles	-5.738	-5.248	-4.771	-4.836	-4.450	-3.300	-2.772	-1.568	-0.368	0.658	
1A3biii	Road transport - Buses	-0.385	-0.296	-0.259	-0.288	-0.350	0.050	0.526	0.628	0.463	0.440	
1A3biv	Road transport - Mopeds & Motorcycles	-0.005	-0.004	-0.003	-0.002	-0.001	0.000	0.002	0.003	0.005	0.006	
1A3c	Rail	-0.665	-0.673	-0.644	-0.641	-0.588	-0.600	-0.611	-0.630	-0.637	-0.667	*"Original EFs" confirmed as being used in 1999 submission*
1A3dii	National Navigation	-2.249	-1.953	-2.064	-2.019	-2.527	-2.492	-2.995	-2.645	-2.925	-3.115	
1A4ai	Commercial Combustion (Stationary)	-0.758	-0.712	-0.740	-0.770	-0.734	-0.748	-0.770	-0.738	-0.772	-0.777	
1A4bi	Residential	-0.469	-0.454	-0.463	-0.534	-0.468	-0.445	-0.369	-0.383	-0.460	-0.298	
1A4ciii	National Fishing	-1.813	-1.502	-1.662	-1.850	-1.762	-1.549	-1.423	-1.685	-2.011	-1.736	
3B1a	Manure management - Dairy cattle	-0.039	-0.039	-0.039	-0.040	-0.040	-0.043	-0.046	-0.059	-0.071	-0.075	*New EF's in 2019 guidebook.*
3B1b	Manure management - Non-dairy cattle	-0.601	-0.591	-0.689	-0.651	-0.595	-0.645	-0.656	-0.681	-0.737	-0.646	
3B2	Manure management - Sheep	-0.047	-0.048	-0.050	-0.050	-0.049	-0.049	-0.049	-0.052	-0.051	-0.050	
3B3	Manure management - Swine	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	
3B4d	Manure management - Goats	-0.002	-0.002	-0.001	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001	
3B4e	Manure management - Horses	-0.039	-0.039	-0.041	-0.037	-0.035	-0.034	-0.034	-0.031	-0.031	-0.030	
3B4f	Manure management - Mules and asses	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.002	-0.002	
3B4gi	Manure management - Laying hens	-0.024	-0.024	-0.029	-0.032	-0.032	-0.036	-0.037	-0.039	-0.040	-0.041	
3B4gii	Manure management - Broilers	-0.077	-0.074	-0.074	-0.069	-0.078	-0.079	-0.079	-0.078	-0.077	-0.083	
3B4giii	Manure management - Turkeys	-0.020	-0.025	-0.028	-0.026	-0.027	-0.028	-0.029	-0.029	-0.032	-0.030	
3B4giv	Manure management - Other poultry	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.005	-0.005	-0.005	-0.005	
3B4h	Manure management - Other animals (please specify in IIR)-solid	-0.012	-0.006	-0.006	-0.006	-0.006	-0.006	-0.005	-0.004	-0.004	-0.003	
3B4h	Manure management - Other animals (please specify in IIR)-slurry	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
3Da1	Inorganic N-fertilizers (includes also urea application)	-13.943	-11.381	-11.409	-13.583	-12.765	-12.695	-13.047	-14.201	-15.717	-14.081	
3Da2a	Animal manure applied to soils	-6.050	-6.009	-6.596	-6.617	-6.355	-6.682	-6.929	-7.167	-7.542	-7.121	
3Da2b	Sewage sludge applied to soils	-0.159	-0.111	-0.131	-0.100	-0.082	-0.090	-0.087	-0.089	-0.085	-0.100	
3Da3	Urine and dung deposited by grazing animals	-10.346	-10.117	-10.411	-10.576	-10.517	-10.599	-10.939	-11.371	-11.640	-11.478	
	Agreed adjustment (kt NO₂)	**-46.581**	**-43.283**	**-44.863**	**-48.328**	**-48.036**	**-47.186**	**-48.302**	**-48.250**	**-49.060**	**-44.289**	*Subtracted from Annex 1 total*

NFR	Source Sector Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Comments
	NOx National Total (kt NO$_2$)	117.448	104.775	108.244	109.764	108.199	107.468	110.176	108.167	107.954	98.031	*All adjustments (agreed and for review)*
	NOx Adjusted Total (kt NO$_2$)	70.867	61.492	63.382	61.436	60.163	60.283	61.875	59.917	58.895	53.743	
	NOx NECD Ceiling (kt NO$_2$)	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	

Table 9.2b. Summary of NMVOC Adjustments

NFR	Source Sector Name	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Comments
	NMVOC Adjustments (kt)	**-54.417**	**-55.295**	**-57.412**	**-59.597**	**-57.587**	**-58.883**	**-61.514**	**-66.861**	**-64.786**	**-67.787**	*Agreed subtracted from Annex 1*
2H2	Food and beverages industry	-12.29	-13.31	-14.69	-16.29	-13.56	-14.38	-15.50	-20.44	-19.284	-22.29	
3B	Manure Management	-37.38	-37.24	-38.04	-38.66	-39.39	-39.90	-41.40	-41.76	-40.817	-40.80	
3De	Cultivated crops	-4.75	-4.74	-4.69	-4.65	-4.63	-4.60	-4.62	-4.66	-4.685	-4.70	*"New" source*
	NMVOC National Total (kt)	110.73	107.92	109.13	110.99	108.01	108.54	109.80	114.85	115.093	113.74	
	NMVOC Adjusted Total (kt)	56.31	52.63	51.72	51.39	50.43	49.66	48.28	47.99	50.307	45.96	
	NMVOC NECD Ceiling (kt)	55.000	55.000	55.000	55.000	55.000	55.000	55.000	55.000	55.000	55.000	

9.2 Meeting the Requirements for an Adjustment

9.2.1 New Emission Sources

Part 4.1.d.i of Annex IV of Directive (EU) 2016/2284 indicates that for new emission source categories, evidence must be provided that:

1. The new source category is acknowledged in scientific literature (and/or the EMEP/EEA Guidebook).
2. The source category was not included in the relevant historic national emissions inventory when the ceilings were set.
3. The emissions from a new source category contribute to the MS not complying with their 2010 emissions ceilings under Directive 2001/81/EC.

All of the new sources identified in this adjustment application are included in the current version of the EMEP/EEA Guidebook, and were not included in the national emissions inventory in 1999 (when the targets contained within Directive 2001/81/EC were set). Tables 9.2a and 9.2b demonstrate that the identified new sources contribute to the exceedance of the NECD emissions ceilings.

As such, it is considered that all of the criteria are met for the new sources that have been identified.

Quantification of the adjustment for each of the new sources is presented in detail in sections 9.3 and 9.4. But the following general approach has been used:

The adjustment for new source has been obtained by multiplying the emission by -1.

9.2.2 Significantly Different Emission Factors

Part 4.1.d.ii of Annex IV of Directive (EU) 2016/2284 indicates that where significantly different emission factors (EFs) are used, the following evidence is required:

1. The original EF, and information on its origin or derivation.
2. Evidence that the original EF was used in determining the emission ceilings when they were set.
3. The updated EF, and information on its origin or derivation.
4. A comparison of the original and updated EFs, demonstrating that the change contributes to a MS being in exceedance.
5. A rationale for deciding whether the changes in EF are significant.

Section 9.3 and 9.4 below present the original and updated EFs and the quantified impact on the emissions estimates of the change. The sources of the EFs are also presented, and the original EFs were all used in the emission inventory in 1999, when the emission ceilings were set.

All of the changes to emission factors that are presented contribute to moving Ireland's national total emissions into compliance. All of changes are therefore considered to be "significant" in the context of attaining compliance with emission ceilings.

In calculating adjustments for revised EFs, it is not necessary to present the current activity data (since this can be derived from the current emission and the current emission factor). In presenting information to quantify the adjustment, the following approach has been used:

Adjustment $=$ $(EF_{Original} \times AD_{Current}) - (E_{Current})$

Given that: $AD_{Current} = E_{Current}/EF_{Current}$

The adjustment can be written:

Adjustment $=$ $(EF_{Original} \times E_{Current}/EF_{Current}) - E_{Current}$

The information provided in the tables for each of the adjustments in the following sections should therefore be sufficient to allow a review of the adjustment quantification.

The final adjustment value has been determined and provided at the individual NFR category level. Where there have been revisions to emission factors for sources within an NFR category, all revisions have been included i.e. both increases and decreases to emission factors have been included. This avoids selectively including only EF revisions which would result in a favourable revision of the national emissions inventory total – a process which is not considered to be appropriate. As a result, the adjustment values that are shown for each NFR category can be considered "net" adjustment values.

9.3 NO$_x$ Adjustment Applications

9.3.1 1A3b Road Transport (NO$_x$)

Justification – Significantly Different EFs

Emission factors for NO$_x$ from road transport were included in the EMEP/CORINAIR Emissions Inventory Guidebook (version 2) in 1999 which were applicable when the emission ceilings were set. However, the EFs used in the current national emissions inventory are higher than these original EFs. Ireland considers that the current NOx EFs for this source are significantly different, as defined by the Directive (EU) 2016/2284 and are eligible for an adjustment

Overall emissions from the different vehicle categories within road transport for the period 2019 to 2018 are;

- passenger cars (1A3bi) are now on average 85.5 per cent higher
- light duty vehicles (1A3bii) are now on average 8.7 per cent higher
- heavy duty vehicles (1A3biii) are now on average 53.6 per cent higher
- buses and coaches (1A3biii) are now on average 1.0 per cent lower (3.9 per cent higher on average in the period 2010-2014)
- mopeds and motorcycles (1A3biv) are now on average 0.6 per cent lower (10.6 per cent higher on average in the period 2010-2014)

Quantification

The adjustment quantification is explained for each mode of road transport in Tables 9.3 to 9.8.

The general approach for quantification is presented in section 9.2.2. In this case the original emission factors are those that were used in the national inventory submission in 1999 and were derived from the COPERT II model using a Tier 3 methodology. The current EFs were derived from the COPERT 5 model using a Tier 3 methodology. The 2021 adjustment application for NO_x submitted under the NECD is based on the same methodology as used for the original approved adjustment application with slight changes to IEFs due to the revisions included in COPERT 5.4.36 in comparison to COPERT 5.3.26 (which was the model version used for the 2020 submission). The adjustment has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.3 Adjustment Quantification for Road Transport-1A3bi Passenger Cars (NO$_x$)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Conventional	0.532	0.560	82.32	63.65	57.91	27.68	23.21	18.14	12.16	6.24	3.70	1.12
	PC Euro 1 - 91/441/EEC	0.466	0.548	481.67	336.05	238.93	82.20	68.95	55.26	36.92	19.17	11.41	4.44
	PC Euro 2 - 94/12/EEC	0.323	0.285	2676.78	2306.30	1884.66	1675.84	1357.61	1057.24	735.74	380.68	238.05	94.42
	PC Euro 3 - 98/69/EC Stage2000	0.208	0.251	3485.91	3552.07	3398.77	3354.03	3115.84	2756.14	2237.79	1168.89	807.08	584.96
	PC Euro 4 - 98/69/EC Stage2005	0.262	0.098	3616.89	3894.11	4124.08	4388.03	4622.38	4468.70	4202.01	3025.68	2678.68	2313.43
	PC Euro 5 - EC 715/2007	0.427	0.121	0.00	772.74	1512.60	2247.75	3276.70	3515.06	3802.10	4142.34	4021.18	3642.68
	PC Euro 6-1 - EC 715/2007	0.370	0.119	0.00	0.00	0.00	0.00	0.00	847.89	2037.65	2915.02	2755.99	2794.98
	PC Euro 6 -2- EC 715/2007	0.053	0.113	0.00	0.00	0.00	0.00	0.00	0.00	0.00	237.54	465.37	758.86
1A3bi Passenger Cars				**10343.57**	**10924.93**	**11216.95**	**11775.53**	**12464.70**	**12718.44**	**13064.36**	**11895.56**	**10981.46**	**10194.90**
									Adjustment (tonnes)				
	Conventional			2.44	1.90	1.73	0.84	0.72	0.56	0.38	0.19	0.11	0.11
	PC Euro 1 - 91/441/EEC			140.84	96.38	66.13	22.91	17.41	14.25	9.89	5.18	3.02	0.78
	PC Euro 2 - 94/12/EEC			-210.00	-195.75	-164.84	-146.37	-106.36	-71.26	-36.32	-8.70	-9.79	-11.22
	PC Euro 3 - 98/69/EC Stage2000			-334.69	-412.45	-462.08	-500.90	-478.05	-385.67	-212.40	127.35	113.71	122.68
	PC Euro 4 - 98/69/EC Stage2005			-2228.27	-2437.49	-2621.02	-2833.83	-3016.64	-2924.71	-2729.27	-1884.03	-1672.01	-1446.74
	PC Euro 5 - EC 715/2007			0.00	-548.63	-1078.85	-1606.25	-2345.04	-2519.72	-2724.58	-2967.02	-2882.12	-2610.83
	PC Euro 6-1 - EC 715/2007			0.00	0.00	0.00	0.00	0.00	-572.10	-1372.85	-1974.61	-1867.30	-1892.12
	PC Euro 6 -2- EC 715/2007			0.00	0.00	0.00	0.00	0.00	0.00	0.00	263.40	512.63	858.71
				-2629.67	**-3496.04**	**-4258.93**	**-5063.59**	**-5927.95**	**-6458.65**	**-7065.15**	**-6438.25**	**-5801.75**	**-4978.63**

Table 9.4 Adjustment Quantification for Road Transport-1A3bii Light Duty Vehicles (NOx)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Conventional	1.315	1.190	121.52	79.86	38.92	28.52	24.95	18.37	8.80	5.59	3.40	1.67
	LD Euro 1 - 93/59/EEC	1.145	0.497	355.56	272.60	218.05	189.48	158.54	117.36	74.28	50.10	31.87	17.54
	LD Euro 2 - 96/69/EEC	1.144	0.298	1367.14	1081.33	862.24	723.32	569.07	445.28	397.73	328.30	246.89	164.42
	LD Euro 3 - 98/69/EC Stage2000	0.951	1.066	2548.66	2208.51	1981.30	1913.77	1786.59	1517.00	1246.03	1047.09	818.29	570.26
	LD Euro 4 - 98/69/EC Stage2005	0.769	0.875	2991.39	2709.27	2542.64	2477.86	2404.60	2130.25	1925.51	1734.93	1514.86	1135.31
	LD Euro 5 - 2008 Standards	1.277	0.876	0.00	493.29	996.17	1472.87	2152.97	2002.84	2226.12	2224.60	2168.58	1763.59
	LD Euro 6-1	1.032	0.876	0.00	0.00	0.00	0.00	0.00	687.53	1744.01	2508.27	2541.79	2193.78
	LD Euro 6-2	0.367	0.876	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	316.31	519.83
				7384.27	**6844.87**	**6639.31**	**6805.82**	**7096.70**	**6918.64**	**7622.48**	**7898.88**	**7642.00**	**6366.42**
1A3bii Light Duty Vehicles								Adjustment (tonnes)					
	Conventional			-11.74	-7.68	-3.74	-2.74	-2.39	-1.76	-0.86	-0.54	-0.32	-0.16
	LD Euro 1 - 93/59/EEC			-201.15	-154.22	-123.37	-107.21	-89.70	-66.38	-42.03	-28.35	-18.03	-9.93
	LD Euro 2 - 96/69/EEC			-1010.81	-799.51	-637.55	-534.84	-420.75	-329.23	-294.08	-242.76	-182.56	-121.58
	LD Euro 3 - 98/69/EC Stage2000			308.94	267.70	240.18	232.01	216.59	183.89	151.04	126.93	99.20	69.13
	LD Euro 4 - 98/69/EC Stage2005			413.80	374.79	351.75	342.79	332.64	294.67	266.36	240.01	209.55	157.04
	LD Euro 5 - 2008 Standards			0.00	-153.46	-310.04	-458.79	-671.69	-625.83	-696.78	-697.09	-680.25	-553.66
	LD Euro 6-1			0.00	0.00	0.00	0.00	0.00	-102.30	-260.58	-378.10	-384.01	-331.99
	LD Euro 6-2			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	439.01	719.62
				-500.95	**-472.39**	**-482.78**	**-528.78**	**-635.30**	**-646.93**	**-876.93**	**-979.89**	**-517.41**	**-71.53**

Table 9.5 Adjustment Quantification for Road Transport-1A3biii Heavy Duty Vehicles (NOx)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Conventional	5.005	7.593	176.38	93.00	56.55	91.39	54.73	37.17	24.95	13.70	9.07	7.87
	HD Euro I - 91/542/EEC Stage I	7.344	5.904	267.74	188.88	145.51	149.46	110.30	67.74	34.04	30.67	17.53	12.25
	HD Euro II - 91/542/EEC Stage II	7.923	4.616	1865.76	1471.01	1170.62	1209.37	1058.39	687.61	600.52	410.39	340.44	194.24
	HD Euro III - 2000 Standards	6.373	3.272	4706.38	4026.86	3582.39	3581.65	3258.33	2666.84	2658.34	2170.01	1675.50	1177.01
	HD Euro IV - 2005 Standards	4.396	2.177	5241.02	5266.76	4976.36	5025.49	4672.76	4128.65	4641.99	4172.41	3662.31	2706.50
	HD Euro V - 2008 Standards	2.513	2.366	0.00	245.43	481.94	770.26	1157.74	1097.04	1358.89	1407.85	1412.57	1164.72
	HD Euro VI	0.184	2.282	0.00	0.00	0.00	0.00	0.00	38.75	106.72	163.98	223.13	241.22
1A3biii Heavy Duty Vehicles				12257.28	11291.94	10413.37	10827.62	10312.26	8723.80	9425.45	8369.00	7340.56	5503.82
				Adjustment (tonnes)									
	Conventional			-15.08	-0.36	1.29	4.85	2.81	2.21	0.21	1.56	0.69	4.07
	HD Euro I - 91/542/EEC Stage I			-51.36	-35.55	-28.70	-28.48	-19.81	-16.72	-6.61	-5.98	-3.55	-2.40
	HD Euro II - 91/542/EEC Stage II			-788.33	-612.69	-488.65	-512.89	-440.38	-283.69	-249.98	-169.25	-140.27	-81.08
	HD Euro III - 2000 Standards			-2293.90	-1956.53	-1739.95	-1741.22	-1584.16	-1300.48	-1294.54	-1054.59	-816.32	-572.74
	HD Euro IV - 2005 Standards			-2589.20	-2623.72	-2478.00	-2503.27	-2329.61	-2064.45	-2329.57	-2095.85	-1843.93	-1365.94
	HD Euro V - 2008 Standards			0.00	-19.52	-37.14	-55.11	-78.83	-69.83	-87.24	-88.49	-86.27	-67.89
	HD Euro VI			0.00	0.00	0.00	0.00	0.00	432.90	1196.09	1844.19	2521.80	2744.30
				-5737.87	-5248.37	-4771.15	-4836.12	-4450.00	-3300.06	-2771.65	-1568.41	-367.86	658.33

Table 9.6 Adjustment Quantification for Road Transport-1A3biii Heavy Duty Vehicles, Buses (NO$_x$)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1A3biii Heavy Duty Vehicles (Buses)	Conventional	13.993	10.595	389.04	317.04	260.52	286.81	387.80	62.13	16.65	10.37	10.61	9.14
	HD Euro I - 91/542/EEC Stage I	8.578	7.417	781.42	702.36	565.44	502.72	492.97	208.98	65.37	55.52	14.25	12.66
	HD Euro II - 91/542/EEC Stage II	7.730	11.652	3413.13	3110.74	2970.04	2851.75	2776.39	2404.04	2297.00	2252.04	1741.51	1090.82
	HD Euro III - 2000 Standards	6.299	3.271	3073.64	2690.09	2548.78	2476.21	2453.37	2174.86	2295.12	2301.70	2302.96	2250.11
	HD Euro IV - 2005 Standards	4.368	3.286	1425.79	1331.55	1325.18	1425.70	1610.97	1557.43	1708.89	1721.92	1779.93	1410.25
	HD Euro V - 2008 Standards	3.783	3.606	91.59	148.61	296.69	425.38	430.49	411.54	547.02	554.35	639.79	440.23
	HD Euro VI	0.295	3.365	0.00	0.00	0.00	0.00	0.00	26.33	87.81	90.20	106.60	129.05
				9174.60	**8300.38**	**7966.65**	**7968.57**	**8151.99**	**6845.31**	**7017.85**	**6986.10**	**6595.64**	**5342.25**
								Adjustment (tonnes)					
	Conventional			-8.17	-7.97	-6.92	-4.26	-1.04	-2.35	-4.04	-2.52	-2.58	-2.22
	HD Euro I - 91/542/EEC Stage I			-160.89	-144.34	-115.92	-103.05	-101.11	-43.29	-12.22	-10.92	-1.93	-1.71
	HD Euro II - 91/542/EEC Stage II			1500.41	1386.72	1354.58	1345.52	1340.24	1221.30	1175.02	1197.67	911.49	553.55
	HD Euro III - 2000 Standards			-1403.78	-1230.72	-1173.07	-1154.95	-1156.60	-1043.71	-1095.45	-1097.52	-1099.10	-1081.80
	HD Euro IV - 2005 Standards			-312.38	-295.87	-300.90	-340.60	-401.38	-399.56	-435.50	-433.09	-452.13	-349.16
	HD Euro V - 2008 Standards			-0.53	-3.60	-16.93	-30.40	-30.29	-18.76	-35.58	-32.68	-48.77	-20.59
	HD Euro VI			0.00	0.00	0.00	0.00	0.00	335.93	933.32	1007.06	1155.69	1341.72
				-385.35	**-295.78**	**-259.16**	**-287.74**	**-350.18**	**49.57**	**525.55**	**628.00**	**462.68**	**439.79**

Table 9.7 Adjustment Quantification for Road Transport-1A3biv Mopeds and Motorcycles (NOₓ)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Conventional	0.052	0.041	0.12	0.09	0.07	0.06	0.05	0.04	0.04	0.04	0.03	0.02
	Mop - Euro I	0.184	0.116	0.56	0.46	0.40	0.35	0.32	0.29	0.29	0.28	0.21	0.19
	Mop - Euro II	0.157	0.083	0.30	0.25	0.22	0.20	0.17	0.16	0.17	0.18	0.15	0.14
	Mop - Euro III	0.272	0.195	0.60	0.58	0.55	0.53	0.54	0.56	0.66	0.69	0.75	0.75
	Conventional	0.197	0.113	11.67	10.07	8.29	7.84	6.89	6.22	5.90	5.46	4.45	4.09
	Mot - Euro I	0.353	0.221	15.01	13.59	12.18	11.73	11.36	10.72	11.10	10.59	9.16	8.86
	Mot - Euro II	0.155	0.221	4.36	4.03	3.59	3.52	3.20	3.17	3.41	3.56	3.29	3.34
	Mot - Euro III	0.065	0.221	2.01	2.15	2.08	2.23	2.39	2.61	3.16	3.28	4.02	4.29
				34.63	31.22	27.39	26.45	24.93	23.78	24.72	24.07	22.07	21.69
1A3biv Mopeds and Motorcycles				Adjustment (tonnes)									
	Conventional			-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
	Mop - Euro I			-0.21	-0.17	-0.15	-0.13	-0.12	-0.11	-0.11	-0.10	-0.08	-0.07
	Mop - Euro II			-0.14	-0.12	-0.10	-0.09	-0.08	-0.08	-0.08	-0.08	-0.07	-0.07
	Mop - Euro III			-0.17	-0.17	-0.16	-0.15	-0.15	-0.16	-0.19	-0.19	-0.21	-0.21
	Conventional			-5.52	-4.73	-3.87	-3.67	-3.21	-2.87	-2.68	-2.45	-1.93	-1.74
	Mot - Euro I			-5.68	-5.14	-4.60	-4.41	-4.27	-4.02	-4.16	-3.97	-3.43	-3.31
	Mot - Euro II			1.50	1.44	1.31	1.35	1.26	1.28	1.39	1.46	1.38	1.42
	Mot - Euro III			4.83	5.15	5.00	5.35	5.75	6.26	7.58	7.88	9.65	10.29
				-5.41	-3.76	-2.58	-1.76	-0.82	0.29	1.76	2.53	5.31	6.31

Table 9.8 Adjustment Quantification for Road Transport-1A3b Road Transport (NO$_X$)

Activity (NFR)	Activity technology	Emission Factors		Current NOx emission (tonnes)									
		Current EF (g/km)	"Original" EF (g/km)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1A3b Road Transport	1A3bi Passenger Cars			10343.57	10924.93	11216.95	11775.53	12464.70	12718.44	13064.36	11895.56	10981.46	10194.90
	1A3bii Light Duty Vehicles			7384.27	6844.87	6639.31	6805.82	7096.70	6918.64	7622.48	7898.88	7642.00	6366.42
	1A3biii Heavy Duty Vehicles and buses			21431.88	19592.33	18380.02	18796.19	18464.25	15569.12	16443.30	15355.10	13936.20	10846.07
	1A3biv Mopeds and Motorcycles			34.63	31.22	27.39	26.45	24.93	23.78	24.72	24.07	22.07	21.69
				39194.35	**37393.35**	**36263.67**	**37404.00**	**38050.58**	**35229.98**	**37154.86**	**35173.60**	**32581.73**	**27429.07**
				Adjustment (tonnes)									
	1A3bi Passenger Cars			-2629.67	-3496.04	-4258.93	-5063.59	-5927.95	-6458.65	-7065.15	-6438.25	-5801.75	-4978.63
	1A3bii Light Duty Vehicles			-500.95	-472.39	-482.78	-528.78	-635.30	-646.93	-876.93	-979.89	-517.41	-71.53
	1A3biii Heavy Duty Vehicles and buses			-6123.22	-5544.15	-5030.30	-5123.87	-4800.18	-3250.49	-2246.10	-940.41	94.82	1098.12
	1A3biv Mopeds and Motorcycles			-5.41	-3.76	-2.58	-1.76	-0.82	0.29	1.76	2.53	5.31	6.31
				-9259.26	**-9516.34**	**-9774.59**	**-10717.99**	**-11364.25**	**-10355.79**	**-10186.42**	**-8356.02**	**-6219.04**	**-3945.73**

9.3.2 1A3c Railways (NO$_x$)

Justification – Significantly Different EFs

Emission factors for NO$_x$ from Railways (1A3c) were included in the EMEP/CORINAIR Emissions Inventory Guidebook (version 2) in 1999 which were applicable when the emission ceilings were set. Ireland used an EF from the "Handbook of Emission Factors, Non Industrial Sources", (Ministry of Health and Environmental Protection, The Netherlands, 1980) in the emission inventory when the emissions ceilings were set. However, the EF used in the current national emissions inventory is higher than this original EF. Ireland considers that the current NOx EF for this source is significantly different, as defined by the Directive (EU) 2016/2284 and is eligible for an adjustment.

The current EF for NOx is 49% higher than the original EF.

Quantification

The adjustment quantification is explained in Table 9.9.

The general approach for quantification is presented in section 9.2.2. The original EF for railways (1A3c) is from the "Handbook of Emission Factors, Non Industrial Sources", (Ministry of Health and Environmental Protection, The Netherlands, 1980). Tables 53, 55 and 57 on pages 80-81 refer to diesel locomotives for freight and passenger trains and for shunting locomotives and show an EF for NOx of 35g/kg of fuel or 808.2 kg/TJ (NCV of Gasoil, 43.31 MJ/kg). This EF is rounded up in the original inventory to 810 kg/TJ.

Ireland now uses the EF from the Inventory Guidebook (EMEP\EEA, 2016) to replace the above referenced EF which was published in 1980. The 2021 adjustment application for NO$_x$ submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.9. Adjustment Quantification for Railways (NO$_x$)

Activity (Fuel)	Emission Factors		Current NO$_x$ emissions (tonnes)									
	Current EF (kg/TJ)	"Original" EF (kg/TJ)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoil/ Diesel	1,209.93	810	2,013.1	2,034.8	1,948.4	1,940.3	1,780.0	1,814.1	1,847.5	1,907.2	1,927.2	2,016.7
			Adjustments (tonnes)									
Gasoil/ Diesel			-665.39	-672.60	-644.03	-641.36	-588.36	-599.62	-610.68	-630.40	-637.01	--666.59
			Total Adjustment (ktonnes)									
Railways			-0.67	-0.67	-0.64	-0.64	-0.59	-0.60	-0.61	-0.63	-0.64	-0.67

9.3.3 1A3dii National Navigation (NO$_x$)

Justification – Significantly Different EFs

Emission factors for NO$_x$ from National Navigation (1A3dii) were included in the EMEP/CORINAIR Emissions Inventory Guidebook (version 2) in 1999 when the emission ceilings were set. Ireland used an EF for shipping from the "Handbook of Emission Factors, Non Industrial Sources", (Ministry of Health and Environmental Protection, The Netherlands, 1980) in the emission inventory when the emissions ceilings were set. However, the EF used in the current national emission inventory is higher

than this original EF. Ireland considers that the current NOx EF for this source is significantly different, as defined by the Directive (EU) 2016/2284 and is eligible for an adjustment.

The current EF for NOx is 85 percent higher than the original EF.

Quantification

The adjustment quantification is explained in the Table 9.10.

The general approach for quantification is presented in section 9.2.2. The original EF for shipping/navigation (1A3dii) is from the "Handbook of Emission Factors, Non Industrial Sources", (Ministry of Health and Environmental Protection, The Netherlands, 1980). Table 66 on page 91 refer to sea-going vessels and show an EF for NOx ranging from 35g/kg of fuel to 44 g/kg fuel depending on the percentage power in use. This would equate to an EF for NOx between 808.2 kg/TJ to 1015.9 kg/TJ (NCV of Gasoil, 43.31 MJ/kg).

Ireland now uses the EF from the Inventory Guidebook (EMEP\EEA, 2016) to replace the above referenced EF which was published in 1980. The 2021 adjustment application for NO_x submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.10. Adjustment Quantification for National Navigation (NO$_x$)

Activity (Fuel)	Emission Factors		Current NO$_x$ emissions (tonnes)									
	Current EF	"Original" EF	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	(kg/TJ)	(kg/TJ)										
Gasoil / Diesel	1,812.59	980	4,897.1	4,251.3	4,492.8	4,394.6	5,501.4	5,426.1	6,520.5	5,757.6	6,368.2	6,782.4
			Adjustments (tonnes)									
Gasoil/Diesel			-2249.4	-1952.8	-2063.7	-2018.6	-2527.0	-2492.4	-2995.1	-2644.7	-2925.1	-3115.4
			Total Adjustment (ktonnes)									
National Navigation			-2.25	-1.95	-2.06	-2.02	-2.53	-2.49	-3.00	-2.64	-2.93	-3.12

9.3.4 1A4ai Commercial/Institutional Stationary Combustion (NO$_x$)

Justification – Significantly Different EFs

Emission factors for NO$_x$ from Commercial/Institutional stationary combustion (1A4ai) are included in the EMEP/CORINAIR Emissions Inventory Guidebook (version 2) in 1999 when the emission ceilings were set. Ireland used EFs for combustion in commercial from Table 3.4 page 16 of "Corinair 1990 Emission Inventory for Ireland" report published by the Environmental Research Unit in July 1993. These EFs can also be referenced as Table 2.2 of "Corinair Technical annexes Volume 2, Default emission factors handbook" published by the European Commission in 1994. However, the EFs used in the current national emission inventory are higher than these original EFs. Ireland considers that

the current NOx EFs for these sources are significantly different, as defined by the Directive (EU) 2016/2284 and are eligible for an adjustment.

The current EFs for each fuel for this source;

- Fuel oil is 16.6 percent lower
- LPG is 16.7 percent lower
- Gasoil is 100 percent higher
- Natural Gas is 48 percent higher
- Biomass is 82 percent higher
- Biogas is 48 percent higher

than the original EFs.

Quantification

The adjustment quantification is explained in Table 9.11.

The general approach for quantification is presented in section 9.2.2. The original EFs for combustion in commercial (1A4ai) are from Table 3.4 page 16 of "Corinair 1990 Emission Inventory for Ireland" report published by the Environmental Research Unit in July 1993. These EFs can also be referenced in Table 2.2 of "Corinair Technical annexes Volume 2, Default emission factors handbook" published by the European Commission in 1994. There are additional older references also available if needed.

Ireland now uses the EFs from the Inventory Guidebook (EMEP\EEA, 2016) to replace the above referenced EFs which were published in 1987, 1993 and 1994. The 2020 adjustment application for NO_x submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018 and 2019.

Table 9.11. Adjustment Quantification for Commercial/Institutional Stationary Combustion (NO_x)

Activity (Fuel)	Emission Factors		Current NOx emissions (tonnes)									
	Current EF (kg/TJ)	"Original" EF (kg/TJ)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Oil	100	120	28.22	23.05	19.05	17.11	14.54	13.11	5.89	5.22	2.69	0.88
LPG	74	50	240.32	234.47	225.95	261.46	211.42	225.23	199.85	201.11	216.01	221.11
Gasoil / Diesel	100	50	606.27	506.53	470.74	530.13	522.44	519.31	541.99	474.62	500.35	500.89
Natural Gas	74	50	1,104.89	1,105.15	1,228.44	1,159.40	1,092.27	1,183.87	1,190.84	1,211.37	1,275.89	1,302.24
Biomass	91	50	45.79	54.03	72.82	95.58	106.01	63.59	94.22	80.21	68.55	53.37
Biogas	74	50	11.87	13.08	12.12	13.78	16.03	16.92	21.48	23.49	23.37	25.67
			Adjustments (tonnes)									
Fuel Oil			5.64	4.61	3.81	3.42	2.91	2.62	1.18	1.04	0.54	0.18
LPG			-77.94	-76.04	-73.28	-84.80	-68.57	-73.05	-64.82	-65.23	-70.06	-71.71
Gasoil / Diesel			-303.13	-253.26	-235.37	-265.06	-261.22	-259.65	-270.99	-237.31	-250.18	-250.44
Natural Gas			-358.34	-358.43	-398.41	-376.02	-354.25	-383.96	-386.22	-392.88	-413.80	-422.35
Biomass			-20.63	-24.34	-32.81	-43.06	-47.76	-28.65	-42.45	-36.14	-30.89	-24.04
Biogas			-3.85	-4.24	-3.93	-4.47	-5.20	-5.49	-6.97	-7.62	-7.58	-8.32
			Total Adjustment (ktonnes)									
Comm/Instit Stationary Combustion			-0.76	-0.71	-0.74	-0.77	-0.73	-0.75	-0.77	-0.74	-0.77	-0.78

9.3.5 1A4bi Residential Stationary Combustion (NO$_x$)

Justification – Significantly Different EFs

Emission factors for NO$_x$ from Residential stationary combustion (1A4bi) were included in the EMEP/CORINAIR Emissions Inventory Guidebook (version 2) in 1999 when the emission ceilings were set. Ireland used EFs for combustion in residential from Table 3.4 page 16 of "Corinair 1990 Emission Inventory for Ireland" report published by the Environmental Research Unit in July 1993. These EFs can also be referenced as Table 2.2 of "Corinair Technical annexes Volume 2, Default emission factors handbook" published by the European Commission in 1994. However, the EFs used in the current national emission inventory are generally higher than these original EFs. Ireland considers that the current NOx EFs for these sources are significantly different, as defined by the Directive (EU) 2016/2284 and are eligible for an adjustment.

The current EFs for each fuel for this source;

- Bituminous coal and Anthracite are 120 percent higher
- Lignite, sod peat and peat briquettes are 10 percent higher
- Kerosene and Gasoil are 2 percent higher
- Petroleum coke is 49 percent lower
- Natural Gas and LPG are 16 percent lower
- Biomass is 20 percent lower

than the original EFs.

Quantification

The adjustment quantification is explained in Table 9.12.

The general approach for quantification is presented in section 9.2.2. The original EFs for stationary combustion (1A4bi) in the residential sector are from Table 3.4 page 16 of "Corinair 1990 Emission Inventory for Ireland" report published by the Environmental Research Unit in July 1993. These EFs can also be referenced in Table 2.2 of "Corinair Technical annexes Volume 2, Default emission factors handbook" published by the European Commission in 1994. There are additional older references also available if needed.

Ireland now uses the EFs from the Inventory Guidebook (EMEP/EEA, 2016) to replace the above referenced EFs which were published in 1987, 1993 and 1994, respectively. The 2021 adjustment application for NO$_x$ submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.12. Adjustment Quantification for Residential Stationary Combustion (NOx)

Activity (Fuel)	Emission Factors		Current NOx emissions (tonnes)									
	Current EF (kg/TJ)	"Original" EF (kg/TJ)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Bituminous Coal	110.00	50.00	815.92	696.48	757.39	794.80	610.42	577.41	460.91	337.85	387.77	273.93
Anthracite[1]	110.00	50.00	306.56	310.39	333.00	442.09	470.53	467.78	451.83	589.63	706.06	508.12
Lignite	110.00	100.00	47.81	48.38	54.87	79.68	58.36	58.22	43.73	40.92	35.90	24.82
Sod Peat	110.00	100.00	761.99	749.14	588.14	588.14	588.14	588.14	588.14	588.14	588.14	588.14
Briquettes	110.00	100.00	405.68	362.01	399.88	415.41	332.81	335.73	318.62	279.21	317.02	256.94
Kerosene	51.00	50.00	2,263.68	1,764.23	1,479.15	1,511.38	1,430.70	1,668.98	1,756.09	1,665.00	1,843.59	1,766.27
LPG	42.00	50.00	65.67	60.27	58.13	70.41	63.25	64.20	84.89	83.99	94.68	87.96
Gasoil / Diesel	51.00	50.00	1,000.79	1,035.82	954.22	695.47	492.32	481.35	495.50	578.45	606.59	607.64
Petroleum Coke	51.00	100.00	28.36	18.49	21.14	23.36	18.07	13.89	11.75	8.07	7.50	4.36
Natural Gas	42.00	50.00	1,248.03	1,001.04	1,055.94	1,066.00	941.96	976.14	989.99	976.82	1,062.27	1,039.88
Biomass[2]	50.00	100.00	29.23	27.78	30.24	32.90	29.14	28.55	26.21	25.72	28.47	23.06
			6,973.72	6,074.04	5,732.11	5,719.65	5,035.70	5,260.39	5,227.65	5,173.80	5,677.99	5,181.11
			Adjustments (tonnes)									
Bituminous Coal			-445.05	-379.90	-413.12	-433.53	-332.96	-314.95	-251.41	-184.28	-211.51	-149.42
Anthracite[1]			-167.22	-169.30	-181.64	-241.14	-256.66	-255.15	-246.45	-321.62	-385.13	-277.15
Lignite			-4.35	-4.40	-4.99	-7.24	-5.31	-5.29	-3.98	-3.72	-3.26	-2.26
Sod Peat			-69.27	-68.10	-53.47	-53.47	-53.47	-53.47	-53.47	-53.47	-53.47	-53.47
Briquettes			-36.88	-32.91	-36.35	-37.76	-30.26	-30.52	-28.97	-25.38	-28.82	-23.36
Kerosene			-44.39	-34.59	-29.00	-29.63	-28.05	-32.73	-34.43	-32.65	-36.15	-34.63
LPG			12.51	11.48	11.07	13.41	12.05	12.23	16.17	16.00	18.03	16.75
Gasoil / Diesel			-19.62	-20.31	-18.71	-13.64	-9.65	-9.44	-9.72	-11.34	-11.89	-11.91
Petroleum Coke			27.25	17.77	20.31	22.44	17.36	13.34	11.29	7.75	7.20	4.19
Natural Gas			237.72	190.68	201.13	203.05	179.42	185.93	188.57	186.06	202.34	198.07
Biomass[2]			39.92	35.50	41.43	43.85	39.68	45.09	43.17	39.49	42.70	34.84
			-469.370	-454.088	-463.339	-533.665	-467.837	-444.948	-369.216	-383.155	-459.962	-298.346
			Total Adjustment (ktonnes)									
Residential Stationary Combustion			**-0.47**	**-0.45**	**-0.46**	**-0.53**	**-0.47**	**-0.44**	**-0.37**	**-0.38**	**-0.46**	**-0.30**

[1] Includes Manufactured Ovoids,

[2] Biomass has a T2 method applied except to residential stoves and fireplaces for nontraded wood with EF 80kg/TJ

9.3.6 1A4ciii National Fishing (NO$_x$)

Justification – A New Source/Significantly Different EFs

Activity data to estimate emission of NO$_x$ from National Fishing (1A4ciii) did not exist in Ireland's national energy balance until 2012, when they were first introduced for the 1990-2010 energy balance. Marine diesel used in National Fishing is now included in the energy balance for all years from 1990 to 2019.

For a new source, Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria are met, and it is therefore concluded that NO$_x$ emissions from national fishing (1A4ciii) are a new source and are eligible for an adjustment.

The fuel allocated to National Fishing (1A4ciii) since 2012 did not increase the overall gasoil/diesel use in the energy balance estimates, as the fuel was re-allocated from the category Commercial/Institutional (1A4ai) stationary combustion. So while National Fishing is in effect a new source introduced in 2012, to avoid double counting it is more appropriate that an adjustment is considered on the basis of significantly different EFs.

Quantification

The adjustment quantification is explained in the table 9.13 below.

The general approach for quantification is presented in section 9.2.2. Ireland used EFs for stationary combustion in the commercial/Institutional category (1A4ai) from Table 3.4 page 16 of "Corinair 1990 Emission Inventory for Ireland" report published by the Environmental Research Unit in July 1993. These EFs can also be referenced in Table 2.2 of "Corinair Technical annexes Volume 2, Default emission factors handbook" published by the European Commission in 1994.

Ireland now uses an EF for NO$_x$ for National Fishing from the 2019 version of the EMEP/EEA Emissions Inventory Guidebook and is used to estimate emissions of NO$_x$ for all years from 1990 to 2019 in the current inventory submission.

Table 9.13. Adjustment Quantification for National Fishing (NO$_x$)

Activity (Fuel)	Emission Factors		Current NO$_x$ emissions (tonnes)									
	Current EF (kg/TJ)	"Original" EF (kg/TJ)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoil/Diesel	1,812.59	50.00	1864.2	1544.1	1709.4	1902.1	1812.3	1593.3	1463.1	1732.5	2068.0	1785.5
			Adjustments (tonnes)									
Gasoil/Diesel			-1812.8	-1501.5	-1662.2	-1849.6	-1762.3	-1549.4	-1422.7	-1684.7	-2010.9	-1736.3
			Total Adjustment (ktonnes)									
National Fishing			-1.86	-1.54	-1.71	-1.90	-1.81	-1.59	-1.46	-1.73	-2.07	-1.79

The current EF for gasoil for this source is 3525% higher than the original EF. The 2021 adjustment application for NO$_x$ submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

9.3.7 3B1a-3B4h Manure Management (NO$_x$)

Justification – New emission source

Emissions of NO$_x$ from Manure Management were not included in Ireland's national emissions inventory in 1999, when the ceilings were set. This sector is to be considered as a new source compared to when the emission ceilings were set, since default methodologies and emission factors were not available in the EMEP/EEA Guidebook until the 2009 edition. A methodology is presented in the 2019 EMEP/EEA Guidebook, and this is currently used to estimate emissions that are included in the Irish national emissions inventory.

For a new source, the Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria are met, and it is therefore concluded that NO$_x$ emissions from manure management are a new source and are eligible for an adjustment.

Quantification

Emissions have been calculated by using the Tier 2 mass-flow methodology for NH$_3$ and the default emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019), Chapter 3. B Manure Management Table 3-10. As a new source, quantification of the adjustment is achieved by subtracting the emissions from the national inventory total as shown in Table 9.14.

Table 9.14. Adjustments for Manure Management (NO$_x$)

Source Sector	Adjustments (ktonnes)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Manure Management – 3B1a Dairy cattle	-0.039	-0.039	-0.039	-0.040	-0.040	-0.043	-0.046	-0.059	-0.071	-0.075
Manure Management – 3B1b Non-dairy cattle	-0.601	-0.591	-0.689	-0.651	-0.595	-0.645	-0.656	-0.681	-0.737	-0.646
Manure Management – 3B2 Sheep	-0.047	-0.048	-0.050	-0.050	-0.049	-0.049	-0.049	-0.052	-0.051	-0.050
Manure Management – 3B3 Swine	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Manure Management – 3B4d Goats	-0.002	-0.002	-0.001	-0.001	-0.001	-0.002	-0.001	-0.001	-0.001	-0.001
Manure Management – 3B4e Horses	-0.039	-0.039	-0.041	-0.037	-0.035	-0.034	-0.034	-0.031	-0.031	-0.030
Manure Management – 3B4f Mules and asses	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.002	-0.002
Manure Management - 3B4gi Laying hens	-0.024	-0.024	-0.029	-0.032	-0.032	-0.036	-0.037	-0.039	-0.040	-0.041
Manure Management - 3B4gii Broilers	-0.077	-0.074	-0.074	-0.069	-0.078	-0.079	-0.079	-0.078	-0.077	-0.083
Manure Management - 3B4giii Turkeys	-0.020	-0.025	-0.028	-0.026	-0.027	-0.028	-0.029	-0.029	-0.032	-0.030
Manure Management - 3B4giv Other poultry	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.005	-0.005	-0.005	-0.005
Manure Management – 3B4h Other animals (solid)	-0.012	-0.006	-0.006	-0.006	-0.006	-0.006	-0.005	-0.004	-0.004	-0.003
Manure Management – 3B4h Other animals (slurry)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total Adjustment – 3B Manure Management	**-0.868**	**-0.856**	**-0.967**	**-0.920**	**-0.873**	**-0.930**	**-0.945**	**-0.985**	**-1.052**	**-0.968**

9.3.8 3D Fertilisers applied to soils (NO$_X$)

Justification – New Emission source

Emissions from fertiliser applied to soils were not included in Ireland's national emissions inventory in 1999, when the ceilings were set. This sector is to be considered as a new source compared to when the emission ceilings were set. A methodology is presented in the 2019 EMEP/EEA Guidebook, and this is currently used to estimate emissions that are included in the Irish national emissions inventory.

For a new source, the Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria are met, and it is therefore concluded that NO$_x$ emissions from fertiliser applied to soils are a new source and are eligible for an adjustment.

Quantification

Emissions for 3Da1 (Inorganic N-fertilizers including urea application), 3D2a (Animal manure applied to soils), 3Da2b (Sewage sludge applied to soils) and 3Da3 (Urine and Dung deposited by grazing animals) have been calculated by using the Tier 1 methodology and emission factors presented in the Inventory Guidebook (EMEP/EEA, 2019), Chapter 3. D Crop production and agricultural soils Table 3-1. as shown in table 9.15.

Table 9.15. Adjustments for Fertilser applied to soils (NO$_X$)

Source Sector	Adjustments (ktonnes)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Inorganic N-fertilizers (includes also urea application)-3Da1	-13.94	-11.38	-11.41	-13.58	-12.77	-12.69	-13.05	-14.20	-15.72	-14.08
Animal manure applied to soils 3Da2a	-6.05	-6.01	-6.60	-6.62	-6.36	-6.68	-6.93	-7.17	-7.54	-7.12
Sewage sludge applied to soils 3Da2b	-0.16	-0.11	-0.13	-0.10	-0.08	-0.09	-0.09	-0.09	-0.08	-0.10
Urine and dung deposited by grazing animals -3Da3	-10.35	-10.12	-10.41	-10.58	-10.52	-10.60	-10.94	-11.37	-11.64	-11.48
Total Adjustment − 3D Fertiliser application	-30.50	-27.62	-28.55	-30.88	-29.72	-30.07	-31.00	-32.83	-34.98	-32.78

9.4 NMVOC Adjustment Applications

9.4.1 Food and Beverage Industry, 2H2: Spirits (NMVOC)

Justification - A New Source

NMVOC emissions from the food and beverage industry were not included in Ireland's national emissions inventory in 1999, when the ceilings were set. A methodology is presented in the 2019 EMEP/EEA Guidebook, and this is currently used to estimate emissions that are included in the Irish national emissions inventory.

For a new source, the Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria were not met, however paragraph 2 bis (a) (i) of Decision 2012/12 (as amended by ECE.EB.AIR/127/Add.1 (2014/1)), indicates that a new source is eligible for an adjustment for a new source if a methodology

existed in the relevant version of the EMEP/EEA Guidebook, but the "Party can demonstrate that it was unable to apply this methodology due to a lack of relevant national statistical data...". The national data for spirit manufacture was confidential and was therefore not available when the ceilings were set. It was therefore concluded that NMVOC emissions from the food and beverage industry are a new source and are eligible for an adjustment.

Quantification

Emissions have been calculated by using the Tier 2 methodologies presented in the Inventory Guidebook (EMEP/EEA, 2016), with EFs taken from Chapter 2H2, Table 3-28

As a new source, quantification of the adjustment is achieved by subtracting the emissions from the national inventory total as shown in Table 9.16. The 2021 adjustment application for NMVOC submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.16. Adjustments for emissions from the Food and Beverage Industry (NMVOC)

Source Sector	Adjustments (ktonnes)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Food and Beverages industry: Spirits	-12.29	-13.31	-14.69	-16.29	-13.56	-14.38	-15.50	-20.44	-19.28	-22.29

9.4.2 Manure Management, 3B (NMVOC)

Justification - A New Source

NMVOC emissions from manure management were not included in Ireland's national emissions inventory in 1999, when the ceilings were set. Emission factors and methodological approaches were included for the first time in the 2013 edition of the Inventory Guidebook. A methodology is presented in the 2019 EMEP/EEA Guidebook, and this is currently used to estimate emissions that are included in the Irish national emissions inventory.

For a new source, the Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria are met, and it is therefore concluded that NMVOC emissions from manure management are a new source and are eligible for an adjustment.

Quantification

Emissions have been calculated by using the methodology presented in the Inventory Guidebook (EMEP/EEA, 2019), Chapter 3B, Section 3.4 using a Tier 2 approach. Estimates are undertaken for each livestock type. Animal population data are combined with data on time spent in housing or at pasture combined with EFs from the Inventory Guidebook (EMEP/EEA, 2019) to give NMVOC emission estimates from housing, storage and application for each livestock type.

As a new source, quantification of the adjustment is achieved by subtracting the emissions from the national inventory total as shown in Table 9.17. The 2021 adjustment application for NMVOC submitted under the NECD is based on the same methodology as used for the original approved adjustment application which has been reviewed and approved by the EC in 2017, 2018, 2019 and 2020.

Table 9.17. Adjustments from Manure Management (NMVOC)

Source Sector	Adjustments (ktonnes)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Manure Management – 3B1a Dairy cattle	-7.92	-8.38	-8.16	-8.13	-8.85	-9.75	-10.20	-10.49	-10.22	-10.75
Manure Management – 3B1b Non-dairy cattle	-23.67	-22.95	-23.79	-24.59	-24.38	-23.98	-24.91	-24.95	-24.26	-23.63
Manure Management – 3B2 Sheep	-0.31	-0.32	-0.35	-0.35	-0.36	-0.35	-0.35	-0.37	-0.37	-0.36
Manure Management – 3B3 Swine	-2.71	-2.77	-2.74	-2.69	-2.73	-2.69	-2.79	-2.84	-2.85	-2.89
Manure Management – 3B4d Goats	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manure Management – 3B4e Horses	-0.20	-0.20	-0.20	-0.19	-0.18	-0.17	-0.17	-0.16	-0.16	-0.15
Manure Management – 3B4f Mules and asses	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Manure Management - 3B4gi Laying hens	-0.35	-0.35	-0.43	-0.47	-0.48	-0.54	-0.55	-0.57	-0.59	-0.60
Manure Management - 3B4gii Broilers	-1.29	-1.24	-1.24	-1.16	-1.31	-1.32	-1.33	-1.31	-1.30	-1.39
Manure Management - 3B4giii Turkeys	-0.43	-0.53	-0.60	-0.55	-0.58	-0.60	-0.62	-0.62	-0.67	-0.64
Manure Management - 3B4giv Other poultry	-0.14	-0.14	-0.14	-0.13	-0.14	-0.15	-0.16	-0.16	-0.16	-0.16
Manure Management – 3B4h Other animals	-0.36	-0.36	-0.38	-0.38	-0.38	-0.35	-0.31	-0.27	-0.23	-0.23
Total Adjustment – 3B Manure Management	**-37.38**	**-37.24**	**-38.04**	**-38.66**	**-39.39**	**-39.90**	**-41.40**	**-41.76**	**-40.82**	**-40.80**

9.4.3 Cultivated Crops, 3De (NMVOC)

Justification - A New Source

NMVOC emissions from Cultivated Crops were not included in Ireland's national emissions inventory in 1999, when the ceilings were set. A methodology is presented in the 2019 EMEP/EEA Guidebook, and this is currently used to estimate emissions that are included in the Irish national emissions inventory.

For a new source, the Directive (EU) 2016/2284 requires that the source is currently included in scientific literature (such as the EMEP/EEA Guidebook), and that the source was not included in the historic national emissions inventory when emission ceilings were set. Both of these criteria are met, and it is therefore concluded that NMVOC emissions from manure management are a new source and are eligible for an adjustment.

Quantification

As a new source, quantification of the adjustment is achieved by subtracting the emissions from the national inventory total as shown in Table 9.18. The 2021 adjustment application for NMVOC submitted under the NECD is based on the same methodology that was used for the approved adjustment application which has been reviewed and approved by the EC in 2020. The Tier 2 methodology using the emission factors presented for the relevant crops in Table 3.4 Chapter 3.D of the Inventory Guidebook (EMEP/EEA, 2019) which exist in Ireland is adopted. Furthermore, Ireland uses a weighted Tier 1 emission factor (0.86 kg/ha) for those crops not included in Table 3.4 which exist in Ireland.

Table 9.18. Adjustment from Inorganic N Fertilisers (NMVOC)

Source Sector	Adjustments (ktonnes)									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Inorganic N Fertilisers	-4.751	-4.742	-4.686	-4.651	-4.633	-4.603	-4.619	-4.658	-4.685	-4.697

9.5 Impact of the flexibility on compliance

The established adjusted annual national emission inventories as allowed under the flexibility in Article 5(1) of Directive (EU) 2016/2284 show Ireland to be in compliance with the NMVOC ceiling and the NOx emission ceiling from 2011 onwards.

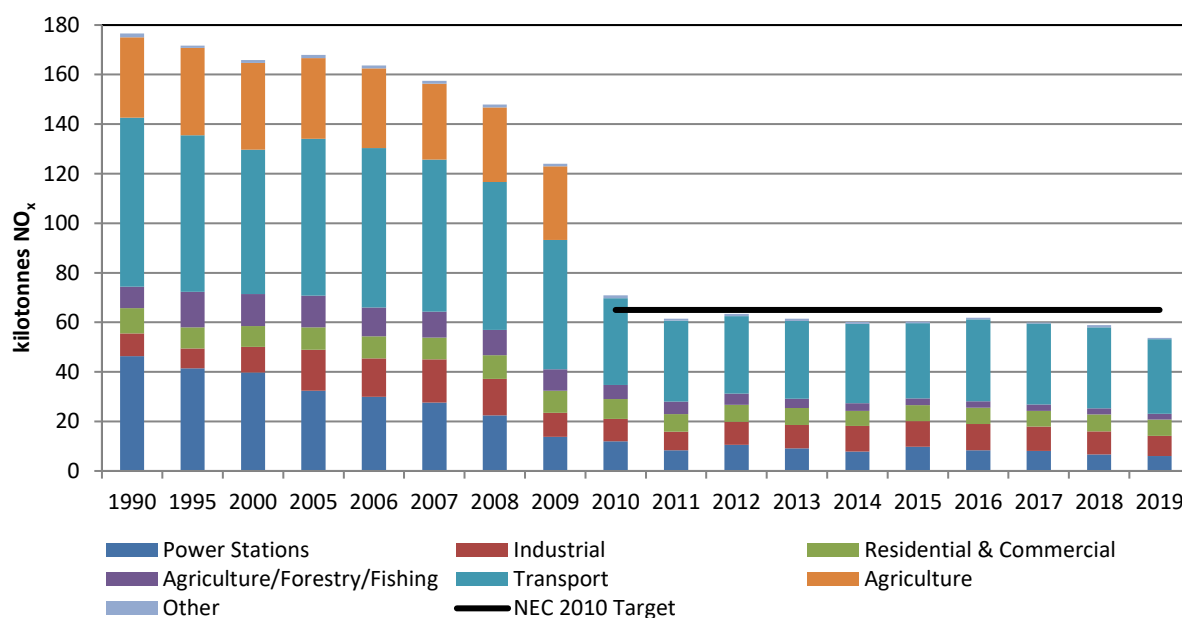The adjusted national inventories for NOx and NMVOC are presented in Figures 9.1 and 9.2

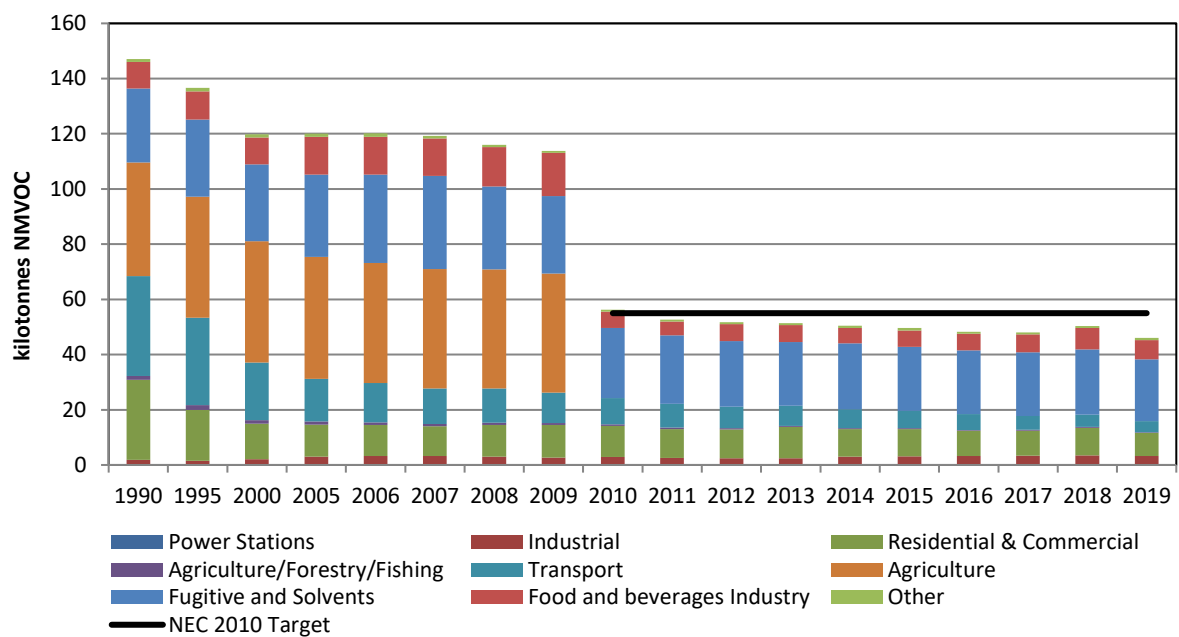*Figure 9.1 Emission Trend for NOx 1990−2019 (Adjusted Article 5(1))*

Figure 9.2 Emission Trend for NMVOC 1990−2019 (Adjusted Article 5(1))

Glossary

ADDF	Annual Average Daily Flow
AER	Annual Environmental Report
AIM	Animal Identification and Movement
As	Arsenic
B[a]P	Benzo[a]pyrene
B[b]F	Benzo[b]fluoranthene
B[k]F	Benzo[k]fluoranthene
BCF	British Coatings Federations
CAP	Common Agricultural Policy
Cd	Cadmium
CEPE	European Council of Producers and Importers of Paints, Printing Inks and Artists Colours
CEPMEIP	Co-ordinated European Programme on Particulate Matter Emission Inventories, Projections and Guidance
CLEEN	Chemical Legislation European Enforcement Network
CLRTAP	Convention on Long Long-Range Transboundary Air Pollution
CO	Carbon monoxide
CORINAIR	Co-ordinated Information on the environment in the European Community-AIR. CORINAIR was one of several collaborative exercises initiated under the CORINE programme to harmonise the collection and dissemination of information on the environment in the EU
CMMS	Cattle Movement and Monitoring Scheme
Cr	Chromium
CSO	Central Statistics Office
Cu	Copper
DEHLG	Department of Environment, Heritage and Local Government
DM	Dry matter
DTTAS	Department of Transport, Tourism and Sport
DQO	Data quality objective
EAPA	European Asphalt Pavement Association
ED	Electoral Division
ELV	End-of-Life Vehicle
EMEP	European Monitoring and Evaluation Programme, a co-operative programme for monitoring and evaluation of the long-range transmissions of air pollutants in Europe
EPA	Environmental Protection Agency
E-PRTR	European Pollutant Release and Transfer Register
ESB	Electricity Supply Board
ESP	Electrostatic precipitators
ETS	Emissions Trading Scheme
EUROSTAT	Statistical Agency of the European Union
FFS	Farm Facilities Survey
Fossil Fuel	Peat, coal, oil and natural gas and associated derivatives
FUS	Fertiliser Use Survey
GHG	Greenhouse gas
Gg	Gigagram (10^9 g) = kilotonne = 1,000 tonnes

GNFR	Gridded Nomenclature for Reporting Codes
HCB	Hexachlorobenzene
HFO	Heavy fuel oil
Hg	Mercury
IBEC	Irish Business and Employers' Confederation
IEA	International Energy Agency
IEF	Implied Emission Factor
IFFPG	Irish Farm Film Producers Group
IIR	Informative Inventory Report
I[123-cd]P	Indeno[1,2,3-cd]pyrene
IPC	Integrated Pollution Control
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
KDP	Key Data Provider
ktoe	Kilotonnes of oil equivalent
LCP	Large Combustion Plant Directive
LFG	Landfill gas
LPS	Large Point Source
LTO	Landing and take-off
MoU	Memorandum of Understanding
MSW	Municipal solid waste
NAIS	National Atmospheric Inventory System
NAEI	National Atmospheric Emissions Inventory
NCT	National Car Testing
NETCEN	National Environmental Technology Centre
NEC	National Emission Ceilings
NFR	Nomenclature for Reporting Codes
NH_3	Ammonia
Ni	Nickel
NMVOC	Non-methane volatile organic compound
NO_x	Nitrogen oxides
NRA	National Roads Authority
OCLR	Office of Climate, Licensing, Research and Resource Use
OLG	Office of Licensing and Guidance
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
PCB	Polychlorinated biphenyl
PER	Pollution Emissions Register
PM	Particulate matter
PM_{10}	Particulate matter <10 μm in diameter
$PM_{2.5}$	Particulate matter <2.5 μm in diameter
POP	Persistent organic pollutant
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
S.I.	Statutory Instrument
Se	Selenium
SEAI	Sustainable Energy Authority of Ireland
SNAP	Selected Nomenclature for Air Pollution

SO₂	Sulphur dioxide
SOₓ	Sulphur oxides
TAN	Total ammoniacal nitrogen
Teagasc	Irish Agriculture and Food Development Authority
TPM	Total particulate matter
TSP	Total suspended particulates
UAN	Uric acid nitrogen
UK NAEI	United Kingdom National Atmospheric Emission Inventory
UNECE	United Nations Economic Commission for Europe
VOC	Volatile organic compounds
WEEE	Waste Electrical and Electronic Equipment Regulation
Zn	Zinc

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Annex A to H

(click on hyperlinks below to view relevant Annex or navigate to http://www.epa.ie/pubs/reports/air/airemissions/airpollutantemissions/iir2021/)

Annex A	A.2 Key Category Analysis 2019 A.3 Fuel Tourism in Road Transport and Nitrogen Oxides Emissions Based on Fuels Used
Annex B	Expanded Energy Balance Sheet for 2019
Annex C	Emission Factors for Energy (NFR 1)
Annex D	Emission Factors for Industrial Processes (NFR 2)
Annex E	Agricultural Activity Data and Emission Factors (NFR 3)
Annex F	Emission Factors for Waste (NFR 5)
Annex G	Uncertainty Analysis
Annex H	2019 NECD Review findings and responses

Annex H

2020 NECD Review findings and responses

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-1A3dii-2017-0001	1A3dii National navigation (shipping), NOX, 1990-2015	The TERT notes with reference to key category 1A3dii National navigation (shipping) for NOx emissions that a tier 1 method is used for a key category. The TERT notes that using a tier 1 method is not best practice and could result in an over and/or underestimate of emissions. This over/underestimate may have an impact on total emissions that is above the threshold of significance. Ireland has not provided a revised estimate. It is currently not possible for the TERT to provide a numerical emission estimate based on a tier 1/tier 2 method, and therefore the issue will be flagged as Potential Technical Correction and will be assessed as a high priority item in future reviews. The TERT recommends that Ireland calculates NOx emissions from 1A3dii category using a tier 2 or tier 3 method for inclusion in next years' inventory submission.	PTC		
IE-1B2b-2017-0001	1B2b Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other), NMVOC, 1990-2015	For category 1B2b Fugitive Emissions from Natural Gas for NMVOC and for all years the TERT noted that Ireland reports 'NE' in the NFR Table. This was raised during the 2017, 2018 and 2019 NECD reviews. In response to a question raised during the review Ireland informs that the possibility to use existing information about leakage from greenhouse gas fugitive reporting to UNFCCC to estimate NMVOC is being investigated, and that Ireland is expecting to be able to include fugitive losses of NMVOC from pipelines and distribution systems in the 2021 submission. Ireland informs that all available data has been reviewed and will be used to include NMVOC emission estimates in the 2021 submission. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT recommends that Ireland estimate NMVOC emissions from 1B2b based on leakage estimates and country specific gas analysis reports and includes the NMVOC emissions estimates for 1B2b in the 2021 submission.	No	included explanation in IIR, included emissions in 2021 submission	section 3.13

	1A2f Stationary Combustion in Manufacturing Industries and Construction: Non-metallic Minerals, Cd, Hg, 2000-2016	The TERT notes with reference to 1A2f Stationary Combustion in Manufacturing Industries and Construction: Non-metallic Minerals, for Cd and Hg in all years that a Tier 1 method is used for a key category. The TERT notes that using a Tier 1 method is not best practice and could result in an over- or under-estimate of emissions. This over- or under-estimate may have an impact on total emissions that is above the threshold of significance. Ireland is not able to provide a revised estimate due to a lack of activity data available as indicated in its response to the review. It is currently not possible for the TERT to provide a numerical emission estimate based on a Tier 2 method, and therefore the issue will be flagged as Potential Technical Correction and will be assessed as a high priority item in future reviews. In responding to the Potential Technical Correction, Ireland declared that they were not in a position to provide a revised estimate. In addition, Ireland requested further guidance from the TERT as to how to implement a Tier 2 methodology for the key category. As the 2019 EMEP/EEA Guidebook only contains specific Tier 2 Hg and Cd emission factors for cement production, this is the only sub-activity where a process oriented emission factor can be applied. The key issue is therefore to separate the cement production from the other activities covered by this NFR category. As pointed out by Ireland, fuel consumption data are available from the EU ETS from 2005 onwards for cement plants. As the specific energy requirement probably did not change much prior, a possible approach could be to calculate the specific energy consumption per ton of clinker produced and use the historical data for clinker production to extrapolate a fuel consumption for cement production back to 1990. Emissions from the residual fuel consumption (other than cement) can be estimated using either Tier 1 or Tier 2 emission factor depending on whether information on combustion technology is available. Emissions from cement production could be estimated using clinker production data and the emission factors presented in Table 3-24 of the 2019 EMEP/EEA Guidebook. The TERT recommends that Ireland should calculate Cd and Hg emissions from 1A2f Stationary combustion in manufacturing industries and construction: Non-metallic minerals using a Tier 2 or Tier 3 method for inclusion in next years' inventory submission.	No	Ireland has estimated Cd, Hg, Pb emissions using reported mass emissions from cement plants and PS efs calculated from this data where it is not available for all years. The residual fuel is used to estimate emissions for the remainder of 1A2f sector (i.e. not cement industry). The remaining non priority metals were estimated for cement industry clinker production data and the emission factors presented in Table 3-24 of the 2019 EMEP/EEA Guidebook.	Chapter 3, section 3.5
IE-1A2f-2018-0002				

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-1A4bi-2018-0002	1A4bi Residential: Stationary, PAHs, PCBs, Cd, Hg, Pb, PCDD/F, 2000-2017	The TERT notes with reference to 1A4bi Residential: Stationary for pollutants PAHs, PCBs, Cd, Hg, Pb and PCDD/F in years 2000-2016 that a Tier 1 method is used for a key category. The TERT notes that using a Tier 1 method is not best practice and could result in an over- or under-estimate of emissions. This over- or under-estimate may have an impact on total emissions that is above the threshold of significance. During the review Ireland commented that it "uses Tier 2 emission factors for liquid, gaseous and biomass fuels where possible and plans to check for more appropriate Tier 2 emission factors for residential stationary emissions from solid fuels for POPs and heavy metals. However, Ireland is experiencing difficulties in moving from a Tier 1 to a Tier 2 approach as the EU 28 average fuel use and technology type is not reflective of Irish conditions and technologies and the fuel use/technology type splits are not available. Therefore, a Tier 1 approach must be used in Ireland's inventory for residential stationary emissions from solid fuels for POPs and heavy metals. Ireland will endeavour to examine the applicability of the Tier 2 emission factors as presented in the 2019 EMEP/EEA Inventory Guidebook and/or country specific information for PAHs, PCB, Cd, Hg and Pb". An update on progress will be included in the 2021 IIR. It is currently not possible for the TERT to provide a numerical emission estimate based on a Tier 2 method, and therefore the issue will be flagged as Potential Technical Correction and will be assessed as a high priority item in future reviews. In response to a question raised during the 2020 NECD review, Ireland explains the difficulties in moving from a Tier 1 to a Tier 2 approach for Ireland as the EU 28 average fuel use. Ireland committed to providing an update on progress in the 2021 IIR. The TERT recommends that Ireland continue the effort to move to a higher Tier and that Ireland should calculate PAHs, PCBs, Cd, Hg, Pb and PCDD/F emissions from 1A4bi Residential: Stationary using a Tier 2 or Tier 3 method for inclusion in next years' inventory submission.	No		Section 3.7

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-2A3-2017-0001	2A3 Glass production, PM2.5, 1990-2017	For category 2A3 Glass Production, for PM2.5 emissions, for the entire time series, the TERT noted that there is a lack of transparency regarding the methodology and the Tier used. This does not relate to an over- or under-estimate of emissions. This was raised during the 2017, 2018 and 2019 NECD reviews. In response to a question raised during the review, Ireland explained that no separate data for fuel consumption are available in the glass industry, and assumes that the emission factors reported for combustion (NFR 1A2f) include the total emissions from the process activity, Ireland proposes investigating subtraction of the emissions from category NFR 2A3 from the total emissions calculated for category NFR 1A2f for its next submission. The TERT recommends that Ireland improves the description of the methodology in its 2021 IIR and keeps on investigating this issue.	No	Subtracted PM2.5 emissions calculated in 2A3 from 1A2f for years 1990-2008 after which there is no glass production in Ireland.	section 4.2.3

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-2A5b-2020-0001	2A5b Construction and Demolition, PM2.5, 2010	For category 2A5b Construction and Demolition, for PM2.5 emissions, for the year 2010, the TERT notes with reference to the Ireland 2020 IIR, section 4.2.5, that a Tier 1 method is used for a key category. In response to a question raised during the review Ireland answered that the very detailed data required to apply the 2019 EMEP/EEA Guidebook Tier 3 method (AP42 method) are not available. The TERT notes that 2A5b is no longer a key category for PM2.5 for 2015-2018, and that there is no Tier 2 method provided by the EMEP/EEA Guidebook. The TERT recommends that Ireland includes an explanation for the use of Tier 1 method in the IIR .	No	Added an explanation in the IIR for 2021 submission	section 4.2.5
IE-2-2018-0001	2K Consumption of POPs and Heavy Metals, Hg, 1990, 2005, 2016	For category 2K Consumption of POPs and Heavy Metals, pollutant Hg and for the whole time series, the TERT noted that Hg emissions are not estimated while there is a Tier 1 method available in the 2016 EMEP/EEA Guidebook. This does not relate to an over- or under-estimate of emissions. This was raised during the 2018, and 2019 NECD reviews. The 2020 review noted that the 2020 IIR states that the issue, regarding button cell batteries, has been included in the list of improvements. The TERT reiterates the recommendation that Ireland keeps working on developing a method for this category and reports back on progress in its NIR in 2021.	No	included explanation in IIR	section 4.10

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-3-2019-0001	3D Crop Production and Agricultural Soils, PM2.5, 1990-2018	The TERT notes with reference to PM2.5 emission from 3Da1, 3Dc and 3Dd (3D Crop Production and Agricultural Soils) years 1990-2018, that there is a lack of transparency regarding the use of emission factors, which also was raised during the 2019 NECD review. In response to a question raised during the review, Ireland explained that the emissions values (kt PM2.5) for 3Da1 and 3Dc were incorrectly swapped around in the NFR submission. This also applies to PM10 and TSP. The TERT notes that this issue does not have an impact on the emissions that relates to the threshold of significance. The TERT recommends that Ireland correct this error for the next submission and adds transparency with activity data for 3Dd and 3Dc on the amount of cereals in its IIR Annex E Table 9.	No	Corrected errors in emissions values.	Section 5.3.1, 5.3.6 & 5.3.7
IE-3-2019-0001	3De Cultivated Crops, NMVOC, 1990-2018	For category 3De Cultivated Crops and pollutant NMVOC the TERT noted that there is a lack of transparency regarding the amount of dry matter (total as well as for each crop type) used in the Tier 2 calculation. This does not relate to an over- or under-estimate of emissions and related to issues with information provided in the guidebook that are being resolved. This was raised during the 2019 NECD review. In response to a question raised during the review, Ireland provided a excel sheet showing all the relevant variable used in the NMVOC calculation. The TERT recommends that Ireland include information on these variables (cultivated ha, dry matter content and yields) in order to improve the transparency of the 2021 submission.	No	See description in Section 5.3.8	Section 5.3.8

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-5B2-2019-0001	5B2 Biological Treatment of Waste - Anaerobic Digestion at Biogas Facilities, NH3, 2000-2017	For NH3 emissions from 5B2 Anaerobic Digestion at Biogas Facilities, the TERT noted there may be an under-estimate of emissions because 'NO' is reported. This was raised during the 2019 NECD review. In response to a question raised during the review Ireland answered that information was collected but relates mainly to agricultural waste which emissions are already accounted for in the agricultural sector. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT recommends that Ireland collect further information regarding the total amount of organic waste in digesters and include an estimate of NH3 emissions from the digesters under CRF 5B2.	No		

Sector/ID	NFR, Pollutant(s), Year(s)	Recommendation	Revised Estimate or Potential Technical Correction	Party response	IIR Section
IE-LPS-GEN-2020-0001	General, NMVOC, PM2.5, PCBs, HCB, Cd, Pb, PCDD/F, 2015	The TERT notes that for the year 2015, no LPS emissions are reported for the following pollutant(s): Cd, NMVOC, Pb, PCBs, PM2.5, HCB, PCDD/F. In its response to the TERT, Ireland indicated that Cd, Pb, PCBs, HCB, PCDD+PCDF to air were not reported under the E-PRTR in 2015 (i.e. either we have no data for the pollutant, or else was below E-PRTR reporting thresholds). PM2.5 was not an E-PRTR pollutant. NMVOC for 2015 has since been reported but was not available at the time of the LPS submission. The TERT recommends that Ireland includes some explanation of the lack of reporting in the E-PRTR relating to potential LPS in its future IIRs, considers deriving PM2.5 emissions from E-PRTR reported PM10 for example using the particle size distribution from the EMEP/EEA Guidebook, and includes the data for NMVOC in future submissions.	No		

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú

Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:

- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Headquarters
PO Box 3000, Johnstown Castle Estate
County Wexford, Y35 W821, Ireland
Bosca Poist 3000, Eastát Chaisleán Bhaile Sheáin
Contae Loch Garman, Y35 W821, Éire

T: +353 53 9160600
F: +353 53 9160699
E: info@epa.ie
W: www.epa.ie
Lo Call: 1890 33 55 99

EPA Regional Inspectorate Dublin
McCumiskey House
Richview
Clonskeagh Road
Dublin 14
D14 YR62
Tel: 01-268 0100
Fax: 01-268 0199

EPA Regional Inspectorate Cork
Inniscarra
Co. Cork
P31 VX59
Tel: 021-4875540
Fax: 021-4875545

EPA Regional Inspectorate Castlebar
John Moore Road
Castlebar
Co. Mayo
F23 KT91
Tel: 094-9048400
Fax: 094-9021934

EPA Regional Inspectorate Kilkenny
Seville Lodge
Callan Road
Kilkenny
R95 ED28
Tel: 056-7796700
Fax: 056-7796798

EPA Regional Inspectorate Monaghan
The Glen
Monaghan
H18 YT02
Tel: 047-77600
Fax: 047-84987

E: info@epa.ie
W: www.epa.ie
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