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Activity Data for Emissions of Non-methane Volatile Organic Compounds

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Rialtas na hÉireann
Government of Ireland

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:

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

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- 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;
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- Supervising the supply of drinking water by public water suppliers.
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- 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.

EPA RESEARCH PROGRAMME 2014–2020

Activity Data for Emissions of Non-methane Volatile Organic Compounds

(2012-CCRP-FS.8)

EPA Research Report

Prepared for the Environmental Protection Agency

by

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DISCLAIMER

This report is based on research carried out/data from 2012 to 2015. More recent data may have become available since the research was completed.

The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

Non-methane volatile organic compound (NMVOC) emissions estimates have been calculated for the sector Nomenclature for Reporting (NFR) 2D–2L: Other Solvent and Product Use for the period 1990–2014. The emission estimates were based on new activity data obtained from Integrated Pollution Prevention and Control (IPPC)-licensed facilities, data gathered as a result of the VOC Solvents Directive (1991/13/EC) and the Decorative Paints Directive (2004/42/EC), state agencies' statistics and information obtained from trade organisations and individual companies. Emission factors were used from the European Monitoring and Evaluation Programme (EMEP)/European Environment Agency (EEA) guidebook 2013 and were also based on country-specific estimates. The results of this project show that, between 1990 and 2014, NMVOC emissions decreased by 18.0%. Emissions from this sector are driven by a relatively small number of emission sources. These sources include Selected Nomenclature for Reporting of Air Pollution (SNAP) codes 060408: Domestic Solvent Usage, 060103/060104: Retail Decorative Coating, 060306: Pharmaceutical Products Manufacturing, 060403: Printing and NFR 2H2: Food and Beverage Industry. These sectors accounted for, on average, 68% of emissions throughout the 1990–2014 time period.

In addition to the completion of the emissions inventory, an uncertainty analysis was completed to assess the overall uncertainty within the inventory (estimated at 44%) for 2014 and to assess which sector contributes most to the uncertainty. The sector with the largest uncertainty was found to be product manufacturing. Pharmaceutical production was found to be the main driver of uncertainty in this sector and this was a result of reporting issues under the IPPC licensing system. Significant sources of uncertainty also included coating applications, printing and road paving with asphalt. Many of these categories are also significant contributors to the emissions estimate and therefore reductions in uncertainty in these categories would probably result in significant improvements in overall uncertainty estimates. Emissions were mapped using the new data sources and this resulted in an improved spatial disaggregation of emissions. Mapping was based on more point sources and more relevant proxy data (e.g. number of houses and population) when point sources were not feasible. An investigation into reporting issues regarding IPPC-licensed facilities was completed and several key findings indicate that reporting of emissions was not being satisfactorily completed by many of the facilities. Recommendations were made to rectify this and, if implemented, these will improve the effectiveness of reporting.

1 Introduction

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 emissions data for a wide range of air pollutants and other substances released into the atmosphere. The European Monitoring and Evaluation Programme (EMEP)/European Environment Agency (EEA) guidebook on annual inventories (EMEP/EEA, 2013) describes the scope and reporting of the emission inventories under the Convention. It specifies the methodologies and procedures to be followed for submitting consistent and comparable data on an annual basis in a timely, efficient and transparent manner to meet the needs of the Convention. The Environmental Protection Agency (EPA) in Ireland has overall responsibility for the national air emissions inventory pursuant to the establishment of the National Atmospheric Emissions Inventory (NAEI) system in 2007. The EPA Office of Climate, Licensing and Resource Use (OCLR) performs the role of inventory agency in Ireland; it undertakes all aspects of inventory preparation and management and is responsible for the submission of results to the CLRTAP.

In its function as the inventory agency, the EPA commissioned a research fellowship hosted by the University of Limerick to update activity data for the non-methane volatile organic compounds (NMVOCs) emissions inventory for other solvent and product use [Nomenclature for Reporting (NFR) 2D–2L] from 1990 to 2014. Previous studies were commissioned (Finn *et al*., 2001; CTC/AEA, 2005) to update NMVOC emissions and this project uses data and findings presented in these studies. In order to update the emissions inventory with new activity data and meet EMEP/EEA (2013) guidelines, several objectives were identified:

- provide the EPA with an updated and comprehensive inventory of NMVOC emissions from solvents and other product use;
- verify emissions estimates using statistical analysis and by comparing emissions with international estimates;
- evaluate the quality of data used in the inventory and highlight areas that require further work;
- provide a speciated list of volatile organic compounds (VOCs) commonly used in the solvent and other product use sector;
- use the new emissions estimates and data to update mapping and assess the spatial variation of emission estimates.

By meeting these objectives, the project will deliver updated activity data that reflect new policy initiatives such as the VOC Solvents Directive (1999/13/EC) and the Decorative Paints Directive (2004/42/EC). The data will be verified and validated using the appropriate methodologies outlined in the EMEP/EEA reporting guidebook (EMEP/EEA, 2013) and the accuracy of the inventory will be assessed through uncertainty analysis and verification procedures. Furthermore, emissions maps will be generated to reflect the new emissions estimates. The outputs of this project can be used to promote and inform more effective policymaking and also improve current knowledge of other solvent and product use emission sources.

2 Literature Review

Non-methane volatile organic compounds are defined in a number of ways:

- The EEA has defined NMVOCs as a collection of organic compounds that differ in their chemical composition but behave in a similar manner in the atmosphere (EEA, 2015).
- The VOC Solvents Directive categorises a VOC as having a vapour pressure of 0.01 kPa or more at 293.15 K (EC, 2001).
- The Decorative Paints Directive defines a VOC as any organic compound having an initial boiling point of less than or equal to 250°C, measured at a standard pressure of 101.3 kPa (EU, 2004).
- National Emission Ceilings (NEC) legislation (Directive 2001/81/EC) defines VOCs as all organic compounds arising from human activities, other than methane, that are capable of producing photochemical oxidants by reactions with nitrogen oxides in the presence of sunlight.

However, these definitions may be incompatible within the context of compiling an emissions inventory of VOCs from solvent use. For instance, methyl chloride [Chemical Abstracts Service (CAS) number: 74-87-3] has a boiling point of −23.8°C and a vapour pressure of 506.09 kPa at 20°C, making it extremely volatile, and 2-phenoxyethanol (CAS number: 122-99-6), another commonly used organic compound (used in domestic products), has a boiling point of 247°C and a vapour pressure of 0.001 kPa (at 20°C), suggesting that it is non-volatile. However, under the definitions above, both are assumed to be emitted to the atmosphere. For certain emission sources this has clear implications. Organic compounds from emission sources such as domestic solvent use including fungicides may not volatilise to the atmosphere when temperatures are too low. However, under many of the definitions above, 100% of organic compounds are assumed to be volatile. In industrial settings, where these chemicals are used for their volatile properties, this is unlikely to be an issue.

Once in the atmosphere, NMVOCs are tropospheric ozone precursors and they also are directly hazardous to human health, having mutagenic and carcinogenic impacts (Wolkoff and Nielsen, 2001; Weichenthal *et al*., 2012). They also contribute to secondary aerosol formation, which results in respiratory and cardiovascular medical conditions (WHO, 2008). Furthermore, NMVOCs are greenhouse gases and contribute to climate change. In order to limit and reduce these emissions a number of legislative measures have been introduced.

Under the CLRTAP, Member States are required to submit emissions inventories of air pollutants that damage the environment or are harmful to human health. These include pollutants that have an acidifying effect, create photochemical smog, result in eutrophication or have a harmful impact on human health (e.g. polychlorinated biphenyls or PCBs). Emissions inventories are compiled using the EMEP/EEA (2013) guidebook, which ensures that a standardised approach is provided for Member States. In order to prepare inventories based on the guidebook, national arrangements must be introduced to ensure that appropriate procedures are developed. In addition, national inventories must be prepared under the principles of transparency, accuracy, completeness, comparability and consistency (TACCC).

Non-methane volatile organic compound emissions sources that are currently accounted for in the EMEP/EEA (2013) guidebook include:

- public electricity and heat production;
- manufacturing industries and construction;
- transport;
- agriculture (manure management);
- the residential and commercial sector;
- agriculture/forestry and fishing;
- the fugitive and solvent use sectors.

The largest sectors within the European Union's (EU) 28 Member States have been transport, other solvent and product use and agriculture (manure management) over the 1990–2014 period. Solvent usage accounted for 40% of emissions and transport accounted for 15% (EEA, 2015). Abatement technologies and national legislation have resulted in large emissions reductions from the transport sector.

This trend has also been observed in Irish NMVOC emissions from 1990 to 2014, with transport emissions reducing by 80% (EPA, 2015). In 2015, emissions from agriculture (manure management) were estimated for the first time in the Irish emissions inventory, resulting in significant increases in NMVOC emissions. However, other solvent and product use remains a significant source of NMVOC emissions (26.7%) according to the EPA (2015).

However, field observations, modelling studies and research conducted by the European Solvent Industry Group suggest that this may not be the case (Niedojadlo *et al*., 2007; ESIG, 2012), as emissions from traffic may be underestimated or alternatively emissions from solvent use are overestimated. Furthermore, it is well established that VOC emissions have different potentials for ozone creation (Derwent *et al*., 1996, 1998; Andersson-Sköld and Holmberg, 2000). Therefore, treating all VOC emissions as equal could be considered an inefficient method for dealing with tropospheric ozone creation. Several modelling studies have been conducted in which photochemical ozone creation potentials (POCPs) were calculated for various VOCs (Derwent *et al*., 1998; Jenkin *et al*., 2000). These POCP values can be used to assess the major contributors to ozone formation and provide a more effective evaluation of the sectorial contribution to tropospheric ozone formation.

3 Methodology

Data sources can be broadly grouped into two categories: regulatory data and non-regulatory data. Regulatory data are defined here as data obtained as a result of environmental legislation. Examples include Integrated Pollution Prevention and Control (IPPC) emissions reporting data, Pollutant Release and Transfer Register (PRTR) emissions reporting data and data obtained from the European VOC Solvents Directive (1991/13/EC). These data can be considered bottom-up data as they are taken from individual operators and can be scaled up based on the number of companies operating within Ireland. Non-regulatory data are considered to be data from trade organisations, government agencies, suppliers and distributors and operators. These data are collected via personal communications with data holders, through questionnaires and by gaining access to state agency databases and manually collating data. These data are considered top-down data as they provide little information with regard to individual solvent users.

Regulatory information has been gathered using online and archived Annual Environmental Reports (AERs), the PRTR database and information provided by the Office of Environment Enforcement in the EPA as a result of reporting obligations arising from the VOC Solvents Directive. Data from these sources were also used to ensure that a complete dataset of operators was captured within the scope of the regulatory system by comparing and contrasting the datasets. Furthermore, the IPPC activity classifications, VOC Solvents Directive activity classifications, PRTR classifications and previous inventory reports (CTC/AEA, 2005) were used to ensure consistency in operator classification. The AER data have been collated for the period 2006–2014. VOC Solvents Directive data were used primarily to calculate emissions from the dry cleaning sector and to verify operator activity classifications and the number of operators in each sector.

3.1 Data Quality

It is important to note that data obtained from AERs varied in quality. In particular, the issues highlighted by the Clean Technology Centre (CTC)/AEA (CTC/AEA, 2005) are observable in the new data, with the quality and detail of the data provided in AERs varying from licence to licence. Examples include inconsistent reporting of direct emissions, usage, fugitive emissions and production quantities. Some facilities track only part of their solvent usage whereas others do not specify what solvents are being used. Data availability remains a challenge for a number of sectors and, where no feasible alternative exists, proxy information has been used.

In addition to obtaining data for 1990–2014, when no suitable data could be found, gap-filling procedures, which included linear trend extrapolation, extrapolating annual emissions based on correlation with independent variables [e.g. gross domestic product (GDP), population, vehicle fleet] and using the previous or subsequent year's emissions values, were used to represent annual emissions estimates.

The transparency, accuracy and comparability of the estimate were evaluated using a number of approaches. Emissions data were compared with a number of variables that were considered relevant. These include population, number of private cars, GDP and employment statistics. In addition, per-capita emissions intensities were calculated for each NFR category for Ireland and the EU15; for some sectors, the EU25 were used. Upper and lower confidence intervals were calculated for the per-capita emissions estimates for these countries and Ireland's emissions estimate was compared with these estimates to assess if Ireland was reporting similar values to other countries.

4 Results for NFR 2D–2L: Other Solvent and Product Use

As can be seen in Figure 4.1, emissions from other solvent and product use decreased by 18.0% between 1990 and 2014 (from 23.4 Gg to 19.1 Gg of NMVOC emissions). Emissions peaked in 2007, reaching 27.6 Gg, with the lowest emissions occurring in 2013 (17.9 Gg). Table 4.1 provides a sectorial breakdown of emissions.

The largest emissions source in 2014 was 2D3a: Domestic Solvent Use including Fungicides. This emission source relates to the domestic use of solvent-containing products such as personal care products, do-it-yourself (DIY) products or car care products.

4.1 NFR 2D3a: Domestic Solvent Use

Emissions from this sector were recalculated in Ireland's 2016 submission of the informative inventory report (Duffy *et al.*, 2016). Previous emissions estimates were based on per-capita calculations outlined in the EMEP/EEA guidebook (2013). However, several difficulties were observed using this method. For instance, for this method consumption patterns were assumed to be the same between all EU countries, domestic products containing solvents were assumed to have similar solvent contents and the methods did not consider economic conditions

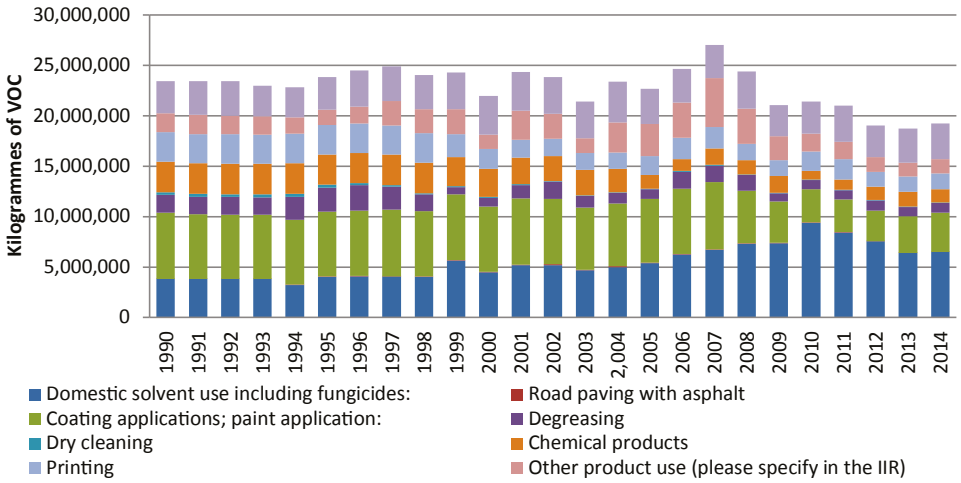

Figure 4.1. NFR 2D–2L: Other Solvent and Product Use – total emissions and sectorial contributions.

Table 4.1. Sectorial contributions of emissions from NFR 2D–2L: Other Solvent and Product Use

NFR	Description	% of emissions in 1990	% of emissions in 2014
2D3a	Domestic Solvent Use including Fungicides	16.2	33.7
2D3b	Road Paving with Asphalt	0.2	0.2
2D3d	Coating Applications	28.1	20.2
2D3e	Degreasing	7.5	4.9
2D3f	Dry Cleaning	1.2	0.37
2D3g	Chemical Products	12.9	7.0
2D3h	Printing	12.4	8.1
2G	Other Solvent Use	8.1	7.3
2H1	Pulp and Paper Manufacture	NO	NO
2H2	Food and Beverage Industry	13.6	18.5

NO, not occurring.

within a country as they simply used population as a proxy for activity data. In addition, this method was a Tier 1 method defined as the most basic method of estimation. The new estimate is based on national statistics and a detailed survey of products available on the Irish market. Activity data consisted of import and export data from the sources shown in Table 4.2. No production data were available because of confidentiality issues and this remains a priority area. However, it is considered that production levels are likely to be relatively low and that the UK exports the majority of these products to Ireland.

The emissions factors were calculated from a survey of 171 products and are summarised in Table 4.3. Metal polishes from the car care sector were found to have the highest VOC content. Body washes and soaps were found to have the lowest VOC content.

Table 4.2. List of emissions sources included under domestic solvent usage

Cosmetics and toiletries	Household products	DIY	Car care	Pesticides/fungicides
Soap and shower gel	Waxes and polishes	Retail adhesives	Polishes for coachwork	Pesticides and fungicides
Hair products	Soaps and detergents		Metal polish	
Colourings and perming solutions	Surface cleaning			
Conditioner and shampoos	Glass cleaning			
Gels, waxes and creams				
Mousses and hairspray				
Deodorants and perfumes				

Table 4.3. NFR 2D3a: Domestic Solvent Usage including Fungicides emissions factors

Source	Emission factor (%)
Cosmetics and toiletries	
Body washes/soaps	1.46
Hair products	15.28
Cosmetics	28.37
Deodorants average	37.45
Household products	
Metal polishes	16.71
Detergents	17.21
Surface cleaning	6
Glass polish	11
DIY	
Adhesives	28.05
Pesticides/fungicides	
Fungicides	16
Car care	
Metal polishes	42
Hydraulic fluid	NE
Coachwork	NE
Polishes	NE

NE, not estimated.

Emissions from domestic solvent use including fungicides are driven by three main sources. Figure 4.2 shows that cosmetic and personal care products, household products and car care products accounted for 88% of emissions in 2014. Among these, cosmetic and personal care products are the most significant sources (53%).

Emissions were verified by comparing them with the confidence intervals calculated from emissions from EU25 countries, as shown in Figure 4.3. Emission intensities for the EU25 ranged from 0.80 to 5.49 kg per capita in 1990 and from 0.85 to 2.85 kg per capita in 2013. Ireland's emissions ranged from 1.27 kg per capita in 1990 to 1.67 kg per capita in 2013. Ireland's emissions are within the confidence intervals for almost all years over the 1990–2014 period, except for 2009. Of note, Ireland's emissions trend is increasing whereas emissions from the EU25 (on average) are decreasing. This may be as a result of population growth within Ireland, with which consumption of these products is strongly correlated ($R = 0.91$).

4.2 NFR 2D3b: Road Paving

Emissions from this sector were estimated for the first time in the 2016 submission. Activity data were obtained from the Irish Asphalt Producers Association (IAPA). Activity data included the production of warm and hot mix asphalt for the period 1993–2014. The Tier 2 emission factor of 16 g/Mg of asphalt was used (batch mix/hot mix plant) and was considered a Tier 2 estimate. Emissions from this sector accounted for 0.2% of total NMVOC emissions in 1990 and this increased to 0.3% of emissions in 2014. Emission intensities from the EU25 ranged from 0.003 to 0.72 kg of NMVOCs per capita in 1990 and from 0.00001 to 0.09 kg of NMVOCs per capita in 2013. Ireland's estimates were 0.01 kg of NMVOCs per capita in 1990 and 0.007 kg of NMVOCs per capita in 2013. As can be seen in Figure 4.4, Ireland's emissions per capita from road paving with asphalt remain relatively constant over the time period and closely match the lower confidence interval calculated from emissions from EU25 countries.

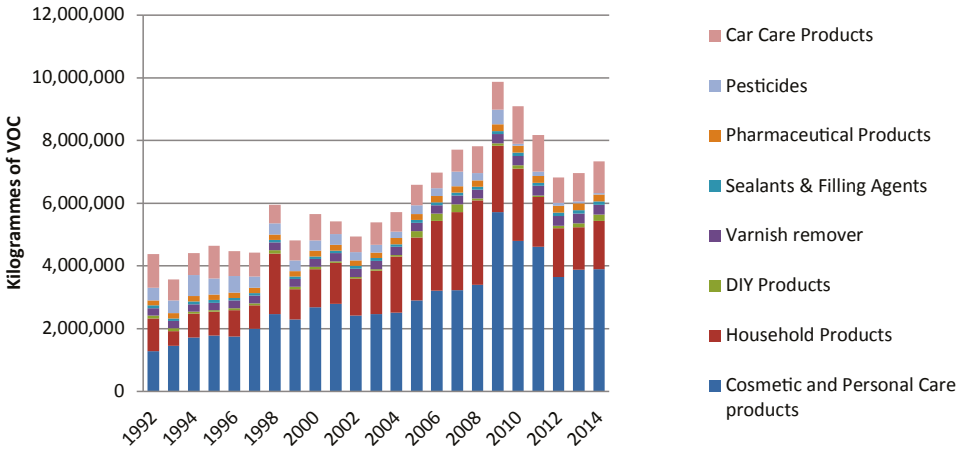

Figure 4.2. Emissions from NFR 2D3a: Domestic Solvent Use including Fungicides in Ireland (1992–2014).

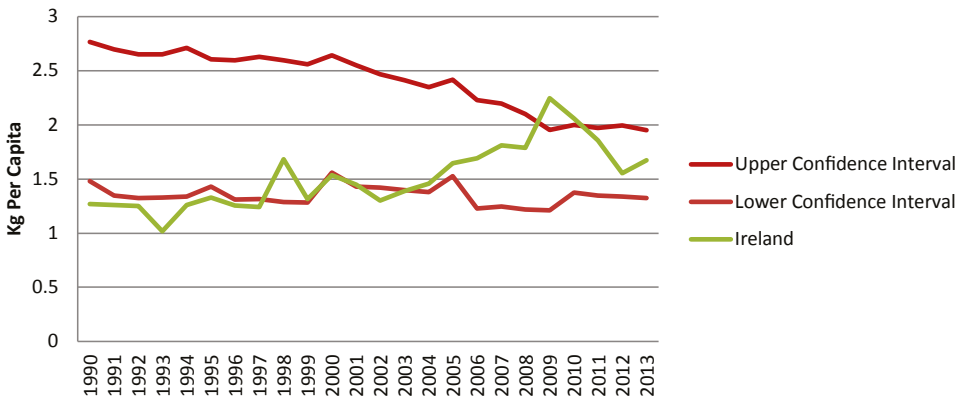

Figure 4.3. Verification of emissions from NFR 2D3a: Domestic Solvent Use including Fungicides (1990–2013).

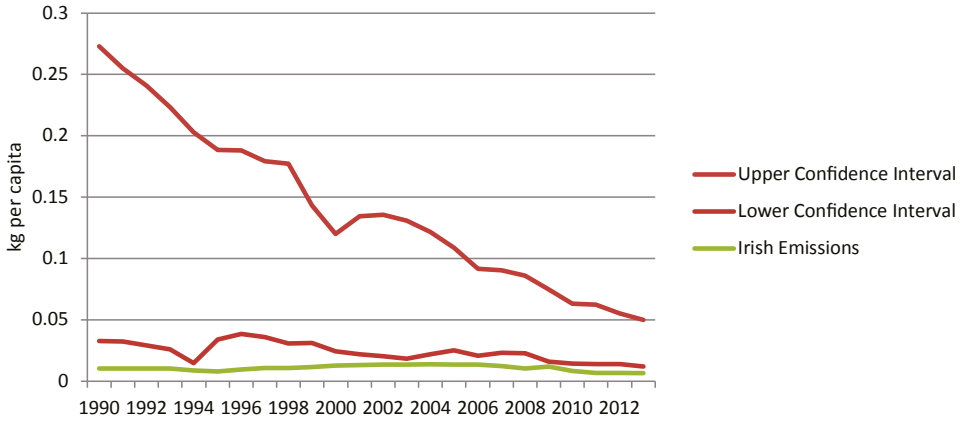

Figure 4.4. Verification of emissions from NFR 2D3b: Road Paving (1990–2013).

4.3 NDR 2D3c: Asphalt Roofing

No data were obtained from this activity; expert opinion indicates that this activity took place until 2000, when fibreglass replaced this method of roofing.

4.4 NFR 2D3d: Coating Applications

The NFR 2D3d: Coating Applications code covers the sectors outlined in Table 4.4. The activities that occur in each sector are outlined in CTC/AEA (2005) and in the EMEP/EEA (2013) guidebook. Although the basic processes are unlikely to have changed significantly in the intervening years, the solvent content of paint has been reduced with the implementation of the VOC Solvents Directive (1999/13/EC) and Decorative Paints Directive (2004/42/EC).

As can be seen from Table 4.4, the new estimates use superior data sources for all sectors within the coating applications sector. However, two proxy sources are used in the estimation of emissions. Reducing the reliance on proxy sources was a priority of this project; however, activity data were not obtainable for these emissions sources. The remaining emissions sources are based on activity data from product suppliers within Ireland or from IPPC emissions monitoring data.

Emissions decreased by 44.7% from 1990 to 2014, as can be seen in Figure 4.5. Emissions peaked in 2007, at 6.65 Gg of NMVOCs, before falling to their lowest value of 2.98 Gg of NMVOCs in 2012. The largest sources of NMVOC emissions from this sector are estimated to be construction and buildings and decorative paint applications [Selected Nomenclature for Reporting of Air Pollution (SNAP) codes: 060103/060104] and industrial paint applications (SNAP code: 060108). These two sources accounted for 94% of emissions in 1990; however, by 2014, decorative paint applications accounted for 63% of emissions whereas industrial paint applications accounted for 36%. Non-industrial emissions were found to be only a minor emissions source.

Table 4.4. Comparison of current emissions sources with new emissions sources for NFR 2D3d: Coating Applications

SNAP code	Description	New source	Current source
060101	Manufacture of Automobiles	NO	NO
060102	Car Repairing	Supplier	Extrapolated
060103	Construction and Buildings	Trade association	Extrapolated
060104	Retail Decorative Coating	Trade association	Extrapolated
060105	Coil Coating	NA	NA
060106	Marine: Paint Application	Supplier	Extrapolated
060107	Wood: Paint Application	Proxy	Extrapolated
060108	Other Industrial Paint Application	IPPC + Solvents Directive	Flat lined
060109	Other Non-industrial Paint Application	Proxy	Proxy

NA, not applicable; NO, not occurring; SNAP, Selected Nomenclature for Reporting of Air Pollution.

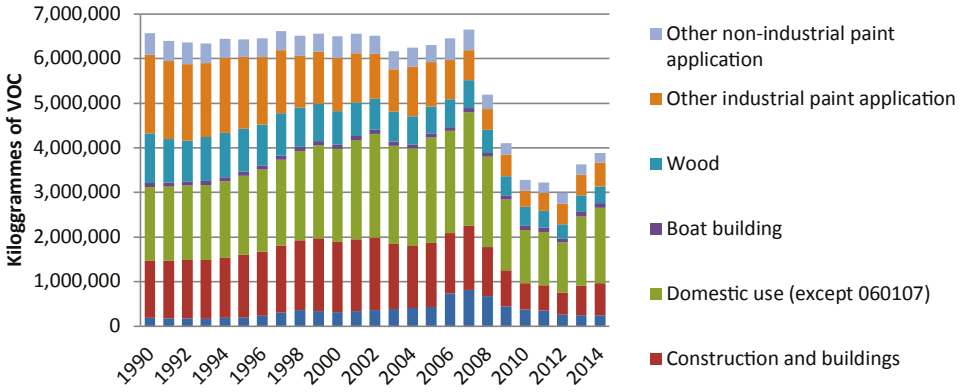

Figure 4.5. Emissions from NFR 2D3d: Coating Applications in Ireland (1990–2014).

Per-capita emission intensities were calculated using reported emissions data from the Centre on Emission Inventories and Projections (CEIP) website and population statistics from the Organisation for Economic Co-operation and Development (OECD) for EU25 countries and European Statistical Office (Eurostat) population data for those not reported under the OECD. EU25 emission intensities ranged from between 0.99 and 6.79 kg of NMVOCs per capita in 1990 to between 0.55 and 3.73 kg of NMVOCs per capita in 2013. Ireland's emission intensity was found to be 1.87 kg of NMVOCs per capita in 1990 and 0.79 kg per capita in 2013. Figure 4.6 shows that Ireland's emissions estimates lie outside the 95% confidence intervals. Many EU countries have well-developed car manufacturing industries that are dominating emissions from this sector. However, as Ireland does not manufacture cars, this accounts for Ireland's lower emissions intensity. Ireland's trend matches the average emission intensity reported by EU25 countries.

4.5 NFR 2D3e: Degreasing

The NFR 2D3e: Degreasing code covers the sectors outlined in Table 4.5. This sector is dominated by the consumption of solvents for the manufacture of cleaning materials, metals and electronics. Activity data from metal degreasing, electronic components manufacturing and surface cleaning (SNAP codes: 060201, 060203 and 060204) were obtained from the Central Statistics Office (CSO) in the form of imports

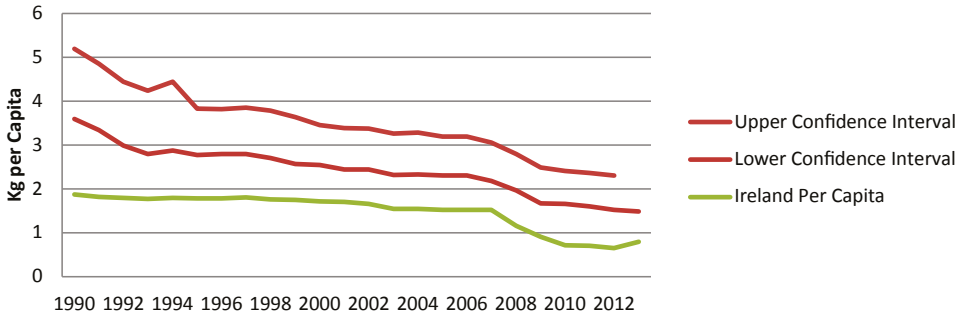

Figure 4.6. Verification of emissions from NFR 2D3d: Coating Applications (1990–2013).

Table 4.5. Comparison of current emissions sources with new emissions sources for NFR 2D3e: Degreasing

NFR	SNAP code	Description	New source	Current source
2D3e	060201	Metal degreasing	CSO statistics	Extrapolated
2D3e	060203	Electronic components manufacturing	IE	IE
2D3e	060204	Other industrial cleaning	IE	IE

IE, included elsewhere.

and exports of dichloromethane, tetrachloroethylene, trichloroethylene and organic compounds. Consumption was calculated by subtracting imports and exports, assuming that the remainder is what was used in Ireland. Emissions from the 2D3e sectors have decreased by over 46.3% since 1990. Emissions from this sector accounted for 7.5% of total emissions in 1990 and 4.9% in 2014.

Per-capita emissions intensities were calculated for the EU25 based on emissions data available on the CEIP website and on OECD population statistics. As can be seen from Figure 4.7, Ireland's emissions estimates are comparable to those from other EU25 countries. Therefore, these estimates are considered to be representative of Irish emissions from degreasing. NMVOC emissions intensities ranged from between 0.00001 and 2.26 kg per capita in 1990 to between 0.000001 and 1.38 kg per capita in 2013 among the EU25 countries. Ireland's NMVOC emissions intensities ranged from 0.49 kg per capita in 1990 to 0.20 kg per capita in 2013.

4.6 NFR 2D3f: Dry Cleaning

Dry cleaning refers to any process to remove contamination from furs, leather, down, textiles or other objects made of fibres using organic solvents. Dry cleaning can be defined as the use of chlorinated organic solvents, principally tetrachloroethene, to clean clothes and other textiles. In general, the process can be divided into four steps:

1. cleaning in a solvent bath;
2. drying with hot air and recovery of solvent;
3. deodorisation (final drying);
4. regeneration of used solvent after the clothes have been cleaned.

Clothes are first cleaned in a solvent bath, followed by drying in hot air. The solvents are regenerated and the dirt and grease from the cleaning process are removed as a waste product. Emissions from dry cleaning were calculated both using emissions data obtained as a result of the VOC Solvents Directive and from national consumption statistics. Emissions data were obtained for 2008, 2009, 2010 and 2012. Emissions data are expected to be available every 3 years.

Emissions from this emissions source decreased by 75.1% over the time period studied. This was a result of increased efficiencies within the dry cleaning sector, which were driven by both legislation and the need to reduce costs. This sector has been only a minor source of emissions throughout the time period, accounting for 1.2% of total emissions in 1990 and 0.37% in 2014.

Emissions intensities among the EU25 ranged from 0.08 to 0.17 kg per capita in 1990 and from 0.01 to 0.05 kg per capita in 2013. Ireland's emission intensity was found to be 0.08 kg per capita in 1990 and 0.01 kg per capita in 2013 (Figure 4.8). As can be seen from Figure 4.8, Ireland's emissions follow the overall trend reported by other countries.

4.7 NFR 2D3g: Chemical Products Manufacturing or Processing

This code covers the emissions from the use of chemical products in processes or manufacturing operations. This includes a large range of emissions sources; however, the EMEP/EEA guidebook (EMEP/EEA, 2013) acknowledges that many of these are insignificant and, in Ireland's case, many simply do not apply as they do not occur in Ireland. In addition, some sectors are too broad in scope and would benefit from some further disaggregation in the EMEP/EEA

Figure 4.7. Verification of emissions from NFR 2D3e: Degreasing (1990–2013).

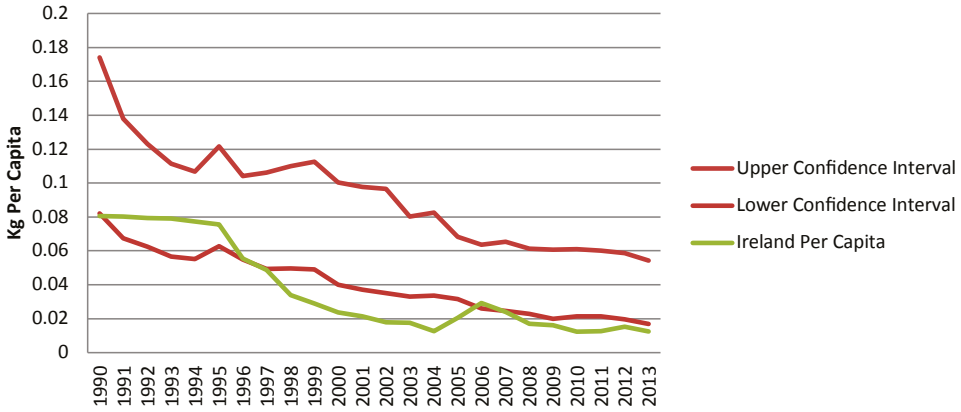

Figure 4.8. Verification of emissions from NFR 2D3f: Dry Cleaning (1990–2013).

Table 4.6. Comparison of current emissions sources with new emissions sources for NFR 2D3g: Chemical Products Manufacturing or Processing

NFR	SNAP code	Description	New source	Current source
NFR 2D3g	060301	Polyester Processing	NO	NO
NFR 2D3g	060302	Polyvinylchloride Processing	Expert opinion	Expert opinion
NFR 2D3g	060303	Polyurethane Processing	One IPPC company	Flatlined
NFR 2D3g	060304	Polystyrene Foam Processing	IPPC	Flatlined
NFR 2D3g	060305	Rubber Processing	IPPC	Flatlined
NFR 2D3g	060306	Pharmaceutical Products Manufacturing	IPPC + NACE codes	Flatlined
NFR 2D3g	060307	Coating Manufacture: Paint	IPPC + NACE codes	Flatlined
NFR 2D3g	060308	Coating Manufacture: Ink	IPPC	Flatlined
NFR 2D3g	060309	Coating Manufacture: Adhesives	IPPC	Flatlined
NFR 2D3g	060310	Other Industry: Asphalt Blowing	NO	NO
NFR 2D3g	060311	Adhesive and Magnetic Tapes	IE	Flatlined since 2006
NFR 2D3g	060312	Textile Coating	IPPC	Flatlined
NFR 2D3g	060313	Leather Tanning	NO	NO
NFR 2D3g	060314	Other Chemical Products, etc.	NO	Flatlined

IE, included elsewhere; NO, not occurring.

guidebook (EMEP/EEA, 2013). Table 4.6 displays a breakdown of the sectors included under this category. The majority of sectors have been updated with new activity data and also upscaled to reflect national emissions using Nomenclature statistique des activités économiques dans la Communauté européenne (NACE) codes.

As can be seen in Figure 4.9, emissions from NFR 2D3g: Chemical Product Manufacturing and Processing are dominated by SNAP code 060306: Pharmaceutical Products Manufacturing. This sector accounted for, on average, 77% of emissions from 1990 to 2014, with emissions ranging from 70% in 1990 to 94% in 2014. However, NMVOC emissions decreased by 51.8% from 1990 to 2014. The pharmaceutical products manufacturing emissions estimate is calculated using IPPC licence data and the number of companies believed to be operating in Ireland and is based on expert opinion to up-scale the emissions estimate to reflect national emissions. Emissions decreased throughout the time period but this is assumed to be the result of a combination of increased abatement technology and the impact of legislation promoting a reduction in solvent usage.

As can be seen from Figure 4.10, the Irish emissions estimates lie within or near the 95% confidence intervals over the 1990–2013 time period. As already stated, the most significant category under NFR 3C is SNAP code 060306: Pharmaceutical Products Manufacturing. Ireland has a significantly more developed pharmaceutical industry than other countries with regard to the number of companies

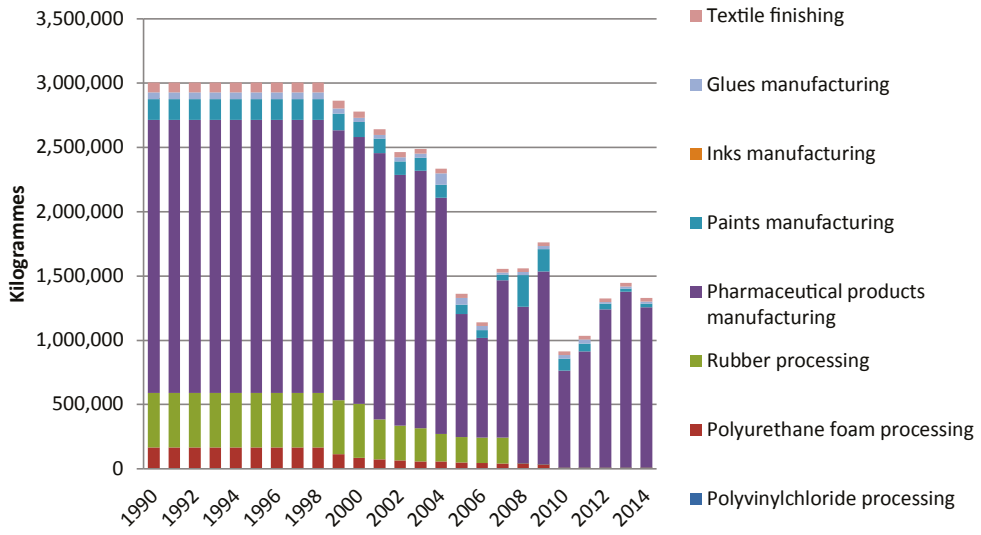

Figure 4.9. Emissions from NFR 2D3g: Chemical Products Manufacturing or Processing in Ireland (1990–2014).

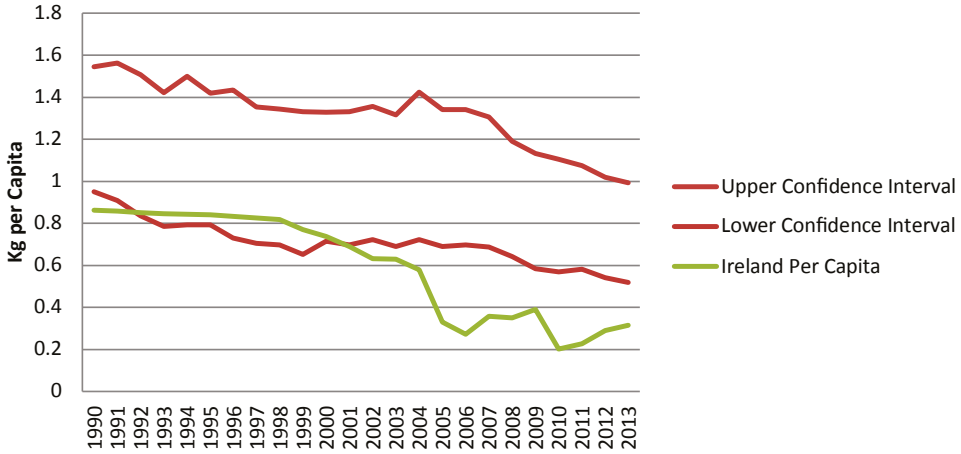

Figure 4.10. Verification of emissions from NFR 32D3g: Chemical Products Manufacturing or Processing (EU15 emissions) (1990–2013).

operating within the sector, production and employment. It is therefore expected that the pharma industry will be driving emissions. This estimate is considered reliable as it is obtained from bottom-up emissions data obtained from AERs as a result of IPPC licensing.

4.8 NFR 2D3h: Printing

Printing involves the use of inks, which may contain a proportion of organic solvents. These inks may then be subsequently 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. Ink solvents, diluents, cleaners and dampeners may all make a significant contribution to emissions from industrial printing.

In Ireland, 10 companies fall under the IPPC licensing system. However, not all of these report VOC emissions annually. According to national statistics, 717 companies were found to be operating in Ireland. However, many of these companies outsourced printing activities and did not use solvents. Expert opinion indicated that approximately 100 companies are actively involved in the print process and therefore generate VOC emissions. Emissions from this sector decreased by 46.9% over the 1990–2014 period. Emissions accounted for 12.4% of total emissions in 1990 and 8.1% of total emissions in 2014.

Emissions intensities were found to range between 0.05 and 1.76 kg per capita in 1990 and between 0.07 and 1.09 kg per capita in 2014. Ireland reported emissions of 0.83 kg per capita in 1990 and 0.32 kg per capita in 2013 (Figure 4.11). In addition, the emission trend reported by Ireland was representative of emissions reported by the EU15, as shown in Figure 4.11.

4.9 NFR 2G: Other Use of Solvents and Related Activities

This code also covers a large variety of sectors, many of which are small contributors to this category of emissions. This category comprises sectors that are not easily categorised and also contains emission sources that are not relevant to Ireland. Table 4.7 shows the sectors included in NFR 2G. Only a small number of emissions sources in NFR 2G were covered under the IPPC licence. As a result, national statistics are the main source of information.

Emissions from this sector decreased by 16.3%, from 1.8 Gg to 1.5 Gg, over the 1990–2014 period. In 1990, emissions from this category accounted for 8.5% of total emissions, whereas in 2014 emissions accounted for 15.1% of total emissions. Application of glues and adhesives was the largest emission source for most of this time period (Figure 4.12). In 2014, emissions from this sector accounted for 75% of emissions and emissions from wood impregnation accounted for 20.2% of emissions.

Figure 4.13 illustrates how Ireland's emissions compare with emissions reported by EU25 countries. The emissions estimates lie between the 95% confidence intervals for the whole time period. Emissions intensities ranged from 0.04 kg to 6.54 kg per capita in 1990 and from 0.08 kg to 6.95 kg per capita in 2013.

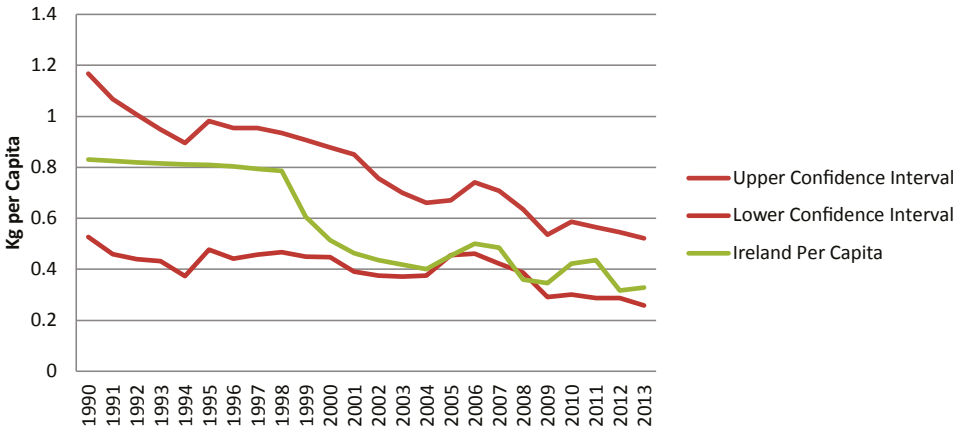

Figure 4.11. Verification of emissions from NFR 2D3h: Printing (EU15 emissions) (1990–2013).

Table 4.7. Comparison of current emissions sources with new emissions sources for NFR 2G: Other Use of Solvents and Related Activities

NFR	SNAP code	Description	New source	Current source
NFR 2G	060401	Glass wool	Based on AEA report	Based on AEA report
NFR 2G	060402	Mineral wool	NO	NO
NFR 2G	060404	Seed oil extraction	CSO statistics	NO
NFR 2G	060405	Industrial adhesives	CSO statistics	UK proxy
NFR 2G	060406	Wood impregnation	IPPC + NACE codes	Flatlined
NFR 2G	060407	Underseal treatment	NO	NO
NFR 2G	060409	Vehicle dewaxing	NO	NO
NFR 2G	060412	Other	NO	NO
NFR 2G	060602	Use of tobacco	Excise statistics	NE

NE, not estimated; NO, not occurring.

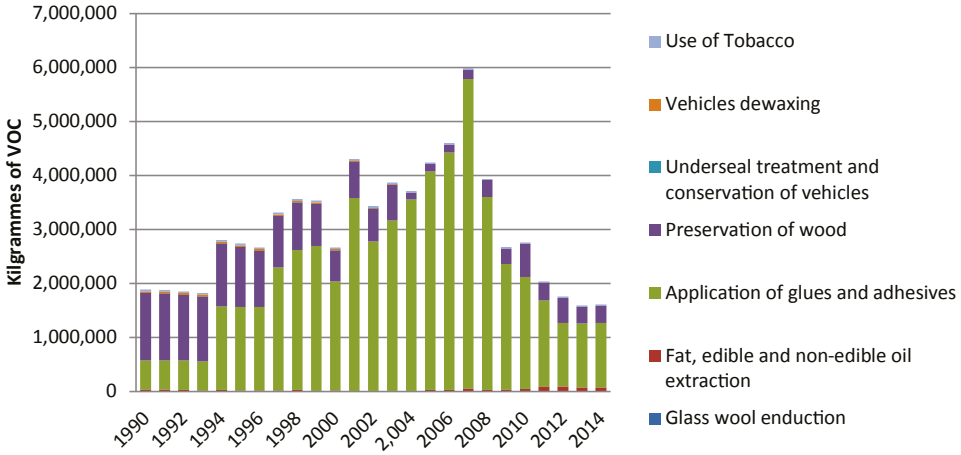

Figure 4.12. Emissions from NFR 2G: Other Use of Solvents and Related Activities in Ireland (1990–2014).

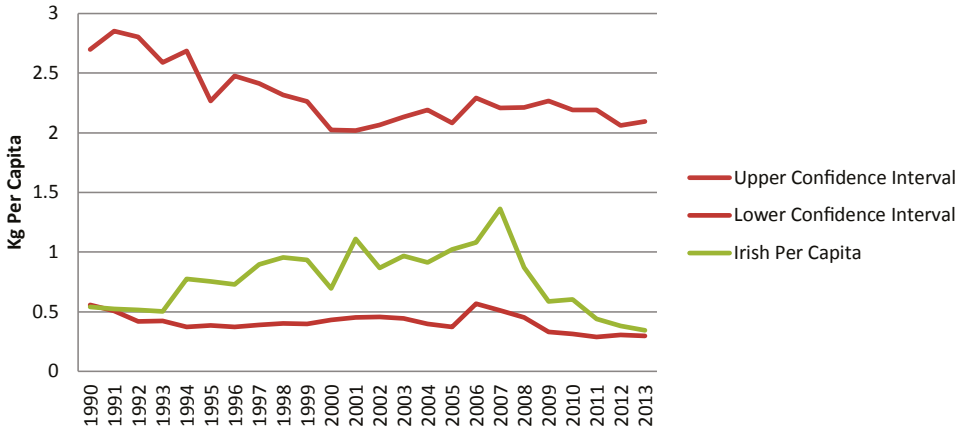

Figure 4.13. Verification of emissions from NFR 2G: Other Use of Solvents and Related Activities (1990–2013).

4.10 NFR 2H2: Food and Beverage Industry

Food manufacturing may involve the heating of fats and oils and foodstuffs containing them, the baking of cereals, flour and beans, fermentation in the making of bread, the cooking of vegetables and meats and the drying of residues. These processes may occur in sources varying in size from domestic households to manufacturing plants. When making any alcoholic beverage, sugar is converted into ethanol by yeast fermentation. The sugar comes from fruit, cereals or other vegetables, which may need to be processed before fermentation. For example, in the manufacture of beer, cereals are allowed to germinate and are then roasted and boiled before fermentation. To make spirits, the fermented liquid is then distilled. Alcoholic beverages, particularly spirits and wine, may be stored for a number of years before consumption.

Emissions data were obtained from the CSO. Consumption was calculated by using import, export and production data. Emission factors were obtained from the EMEP/EEA guidebook (EMEP/EEA, 2013). Emissions were estimated for coffee roasting, meat frying and curing and spirit, beer and bread production. Data sources provided in the EMEP/EEA guidebook, the data sources used in Ireland and the emission factors are outlined in Table 4.8.

Emissions from the food and beverage sector accounted for 13.6% of emissions in 1990 and 18.5% of emissions in 2014. Emissions have increased by 11% since 1990. The main driver of emissions in the food and beverage sector is animal feed, which accounted for 47% of emissions in 1990 and 69% of emissions in 2014 (Figure 4.14). Given the Food Harvest 2020 targets (DAFF, 2010), this sector may continue to increase if left unabated.

Table 4.8. Data sources used for NFR 2H2: Food and Beverage Industry

EMEP/EEA (2013) activity data	Data sources in Ireland	Emission factor
Production of home-killed meat	CSO	EMEP/EEA (2013) Tier 2
Total fish and seafood landed	Import, export and production statistics	EMEP/EEA (2013) Tier 2
Total production of poultry meat	CSO (total meat production)	EMEP/EEA (2013) Tier 2
Total sugar production	Eurostat	EMEP/EEA (2013) Tier 2
Production of fats excluding butter	NE	NE
Total production of bread	CSO (wheat consumed by humans)	EMEP/EEA (2013) Tier 2
Production of cakes, biscuits and cereals	IE	IE
Total production of feedstuffs	CSO (crops consumed by humans)	EMEP/EEA (2013) Tier 2
Beans roasted to produce coffee	CSO	EMEP/EEA (2013) Tier 2
Total production of wine	NO	NO
Production of beer and cider	CSO	EMEP/EEA (2013) Tier 2
Total production of spirits	CSO	EMEP/EEA (2013) Tier 2

IE, included elsewhere; NE, not estimated; NO, not occurring.

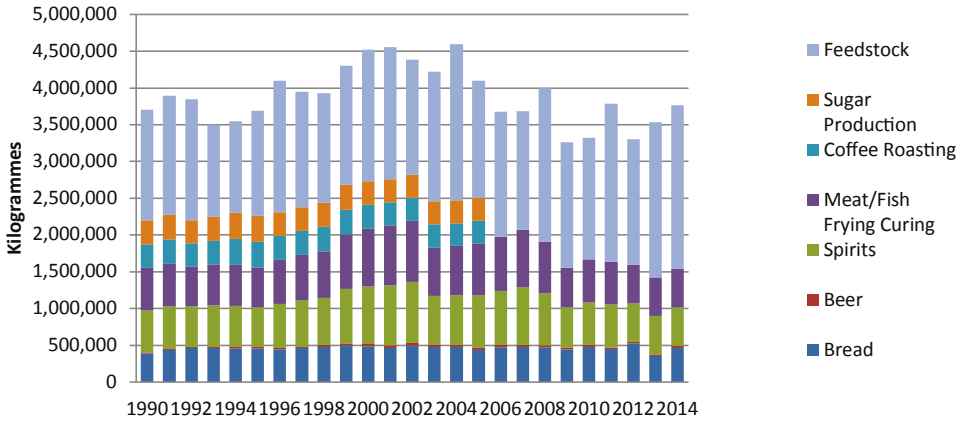

Figure 4.14. Emissions from NFR 2H2: Food and Beverage Industry in Ireland (1990–2014).

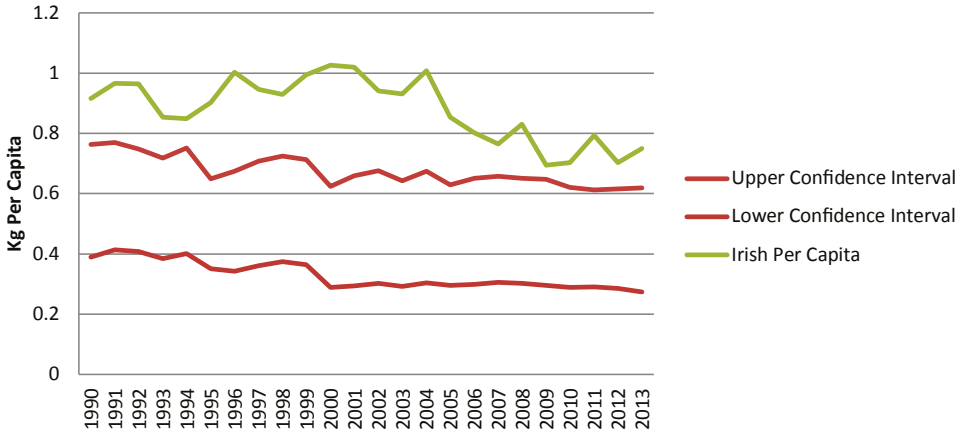

Figure 4.15. Verification of emissions from NFR 2H2: Food and Beverage Industry (1990–2013).

Figure 4.15 shows the emissions intensities from 1990 to 2013. Emissions from Ireland lie outside the 95% confidence intervals. In 1990, emissions intensities in the EU25 ranged from 0.19 kg to 1.27 kg per capita and in 2013 emissions intensities ranged from 0.001 kg to 1.44 kg per capita. Ireland's emissions intensities ranged from 0.91 kg per capita in 1990 to 0.75 kg per capita in 2013. Ireland's animal agricultural industry

is large and therefore emissions from feedstock are also large.

4.11 Total NMVOC Emissions Inventory Verification

Per-capita emissions intensities were compiled from the CEIP (2014) database for all NMVOC sources and Member States under the CLRTAP. The Irish NMVOC emissions inventory using the new NMVOC emissions estimate for solvent and other product use was plotted against the 95% confidence intervals for reported emissions intensities from the EU25 and is shown in Figure 4.16. Ireland's emissions intensity is closer to the lower confidence interval of the Member States that report emissions. Emissions intensities from the EU25 ranged from 9.18 to 11.23 kg per capita in 1990 and from 5.03 to 6.51 kg per capita in 2013. Ireland's emissions intensities were found to be 6.84 kg per capita in 1990 and 4.41 kg per capita in 2013.

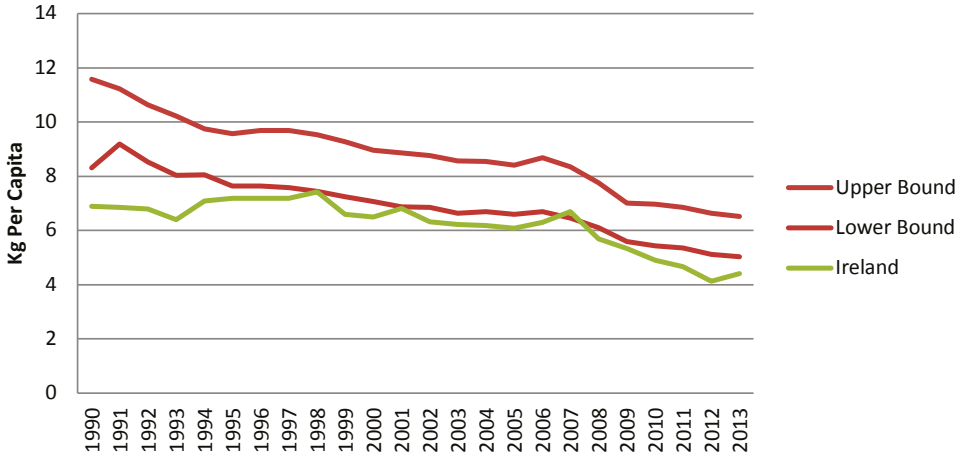

Figure 4.16. Verification of total NMVOC emissions (1990–2013).

5 Uncertainty Analysis

In order to provide an estimate of the accuracy of the data used in the inventory, an uncertainty analysis (Tier 1), in conjunction with a bootstrap simulation (when data were non-normally distributed or when small sample sizes were found), was completed. In addition, a sensitivity analysis (analysis of variance or ANOVA) was completed. This analysis provided a statement on the level of uncertainty in the inventory for 2014 and also in the emission trend. It also provided an uncertainty estimate for each NFR category in other solvent and product use. The overall uncertainty in the inventory for 2014 was estimated to be 45%. Figure 5.1 shows the uncertainty estimate for 2014 per NFR sector. The largest uncertainty was associated with NFR 2D3g: Chemical Products Manufacturing or Processing.

The uncertainty analysis facilitated a more robust approach to reducing uncertainty and variability. It does this by providing quantitative outputs for measuring the success of reducing emissions uncertainty. This allows a more focused efficient use of resources. Furthermore, the uncertainty analysis provides a more explicit statement of confidence in the data, on which policymakers can base their policies.

The limitations of the approach taken are well documented (Ramírez *et al*., 2008), namely the failure to capture correlations between parameters. However, this method is considered sufficient for year-to-year uncertainty calculations. The Monte Carlo method is recommended for occasions when major changes are anticipated in the inventory system. The Monte Carlo method may also help clarify assumptions with regard to data distribution.

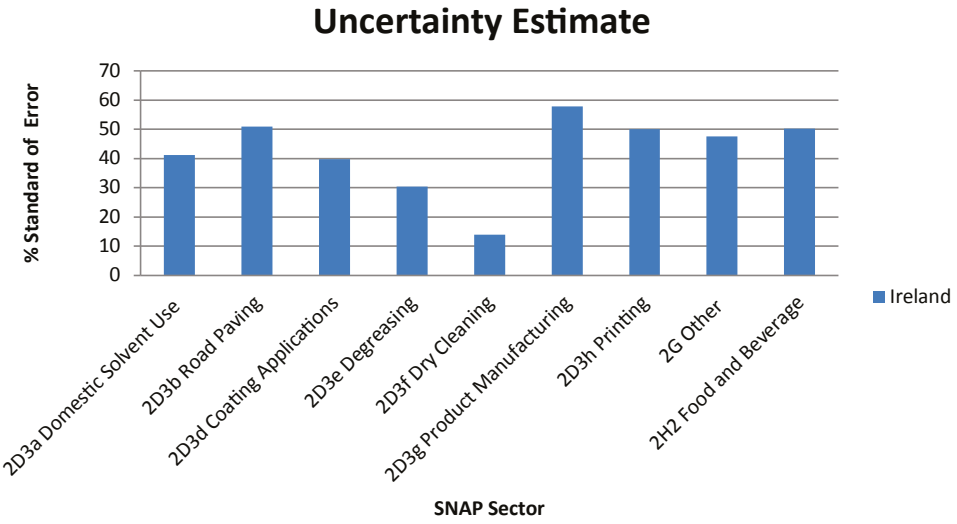

Figure 5.1. Standard errors for NFR sectors in Ireland in 2014.

6 Spatial Distribution from NFR 2D–2L: Other Solvent and Product Use

The goal of this chapter is to map NMVOC emissions from solvent usage in Ireland using an updated emissions inventory for 2014. Ireland reports annual emissions data under the CLRTAP as a party of the UNECE to the Executive Body of the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (unofficially EMEP).The updated emissions inventory was spatially disaggregated according to the EMEP/EEA guidebook (EMEP/EEA, 2013). Emissions estimates are required to be disaggregated and mapped at 5-year intervals, with the aim of supporting the link between emissions data and air quality models that need emissions information at a proper spatial, temporal and sectorial resolution.

Detailed emissions inventories have been used in many countries as a valuable resource for air quality experts to assess current and future air quality, a resource that may be currently underutilised in Ireland. These can be used to study both national and local emissions patterns. The maps are frequently used as a starting point for many local emissions inventories, which may then be used to assess current and future air quality. Emissions estimates for point sources and emissions arising from the surrounding area are used in modelling studies as part of Environmental Impact Assessments by developers and their consultants. By analysing the spatial disaggregation of emissions across Ireland, more effective monitoring and controls can be implemented, particularly at the regional or local level.

Previous NMVOC emissions mapping studies used relatively simple methodologies in which emissions were disaggregated based on industrial employment statistics. This current project used a superior methodology to map NMVOC emissions from solvent usage. This included using more point sources (co-ordinates were taken from various databases), using Coordination of Information on the Environment (CORINE) land use data when no co-ordinates were available, and using CSO population and household statistics as proxies for emissions distributions.

Figure 6.1 shows the spatial distribution of emissions per county in Ireland. As can be seen from these data, emissions are more concentrated in urban areas such as Dublin and Cork. Although the mapping of emissions using this grid is necessary for input into the EMEP database and air dispersion models, it is important to analyse the data at scales at which air quality issues are managed.

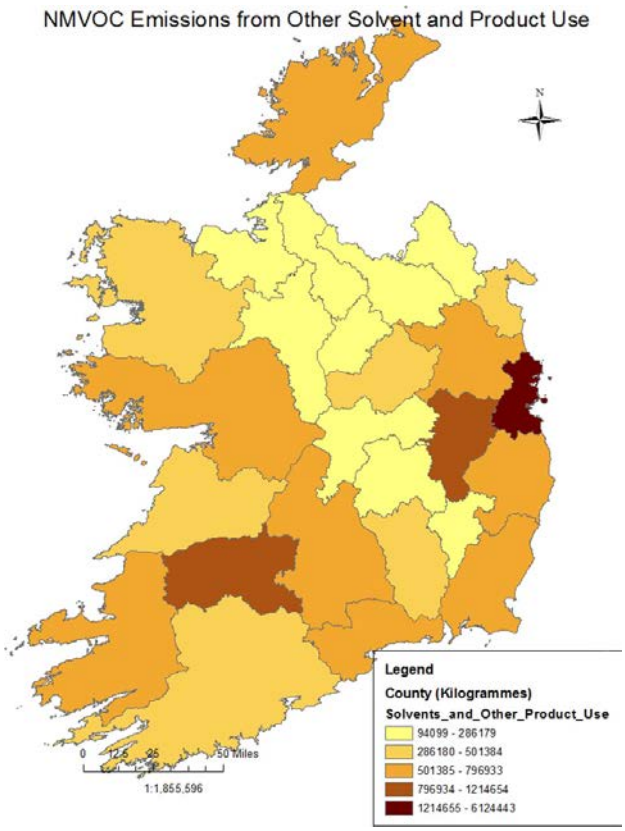

Figure 6.1. Spatial distribution of emissions from other solvent and product use in Ireland (2014).

7 Speciation of VOC Emissions Found in the NFR 2D–2L: Other Solvent and Product Use Category

As VOCs have different POCPs, sectors that have the highest emissions may not necessarily be the most significant in terms of the creation of tropospheric ozone (Derwent *et al.*, 1998). In addition, by not accounting for POCPs, it is unclear which sector is contributing to ozone formation (e.g. transport or solvent usage), therefore making it more difficult for policymakers to effectively deal with tropospheric ozone formation. In order to address this, Theloke and Friedrich (2007) provide sectorial speciation profiles; however, it is unclear if these data are appropriate for use in Ireland.

The development of speciation profiles in Ireland will enable the development of a more robust VOC monitoring programme. Currently, VOC emissions are monitored in only one location, with a small number of VOCs being monitored. The advantages of developing a VOC monitoring system are numerous. Used in conjunction with emissions mapping, measurements and inverse modelling projects can also be used to validate the emissions inventory and modelling studies can be conducted to analyse VOC/NO_x limiting factors. Furthermore, the health impacts associated with VOC emissions are coming to the forefront and therefore warrant a more robust monitoring programme.

Data obtained from two solvent distributors in Ireland were used to develop a database of the main solvents used in Ireland, as well as the sectors that they are used in. Fifty-two solvents were identified in this survey, occurring in 12 sectors.

Figure 7.1 shows that ethyl acetate was found to be the most commonly used solvent within the Irish emissions inventory and accounted for 37.4% of emissions in 2014. Methanol accounted for 12.3% of emissions. Domestic solvent usage accounted for 99% of emissions of ethyl acetate in 2014. Coating applications were found to account for 93.6% of methanol emissions. The degreasing sector accounted for 86% of emissions of dichloromethane.

The results of this study show that a small number of solvents account for the majority of emissions of NMVOCs. In order to verify the findings of this study, monitoring regimes could be used to provide additional information, particularly in industrial areas or near facilities such as pharmaceutical plants or paint manufacturers. This type of data is important in developing more complete air quality management assessments, policies and monitoring regimes, which in turn will feed back into the development of more complete and robust emissions inventories.

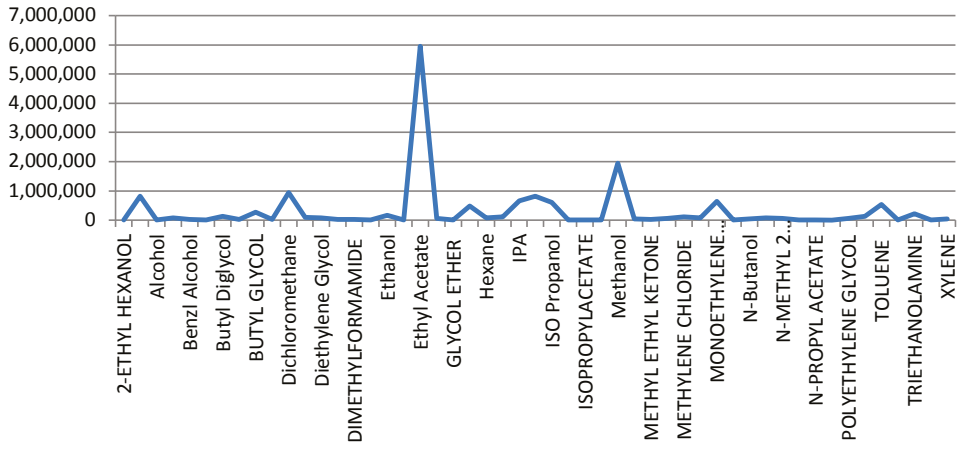

Figure 7.1. Speciation of VOCs in Ireland's emissions inventory.

8 Reporting Issues Found in the Integrated Pollution Prevention and Control Data Collected during the Course of the Study

As outlined in CTC/AEA (2005) and Styles *et al*. (2009), a number of reporting issues made the compilation of an emissions estimate challenging. This resulted in considerable gap-filling procedures being implemented in order to overcome the poor quality of data found in submitted AERs. In response to this, the project reviewed all licensed facilities that reported NMVOC emissions from solvent usage and assessed them based on a number of criteria outlined in Barry and O'Regan (2014). The output from this review showed that a significant number of AERs (over 50% of those reviewed) were considered to be poor. As can be seen in Figure 8.1, the most frequently occurring issue was licensed facilities not submitting solvent mass balances. Solvent mass balances are considered the best method of reporting emissions.

Other issues included reports that were illegible, reports that were not transparent (large appendices were attached that made finding relevant information difficult, not including sections that were in the table of contents, quoting several different NMVOC estimates in the air monitoring section or AER workbook) and not using the most up-to-date format.

Barry and O'Regan (2014) also made several recommendations to overcome these obstacles, ranging from increased quality control measures by the EPA, introducing mandatory reporting of NMVOC emissions using the online reporting systems, streamlining of monitoring methodologies and parameters reported, and engaging with licence holders to identify the barriers to reporting emissions accurately.

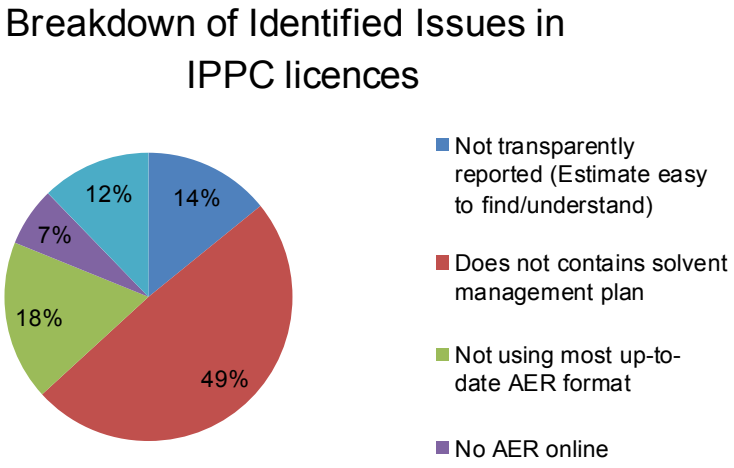

Figure 8.1. IPPC reporting issues.

9 Policy Assessment

Ireland is a member party to a number of international treaties (e.g. the Kyoto Protocol, CLRTAP), which oblige the state to report national and spatial emissions of NMVOCs. Under these treaties, Ireland is required to estimate emissions in a transparent, accurate, complete, consistent and comparable manner. In addition, member parties are required to determine the impact of air pollutants on the environment and human health (Article 2 of CLRTAP) and develop policies and strategies to combat the discharge of air pollutants (Article 2 of CLRTAP). These objectives are met under eight protocols, of which 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. Therefore, Ireland voluntarily reports NMVOC emissions under the CLTRAP.

European Union legislation (namely the National Emission Ceilings Directive) sets national targets for NMVOC emissions reductions (55 kt in Ireland's case). Figure 9.1 shows Ireland's sectorial emissions for 1990–2013. Two emissions sources accounted for the majority of NMVOC emissions in 2013: agriculture accounted for 47.3% of NMVOC emissions in 2013, whereas other fugitive and solvents accounted for 26.7% of emissions. Large reductions in emissions from residential and commercial combustion, agricultural/forestry/fishing combustion and transport were reported over the time period from 1990 to 2013.

Emissions reductions in these sectors were driven by technological controls in the case of transport emissions and reductions in coal and peat consumption. In the case of agriculture (manure management), emissions are closely linked to the Food Harvest 2020 targets and herd populations. Other solvent and product use emissions have decreased by 9% over the 1990–2014 period. A number of policies have been introduced to reduce NMVOC emissions. The IPPC Directive (96/61/EC) regulates VOC emissions in facilities that use solvents of a certain threshold. The Decorative Paints Directive limits the amount of VOCs in decorative coatings and the VOC Solvents Directive regulates a wide range of solvent-using activities, e.g. printing, surface cleaning, vehicle coating, dry cleaning and the manufacture of footwear and pharmaceutical products. Figure 9.2 shows that emissions from decorative paint applications have begun to decline, although sales of solvent-based paints have increased.

In some instances the impact of policy is not as clear. Figure 9.3 shows the emissions trend for pharmaceutical production (kg) and also the

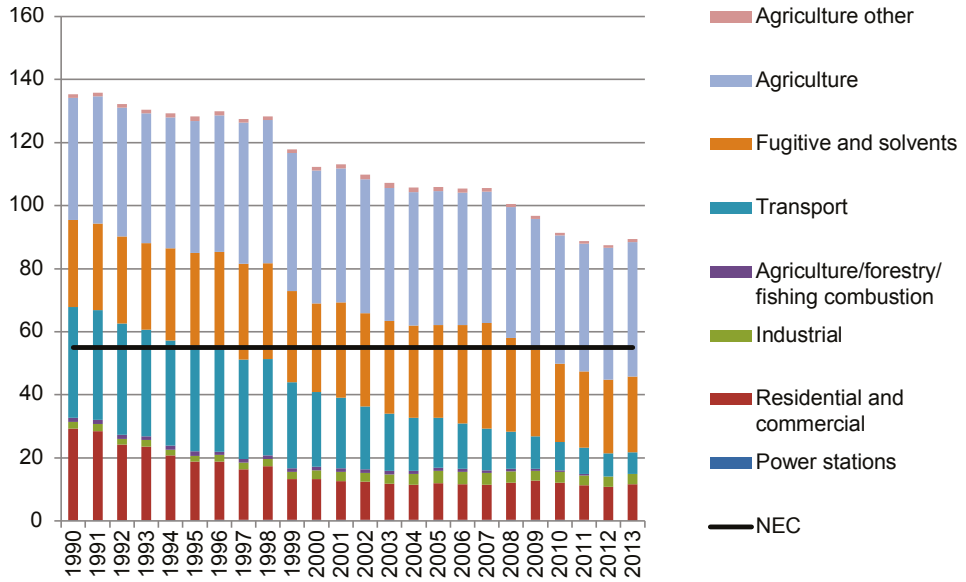

Figure 9.1. Emissions sources contributing to total NMVOC emissions in Ireland (1990–2013).

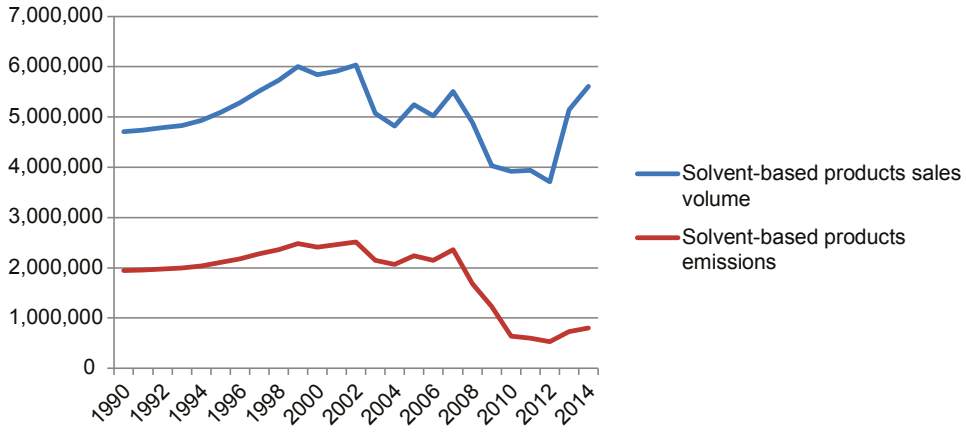

Figure 9.2. Solvent-based product sales compared with solvent-based product VOC emissions in Ireland (1990–2014).

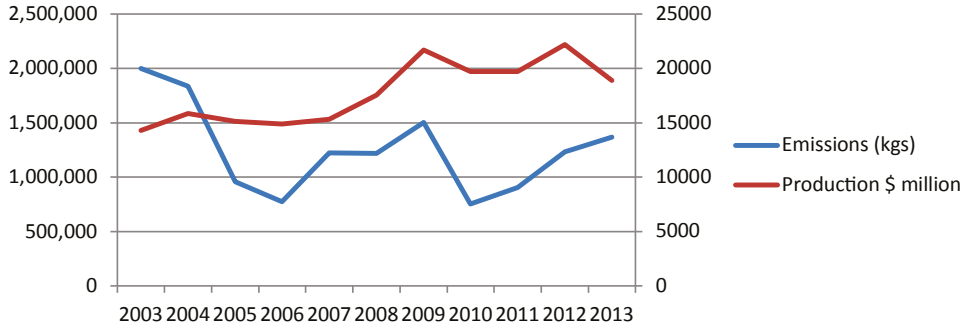

Figure 9.3. Pharmaceutical VOC emissions compared with pharmaceutical production in Ireland (2003–2013).

production trend (millions of dollars) from 2003 to 2013. Emissions and production remain closely linked and the VOC Solvents Directive does not seem to have had a significant impact. As mentioned, several reporting issues exist concerning the pharmaceutical sector and this introduces uncertainty into the emissions estimate.

Current policy initiatives can therefore be described as having only a marginal impact on the use of solvents within Ireland. However, two large emissions sources are currently unregulated (in terms of solvent usage or VOC emissions). Taken together, domestic solvent usage including fungicides and food and beverage production accounted for 52.9% of emissions in 2014. In the case of domestic solvent use including fungicides, emissions of NMVOCs occur as VOCs that are used as propellants and also as binders and solvents. Given the increasing population (a main driver of domestic product consumption) and the lack of policy addressing this emission source, emissions are likely to increase and result in the 2020 and 2030 targets being exceeded. Food and beverage industry emissions occur mostly as a result of the cooking, processing, baking or roasting of foodstuffs, for either human consumption or animal feed. The major emissions source in this sector is the production of animal feedstuffs. Given Food Harvest 2020 targets and the intensification of the production of animal products that will follow, these emissions are also likely to increase.

Figure 9.4 shows projections for total NMVOC emissions from power stations, residential, commercial and industrial sectors, agricultural combustion, fugitive and solvents, agriculture (manure spreading) and other. Current projections (Duffy *et al.*, 2015) were used for all sources except solvent use. Projections were calculated based on the average rate of change or, when a strong correlation was found, emissions were extrapolated using an independent variable (e.g. population, GDP). Based on the present NEC target, Ireland is currently on course to exceed this significantly. Even ambitious emissions reduction

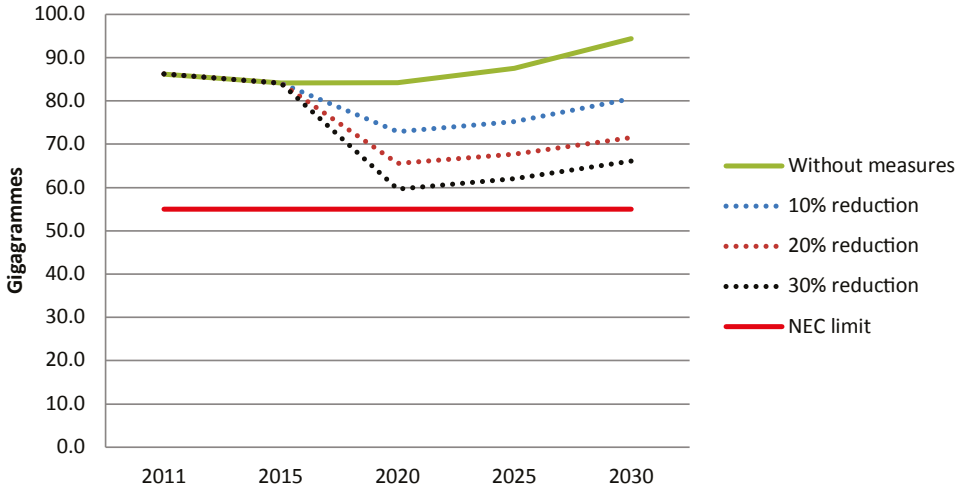

Figure 9.4. Projections for NMVOC emissions in Ireland until 2030.

measures (30% reduction) will not bring Ireland below the current NEC target.

Potential strategies should focus on reducing emissions from domestic solvent use including fungicides, from the food and beverage industry, from other solvent and product use and from agriculture (manure management). With regard to domestic solvent use including fungicides, manufacturers should be encouraged to substitute VOC-containing products or reduce their use.

10 Discussion

Non-methane volatile organic compound emissions were calculated for the NFR 2D–2L: Other Solvent and Product Use sectors. The results show that emissions decreased by 18% from 1990 to 2014. Relatively few sectors were found to contribute the majority of emissions. SNAP codes 060408: Domestic Solvent Use including Fungicides, 060103/060104: Retail Decorative Coating, and 060306: Pharmaceutical Products Manufacturing and NFR 2H2: Food and Beverage Industry accounted for 79% of emissions in 2014, an increase of 15 percentage points compared with 1990, when these sources accounted for 64% of total emissions. Based on this evidence, future reporting iterations should continue to prioritise these sectors in terms of improving data quality, clarifying underlying assumptions and reducing the uncertainty and variability within these sectors. This study resulted in the quantification of new emissions sources, including food and beverage production, road paving with asphalt and tobacco burning. Of these sectors, food and beverage production is the most significant source of emissions (accounting for 18.5% in 2014).

The methods used to estimate emissions have changed for the vast majority of emissions sources included in the NFR 2D–2L: Other Solvent and Product Use sector. More emphasis was placed on key category emissions sources such as SNAP codes 060103/060104: Retail Decorative Coating, 060306: Pharmaceutical Products Manufacturing and 060408: Domestic Solvent Use including Fungicides. A significant improvement included the recalculation of emissions from SNAP code 060408. Using activity data obtained from national statistics and emission factors obtained from a survey of 171 products over the period 1992–2014, this study accounted for the environmental pathway for these products. Products mixed with water prior to or during use were adjusted to ensure that accurate emissions to the atmosphere were calculated. The results show that emissions have increased by 57%, from 4.4 kt to 8.0 kt, over the 1990–2014 period. The largest sources in 2014 were cosmetic and personal care products (51%), household products (16%) and car care products (11%). Emissions were calculated to be, on average, 38% lower than in the EMEP/EEA (2013) Tier 1 method.

In addition, new methods were developed to calculate emissions from SNAP codes 060103/060104. This included using activity data obtained from a major trade organisation and emission factors based on a comprehensive survey of products available on the Irish market. In addition, data were extrapolated to estimate the historical solvent content of paint in order to reflect emissions reductions. Improved methods were also used in several other emissions source categories, for example pharmaceutical production, industrial paint application and the printing industry. For these sources, emission monitoring data were obtained from solvent mass balance calculations or from solvent usage and emission data collected under the VOC Solvents Directive, (e.g. dry cleaning). When bottom-up data were not available, national statistics were used as activity data.

New emissions sources were included in the 2016 submission, including NFR 2D3b: Road Paving with Asphalt, NFR 2H1: Pulp and Paper Production and NFR 2H2: Food and Beverage Production. Of these, the food and beverage industry is the most significant emission source. Emissions were calculated using national statistics, gathered either by the CSO or by state institutions such as Inland Fisheries Ireland and Bord Iascaigh Mhara. The largest emission source was found to be the animal feed sector. However, some methodological issues exist with this emission source. For instance, Ireland's emissions intensity is among the highest of the EU25. Ireland's main agricultural industry is the beef and dairy sector. This sector is largely grass fed and therefore the use of animal feed in Ireland should not be significantly higher than in other countries. Further investigation is required to ascertain the drivers of these emissions.

A major objective of this study was to produce procedures to verify both the sectorial emissions estimates and the national emissions estimates. This was achieved by comparing Ireland's emissions intensity with those of EU25 countries by comparing Ireland's emissions intensity with the confidence

intervals reported by other countries and analysing the underlying reasons for any differences. For instance, Ireland reports a significantly lower emissions intensity than other EU25 members for NFR 2D3d: Coating Applications. Further investigation showed that emissions in this sector were driven by the vehicle manufacture sector. This sector does not operate in Ireland and this explains Ireland's low per-capita emissions estimate for this sector. As a result of these types of analyses, a method is now in place to assess if Ireland is reporting comparable estimates to those of other countries and if this meets reporting requirements under the EMEP/EEA guidebook (EMEP/EEA, 2013) (namely TACCC). In addition to verification procedures, an uncertainty analysis was conducted to assess the overall inventory uncertainty and also to identify sectors that were most uncertain. The pharmaceutical sector was the sector containing the most uncertainty. However, all emissions estimated based on IPPC data were found to have high uncertainty. Future studies should focus on reducing uncertainty within the reporting of emissions covered under the IPPC licensing system. Overall uncertainty was estimated at 45% in 2014.

Sales statistics aggregated per sector were used to develop speciation profiles. Using the profiles, solvents commonly used in Ireland were identified. This has a number of benefits, including enabling an assessment of PCOP's sectorial contribution to ozone-creating VOCs, informing which solvents the EPA should conduct air modelling assessments on and providing information with which to assess the impact of policymaking decisions in terms of working with industry to reduce the use of harmful VOCs.

Emissions were spatially distributed for 2014 using the new activity data obtained from the project. Point sources and area sources were used in the development of this map. When the locations of some emissions sources were not known (e.g. when data were up-scaled based on emissions data and NACE codes), emissions were allocated to an appropriate land use type using CORINE land use data. The spatial distribution of emissions shows that urban areas are often the areas associated with higher emissions. This is because of greater housing densities and populations than in non-urban areas, with emissions from sectors such as decorative coating applications and domestic solvent usage therefore likely to be greater. In addition, industrial areas are often located in areas that are served by good infrastructure, are likely to be closer to urban areas than non-urban areas and are therefore more attractive for pharmaceutical companies to operate in, resulting in higher emissions.

Integrated Pollution Prevention and Control reporting issues were investigated and several issues were highlighted. In general, the level of reporting from IPPC facilities was considered poor. A number of factors contributed to this but, in general, it was observed that only a few licensed facilities completed the necessary reporting sections in an accurate and reliable manner. Recommendations were made to address these issues, including implementing more robust quality assurance/quality control procedures by the EPA and also implementing mandatory reporting (e.g. users of solvents must report the quantities used). Improved data collection will enable far better emissions estimates to be generated and also ensure that emissions estimates can be compiled more efficiently (e.g. reduce the time necessary to decipher large or unclear emissions data).

Based on reported total national emissions of NMVOCs by all sectors covered under NEC legislation over the 1990–2014 period, Ireland has exceeded its target of 55 kt. This is largely driven by emissions from agriculture (manure management), which accounted for 47.3% of total emissions in 2013, with other solvent and product use remaining a significant source of emissions (26.7% in 2013). Overall, NMVOC emissions from Ireland decreased by 12.4% over the 1990–2013 period according to data obtained from https://www.ceip.at. Among EU25 countries (excluding Ireland), emissions reductions of 23–70% were seen over the 1990–2013 period. The average reduction in emissions was calculated to be 54%. Based on these statistics, Ireland was found to have reported lower emissions reductions than other EU25 countries. The reasons for this are complex, multifactorial and require further study. However, emissions in the EU25 decreased by 30% over the period 1990–2013 for solvent usage, whereas in Ireland emissions reduced by 15%. As emissions are driven by domestic solvent usage including fungicides, policies should be aimed at reducing emissions from this sector.

11 Conclusion

Non-methane volatile organic compound emissions from solvent and other product use have been estimated for the period 1990–2014. This included updating activity data, emission factors and emissions data and compiling this information into a national emissions estimate for the specified years. Emissions were found to have decreased by 12.8% over the 1990–2014 period. NMVOC emissions are dominated by a small number of sectors. These include domestic solvent usage, pharmaceutical production, decorative coating applications, printing and the food and beverage industry. Combined, these sectors accounted for 68% of emissions on average throughout the period from 1990 to 2014. Future work should focus on refining emissions estimates from these sectors with the aim of improving data collection exchange with data holders, clarifying underlying assumptions of emission models and also working with the relevant offices within the EPA to ensure that accurate and reliable data are collected from licensed facilities.

Emissions estimates were verified using per-capita emissions intensities from the EU25, compared at sectorial level. Total NMVOC emissions (from all sectors) were compared using per-capita emissions estimates obtained from the CEIP website for all reporting parties. Ireland's emissions estimates are comparable to other national emissions estimates in the majority of cases. The estimate can be considered low in some instances and this is because Ireland does not have the same level of industry as many of the other member parties (particularly vehicle manufacturing). These types of verification procedures were considered a valuable tool in compilation of the inventory and provided a quick method of assessing the representativeness of the inventory.

In conjunction with the verification procedures, an uncertainty analysis was conducted to help ascertain the quality of the data being used and also highlight areas that require additional investigation. The uncertainty analysis showed that Ireland's annual uncertainty estimate was ±45. As NFR 2D–2L: Other Solvent and Product Use is known to be a sector with large uncertainties, and given some of the challenges in obtaining accurate activity data, this estimate is considered a fair representation of the uncertainty. In addition, valuable information was obtained with regard to the uncertainty associated within each sector. This allows a more targeted approach to improving the data used in the inventory.

Emissions were mapped for NFR 2D–2L: Other Solvent and Product Use using a combination of point sources, using data from IPPC licensing and the VOC Solvents Directive, and area sources, using data based on population and household statistics at electoral district level. This represented a significant improvement over the previous method, which disaggregated national emissions using industrial employee statistics.

In general, the compilation of the NMVOC emissions estimate for solvent usage was considered successful. The estimate is comparable to other countries' emissions estimates, and uncertainty has been estimated for each sector and emissions have been mapped. The principles of the EMEP/EEA (2013) reporting guidebook are represented throughout the compilation of the emissions estimate. Furthermore, a framework for the continued improvement of the NMVOC inventory has been established, with well-defined priority areas.

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Abbreviations

AER	Annual Environmental Report
CAS	Chemical Abstracts Service
CEIP	Centre on Emission Inventories and Projections
CLRTAP	Convention on Long-range Transboundary Air Pollution
CORINE	Coordination of Information on the Environment
CSO	Central Statistics Office
DIY	Do-it-yourself
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency
EU	European Union
Eurostat	European Statistical Office
GDP	Gross domestic product
IPPC	Integrated Pollution Prevention and Control
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NEC	National Emission Ceilings; Directive 2001/81/EC
NFR	Nomenclature for Reporting
NMVOC	Non-methane volatile organic compound
OECD	Organisation for Economic Co-operation and Development
POCP	Photochemical ozone creation potential
PRTR	Pollutant Release and Transfer Register
SNAP	Selected Nomenclature for Reporting of Air Pollution
TACCC	Transparency, accuracy, completeness, comparability and consistency
UNECE	United Nations Economic Commission for Europe
VOC	Volatile organic compound

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.

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Activity Data for Emissions of Non-methane Volatile Organic Compounds

Authors: Stephen Barry and Bernadette O'Regan

Non-methane volatile organic compound (NMVOC) emissions from Solvent and Other Product Use have been estimated for 2006–2012. This included updating the activity data, emission factors and emissions data and compiling this information into a national emissions estimate for the specified years.

Identifying Pressure

Emission estimates were verified using per-capita emission intensities compared at a sectorial level with those for EU15 and EU27 countries. Total NMVOC emissions (from all sectors) were compared using per-capita emission estimates obtained from the Centre on Emission Inventories and Projections (CEIP) website for all reporting parties. Ireland's emission estimate is comparable to other national emission estimates in the majority of cases.

Informing Policy

Emissions were mapped for Nomenclature for Reporting (NFR) 3 Solvent and Other Product Use using a combination of point sources using data from Integrated Pollution Prevention and Control (IPPC)-licensed facilities, data gathered as a result of the Solvents Directive and area sources, which used data based on population and household statistics at electoral district level. This represented a significant improvement over the previous method, which disaggregated national emissions using industrial employee statistics.

Developing Solutions

Emissions were found to have increased by 15.1% over the period from 1990 to 2012. NMVOC emissions are dominated by a small number of sectors. These include domestic solvent usage, pharmaceutical production and decorative coating applications. Combined, these accounted for 67% of emissions, on average, throughout 1990–2012. Future work should focus on refining emissions estimates from these sectors, with the aim of improving data collection exchange with data holders, clarifying underlying assumptions of emissions models and working with the relevant offices within the Environmental Protection Agency to ensure that accurate and reliable data are collected from licensed facilities.

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