UK Informative Inventory Report (1990 to 2015)

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Executive Summary

This is the 12th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) Programme. The report accompanies the UK's 2017 data submission under the revised EU Directive 2016/2284/EU on National Emissions Ceilings (NECD) and the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP). It contains detailed information on annual emission estimates of air quality pollutants by source in the UK from 1990 onwards. Emission estimates are presented in this report for a large number of pollutants, focusing on the pollutants that must be reported under the NECD and the CLRTAP.

The scope of emissions reported under the CLRTAP covers anthropogenic emissions to atmosphere from the UK and Gibraltar from sources defined under the CLRTAP. The reporting requirements under the revised NECD (which entered into force on 31 December 2016) are closely aligned with those of the CLRTAP, including a common scope of reporting of pollutant inventories. The UK submission to the NECD[1] and the CLRTAP[2] comprises annual emission estimates presented in Nomenclature for Reporting (NFR14) format, for:

- Nitrogen oxides (NO_x (as NO_2)), carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_x (as SO_2)), non-methane volatile organic compounds (NMVOCs), particulate matter (PM), persistent organic pollutants, and heavy metals (1990 to 2015).

Both the NECD and the Gothenburg Protocol to the UNECE CLRTAP set 2010 emissions ceilings for NO_x, SO_x, NMVOCs and NH_3. The Gothenburg Protocol was revised in May 2012 to set stricter emission reduction obligations from 2020. This Protocol has also been extended to set emission reductions for $PM_{2.5}$[3]. The revised NECD sets ceilings for 2020 (in line with Gothenburg Protocol ceilings) and 2030 for the same air pollutants.

An overview of emissions from 1990-2015 by source sector for each of these pollutants is provided in Figure ES.1-1 through to Figure ES.1-4. The codes accompanying the definition of each source category in these figures refer to the NFR14 codes for the source sectors shown.

[1] See http://ec.europa.eu/environment/air/pollutants/ceilings.htm for Information on the new NEC Directive (2016/2284/EU)
[2] See http://www.ceip.at/reporting-instructions/reporting-programme/ for reporting requirements set up by TFEIP/UNECE Guidelines for estimating and reporting emissions data under CLRTAP.
[3] $PM_{2.5}$ refers to particulate matter with a diameter less than 2.5μm, PM_{10} refers to particulate matter with a diameter less than 10μm

Figure ES.1-1 Total UK Emissions by Source Sectors of Oxides of Nitrogen (NO_x as NO_2), 1990-2015.

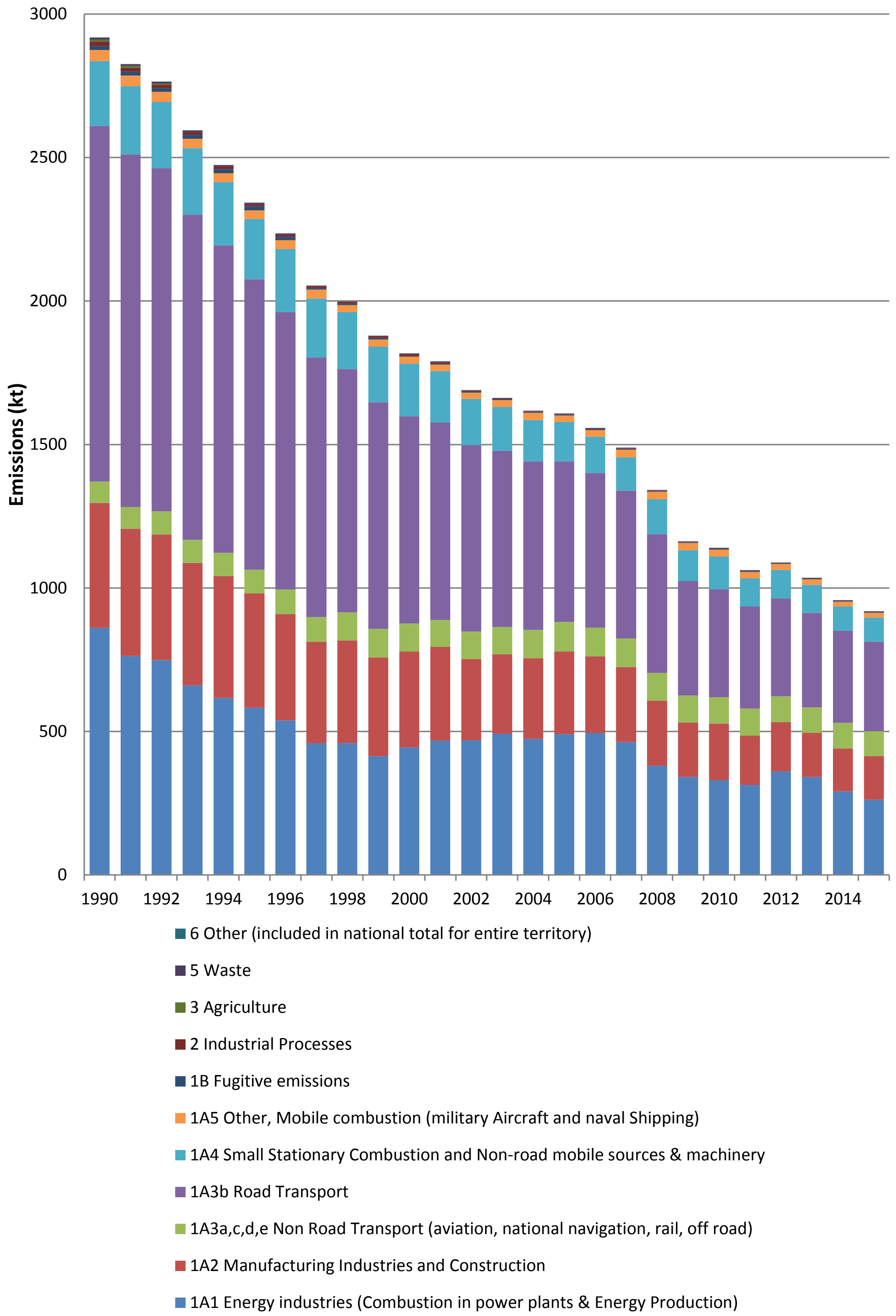


Figure ES.1-2 Total UK Emissions by Source Sectors of Non-Methane Volatile Organic Compounds (NMVOCs), 1990-2015.

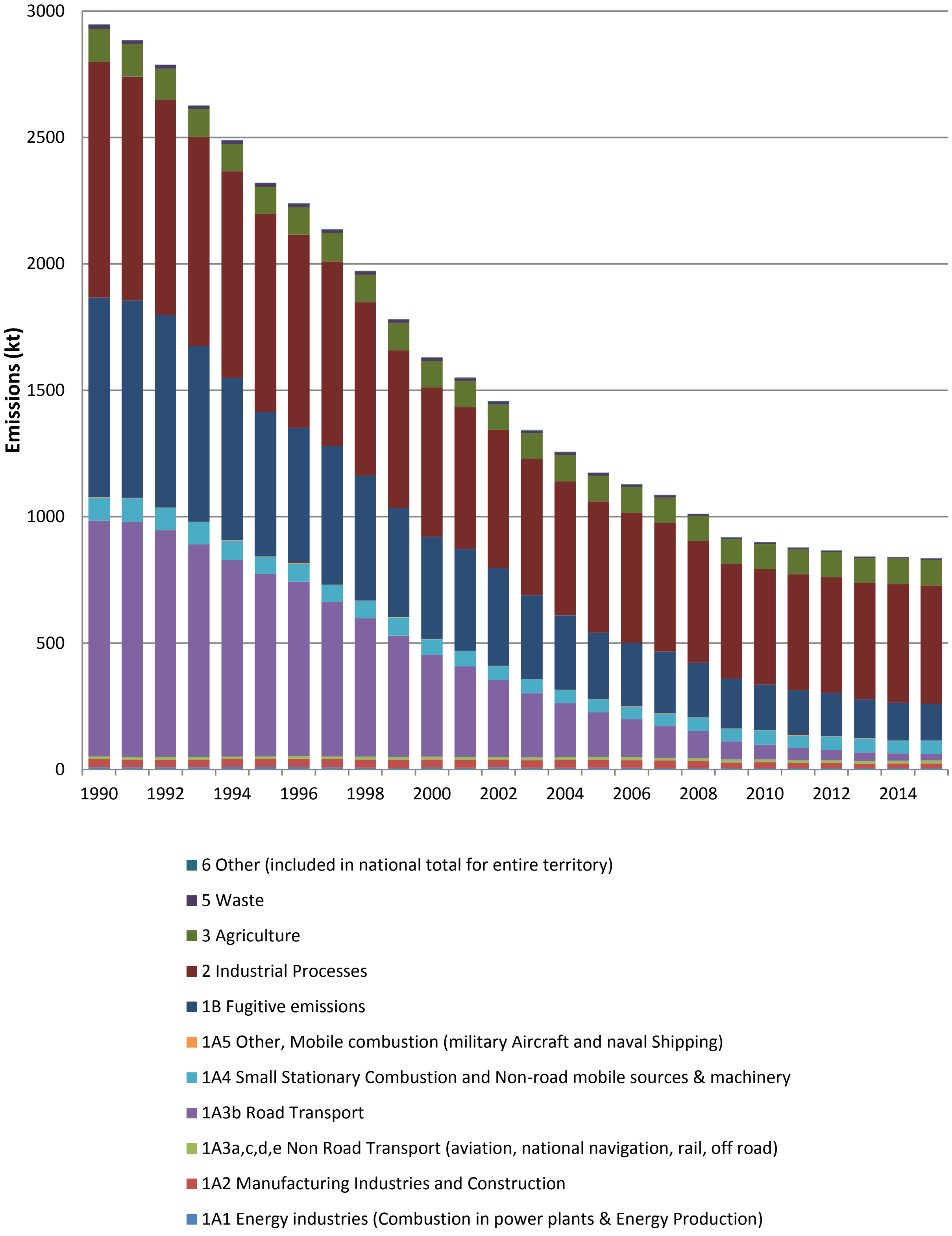


Figure ES.1-3 Total UK Emissions by Source Sectors of Sulphur Dioxide (SO_x as SO_2), 1990-2015.

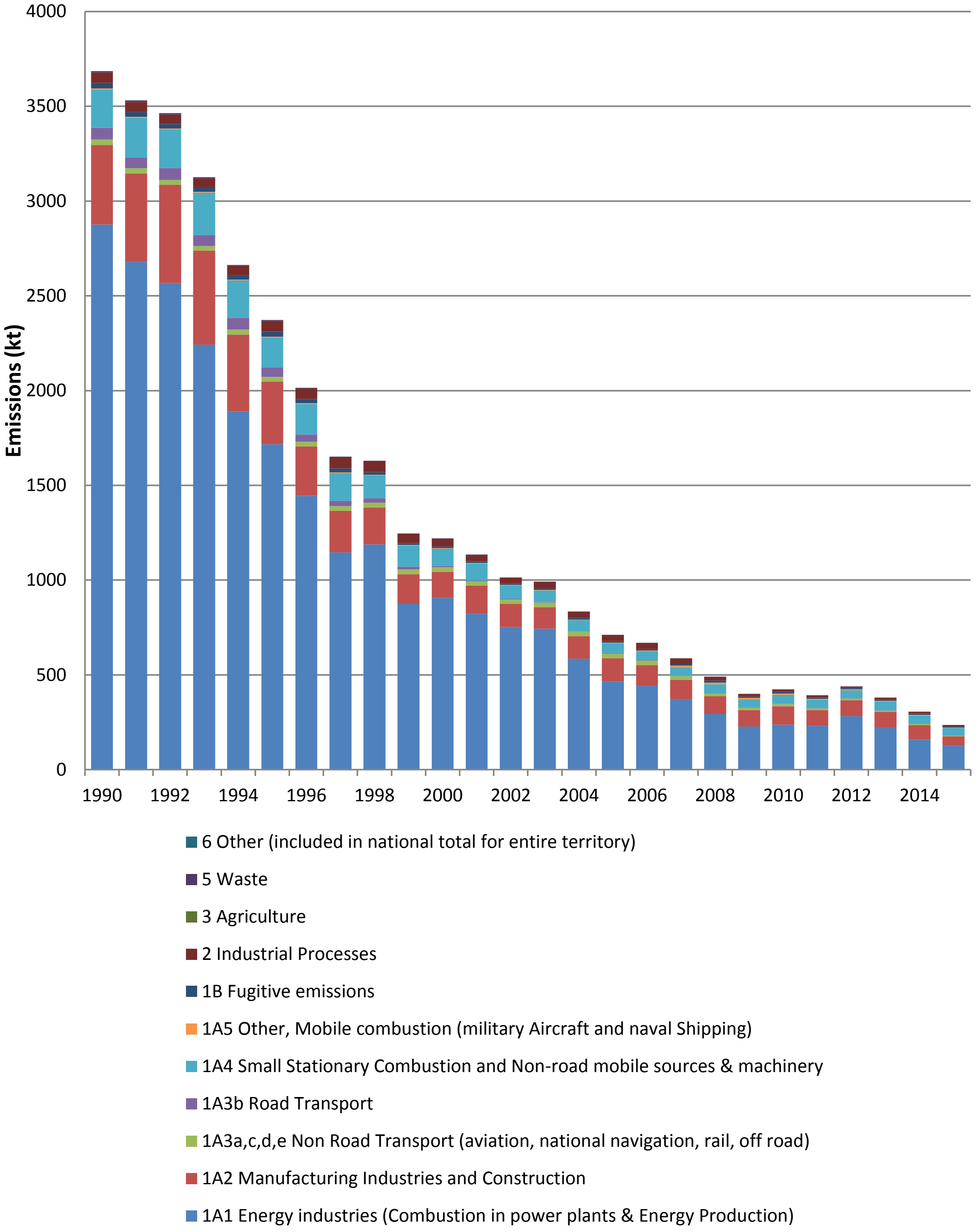
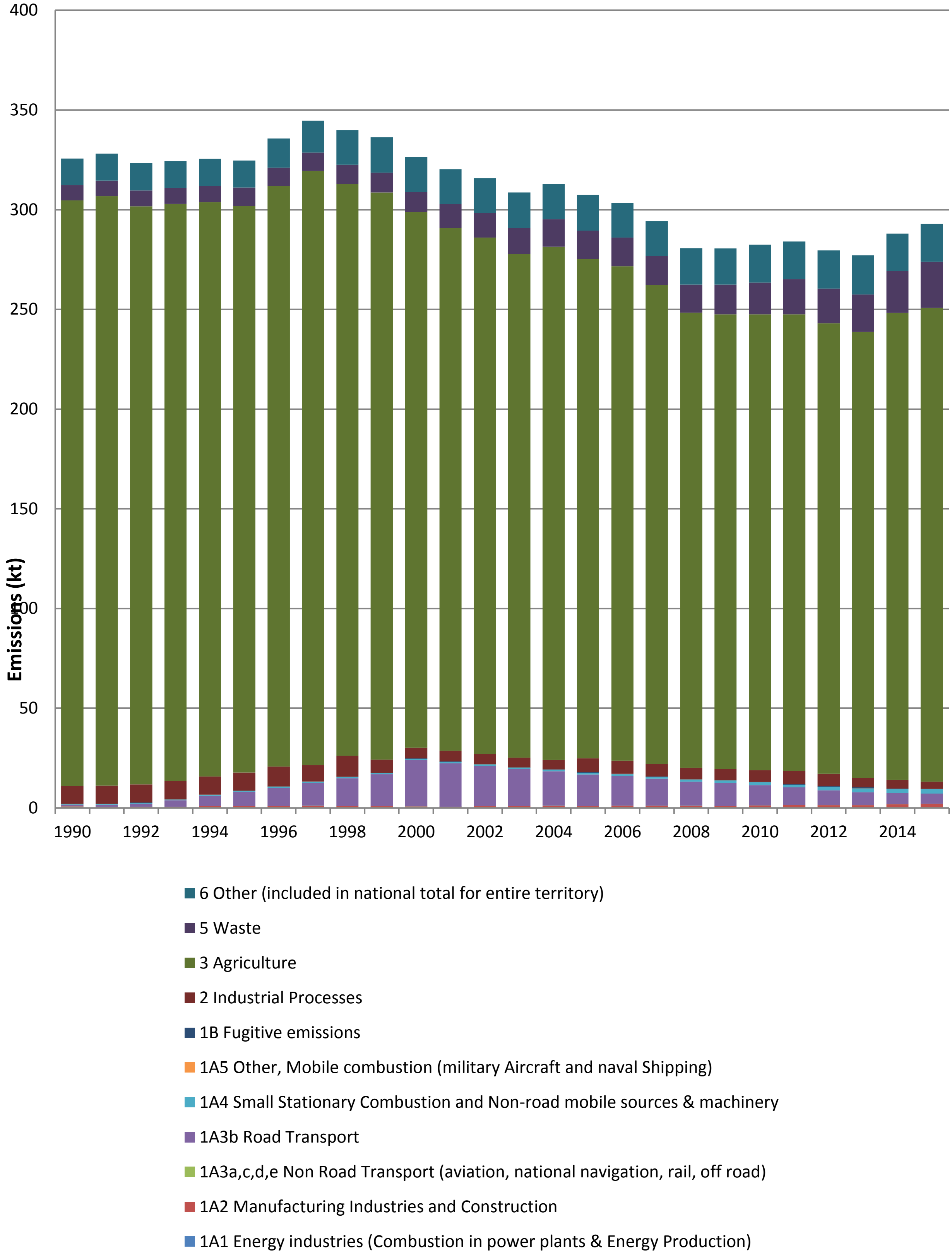


Figure ES.1-4 Total UK Emissions by Source Sectors Ammonia (NH_3), 1990-2015.



Total percentage reductions in emissions of these pollutants from 1990-2015 are summarised in Table ES.1-1.

Table ES.1-1 Air Quality Pollutant Emission Reductions between 1990 and 2015

Pollutant	% Change from 1990 to 2015
NO_x (as NO_2)	-69%
SO_x (as SO_2)	-94%
NH_3	-10%
NMVOC	-72%
CO	-78%
PM_{10}	-51%
$PM_{2.5}$	-47%

The emissions inventory makes estimates of all anthropogenic emissions to the atmosphere, at the highest level of source sector disaggregation possible. Estimated emissions are allocated to the corresponding NFR14 codes. However, in accordance with international guidelines[4] on emissions inventory reporting, there are a number of known sources that are excluded from the inventory emission estimates:

- Natural sources are not included in the national totals (although estimates of some sources are made)
- The inventory refers only to primary emission sources (as per international guidelines). Consequently, sources such as re-suspension of particulate matter from road dust or data on secondary pollutants formed by atmospheric transformation of primary air pollutants (such as trophospheric ozone) are not included in the national totals (although estimates for some re-suspension terms are made).
- Cruise emissions from civil and international aviation journeys are not included in the national totals.
- Estimates of "International" emissions such as from shipping are made, and reported as memo items (excluded from the UK national totals).

National totals reported for the UK in the CLRTAP and the United Nations Framework Convention on Climate Change (UNFCCC) submissions differ because the sources included in the national totals differ under the CLRTAP[5] and the UNFCCC reporting guidelines. The historical time-series of emissions data from the 2015 inventory submitted under the CLRTAP and the NECD are identical.

The purpose of this report is to:

1. Present an overview of institutional arrangements and the emission inventory compilation process in the UK;
2. Present the emission estimates for each pollutant up to 2015 with analysis of the time-series trends for each pollutant;
3. Explain the methodologies for key pollutants and key sectors used to compile the inventories, including a brief summary of estimates for future projections;
4. Provide other supporting information pertinent to the NECD and CLRTAP data submissions.

Information contained in this report is derived from the UK emissions inventory, which includes the UK Greenhouse Gas Inventory, used for reporting to the UNFCCC. The compilation of the inventories for the pollutants reported to the NECD, the CLRTAP and the UNFCCC are strongly linked; and share many common data sources, data management, data analysis, QA/QC and reporting procedures. This report summarises the data sources and emission estimation methodologies used to compile the inventories for each pollutant covered by the NECD and CLRTAP submission. The latest emission factors used to compile emissions estimates and the estimates themselves will be made available at http://naei.defra.gov.uk/data_warehouse.php in summer 2017. The complete 2017 UK NECD and CLRTAP submission templates are available from the European Environment Information and Observation Network (EIONET) under the following folders respectively:

[4] http://www.ceip.at/ms/ceip_home1/ceip_home/reporting_instructions/reporting_programme/
[5] Includes the United Kingdom (England, Scotland, Wales, Northern Ireland) and Gibraltar only

- http://cdr.eionet.europa.eu/gb/eu/nec_revised/
- http://cdr.eionet.europa.eu/gb/un/clrtap/

Emission trends for key source sectors are given and discussed in Chapter 2, whilst revisions in source data or estimation methodology are summarised for each NFR14 source sector in respective chapters. The NAEI is subject to methodology revisions on an annual basis with the aim of improving overall completeness and accuracy of the inventory and some of the planned improvements that were outlined within the previous Informative Inventory Report (1990 to 2014) have been addressed in the 2015 inventory. Planned improvements for future national inventory compilation cycles are discussed at the end of each Chapter on each NFR14 source sector.

Table ES.1-2 compares overall emission estimates for each pollutant between the 2016 and 2017 (current) submissions, summarising any differences in emissions for the year 2014 between the two submissions that are associated with methodological improvements or source data revisions.

Table ES.1-2 UK Inventory Recalculations, Comparing emissions data for year 2014 between the 2016 and 2017 CLRTAP Submissions, and emissions data for year 2015 from the 2017 CLRTAP Submission.

Pollutant	2016 Submission 2014	2017 Submission 2014	2017 Submission 2015	Units	(% change for 2014 values)	Comment/Explanation (changes between the 2016 and 2017 CLRTAP Submissions)
NO_x (as NO_2)	949.2	956.7	918.3	kt	0.8%	Emission factors for stationary combustion processes have been reviewed and key assumptions revised, particularly regarding the calorific value of fuels. The factors have been harmonised with the 2016 EMEP/EEA Guidebook, in place of the 2013 edition used in the previous inventory. In recent years (2011 onwards) transport emissions have been revised upward due to use of COPERT 5 emission factors for NO_x (as NO_2) from Euro 5 diesel LGVs.
CO	2,072	1,709	1,645	kt	-17.5%	The large change between the 2016 submission and 2017 submission is mainly due to a revised approach for industrial and agricultural use of biomass fuels. Emission factors are now taken from the EMEP/EEA Emission Inventory Guidebook, and these are much lower than the values used previously. In addition, emissions from cars and LDVs are lower in the 2017 submission due to changes in methodology to account for emission degradation (switching from TRL method to COPERT method).
NMVOC	818.7	840.6	835.4	kt	2.7%	The increase in emissions between the 2016 submission and 2017 submission is predominantly due to the addition of a source not previously estimated - NMVOC emissions from the mining of coal. Updates to the NMVOC emission estimates for solvent use are also slightly higher.
SO_x (as SO_2)	307.6	305.4	236.1	kt	-0.7%	The 2016 submission and 2017 submission are very similar, although some updates to industrial coal consumption data in DUKES result in a small decrease in emission estimates for 2014.
NH_3	281.3	288.0	292.8	kt	2.40%	The 2017 submission is higher than the 2016 submission largely as the result of the inclusion of anaerobic digestion in the total this year (previously this source was only included as a memo item), although a revision to the factors used for residential combustion of wood fuel partly offsets this increase.

Pollutant	2016 Submission 2014	2017 Submission 2014	2017 Submission 2015	Units	(% change for 2014 values)	Comment/Explanation (changes between the 2016 and 2017 CLRTAP Submissions)
TSP	191.3	207.7	206.5	kt	8.6%	Emissions of TSP have been revised upward for all years in the time series, dominated by significant increases in emissions from construction and agriculture, reflecting updated emission factors in the latest EMEP/EEA Guidebook.
PM_{10}	148.4	145.5	145.5	kt	-1.9%	Emission factors for stationary combustion processes have been reviewed and key assumptions revised, particularly regarding the calorific value of fuels (notably of biomass fuels). The factors have been harmonised with the 2016 EMEP/EEA Guidebook, in place of the 2013 edition used in the previous inventory. Estimates of emissions from livestock have been revised to use Tier 1 EFs from the Guidebook, but the overall change for 2014 is small.
$PM_{2.5}$	105.09	103.9	104.8	kt	-1.2%	Emission factors for stationary combustion processes have been reviewed and key assumptions revised, particularly regarding the calorific value of fuels (notably of biomass fuels). The factors have been harmonised with the 2016 EMEP/EEA Guidebook, in place of the 2013 edition used in the previous inventory. Estimates of emissions from livestock have been revised to use Tier 1 EFs from the Guidebook, but the overall change for 2014 is small.
BC	18.90	18.3	17.8	kt	-3.3%	The small reduction in estimates result from a series of revisions to use EMEP-EEA 2016 Guidebook factors for stationary combustion processes, especially for wood, straw and petcoke in industrial, residential and commercial sectors. In addition, gas oil activity data revisions for use in industrial mobile machinery led to lower estimates.
Pb	66.12	69.2	65.1	tonnes	4.6%	The increase in emissions between the 2016 submission and 2017 submission is predominantly due to the incorporation of additional data from PRTR for processes manufacturing chipboard and similar wood products. Previous estimates were extrapolated from a much smaller set of data and were significantly lower.

Pollutant	2016 Submission 2014	2017 Submission 2014	2017 Submission 2015	Units	(% change for 2014 values)	Comment/Explanation (changes between the 2016 and 2017 CLRTAP Submissions)
Cd	3.10	3.71	3.51	tonnes	19.6%	The 2017 submission is significantly higher than the 2016 submission largely as the result of a revision to the emission factors used for industrial combustion of wood & other biomass fuels. The factors used are now taken from the EMEP/EEA Emission Inventory Guidebook.
Hg	5.44	5.30	4.76	tonnes	-2.48%	The largest change revision across the time series is due to the revision of Emission Factors for industrial wood and other biomass combustion to reflect the latest EMEP/EEA Guidebook factors, which are lower than those used in the previous inventory. In 2013 and 2014 however, revisions are dominated by a 75% reduction in DUKES 'heat sold' coal reallocation for chemical industry.
As	17.92	17.45	16.38	tonnes	-2.65%	The 2017 submission is slightly lower than the 2016 submission largely as the result of a revision to the emission factors used for industrial combustion of wood & other biomass fuels. The factors used are now taken from the EMEP/EEA Emission Inventory Guidebook.
Cr	27.61	28.51	27.85	tonnes	3.3%	The 2017 submission is slightly higher than the 2016 submission largely as the result of a revision to the emission factors used for industrial combustion of wood & other biomass fuels. The factors used are now taken from the EMEP/EEA Emission Inventory Guidebook.
Cu	53.20	51.8	51.5	tonnes	-2.7%	The 2017 submission is slightly lower than the 2016 submission largely as the result of a revision to the emission factors used for industrial combustion of wood & other biomass fuels. The factors used are now taken from the EMEP/EEA Emission Inventory Guidebook.
Ni	103.9	107.9	85.5	tonnes	3.9%	Emissions are largely unchanged for most of the time series, but for a 4% increase in emissions in 2014. This is due to an increase in the use of petroleum coke in industrial combustion.

Pollutant	2016 Submission 2014	2017 Submission 2014	2017 Submission 2015	Units	(% change for 2014 values)	Comment/Explanation (changes between the 2016 and 2017 CLRTAP Submissions)
Se	16.3	16.1	13.5	tonnes	-1.4%	The 2016 submission and 2017 submission are very similar, although some updates to industrial coal consumption data in DUKES result in a small decrease in emission estimates for 2014.
Zn	438.7	455.6	453.4	tonnes	3.9%	The 2017 submission is slightly higher than the 2016 submission largely as the result of a revision to the emission factors used for industrial combustion of wood & other biomass fuels. The factors used are now taken from the EMEP/EEA Emission Inventory Guidebook.
PCB	732.5	660.9	622.9	kg	-9.8%	The main change between the 2016 submission and 2017 submission is due a revised methodology for calculations in transformers and capacitors and improvements in the time series model for waste burnt on domestic grates, based on numbers of households using solid fuels as a main fuel.
PCDD/PCDF (dioxins/furans)	215.0	205.5	210.6	grams TEQ	-4.4%	The small change contributing to reduction in emissions between the 2016 submission and 2017 submission is due to a revised methodology for waste burnt on domestic grates.
benzo(a)pyrene	8.33	7.09	7.53	tonnes	-15%	The change between the 2016 submission and 2017 submission is mainly due to an improved methodology for calculating domestic wood emission factors, taking into account differences in emission characteristics of installed appliances according to age.
benzo(b) fluoranthene	7.52	6.46	6.89	tonnes	-14.2%	The change between the 2016 submission and 2017 submission is mainly due to an improved methodology for calculating domestic wood emission factors, taking into account differences in emission characteristics of installed appliances according to age.
benzo(k) fluoranthene	3.16	2.72	2.88	tonnes	-13.8%	The change between the 2016 submission and 2017 submission is mainly due to an improved methodology for calculating domestic wood emission factors, taking into account differences in emission characteristics of installed appliances according to age.

Pollutant	2016 Submission 2014	2017 Submission 2014	2017 Submission 2015	Units	(% change for 2014 values)	Comment/Explanation (changes between the 2016 and 2017 CLRTAP Submissions)
Indeno(1,2,3-cd)pyrene	4.90	4.11	4.35	tonnes	-16%	The change between the 2016 submission and 2017 submission is mainly due to an improved methodology for calculating domestic wood emission factors, taking into account differences in emission characteristics of installed appliances according to age.
HCB	21.0	22.57	27.45	kg	7.4%	The main change between the 2016 submission and 2017 submission is due to updated activity data for power stations, following a revision to DUKES.

(I) Contacts and Acknowledgements

The National Atmospheric Emission Inventory is prepared by Ricardo Energy & Environment under the National Atmospheric Emissions Inventory contract to the Department for Business, Energy and Industrial Strategy (BEIS).

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For non-agricultural and non-combustion emission sources, NH_3 emission estimates and NH_3 mapping information are provided by the Centre for Ecology and Hydrology (CEH) Edinburgh.

NH_3 emissions from agriculture are provided for Defra under a separate contract by a consortium led by Rothamsted Research in Okehampton, Devon.

A copy of this report and related documentation may be found on the NAEI website maintained by Ricardo Energy & Environment on behalf of BEIS and Defra: http://naei.defra.gov.uk/.

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(II) Glossary

Emission Units

Pollutant emissions are presented using a number of different mass and / or toxicity units, according to convenience, with specific reporting protocols including:

- NO_x emissions are quoted in terms of NO_x as mass of NO_2
- SO_x emissions are quoted in terms of SO_x as mass of SO_2
- PCDD and PCDF are quoted in terms of mass, but accounting for toxicity. This is the I-TEQ scale and is explained further in the relevant chapters.
- Pollutant emissions are quoted as mass of the full pollutant unless otherwise stated, e.g. NH_3 emissions are mass of NH_3 and not mass of the N content of the NH_3.

Acronyms and Definitions

ABI	Annual Business Inquiry
ANPR	Automatic Number Plate Recognition
AS	Aviation Spirit
ATF	Aviation Turbine Fuel
ATM	Air Traffic Movement
ATOC	Association of Train Operating Companies
APU	Auxiliary Power Unit
AP-42	Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors
BAU	Business as usual
BCA	British Cement Association
BCF	Bureau for Computer Facilities
BEIS	Department for Business, Energy and Industrial Strategy
BERR	Department for Business, Enterprise & Regulatory Reform
BGS	British Geological Survey
BSOG	DfT's Bus Services Operators Grant
BREF	Best Available Technology Reference
BMW	Biodegradable Municipal Waste
CAA	Civil Aviation Authority
CCA	Climate Change Agreement
CCGT	Combined Cycle Gas Turbine
CD	Crown Dependency
CEH	Centre for Ecology and Hydrology
CHP	Combined Heat and Power
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COPERT	COmputer Programme to calculate Emissions from Road Transport
DECC	Department of Energy & Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DERV	Road diesel fuel
DoENI	Department of Environment Northern Ireland
DRDNI	Department for Regional Development Northern Ireland
DPF	Diesel Particulate Filters
DUKES	Digest of UK Energy Statistics
DVLA	Devolved Administration-country specific vehicle licensing data
EE	Energy Efficiency
EEMS	Environmental Emissions Monitoring System
EF	Emission Factors
EfW	Energy from Waste
EIONET	European Environment Information and Observation Network
EMEP/CORINAIR	After 1999 called EMEP/EEA
EMEP/EEA	European Monitoring and Evaluation Program Emission Inventory Guidebook
EPR	Environmental Permitting Regulations
E-PRTR	European Pollutant Release and Transfer Register
EU ETS	European Union Emissions Trading System

FGD	Flue gas desulphurisation
FYM	Farm Yard Manure
GCV	Gross Calorific Value
GHG	Greenhouse gases
GHGI	Greenhouse gas inventory
GWh	Giga Watt Hour (unit of energy)
GWP	Global Warming Potential
HGV	Heavy Goods Vehicles
HMIP	Her Majesty's Inspectorate of Pollution (former name for regulatory agency in England and Wales, its functions now carried out by the Environment Agency and Natural Resources Wales)
ICAO	International Civil Aviation Organisation
IED	Industrial Emissions Directive
IEF	Implied Emission Factor
IPPC	Integrated Pollution Prevention and Control
ISR	Inventory of Statutory Releases (DoENI)
ISSB	Iron and Steel Statistics Bureau
kt	Kilotonne
ktC	Kilotonne of Carbon
ktC-e	Kilotonne of Carbon-equivalent (taking account of GWP)
LA-IPPC	Local Authority Integrated Pollution Prevention and Control
LAPC	Local air pollution control
LGV	Larger Goods Vehicles
LPG	Liquefied petroleum gas
LTO	Landing & Take Off
MoD	Ministry of Defence
MPP	Major Power Producers (i.e. large power station operators)
MPG	miles per gallon
MSW	Municipal Solid Waste
Mt	Megatonne
Mtherms	Megatherms
NFR14	2014 Reporting Guidelines Nomenclature for Reporting
NHS	National Health Service
NAEI	National Atmospheric Emissions Inventory
NECD	National Emission Ceiling Directive
NIEA	Northern Ireland Environment Agency
NIPI	Northern Ireland Pollution Inventory
NRTY	National Rail Trends Yearbook
NRW	Natural Resources Wales
OCGT	Open Cycle Gas Turbine
OGUK	Oil and Gas UK (trade association for upstream oil and gas industry)
ONS	Office for National Statistics
OPG	Other petroleum gases
ORR	Office of Rail and Road
OT	Overseas Territories
PAMs	Policies and Measures
PI	Pollution Inventory (of the Environment Agency and Natural Resources Wales)
POC	Port of call
POPs	Persistent Organic Pollutants
ppm	Parts per million
PPRS	Petroleum Production Reporting System
PRODCOM	PRODuction COMmunautaire
PSDH	Project for the Sustainable Development of Heathrow
QA/QC	Quality assurance and quality control
RASCO	Regional Air Services Co-ordination
RDF	Refuse-Derived Fuel
RESTATs	Renewable Energy Statistics (published by BEIS)
RTFO	Renewable Transport Fuels Obligation
RVP	Reid Vapour Pressure
SCCP	Short Chain Chlorinated Paraffins

SEPA	Scottish Environmental Protection Agency
SMMT	Society of Motor Manufacturers and Traders
SPRI	Scottish Pollutant Release Inventory
SSI	Sahaviriya Steel Industries (UK)
SWA	Scotch Whisky Association
THC	Total Hydrocarbons
TSP	Total Suspended Particulate
TRL	Transport Research Laboratory
TFEIP	Task Force on Emission Inventories and Projections
UEP	Updated Energy Projection (UK energy forecasts produced by BEIS)
UKCCP	UK Climate Change Programme
UKD	UK Gas Distributors
UKMY	UK Minerals Yearbook
UKOOA	UK Offshore Operators Association (now Oil and Gas UK)
UKPIA	UK Petroleum Industries Association
UN/ECE	United Nations Economic Commission for Europe
US EPA	United States Environment Protection Agency
USLP	Ultra-low Sulphur Petrol
WEI	Welsh Emissions Inventory
WID	Waste Incineration Directive
WML	Waste Management Licensing

Abbreviations for Chemical Compounds covered in the UK Air Quality Inventory

Chemical Name	Abbreviation
Nitrogen Oxides	NO_x as NO_2
Sulphur Dioxide	SO_x as SO_2
Carbon Monoxide	CO
Non-Methane Volatile Organic Compounds	NMVOC
Black Smoke	BS
Black Carbon	BC
Particulates < 10 μm	PM_{10}
Particulates < 2.5 μm	$PM_{2.5}$
Particulates < 1 μm	$PM_{1.0}$
Particulates < 0.1 μm	$PM_{0.1}$
Total Suspended Particulates	TSP
Ammonia	NH_3
Hydrogen Chloride	HCl
Hydrogen Fluoride	HF
Lead	Pb
Cadmium	Cd
Mercury	Hg
Copper	Cu
Zinc	Zn
Nickel	Ni
Chromium	Cr
Arsenic	As
Selenium	Se
Vanadium	V
Beryllium	Be
Manganese	Mn
Tin	Sn
Polycyclic Aromatic Hydrocarbons	PAH
- Benzo[a]pyrene	B[a]P
- Benzo[b]fluoranthene	B[b]F
- Benzo[k]fluoranthene	B[k]F
- Indeno(1,2,3-cd)pyrene	I[123-cd]P
Polychlorinated dibenzo-p-dioxins/ Polychlorinated dibenzofurans	PCDD/PCDF
Polychlorinated Biphenyls	PCBs
Hexachlorocyclohexane	HCH
Pentachlorophenol	PCP
Hexachlorobenzene	HCB
Short-chain chlorinated paraffins	SCCP
Polychlorinated Naphthalene	PCN
Polybrominated diphenyl ethers	PBDE
Sodium	Na
Potassium	K
Calcium	Ca
Magnesium	Mg

Contents

Figures

Tables

1. Introduction

This chapter provides an overview of the management and delivery of the UK emissions inventory programme, including:

- Section 1.1 summarises the scope of the inventory and the reporting requirements.
- Section 1.2 describes the institutional arrangements that underpin the inventory activities.
- Section 1.3 summarises the process of inventory preparation, providing an overview of data management throughout the annual inventory cycle.
- Section 1.4 provides a summary of compilation methods and inventory input data.
- Section 1.5 provides the results from a key category analysis. This identifies the sources which make the most important contributions to the emissions totals and trends.
- Section 1.6 summarises the inventory QA/QC system, including insight into inventory data quality objectives, key QA/QC activities and the roles and responsibilities within the inventory team.
- Section 1.7 summarises the results from the uncertainty analysis across a range of the pollutants in the UK inventory.
- Section 1.6 gives an overview of the completeness assessment that is conducted every year.

1.1 NATIONAL INVENTORY BACKGROUND

1.1.1 UK Inventory Reporting Scope: Pollutants & Time series

The UK emissions inventory compiles annual pollutant emission estimates from 1970 to the most current inventory year for the majority of pollutants. A number of pollutants are estimated only from 1990 or 2000 to the most current inventory year due to the lack of adequate data prior to these dates, but this does not affect the UK's ability to submit a full and complete submission under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The pollutants that are required to be reported to the (CLRTAP) are highlighted in Table 1-2. Black Carbon and a number of heavy metals are reported on a voluntary basis.

Inclusion of new pollutants in the inventory is usually a result of newly introduced legislation that sets limits on total emissions and/or requires quantitative information on this to be reported. However, the UK government continues to take a pro-active approach to the inventory programme, enabling the national inventory agency to be typically able to prepare, review and improve pollutant emission estimates before they become a reporting obligation (see Section 1.2 on the Institutional Arrangements for Inventory Preparation).

In addition, the UK's national inventory programme includes emission estimates of pollutants which are not currently required by international or national reporting obligations, but which are of use to the research community. For example, generating emission estimates of base cations (sodium, potassium, calcium and magnesium) enables air pollution models to better recreate real world atmospheric processes and generate more accurate estimates for the impact of acidic gases on human health and the environment. The scope of pollutants relating to air quality issues that are compiled in the national inventory programme are listed in Table 1-1.

The national inventory programme operates a continuous improvement programme. Improvements to data sources, method options and reporting outputs are identified through QA activities such as peer, bilateral and expert reviews, or are identified and logged by the UK inventory agency experts as a central part of the annual compilation process. A list of potential improvements is then compiled and reviewed by the UK Government, the inventory agency and other stakeholders every six to twelve months to generate a prioritised list of improvement tasks. Improvements can then be implemented (depending on resources) in time for the next inventory cycle.

Table 1-1 Scope of UK Inventory Reporting: Pollutants by Type, Time series

Pollutant	Reported under CLRTAP	Inventory Time series[1]	Type of Pollutant[2]
Nitrogen Oxides	✓	1970-2015	NAQS, AC, IGHG, O, E
Sulphur Dioxide	✓	1970-2015	NAQS, AC, IGHG
Carbon Monoxide	✓	1970-2015	NAQS, O, IGHG
Non-Methane Volatile Organic Compounds *	✓	1970-2015	NAQS, O, IGHG
Black Smoke		1970-2015	NAQS
Black Carbon	✓	1990-2015	-
Particulates < 10 μm	✓	1970-2015	NAQS
Particulates < 2.5 μm	✓	1970-2015	NAQS
Particulates < 1 μm		1970-2015	-
Particulates < 0.1 μm		1970-2015	-
Total Suspended Particulates	✓	1970-2015	-
Ammonia	✓	1980-2015	AC, E
Hydrogen Chloride		1970-2015	AC
Hydrogen Fluoride		1970-2015	AC
Lead	✓	1970-2015	NAQS, TP
Cadmium	✓	1970-2015	TP
Mercury **	✓	1970-2015	TP
Copper	✓	1970-2015	TP
Zinc	✓	1970-2015	TP
Nickel **	✓	1970-2015	TP
Chromium **	✓	1970-2015	TP
Arsenic	✓	1970-2015	TP
Selenium	✓	1970-2015	TP
Vanadium		1970-2015	TP
Beryllium		2000-2015	TP
Manganese		2000-2015	TP
Tin		2000-2015	TP
Polycyclic Aromatic Hydrocarbons *	✓	1990-2015	TP
PCDDs and PCDFs	✓	1990-2015	TP
Polychlorinated Biphenyls *	✓	1990-2015	TP
Hexachlorocyclohexane (HCH)[3]		1990-2013	TP
Pentachlorophenol		1990-2015	TP
Hexachlorobenzene	✓	1990-2015	TP
Short-chain chlorinated paraffins		1990-2015	TP
Polychlorinated Naphthalene		NE	TP
Polybrominated diphenyl ethers		SE	TP
Sodium		1990-2015	BC
Potassium		1990-2015	BC
Calcium		1990-2015	BC
Magnesium		1990-2015	BC

[1] An explanation of the codes used for time series:

SE A "Single Emission" not attributed to a specific year **NE** "Not Estimated"

[2] An explanation of the codes used for pollutant types:

O	Ozone precursor	**NAQS**	National Air Quality Standard/Local Air Quality Management pollutant
AC	Acid gas	**TP**	Heavy metals and POPs are generally referred to as "Toxic Pollutants"
BC	Base cation	(although other pollutants also have toxic properties)	
IGHG	Indirect Greenhouse Gas	E	Eutrophying pollutant

[3] Total HCH is dominated by lindane, an organochlorine chemical variant of HCH that has been used as an agricultural insecticide.

* The inventory also makes emission estimates of the individual compounds within this group of compounds.
** Metals for which the inventory makes emission estimates for each of the chemical form of the emissions

1.1.2 Reporting Requirements: NECD and CLRTAP

The UK National Atmospheric Emissions Inventory (NAEI) programme, managed by the Department for Environment, Food and Rural Affairs (Defra), is responsible for submitting the official UK emissions datasets to the EU National Emissions Ceilings Directive (NECD) and CLRTAP.

NECD
The revised NECD (2016/2284/EU)[6], which entered into force on 31 December 2016, sets new emission reduction commitments for each Member State for the total emissions of NO_x, SO_x, NMVOC, NH_3 and $PM_{2.5}$ in 2020 and 2030. The new Directive repeals and replaces Directive 2001/81/EC. These pollutants contribute to acidification and eutrophication of ecosystems whilst also playing a major role in the formation of ground-level ozone. EU Member States are required to prepare and annually update national emissions inventories for these pollutants.

The UK met all of its NECD emission ceilings for 2010 and all subsequent years to date. Under the revised NECD, each Member State is required to publish by April 2019 a National Air Pollution Control Programme, setting out the measures it will put in place to reduce emissions to meet the 2020 and 2030 emission reduction commitments.

The revised NECD submission uses the latest CLRTAP reporting templates (as requested by the European Environment Agency). These are closely aligned with those for CLRTAP, including a common scope of reporting of pollutant inventories) and similar reporting timeframe, as shown in Table 1-2:

The deadlines for NECD and CLRTAP are as follows:

- Emission inventories – 15th February 2017 and every year thereafter
- Informative Inventory Report (IIR) – 15th March 2017 and every year thereafter
- Emission projections – 15th March 2017 and every two years thereafter[7];
- Spatially-disaggregated emissions (gridded emissions) – 1St May 2017 and every four years thereafter (CLRTAP only)
- Large point source (LPS) emissions – 1St May 2017 and every four years thereafter (CLRTAP only)

CLRTAP
There are several protocols within the CLRTAP, which require national emission estimates to be reported on an annual basis. The most extensive commitments are specified in the ‘multi-pollutant’ protocol (the so-called Gothenburg Protocol agreed in November 1999 and revised in 2014), but there are also reporting requirements included in the Heavy Metals Protocol and Persistent Organic Pollutants Protocol. The 2017 UK inventory submission to the NECD and Gothenburg Protocol has been compiled in line with the revised Gothenburg Protocol Guidance[8].

The pollutants required for reporting under the CLRTAP (and revised NECD) are listed in Table 1-2 below.

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[6] http://ec.europa.eu/environment/air/pollutants/ceilings.htm

[7] Under the CLRTAP, Parties are required to update their projections and report every four years from 15th March 2015 onward their updated projections.

[8] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf

Table 1-2 Summary of annual reporting requirements for estimating and reporting emissions under the CLRTAP and revised NECD

Group	Pollutant	Required reporting years	Reported years in 2017 UK submission
Main Pollutants	Nitrogen Oxides	1990 – reporting year minus 2	1990-2015
	Sulphur Dioxide		
	Carbon Monoxide		
	Non-Methane Volatile Organic Compounds		
	Ammonia		
Particulate Matter	Particulates < 10 μm	2000 – reporting year minus 2	1990-2015
	Particulates < 2.5 μm		
	Total Suspended Particulates		
	Black Carbon (voluntary)		
Priority Heavy Metals	Lead	1990 – reporting years minus 2	1990-2015
	Cadmium		
	Mercury		
Other Heavy Metals	Copper (voluntary)	1990 – reporting year minus 2	1990-2015
	Zinc (voluntary)		
	Nickel (voluntary)		
	Chromium (voluntary)		
	Arsenic (voluntary)		
	Selenium (voluntary)		
Persistent Organic Pollutants	Benzo[a]pyrene	1990 – reporting year minus 2	1990-2015
	Benzo[b]fluoranthene		
	Benzo[k]fluoranthene		
	Indeno(1,2,3-cd)pyrene		
	PCDD/PCDFs		
	Polychlorinated Biphenyls		
	Hexachlorobenzene		
Activity data by source category		1990 – reporting year minus 2	1990-2015

Emission Projections and Spatially-Referenced Data Submissions:
Every two years, starting in 2017, under the NECD EU Member States have to report projected emissions for key pollutants SO_2, NO_X, NMVOC, NH_3, $PM_{2.5}$, (BC if available) for the years 2020, 2025 and 2030 and, where available, also for 2040 and 2050. In contrast, projections for the same pollutants are reported to the LRTAP Convention every four years (starting in 2015). The UK decided to report updated projections as part of the 2017 CLRTAP submission.

Starting in 2017 (2015 emissions), EU Member States have to report spatially allocated emissions (gridded data) and emissions from large point sources as defined in Section A of Annex VI to the CLTRAP Reporting Guidelines. As requested by the Centre on Emission Inventories and Projections the gridded emissions do not include emissions from large-point sources, which are reported separately.

A summary of the 2 yearly and 4-yearly reporting requirements, and the UK provision, is included in Table 1-3 below.

Table 1-3 Summary of two yearly and four yearly reporting requirements for estimating and reporting emissions under the CLRTAP and the revised NECD

Group	Pollutant	Required reporting years starting in 2017	Reported years in the 2017 UK submission
Gridded data in the new EMEP grid (0.1° × 0.1° long-lat)	SO_x as SO_2, NO_x as NO_2, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, PCDD/PCDFs, PAHs, HCB, PCBs	Every four years for reporting year minus 2 (X-2) as from 2017	2015
Emissions from large-point sources (LPS)	SO_x as SO_2, NO_x as NO_2, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg, PCDD/PCDFs, PAHs, HCB, PCBs	Every four years for reporting year minus 2 (X-2) as from 2017	2015
Projected emissions	SO_x as SO_2, NO_x as NO_2, NH_3, NMVOC, $PM_{2.5}$, BC (voluntary)	**NECD**: report every two years from 2017 onwards, for years 2020, 2025, 2030, (2040 and 2050 if available) **LRTAP**: report every four years from 2015 onwards, for years 2020, 2025, 2030, (2040 and 2050 if available)	2015, 2020, 2025, 2030
Quantitative information on parameters underlying emission projections		Reported for the projection target year and the historic year chosen as the starting year for the projections	2020, 2025, 2030

Table 1-4 to Table 1-6 provide a summary of the emission targets set under the revised NECD and Gothenburg Protocol. The UK met all of its 2010 targets, and all subsequent years based on the current 2015 inventory.

Table 1-4 Comparison of UK 2015 national emissions with 2010 NECD and Gothenburg Protocol emission ceilings for UK

Pollutant	NH_3	NO_x as NO_2	SO_x as SO_2	NMVOCs
UK NECD 2010 Ceiling, kilotonnes	297	1167	585	1200
2010 Gothenburg Protocol Ceiling, kilotonnes	297	1181	625	1200
UK 2015 National Total, kilotonnes	293	918	236	835
Percentage of NECD 2010 ceiling, %	99%	79%	40%	70%

Table 1-5 Comparison of UK 2015 national emissions with 2020 NECD and Gothenburg emission targets

Pollutant	NH_3	NO_x (as NO_2)	SO_x (as SO_2)	NMVOC (include 3B)[b]	NMVOC (exclude 3B)	$PM_{2.5}$
2005 National Total, kilotonnes	307	1608	711	1174	1072	113
2020 Gothenburg/NECD Emission reduction commitment	8%	55%	59%	NR	32%	30%
2020 target, kilotonnes[a]	283	724	292	NR	729	79
2015 National Total, kilotonnes	293	918	236	835	733	105
Progress to date towards 2020 reductions	59%	78%	113%	NR	99%	26%
Emission reduction required from 2015, kilotonnes	10	195	0	NR	4	25

[a] Calculated from the 2020 NECD/Gothenburg Emission Reduction Commitments using the current emission estimate for the 2005 base year. Note that all emission totals are rounded.

[b] The UK inventory currently covers NMVOCs emissions from 3B Manure management; under the revised NECD, NMVOCs and NO_x emissions from 3B Manure management and 3D Agriculture Soil are not accounted for the purpose of complying with the 2020 (or 2030) ceiling targets; however, the NMVOCs figures quoted in this column include emissions from 3B, which are the currently reported national total for NMVOCs consistent with the 2017 NECD and CLRTAP data submissions. This is to be in line with the reporting requirement for the 2010 ceiling target which is in place up to the inventory year 2019.

[c] NR = not relevant

Table 1-6 Comparison of UK 2015 national emissions with 2030 NECD emission targets

Pollutant	NH_3	NO_x (as NO_2)	SO_x (as SO_2)	NMVOC (include 3B)[b]	NMVOC (exclude 3B)	$PM_{2.5}$
2005 National Total, kilotonnes	307	1608	711	1174	1072	113
2030 NECD Emission reduction commitment	16%	73%	88%	NR	39%	46%
2030 target, kilotonnes[a]	258	434	85	NR	654	61
2015 National Total, kilotonnes	293	918	236	835	733	105
Progress to date towards 2030 reductions	30%	59%	76%	NR	81%	17%
Emission reduction required from 2015, kilotonnes	35	484	151	NR	79	43

[a] Calculated from the 2030 NECD Emission Reduction Commitments using the current emission estimate for the 2005 base year. Note that all emission totals are rounded.

[b] The UK inventory currently covers NMVOCs emissions from 3B Manure management; under the revised NECD, NMVOCs and NO_x emissions from 3B Manure management and 3D Agriculture Soil are not accounted for the purpose of complying with the 2020 (or 2030) ceiling targets; however, the NMVOCs figures quoted in this column include emissions from 3B, which are the currently reported national total for NMVOCs consistent with the 2017 NECD and CLRTAP data submissions. This is to be in line with the reporting requirement for the 2010 ceiling target which is in place up to the inventory year 2019.

[c] NR = not relevant

In addition to the reporting under the NECD and the CLRTAP, the UK National Atmospheric Emissions Inventory team reports GHG emissions to the United Nations Framework Convention on Climate Change (UNFCCC). This is to comply with UNFCCC reporting requirements and the Kyoto Protocol commitments on behalf of the UK Government Department for Business, Energy & Industrial Strategy (BEIS). There are some differences between the reporting requirements for each of the NECD, CLRTAP and UNFCCC. The major differences between the source sector coverage are highlighted in Table 1-7, although there are also differences in the geographical coverage (see Section 1.1.4).

Table 1-7 Scope of UK Emissions Inventory Reporting under the CLRTAP, NECD and UNFCCC

Sector category	CLRTAP/NECD (included)	UNFCCC (included)
Domestic aviation (cruise)	No	Yes
International aviation (LTO)	Yes	No
International inland waterways	Yes	No

1.1.3 Emission Sources Reported in the UK Inventory

In principle, the UK emissions inventory makes estimates of all anthropogenic emissions to the atmosphere at the highest level of disaggregation possible. However, in accordance with international guidelines[9] on emissions inventory reporting, there are a number of known sources that are excluded from the inventory emission estimates:

- Natural sources are not included in the national totals (although estimates of some sources are made). Only anthropogenic emission sources are reported.
- The inventory reports only primary source emissions to atmosphere (as per international guidelines). Consequently, re-suspension of particulate matter is not included in the national totals (although estimates for some re-suspension terms are made) or any secondary pollutants, such as tropospheric ozone.
- Cruise emissions from civil and international aviation are not included in the national totals (only estimates from landing and take-off (LTO) for civil and international aviation are included in the national totals).
- Estimates of “International” emissions such as shipping are made, and reported as memo items (i.e. excluded from the UK national totals).

Assessing the completeness of the emissions inventory, and the use of validation studies are explained under the Quality Assurance and Quality Control sections of this report (Section 1.6).

1.1.4 Geographical Scope

The geographical coverage of the emissions data in this report is the UK plus Gibraltar. Overseas Territories (OTs), other than Gibraltar, and Crown Dependencies (CDs) are excluded.

Under the UNFCCC[10], GHG emissions from the UK CDs and OTs who have chosen to “opt in” to the “UK umbrella agreement” are included in the national totals. This leads to differences in the NO_x (as NO_2) and NMVOCs emissions reported to the NECD/CLRTAP and the UNFCCC, where they are reported as indirect GHGs.

[9] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf

[10] Under the EU Monitoring Mechanism emissions are reported for the United Kingdom and Gibraltar only.

1.2 Institutional Arrangements for Inventory Preparation

The NAEI is maintained under contract to the Science and Innovation Climate and Energy (SICE) Division at the Department for Business, Energy and Industrial Strategy (BEIS) and the National Air Quality Evidence Team, Environmental Quality (EQ), of the Department for Environment, Food and Rural Affairs (Defra). The NAEI work programme is also co-funded by the Scottish Government, Welsh Government and Northern Ireland Department of Environment.

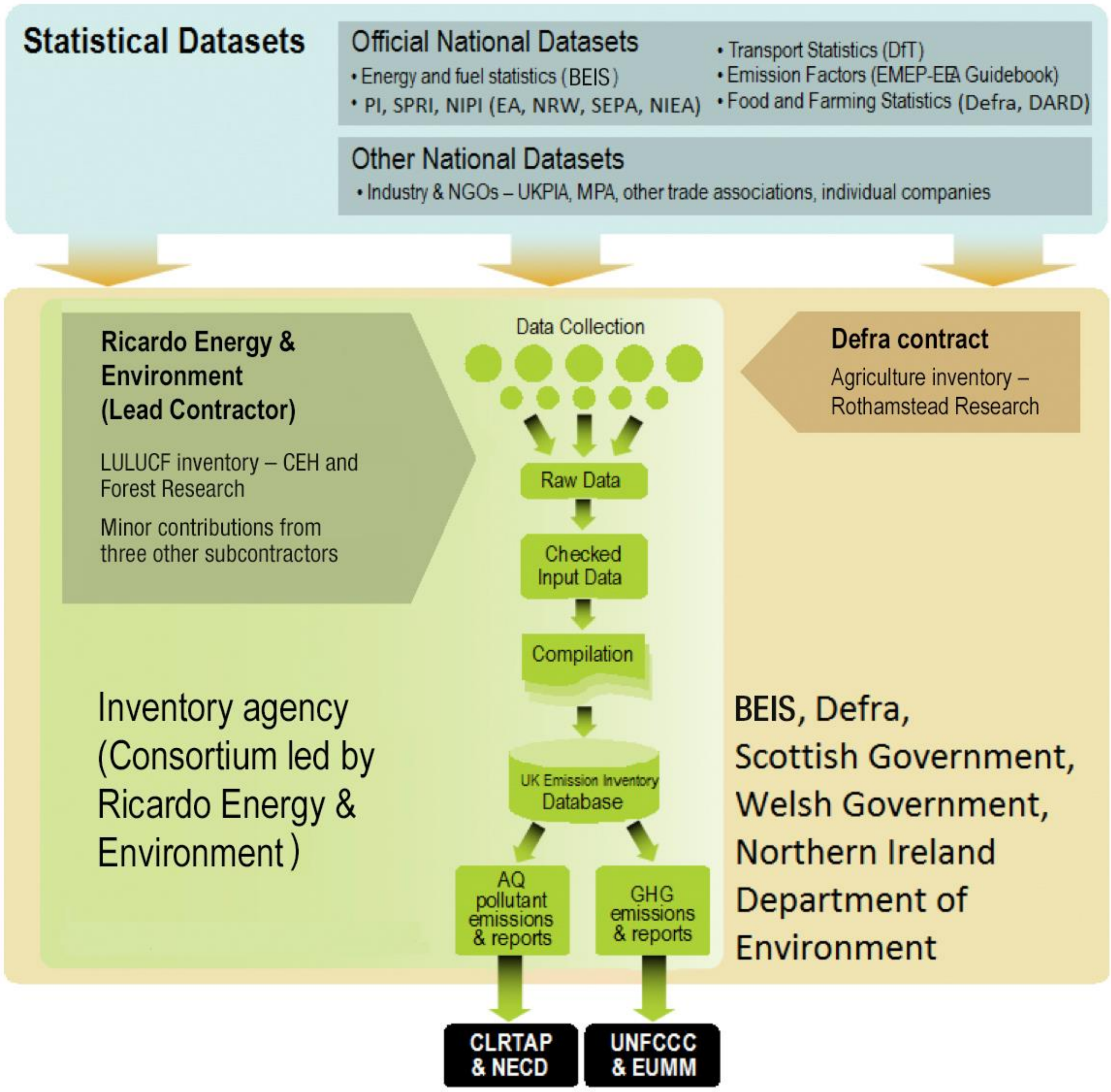
The UK emission inventories are compiled and maintained by the National Atmospheric Emissions Inventory (NAEI) team, led by Ricardo Energy & Environment (the Inventory Agency).

Rothamsted Research compiles emissions of NH_3 and GHGs from agricultural emission sources under a separate contract to Defra. Rothamsted Research provides the agriculture inventory data to Ricardo Energy & Environment for inclusion within the UK inventory submissions.

An overview of the organisational structures, roles and responsibilities within the NAEI work programme is provided in Figure 1-1 below. The figure also illustrates the data flow from official statistical datasets, other data provider organisations through the inventory compilation system and NAEI database to the main international reporting outputs.
Key Data Providers to the NAEI work programme include:

- Government departments, such as the BEIS and Department for Transport (DfT);
- Devolved Administration governments of Scotland, Wales and Northern Ireland
- Non-departmental public bodies such as the Environment Agency (EA), Natural Resources Wales (NRW), the Scottish Environment Protection Agency (SEPA), the Northern Ireland Environment Agency (NIEA), the Office of National Statistics (ONS)
- Other contractors including the Centre for Ecology and Hydrology (CEH) and Rothamsted Research;
- Private companies such as Tata Steel, Rio Tinto Alcan, BP Chemicals, gas network operators, water companies; and
- Business organisations such as UK Petroleum Industry Association (UKPIA), the Mineral Products Association (MPA), the Iron and Steel Statistics Bureau (ISSB) and Oil & Gas UK.

Figure 1-1 Overview of the Roles within the Inventory Programme



1.2.1 Defra

Defra is responsible for meeting the UK Government's commitments to international reporting on air quality pollutant emissions. Defra has the following roles and responsibilities:

National Level Management & Planning

- Overall control of the inventory programme development & function;
- Procurement and management of contracts which deliver emissions inventories;
- Definition of performance criteria for key organisations involved in the compilation process.

Development of Legal & Contractual Infrastructure

- Review and evolution of legal & organisational structure;
- Implementation of legal instruments and contractual developments as required, to meet guidelines.

1.2.2 Ricardo Energy & Environment

As the UK's inventory agency, the NAEI team, led by Ricardo Energy & Environment, is responsible for compiling the emission inventories, and submitting them on behalf of Defra. Other roles and responsibilities include the following:

Planning

- Co-ordination with Defra and BEIS to compile and deliver the emission inventories to meet international reporting requirements and standards;
- Review of current performance and assessment of required development action;
- Scheduling of tasks and responsibilities of the range of inventory stakeholders to ensure timely and accurate delivery of emissions inventory outputs.

Preparation

- Drafting of data supply agreements with key data providers;
- Review of source data & identification of developments required to improve the inventory data quality.

Management

- Documentation & secure archiving of data and relevant information;
- Dissemination of information to inventory stakeholders, including data providers;
- Management of inventory QA/QC plans, programmes and activities.
- Archiving of historic datasets (and ensuring the security of historic electronic data), maintaining a library of reference material. The emission inventory database is backed up whenever the database has been changed.

Inventory Compilation

- Data acquisition, analysis, processing and reporting;
- Delivery of the Informative Inventory Report (IIR) and associated datasets to time and quality.

Ricardo Energy & Environment is the lead contractor in the consortium responsible for compiling and maintaining the NAEI and has direct responsibility for the items listed above, as well as managing the inputs from sub-contractors, and incorporating the inputs from other contracts directly held by other organisations with Defra:

- Agricultural emissions of NH_3 are prepared by a consortium led by Rothamsted Research, under contract to Defra.

Information Dissemination

Data from the NAEI are made available to national and international bodies in a number of different formats. The NAEI team also liaise regularly with representatives from industry, trade associations, UK Government and the Devolved Governments in Scotland, Wales and Northern Ireland.

In addition, there is a continuous drive to enhance the information made available and accessible to the public. The NAEI website is updated annually, giving the most recent emissions data and other information such as temporal trends, new pollutants and methodology changes.

The NAEI web pages may be found at http://naei.defra.gov.uk/

The web pages are arranged to allow easy and intuitive access to the detailed emissions data, as well as providing general overview information on air pollutants and emissions inventories for non-experts. Information resources available on the NAEI web pages include:

- **Data Warehouse: -** Emissions data are made available in numerous formats through a database. This allows extraction of overview summary tables, or highly detailed emissions data.

- **Emissions Maps: -** Emissions of pollutants are given in the form of UK maps updated annually. These are interactive maps illustrating emissions of various pollutants on a 1 x 1 km resolution. The maps are available as images, but in addition the data behind the maps can also be accessed directly from the website. An interactive interface to the maps may be found at http://naei.defra.gov.uk/data/gis-mapping.

- **Reports: -** The most recent reports compiled by the inventory team on related subjects are made available in electronic format.

- **Methodology: -** An overview of the approach used for the compilation of the NAEI is included on the website.

In addition, the NAEI website provides links to web-pages that explain technical terms, provide airborne pollutant concentration data and to sites that outline the scientific interest in specific pollutants and emission sources. In particular there are links to the various Defra pages containing comprehensive measurement data on ambient concentrations of various pollutants. The Defra air quality sites can be found at:

http://uk-air.defra.gov.uk/

Information Archiving and Electronic Back-ups
The UK emissions inventory team also have the responsibility of maintaining an archive of reference material and previously conducted work. This archive is both in paper format (held on site at the Ricardo Energy & Environment office in Oxfordshire), and in electronic format.

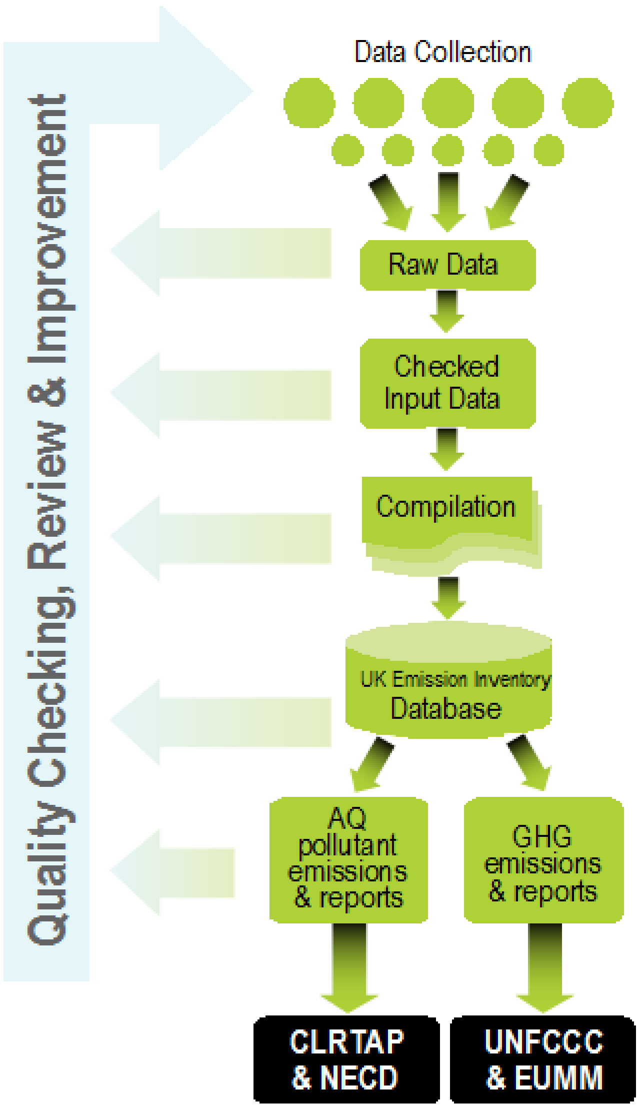
Electronic information is held on networked servers. This allows efficient access and maintains good version control. The data on the servers are mirrored to a second server to ensure data security, with incremental tape backups performed to maintain currency. The data files (in particular the compilation data and central database) are backed up whenever the files are being changed.

1.3 Inventory Preparation

1.3.1 Introduction

Figure 1-2 shows the main elements of the UK emissions inventory system, from collection of source data from UK organisations through to provision of data to international organisations. Further details of these elements are discussed in Section 1.3.4 to Section 1.3.8.

Figure 1-2 Overview of the Inventory Preparation Process



1.3.2 The Annual Cycle of Inventory Compilation

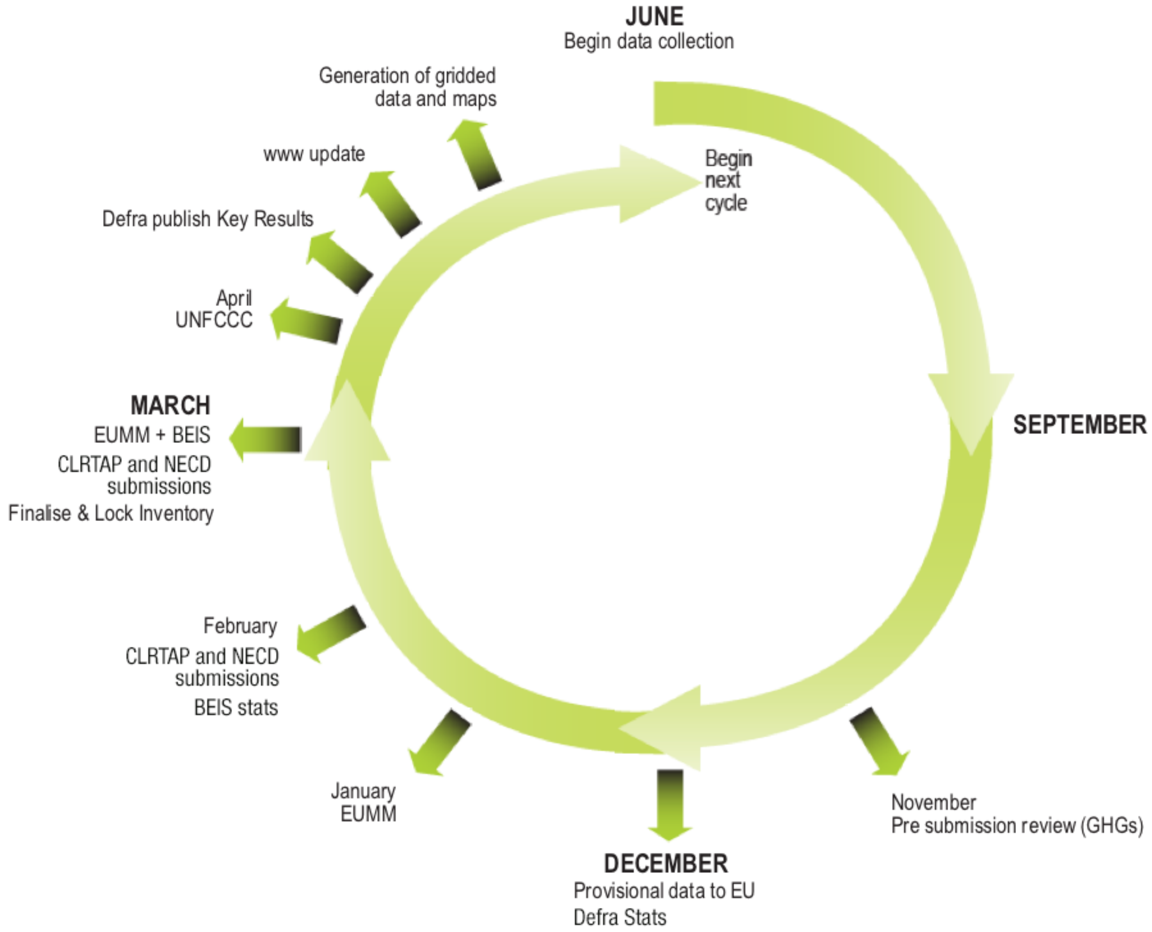
The activities outlined above in Figure 1-2 comprise the annual cycle of NAEI delivery from data acquisition, method selection and development through to reporting. Each year the latest data are added to the inventory and the full time series is updated to take account of improved data and any advances in the methodology used to estimate the emissions. Updating the full time series, making re-calculations where necessary, is an important process as it ensures that:

- The full NAEI dataset/time series is based on the latest available data, using the most recent research, inventory guidance, methods and estimation models available in the UK;

- The inventory estimates for a given source are calculated using a consistent approach across the full time-series and the full scope of pollutants;
- All of the NAEI data are subject to an annual review, and findings of all internal & external reviews and audits are integrated into the latest dataset.

This annual cycle of activity is represented schematically in Figure 1-3, and is designed to ensure that the UK inventory data are compiled and reported to meet all quality requirements and reporting timescales of the UNECE and other international fora.

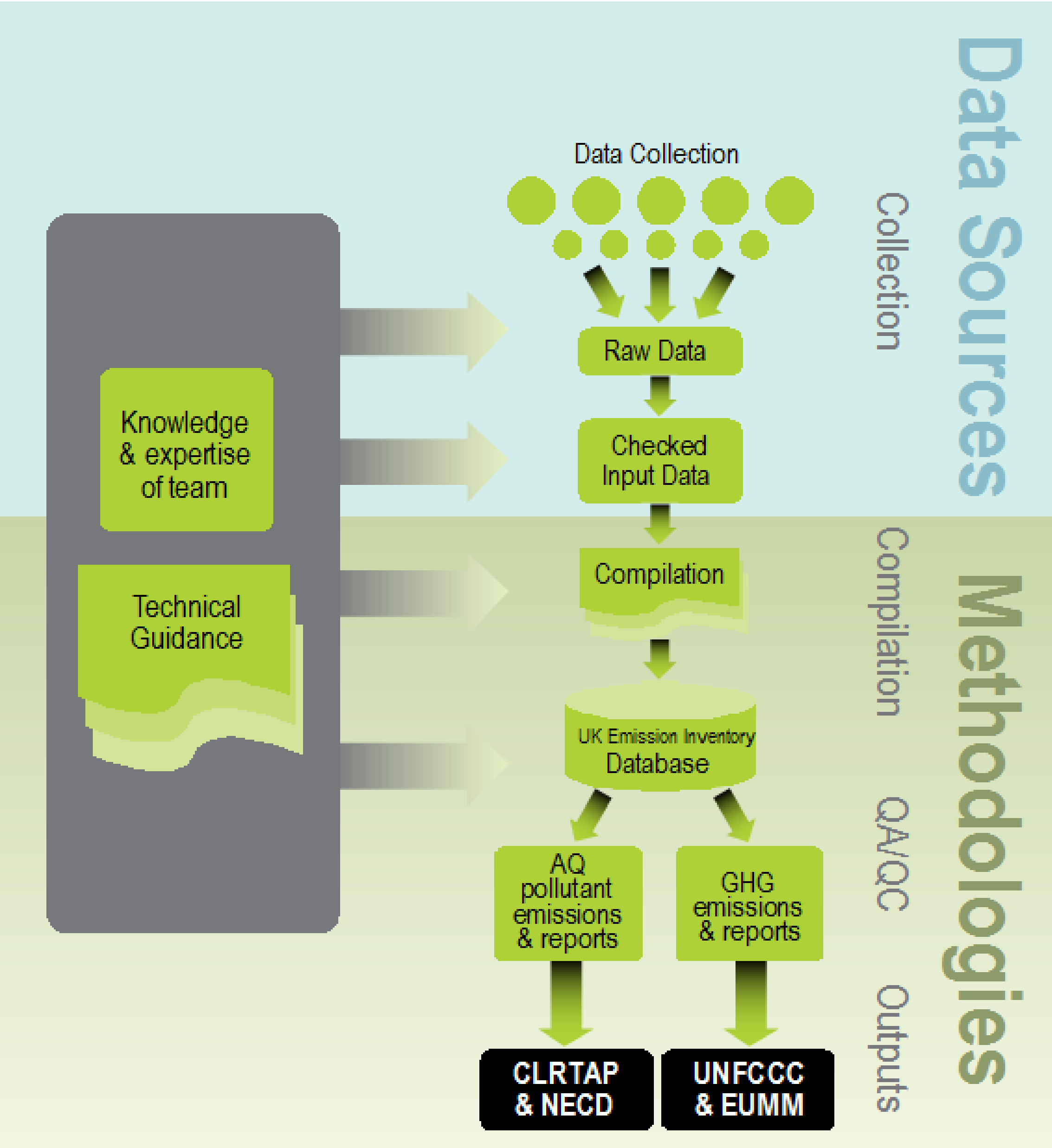
Figure 1-3 The Annual Inventory Cycle in the UK



1.3.3 The UK Inventory Compilation System

The compilation of the UK inventory requires a systematic approach to the collection and collation of statistical and source emission measurement information, and the subsequent calculation of comprehensive, coherent and comparable air emissions data to a range of users as illustrated in Figure 1-4.

Figure 1-4 Summary of UK Inventory data flows



The compilation method can be summarised as follows:

1. **Method Review and Data Collection** – Findings from inventory reviews and previous inventory compilation cycles are reviewed, method improvements are planned / implemented and the source data that will be required for all inventory methods are requested, collected and logged, from a wide variety of data providers.
2. **Raw Data Processing** - The raw data that are received from data provider organisations are checked, and where necessary formatted for use in the UK inventory system of data processing.
3. **Spreadsheet Compilation -** Formatted input data are used in calculations within bespoke spreadsheets to generate all required emission factors, activity data, data references and recalculation references, that are all required for use in the NAEI database. The spreadsheets include many QAQC features to ensure that the processed data meet the inventory data quality objectives.
4. **Database Population –** All emission factors, activity data, references and recalculation references are uploaded to the central NAEI database, and QAQC routines are run across the UK data to ensure that data are complete, internally consistent and accurate.

5. **Reporting Emissions Datasets –** Emissions data are extracted from the database and formatted to generate a variety of datasets used for national or international reporting requirements. These NAEI output datasets serve a range of national and international reporting requirements, and may vary in their level of detail, geographical coverage and spatial resolution.

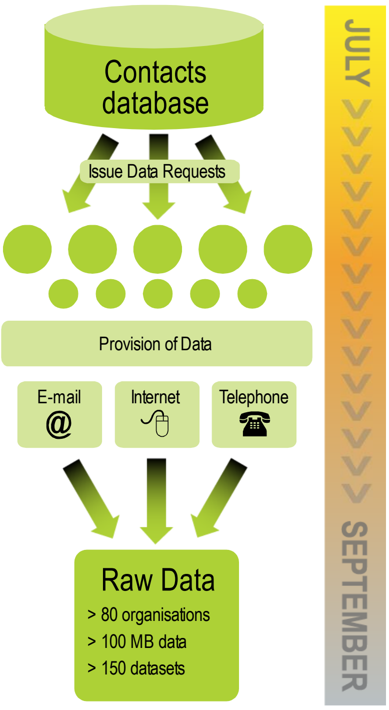
Each of these stages are explained in more detail in the following sections and the QA/QC programme that operates across the inventory programme is explained in Section 1.6. After finalisation, all different aspects of the compilation process are reviewed for improvement e.g. quality of the input data, the emissions calculation methods, the thoroughness of the QA/QC checks, efficiency of data handling etc. All review findings then feed into stage 1 of the next inventory cycle.

1.3.4 Stage 1: Data Collection

1.3.4.1 Data Management

Figure 1-5 describes the data collection process for core inventory compilation. Data requests are made by letter, e-mail, telephone, and via internet based queries. The process is managed by the NAEI Data Acquisition Manager who follows-up on the initial data requests, receipts and ensures initial QC of data by sector or pollutant experts. The primary tool used to monitor requests for and collection of data is a Contacts Database, which holds contact details of all data providers, and references to the data provided in the past. All data requests and details of incoming data are logged and tracked through the database. All incoming data (and all outgoing data) are given a unique reference number to allow effective data tracking.

Figure 1-5 Data collection for core inventory compilation



A wide variety of organisations provide data that is essential for the UK inventories to be compiled to deliver complete, accurate emission estimates. Much of the data is available from statistical agencies or from Government Departments and agencies. Other essential data is provided voluntarily by private companies and trade associations. Secure data provision is aided by the development of strong working relationships with these data providers and a programme of stakeholder consultation to enable the inventory agency to address any emerging data requirements, for example for any new emission sources evident in the UK.

1.3.4.2 Key Data Providers

Whilst there are legal provisions[11] in place in the UK to secure the data provision to the emissions inventory (via the GHG inventory), there is currently no obligation for these organisations to provide data pertinent specifically to the air quality pollutant inventories. However, the key data providers to the emissions inventory are encouraged to undertake the following responsibilities relating to data quality, data formats, timeliness of provision and data security:

- Delivery of source data in appropriate format and in time for inventory compilation.
- Assessment of their data acquisition and processing & reporting systems;
- Application and documentation of QA/QC processes;
- Identification of any required organisational or legal development and resources to meet more stringent data requirements, notably the security of data provision in the future;
- Communication with Defra or BEIS, the inventory agency and their peers / members to help to disseminate information.

Energy statistics required for compilation of the UK inventory are obtained from the UK Digest of Energy Statistics (DUKES), which is compiled and published annually by a team of energy statisticians within BEIS.

Information on industrial processes is provided either directly to the inventory agency by the individual plant operators or from:

- The Environment Agency's Pollution Inventory for England;
- Natural Resources Wales's Pollution Inventory for Wales
- The Scottish Environment Protection Agency's European Pollution Emissions Register;
- The Northern Ireland Environment Agency's Inventory of Statutory Releases; and
- EU Emissions Trading System (*EU ETS data are provided by BEIS*).

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries covered by the Industrial Emissions Directive (IED) and the UK Environmental Permitting Regulations that transposes this. The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to the inventory agency.

Other Government Departments and agencies provide essential inputs ranging from annual statistics to periodic research and analysis, including:

- BEIS Offshore Inspectorate provides data on activities and emissions from upstream oil and gas operators;
- DfT provides annual transport statistics for different modes of transport;
- DCLG provides housing statistics;
- Defra provides waste management annual statistics;
- ONS provides economic activity data and production statistics.

Other key data providers or inventory compilers that feed into the UK inventory programme include:

- Rothamsted Research compiles the inventory for agricultural emissions using agricultural statistics from Defra and the Northern Ireland Department of Agriculture and Rural Development (DARDNI).

- The Centre of Ecology and Hydrology (CEH) compiles NH_3 emission estimates for sources in the natural and waste sectors, and provides information for mapping NH_3 emissions.

- Trade associations, statistical agencies and individual companies such as:
    - Tata Steel and SSI Steel
    - UK Petroleum Industries Association
    - Iron and Steel Statistics Bureau

[11] Greenhouse Gas Emissions Trading System (Amendment) and National Emissions Inventory Regulations 2005, available at: http://www.opsi.gov.uk/si/si2005/20052903.htm

  - Mineral Products Association
  - Civil Aviation Authority
  - British Geological Survey

- Aether contributes to the compilation of the inventory for the Devolved Administrations, and compiles rail sector emission estimates.

Defra also funds research to provide emission estimates for certain sources. The results of all research thought to be of use are investigated to determine whether they can usefully contribute to the UK emissions inventory.

1.3.5 Stage 2: Raw Data Processing

The data received from the data providers are stored in a file structure according to the provider. All data is traceable back to the original source.

The majority of data received is used directly in the compilation spreadsheets (Stage 3 below). However, for some datasets further processing is required before it is possible to use in Stage 3. For example, extensive data pre-processing is conducted to convert the detailed installation-specific energy and emissions data from the EU Emissions Trading System and the England Pollution Inventory / Wales Pollution Inventory/ Scottish Pollutant Release Inventory / Northern Ireland Pollution Inventory into data that are in the correct units and format for use within the NAEI spreadsheet system.

The data checking and QA/QC procedures associated with this stage of the work are detailed in Section 1.6.

1.3.6 Stage 3: Spreadsheet Compilation

Raw data are compiled into a series of data processing spreadsheets. These spreadsheets are used to perform the bespoke calculations and data manipulations necessary to compile appropriate and consistent component statistics or emission factors for use in the NAEI emissions database. The spreadsheets also record the source of any originating data and the assumptions and calculations conducted to create the data necessary for the emissions database. There are thorough checks on the compilation spreadsheets as detailed in Section 1.6. All data are ultimately transferred into the central NAEI database.

1.3.7 Stage 4: Database Population

A core database is maintained containing all the activity data and emission factors. Annually, this core database is updated with activity data for the latest year, updated data for earlier years and for revised emission factors and methods. The transfer of data to the database from the compilation spreadsheets is automated to increase efficiency and reduce the possibility of human error.

The core database system calculates all the emissions for all the sectors required by the NAEI and GHGI to ensure consistency.

All activity data and emission factors in the database are referenced with data origin, a text reference/description, and the literature reference. This referencing identifies the underlying data and data sources as well as any assumptions required to generate the estimates.

Once populated there are numerous checks on the data held in the database before use. These checks are detailed in Section 1.6

1.3.8 Stage 5: Reporting Emissions Data

There are numerous queries in the database to allow the data to be output in a variety of different formats. Database forms allow data output handling to be conducted more efficiently and consistently

For the CLRTAP submission, data for the relevant pollutants and years are extracted from the database in NFR14 format, with post-processing then conducted in a spreadsheet which is set-up to enable automated population of reporting forms. The NFR14 reporting templates are then populated automatically, and a number of manual amendments are then required before the data are thoroughly checked and submitted.

1.4 Methods and Data Sources

The UK emission inventories are compiled according to international good practice guidance for national inventories; for air quality pollutant inventories the inventory methodological guidance is the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016[12] (or the 2013 version[13]), whilst for Greenhouse Gas inventories the latest guidance is the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[14].

Each year the emission inventories are updated to include the latest data available and any new research to improve the emission estimation methods. Improvements to the inventory methodology are made and are backdated to ensure a consistent time series for emissions reporting. Methodological changes are made to take account of new data sources, or new guidance from EMEP-EEA, relevant work by IPCC, new research, or specific research programmes sponsored by Defra or BEIS. Information on improvements and recalculations can be found throughout this report, in Chapters 3 to 7, which describe the methods used in the different source sectors.

This section provides an overview of the UK inventory data and methods, and then greater details for the two most significant data sources: (i) the UK energy statistics, and (ii) industrial emissions reported via the UK environmental regulatory agencies. Finally, the planned improvements are summarised.

1.4.1 UK Inventory Data and Methods Overview

Overview information on primary data providers and methodologies has been included in the above sections. Table 1-8 indicates where UK-specific data are used in the emissions inventory, and where methodologies that are more generic are used (i.e. where UK specific information is not available).

Table 1-8 UK Emissions Inventory Compilation Methodologies by NFR14

NFR14 Category	Activity Data	Emission Factors
1A1a Public Electricity & Heat Production	UK statistics (DUKES), EU ETS	Operator reporting under IED/E-PRTR
1A1b Petroleum refining	UK statistics (DUKES), EU ETS	Operator reporting under IED/E-PRTR
1A1c Manufacture of Solid Fuels etc.	UK statistics (DUKES), EU ETS	Operator reporting under IED/E-PRTR and EEMS
1A2a Iron & Steel	UK statistics (DUKES), ISSB, EU ETS	Operator - Majority of EFs reported form Tata Steel
1A2b Non-ferrous Metals	UK statistics (DUKES), EU ETS	UK factors & Operator reporting under IED/E-PRTR
1A2c Chemicals	UK statistics (DUKES), EU ETS	UK factors & Operator reporting under IED/E-PRTR
1A2d Pulp, Paper & Print	UK statistics (DUKES)	UK factors & Operator reporting under IED/E-PRTR
1A2e Food Processing, Beverages & Tobacco	UK statistics (DUKES)	UK factors & Operator reporting under IED/E-PRTR
1A2f Non-metallic minerals	UK statistics (DUKES), EU ETS	UK factors & Operator reporting under IED/E-PRTR

[12] http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook
[13] The 2016 version of the Guidebook was released late during the UK's inventory compilation cycle and so the UK inventory is still in a transition period of reviewing and updating the relevant sources based on the 2013 Guidebook to the 2016 Guidebook version.
[14] http://www.ipcc-nggip.iges.or.jp/public/2006gl

NFR14 Category	Activity Data	Emission Factors
1A2g Other	UK statistics (DUKES)	UK factors & Operator reporting under IED/E-PRTR
1A3ai(i) International Aviation (LTO)	UK statistics (CAA)	UK Literature sources
1A3aii(i) Civil Aviation (Domestic, LTO)	UK statistics (CAA)	Literature sources
1A3b Road Transportation	UK statistics (DfT)	Literature sources and UK factors
1A3c Railways	UK statistics (ORR) and estimated	UK factors
1A3di (ii) International inland waterways	NA	NA
1A3d ii National Navigation	UK statistics and sector research (Entec, 2010)	Literature sources
1A3e Pipeline compressors	IE *(Emissions are reported under 1A1c)*	
1A4a Commercial / Institutional	UK statistics (DUKES)	UK factors
1A4b i Residential	UK statistics (DUKES)	Literature sources and UK factors
1A4b ii Household & gardening (mobile)	Estimated	Literature sources
1A4c i Agriculture/Forestry/Fishing: Stationary	UK statistics (DUKES)	UK factors
1A4c ii/iii Off-road Vehicles & Other Machinery	Estimated	Literature sources
1A5a Other, Stationary (including Military)	IE *(Emissions are reported under 1A5b)*	
1A5b Other, Mobile (Including military)	UK statistics	Literature sources
1B1a Coal Mining & Handling	UK statistics (DUKES, UK Coal)	UK factors
1B1b Solid fuel transformation	UK statistics (DUKES), EU ETS	Operator reporting under IED/E-PRTR, literature sources
1B1c Other	IE *(Emissions are reported under 1B1b)*	
1B2Oil & natural gas	UK statistics & Industry, EU ETS	Operator reporting under IED/E-PRTR and via EEMS, data from UKPIA, data from UK gas network operators and from BEIS
2 A Mineral Products	Industry & Estimated, EU ETS	Industry & Operator reporting under IED/E-PRTR
2 B Chemical Industry	Industry & Estimated, EU ETS	Operator reporting under IED/E-PRTR
2 C Metal Production	UK statistics & Industry, ISSB, EU ETS	Industry & Operator reporting under IED/E-PRTR
2 D Solvents	Industry	UK factors, Industry & Estimated
2 G Other product use	UK statistics	Literature sources and UK factors
2 H Pulp and paper industry, Food and beverages industry	UK statistics & Industry	UK factors
2 I Wood processing	UK statistics & Industry	UK factors
2 J Production of POPs	NA	NA
2 K Consumption of POPs and heavy metals	Industry	Industry & Estimated
2 L Other production, consumption, storage, transportation or handling of bulk products	NA	NA
3B Manure Management	UK statistics	UK factors
3D Agricultural Soils	Majority based on UK farm surveys and fertiliser sales data	Literature sources
3F Field Burning Of Agricultural Wastes	Majority based on UK farm surveys and fertiliser sales data, Estimates used for foot and mouth pyres	Literature sources
3I Other	UK Statistics & Estimated	UK factors
5A Solid Waste Disposal On Land	UK waste and disposal statistics	UK model and assumptions
5B Biological treatment of waste	UK statistics	UK factors
5C Waste Incineration	UK Statistics & Estimated	Operator reporting under IED/E-PRTR & UK factors
5D Waste-Water Handling	UK statistics	UK factors
5E Other Waste	Estimated	UK factors
6A Other	Estimated	UK factors
1A3aii(ii) Civil Aviation (Domestic, Cruise)	UK statistics (CAA)	Literature sources
1A3ai(ii) International Aviation (Cruise)	UK statistics (CAA)	Literature sources
1A3di(i) International maritime Navigation	UK statistics and sector research (Entec, 2010)	Literature sources

NFR14 Category	Activity Data	Emission Factors
6B Other (Memo)	UK statistics	UK factors
11 Other (Memo)	Estimated	UK factors

The terms used to summarise the data and methods in the table above are defined as follows:

For activity data:

- **UK Statistics**: UK statistics, including energy statistics published annually in DUKES. Almost all statistics are provided by UK Government, but the NAEI also relies on some data from other organisations, such as: iron and steel energy consumption and production statistical data, provided by the Iron and Steel Statistics Bureau (ISSB), the UK Minerals Yearbook provided by the British Geological Survey (BGS), energy use data from the EU Emissions Trading System (EU ETS).
- **Industry**: Process operators or trade associations provide activity data directly, for example from the UK Petroleum Industries Association (UKPIA), the Mineral Products Association (MOA), the British Coatings Federation.
- **Estimated**: Activity data have been estimated by the inventory agency (or other external organisations). This approach is necessary where UK statistics are not available or are available only for a limited number of years or sites. The estimates are based on published data or the best available proxy information such as UK production, site-specific production, plant capacity etc.

For emission factors:

- **Operator**: emissions data reported by operators is used as the basis of emission estimates and emission factors.
- **UK factors**: Country-specific emissions factors based on UK research and literature sources from UK analysis.
- **Industry**: Process operators or trade associations have provided emissions data or emission factors directly
- **Estimated**: Emissions have been estimated by the inventory agency, based on parameters such as: plant design and abatement systems, reported solvent use, plant-specific operational data.
- **Literature Sources:** For many UK emission sources there may not be any specific data from UK sources or research, and in these cases the inventory agency refers to literature sources for emission factors that best characterise the emissions. These literature sources are mainly from international guidance for inventory reporting such as the EMEP-EEA Guidebook, the USEPA AP-42, IPCC guidelines. Other useful resources are sector-specific operator reporting guidance such as BREF notes produced by the EU IPPC bureau, or the API Compendium for oil and gas emission estimates.

The specific emission factors used in the calculation for all sources and pollutants for the latest inventory are available at the data warehouse of the NAEI website:
http://naei.defra.gov.uk/data_warehouse.php

1.4.2 National Energy Statistics

BEIS provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the BEIS publication – *The Digest of UK Energy Statistics* (DUKES) – which is produced in accordance with QA/QC requirements stipulated within the UK Government's – *National Statistics Code of Practice (ONS, 2002)* – and as such is subject to regular QA audits and reviews.

DUKES is available at:
https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

The BEIS team follows a number of steps to ensure the energy statistics are reliable. At an aggregate level, the energy balances are the key quality check with large statistical differences used to highlight areas for further investigation. Prior to this, BEIS tries to ensure that individual returns within DUKES are as accurate as possible. A two-stage process is used to achieve this. Initially the latest data returns are compared with those from previous months or quarters to highlight any anomalies. Where data are seasonal, comparison is also made with corresponding data for the same month or quarter in the previous year. BEIS also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. BEIS depends on data from a range of companies, and work closely with these reporting companies to ensure returns are completed as accurately as possible and in good time for the annual publications of statistics.

The activity data used to derive emission estimates in the UK inventory may not exactly match the fuel consumption figures given in DUKES and other national statistics. This occurs for one of four reasons:

1) Data in DUKES and other national statistics are not always available to the level of detail required for inventory reporting. *For example, activity data within DUKES do not distinguish between fuel used in stationary and mobile combustion units. Emissions from these different types of appliances have to be separately reported in the inventory and furthermore they exhibit very different combustion characteristics and therefore require application of different emission factors in the UK inventory.*
2) Data in DUKES and other national statistics are subject to varying levels of uncertainty, especially at the sector-specific level, and in some cases more accurate data are available from other sources. *For example, the EU Emissions Trading System provides more accurate fuel use data for several high-emitting industrial sectors which is used in preference to DUKES data.*
3) DUKES and other national statistics do not include any data for a given source. *For example, DUKES does not provide any information on secondary fuels such as process off-gases that are derived from petroleum feedstocks and are commonly used as fuels in petrochemical and chemical industries.*
4) Where the BEIS DUKES team make improvements to national energy statistics, they typically do not revise the full time series of data; usually, DUKES data are retrospectively revised for up to the 5 most recent years. This can lead to step changes in the DUKES time-series that are due to methodological differences rather than reflecting real changes in fuel use. Therefore, to ensure time series consistency of reported emissions, the inventory agency works with the BEIS energy statistics team to derive a defensible historic time series back to at least 1990 for use in the UK inventory. *For example, residential wood use in 1990-2012 has been estimated by the inventory agency in light of new research that led to significantly higher estimates derived for 2008 onwards, within DUKES 2015, which was subsequently revised further for 2013 onwards in DUKES 2016.*

There is a high degree of confidence in the overall fuel commodity balance data in DUKES, with the statistics for production, imports, exports and final demand for fuels across the UK economy believed to be complete and accurate. However, fuel use allocations within DUKES *to specific economic sectors* are considered subject to greater uncertainty due to the difficulties in obtaining comprehensive survey or sales data by sector. Based on this understanding of uncertainty within DUKES, the inventory agency normally assumes that where an alternative source indicates DUKES data for a sector is inaccurate, there is no reason to suppose that this implies any inaccuracy in overall fuel usage in DUKES. Therefore, introducing a deviation from DUKES in one area of the inventory should be accompanied by an equal and opposite deviation in another area of the inventory. As a result, there are very few instances where the total amount of fuel used to underpin inventory estimates differs from the total fuel consumption data presented in DUKES; in most cases the inventory deviations from DUKES data are merely *re-allocations* of fuel use between source sectors across the UK economy, whilst retaining consistency with the total DUKES consumption of that fuel.

Deviations from sector-specific allocations in DUKES is most significant in the case of gas oil. This fuel is used in off-road machinery engines (e.g. agricultural and construction machinery), railway locomotives, marine engines, stationary engines and other stationary combustion plants such as furnaces. DUKES relies on data provided by fuel suppliers and importers / exporters but data on industrial use of gas oil is very uncertain. The distribution chain for refinery products is complex, and the gas oil producers and importers have very little knowledge of where their product is used once it is sold into the marketplace. Furthermore, the inventory agency needs to distinguish between gas oil burnt in mobile machinery and gas oil burnt in stationary combustion plant and this information is not available from fuel suppliers and importers.

As a result of these data limitations, the inventory agency makes estimates of gas oil consumption for many sectors using alternative bottom-up methods (e.g. for off-road machinery based on estimates of population and usage of different types of equipment) or gathers data from other sources (e.g. the Office of Rail and Road, power station operators). DUKES data are not used directly; however, estimates of gas oil consumption by other sectors are then adjusted in the inventory in order to maintain consistency with the total DUKES gas oil consumption.

Other fuels with significant deviations from the sector-specific allocations presented in DUKES include fuel oil, aviation turbine fuel, petroleum coke, wood, other petroleum gases (OPG) and coal. Minor reallocations are also made for natural gas and burning oil.

There are a small number of exceptions where the inventory estimates are based on data that lead to a deviation from the reported DUKES total consumption for a specific fuel, including:

- Energy consumption data and process-related activity data are available for installations that operate within the EU Emissions Trading System (EU ETS). These EU ETS data undergo third party verification as part of the EU ETS regulatory system, and hence are a high quality dataset that are provided to the inventory agency for the purposes of inventory compilation. Where the EU ETS data provides complete coverage of fuel use within a specific economic sector, the EU ETS data by installation are aggregated and applied within the UK inventory.
- Natural gas consumption at a number of compressor sites operating international import-export pipelines are known to be omitted from the DUKES data, and are included in the inventory;
- Restructuring of the data supply systems to the DUKES team in the early 2000s identified that throughout the 1990s there were omissions in reported gas use from upstream oil and gas terminals; the inventory therefore estimates the own gas use by these installations based on oil and gas production data as a proxy indicator of activity;
- DUKES has no mechanism to collect data on the use of process off-gases, for example once petroleum feedstocks have been delivered for petrochemical and chemical production processes (and therefore are rightly within DUKES allocated to “Non Energy Use”) but are subsequently used as a secondary fuel. The inventory totals for Other Petroleum Gases (OPG) includes an estimate for consumption of these secondary fuels based on data from the EU ETS;
- Residential wood use in 1990-2012 has been estimated by the inventory agency in light of new research that led to significantly higher estimates derived for 2008 onwards, within DUKES 2015, which was subsequently revised further for 2013 onwards in DUKES 2016; given the significance of this source for emissions in the UK of particulate matter and other air quality pollutants, a revised historic time series for this fuel use has been estimated.
- Estimates for the consumption of petroleum coke in various energy and non-energy applications are made based on EU ETS and other data, In the years 1990-1991, 1999, 2001 and 2005-2007, there is insufficient petroleum coke reported in DUKES to cover all of these uses and so the inventory activity total deviates from DUKES. Note that the comparison between DUKES and inventory data also indicates certain years (most notably 1992-1997, 2004, and 2010) where there is a large surplus in DUKES compared with the uses identified in the inventory, and this petroleum coke is then assumed to be used in various unidentified non-energy uses. It is conceivable, however that there is actually some stockpiling of petroleum coke, with increases in stocks in those years of surplus, and reduction in stocks in those years where there is a deviation from DUKES. Note that the inventory agency assumes that the unidentified non-energy use of petroleum coke does not lead to any emissions of AQ pollutants.

1.4.3 Industrial Process Emissions Data

Information on industrial process emissions are provided either directly to the inventory agency by the individual plant operators or from:

The Environment Agency, Natural Resources Wales - Pollution Inventory
The Environment Agency and Natural Resources Wales compile a Pollution Inventory (PI) of emissions from around 2,000 major point sources in England and Wales. This requires the extensive compilation of data from a large number of different source sectors. This valuable source of information is incorporated into the inventory wherever possible, as either emissions data, or surrogate data for

particular source sectors. The information held in the PI is also extensively used in the generation of the emissions maps, as the locations of individual point sources are known. The Inventory Agency, the EA and the NRW work closely to maximise the exchange of useful information. The PI allows access to air emissions through postcode interrogation with a map facility on the Environment Agency website:

https://www.gov.uk/check-local-environmental-data

The Scottish Environment Protection Agency – SPRI Inventory
The Scottish Environment Protection Agency (SEPA) compiles an emissions inventory for emissions reporting under the Industrial Emissions Directive (IED) 2010/75/EU and the European Pollutant Release and Transfer Register (E-PRTR). The reporting of emissions is required for all activities listed in Annex I of the IED. Industrial process emissions are reported to the Scottish Pollutant Releases Inventory (SPRI), and the data covers emissions in 2002 and from 2004 onwards. As with the data from the EA and NRW Pollution Inventory, the point source emissions data provided via the SPRI are used within the NAEI in the generation of emission totals, emission factors and mapping data. The SEPA inventory can be found at:

http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx

The Northern Ireland Environment Agency – Pollution Inventory
The Northern Ireland Environment Agency compiles a Pollution Inventory of industrial emissions for the purposes of E-PRTR and this point source data, although not yet available via the web, is readily available to the public via the Department itself. The NAEI utilises this valuable point source emissions data for the development of emissions totals, factors and mapping data. Information can be found at:

http://www.doeni.gov.uk/niea//environment/industrialPollution/ipc.shtml

1.4.4 Improvements to Inventory Data and Methods

As noted above, each year the inventory is updated to include the latest data available; improvements to the methodology are made and are backdated to ensure a consistent time series. The UK inventory has been developed and improved over many years and for most emission sources the methodologies used are well-established and cannot be improved upon without committing significant resources to the task. However, the inventory improvement programme (described in section 1.1.1) enables research to be undertaken aimed at improving the inventory, for example to address any new / emerging emission sources and to take account of any changes and additions to the following:

- UK Government energy, transport and production statistics used in the inventory;
- EU ETS data;
- emissions data given in the PI/SPRI/NIPI;
- emissions data from the EEMS data set;
- data sets routinely supplied by industry to the inventory agency as part of the annual data collection process;

The UK inventory improvement plan is constantly under review by Defra and BEIS, to take account of expert and peer review findings as well as issues identified by the inventory agency in the post-submission review which collates findings from the latest inventory cycle.

In addition to formal reviews of the inventory, the inventory agency seeks new information and accesses new data sources through an annual programme of consultation with industrial trade associations, specific organisations, government departments and agencies, and other stakeholders. These meetings, phone calls and email exchanges often highlight areas of the inventory where further refinements could be made, for example where new industry-specific research or investment highlights an improvement in emissions performance or understanding of emission sources on existing UK plant.

Sector-specific planned improvements are detailed throughout this report in the relevant sections.

1.5 Key Source Analysis

Table 1-9 provides an overview of the most important sources for selected pollutants, for the year 2015, reported under the CLRTAP in the 2017 inventory submission. Key sources are those which, when summed up in descending order of magnitude, cumulatively add up to 80 % of the total level, as per reporting guidance[15].

For SO_x (as SO_2), and NO_x (as NO_2), the single dominant source is 1A1a Public Electricity and Heat Production. Six of the seven key sources for NH_3 are from the agriculture sector, with 25% of the emissions from cattle. The largest source of NMVOC emissions is from the use of domestic solvents including fungicides. 1A4bi (residential stationary combustion) remains as the dominant source of CO, TSP, PM_{10}, $PM_{2.5}$, PAH, and PCDD/PCDF emissions. 1A4bi is the dominant source of Cd emissions in the 2017 submission too.

Sinter production in the iron and steel production sector is the dominant source for Pb emissions in 2015. There are only two key source categories for HCBs, which are from public electricity and heat production and the use of pesticides in the agriculture sector.

[15] http://www.ceip.at/fileadmin/inhalte/emep/pdf/2014/Methodology_Report_2014_final.pdf

Table 1-9 Key NFR14 Sources of Air Quality Pollutants in the UK in 2015 (that together contribute at least 80% to the pollutant emissions totals). Different colours are used to highlight NFR sectors (1A1, 1A2, 1A3, 1A4, 1B, 2, 3, 5, and 6).

Component	Key categories (Sorted from high to low from left to right)																Total (%)
SO_x	1A1a 38%	1A4bi 16%	1A1b 13%	1A2gviii 11%	1A2a 5%												82.6
NO_x	1A1a 21%	1A3bi 16%	1A3bii 10%	1A3biii 8%	1A2gviii 7%	1A1c 6%	1A3dii 4%	1A3c 4%	1A4bi 4%	1A2gvii 4%							83.4
NH_3	3Da2a 21%	3Da1 15%	3B1a 15%	3B1b 10%	3Da3 9%	6A 7%	3B3 5%										80.5
NMVOC	2D3a 18%	2D3d 13%	2H2 12%	2D3i 6%	3B1b 6%	1A4bi 5%	1B2ai 4%	3B1a 4%	1B2c 4%	1B2b 3%	1B2av 3%	1B2aiv 3%	2D3h 2%				81.8
CO	1A4bi 24%	1A3bi 15%	1A2gvii 13%	1A2a 11%	2C1 5%	1A2gviii 5%	1A4bii 4%	1A1a 4%									81.0
TSP	1A4bi 23%	2A5b 8%	1A2gviii 7%	1A3bvi 6%	2A5a 6%	2C1 5%	1A3bvii 5%	3B4gi 5%	3Dc 5%	1A1a 3%	3B1a 2%	2D3d 2%	3B4gii 2%	1A2gvii 2%	3B1b 2%		81.6
PM_{10}	1A4bi 31%	1A2gviii 9%	1A3bvi 6%	2C1 4%	2A5a 4%	1A3bvii 3%	2A5b 3%	1A1a 3%	3Dc 3%	2D3d 3%	1A3bi 2%	1A2gvii 2%	1A3dii 2%	6A 2%	3B4gii 2%	3B1a 2%	80.9
$PM_{2.5}$	1A4bi 42%	1A2gviii 12%	1A3bvi 5%	2C1 3%	1A3bi 3%	1A1a 3%	1A2gvii 3%	1A3bvii 3%	1A3dii 2%	6A 2%	2D3d 2%	1A3bii 2%					80.6
Pb	2C1 41%	1A2gviii 14%	1A4bi 7%	2B10a 6%	1A1a 5%	2I 5%	2C7c 5%										81.9
Hg	1A1a 25%	1A2gviii 13%	5C1bv 13%	2C1 10%	5A 7%	2B10a 6%	2C7c 4%	1A4bi 4%									82.3
Cd	1A4bi 28%	1A2gviii 25%	2C1 18%	1A3bi 6%	1A1a 4%												81.8
PCDD/F	1A4bi 28%	1A2gviii 14%	2C1 12%	6A 11%	1A4ci 9%	5C2 7%											80.8
PAH	1A4bi 87%																86.6
HCB	1A1a 64%	3Df 33%															97.5

1.6 Quality Assurance and Quality Control

This section provides details of the QA/QC system for the UK NAEI, including verification and treatment of confidentiality issues. QA/QC activities comprise:

- ***Quality Control*** (e.g. raw data checks, calculation checks, output checks) to minimise the risk of errors within the available resources to deliver the inventory.
- ***Quality Assurance*** (e.g. peer reviews, bilateral reviews, expert reviews) whereby independent experts periodically review all or part of the inventory to identify potential areas for improvement.
- ***Verification*** where alternate independent datasets are available to compare against inventory data and trends).

The NAEI QA/QC system complies with the guidance published in the EMEP/EEA Emissions Inventory Guidebook (GB), and the more comprehensive guidance on GHG emissions inventories (Tier 1 procedures outlined in the 2006 IPCC Guidelines). The QA/QC plan sets out a timeline for QA/QC checks, designed to fit in with compilation and reporting requirements for all UK Air Pollutant and GHG inventory reporting commitments.

Ricardo Energy & Environment (the inventory agency) is fully certified to BS EN ISO 9001:2008 (see Box 1 below). This certification provides assurance that through application of the ISO 9001 standard by Ricardo Energy & Environment, we will continue to ensure a consistent quality approach across all aspects of the inventory project. We will also conform to good practice in project management.

Box 1: BS EN ISO 9001:2008:
In addition to the UK's own AQPI specific QA/QC system, through Ricardo Energy & Environment, the Inventory has been subject to ISO 9000 since 1994 and is now subject to BS EN ISO 9001:2008. It is audited by Lloyds Register Quality Assurance (LRQA) and the Ricardo Energy & Environment internal QA auditors. The NAEI has been audited favourably by LRQA on four occasions in the last 12 years. The emphasis of these audits was on authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking and project management. As part of the Inventory management structure there is a nominated officer responsible for the QA/QC system – the QA/QC Co-ordinator. Ricardo Energy & Environment is currently accredited to BS EN ISO 9001:2008. Lloyds Register Quality Assurance carried out a three yearly recertification audit of Ricardo Energy & Environment in September and October 2014. Ricardo Energy & Environment successfully passed the recertification, with no major non compliances, and a new certificate was issued. Ricardo Energy & Environment is currently certificated both for the Quality Assurance ISO 9001:2008 and Environmental Management System ISO 14001 standard.

The main elements of the Tier 1 QA system requirements are:

- There is an Inventory Agency (consortium managed by Ricardo Energy & Environment)
- A QA/QC plan
- A QA/QC Manager
- Reporting documentation and archiving procedures
- General QC (checking) procedures
- Checks for data calculation errors and completeness
- Reviews of methods, data sources and assumptions
- Review of internal documentation
- Documentation of methodologies and underlying assumptions
- Documentation of QA/QC activities

The UK inventory QA/QC system complies with all of the above Tier 1 requirements and in addition, there are a range of source-specific (Tier 2) QA/QC measures within the UK system and typically applied to the most important "key categories" and/or where complex estimation methods (tier 2-3) are applied. Details of source-specific QA/QC activities are presented in the relevant sections within Chapters 3 to 7 of this report.

1.6.1 Description of the current Inventory QA/QC system

The National Atmospheric Emissions Inventory and the UK Greenhouse Gas Inventory are compiled and maintained together by Ricardo Energy & Environment (the Inventory Agency), on behalf of the UK Department for Business, Energy & Industrial Strategy (BEIS) and the Department for Food and Rural Affairs (Defra).
Most of the data received by the inventory agency for the UK inventory compilation come from other government departments, agencies, research establishments or consultants working on behalf of UK government or for trade associations. Several of the organisations (e.g. BEIS, the Office of National Statistics and British Geological Survey) qualify as the UK's National Statistical Agencies referred to in IPCC Guidance and abide by strict statistical QA/QC standards. Other organisations (e.g. the Environment Agency, providing regulated point source data) supply important datasets for the Inventory and have their own QA/QC systems. The data compilation for some source sectors of the UK inventory is performed by other contractors (i.e. Rothamsted Research compile the inventory for the agriculture sector).

Whilst these organisations have their own QA/QC systems, Ricardo Energy & Environment is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, Ricardo Energy & Environment is working continuously with organisations supplying data to the NAEI to encourage them to demonstrate their own levels of QA/QC that comply with either 2006 IPCC Guidelines or the UK's National Statistics standards.

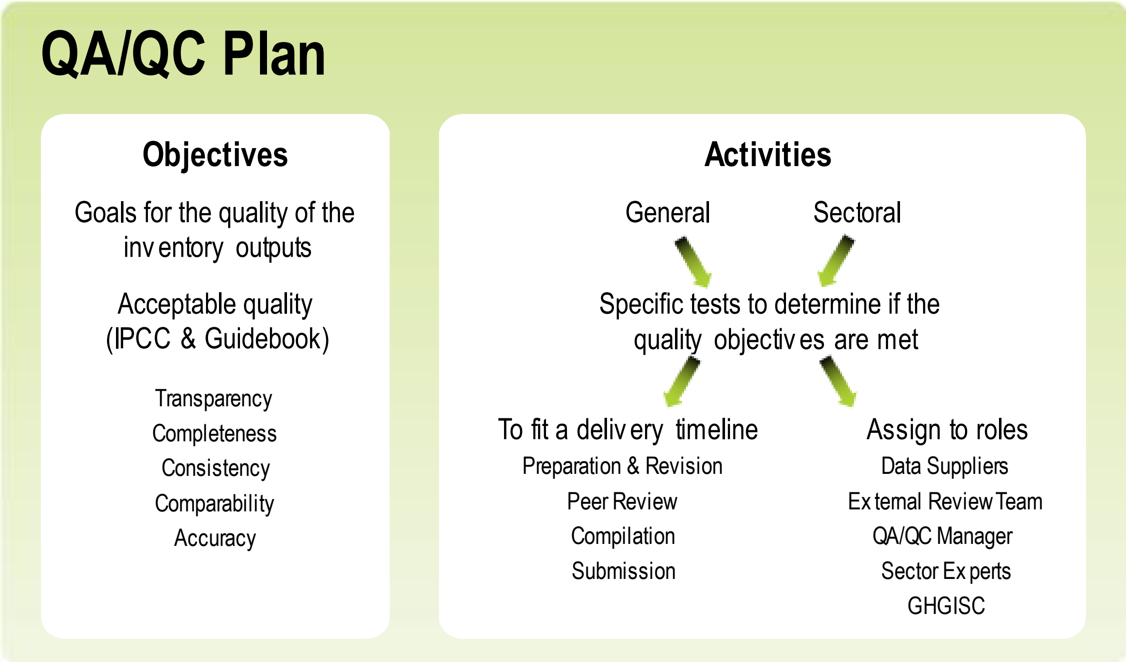
The UK inventory QA/QC system encompasses a wide range of activities to cover:

- planning tasks, including: *review of historic data and methods, identification of improvement priorities, data and method selection, inventory team training and development*;
- compilation and reporting tasks, including: *management and documentation of data flows from raw data through calculation of emission estimates to reporting, input data requests/acquisition, management of compilation processes and quality checking systems, documentation of data, methods and assumptions, assessment of key source categories and uncertainties, reporting of inventory outputs*;
- checking tasks, including: *raw data checks, inventory model / calculation checks, source-specific and cross-cutting output checks, checking reasons for changes compared to previous inventory estimates, emission trend checks, emission factor checks*; and,
- QA review tasks, including: *pre-submission reviews, post-submission reviews, peer reviews, bilateral reviews, expert reviews*.

To control and deliver across all these tasks, the inventory QA/QC system includes three core components:

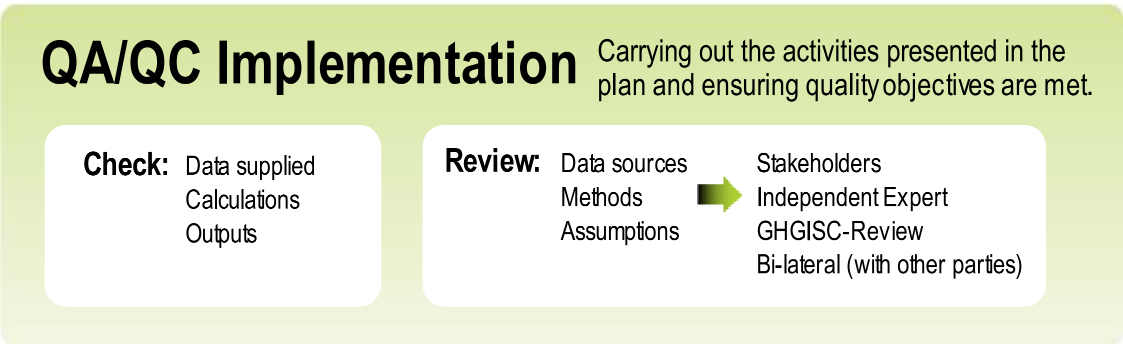
1. A QA/QC Plan is maintained by the inventory agency's QA/QC manager and defines the specific Quality Objectives and QA/QC activities required in undertaking the compilation and reporting of the inventory estimates. The plan sets out source-specific and general (cross-cutting) activities to ensure that quality objectives are met within the required inventory reporting time-frame. The QA/QC plan also assigns roles and responsibilities for the inventory agency team, and records the key outcomes from inventory QA activities in order to underpin a programme of continuous improvement.

Figure 1-6 QA/QC Plan



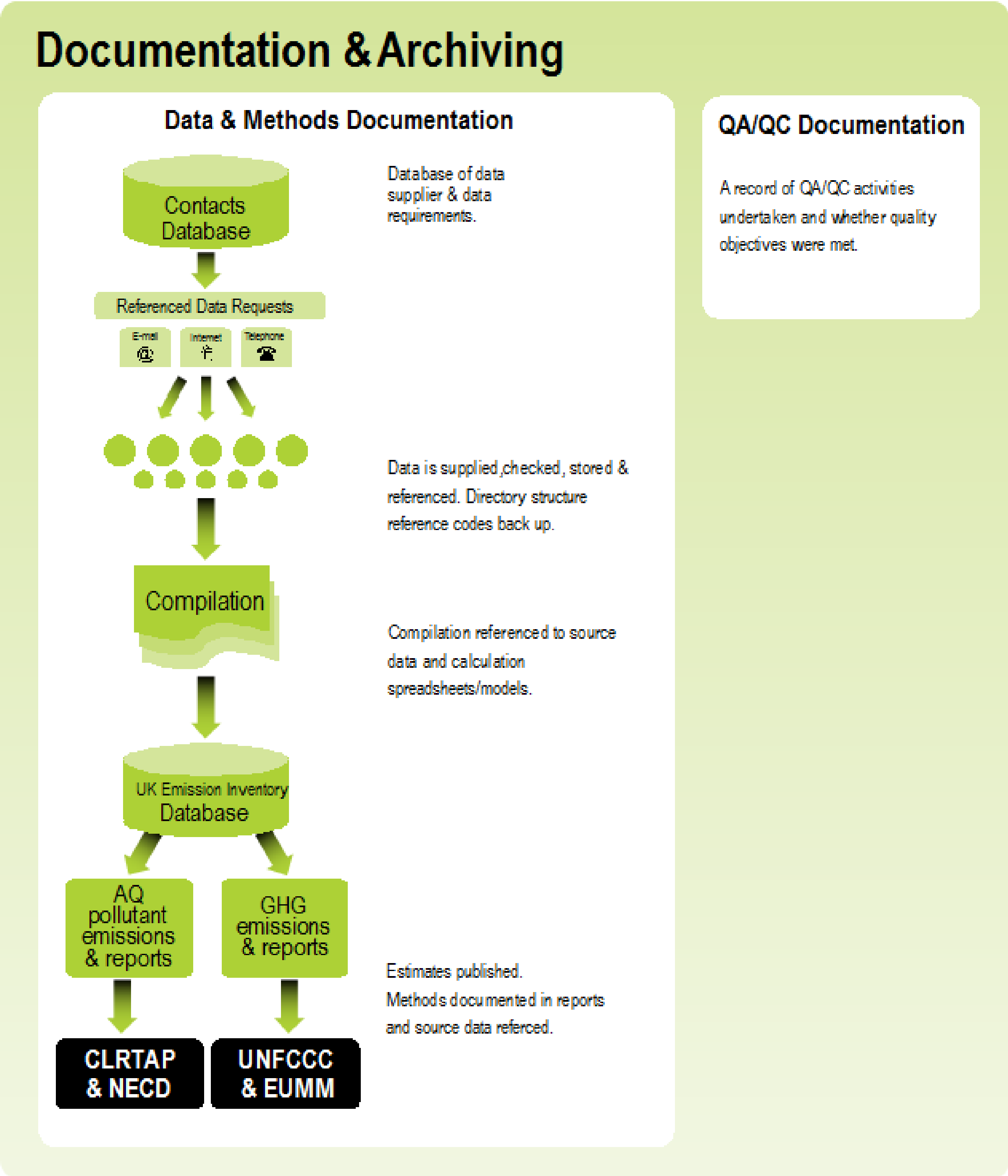
2. QA/QC implementation includes the physical undertaking of the QA/QC activities throughout the data gathering, compilation and reporting phases of the annual emission estimation cycle and in accordance with the QA/QC plan, and as agreed with Defra. A number of systems and tools for QA/QC implementation are described in the sections that follow.

Figure 1-7 QA/QC Implementation



3. Documentation and archiving which includes a) transparent documentation of all data sources, methods, and assumptions used in estimating and reporting the NAEI. These are included in the calculation tools used for calculating the estimates and in the GHG (NIR) and Air Quality Pollutants (IIR) inventory reports; b) transparent documentation of all QA/QC implementation including records of activities undertaken, findings, recommendations and any necessary actions taken or planned; and c) archiving.

Figure 1-8 Documentation and Archiving



Improvements made to the UK inventory QAQC system for the 2017 submission include:

- Enhancements to the central QA/QC dashboard developed to track and document progress of checking routines. The dashboard summarises the checks done in several dimensions, including by pollutant, by model, and by sector;
- Further improvements to inventory model design to ensure consistent and transparent documentation of model compilation, QC, version control, with supporting guidance to the inventory compilation team;
- Model upgrades for a number of inventory models, to re-build and test inventory models against UK Government QA guidelines; this process included third party reviews of models upgraded;

1.6.2 Quality Objectives

The key objectives of the QA/QC plan are to ensure that the estimates in the GHG and air pollutant inventories are of a suitably high quality and will meet the methodological and reporting requirements for UK submissions to the UNECE, UNFCCC and EU, as set out within national inventory reporting guidance from the Intergovernmental Panel on Climate Change (IPCC)[16] and European Environment Agency (EEA)[17]. The inventory data quality objectives are to achieve the principles of Transparency, Completeness, Consistency, Comparability and Accuracy (TCCCA):

- **Transparent in:**
    - The description of methods, assumptions, data sources used to compile estimates in internal (spreadsheets and other calculation tools) and published material (e.g. the IIR) and on the inclusion of national and EU wide assumptions (e.g. source category detail and the split between EU ETS and non EU ETS sources, implementation of policies and measures, carbon contents of fuels, site specific estimates, national statistics such as population, GDP, energy prices, carbon prices etc.).
    - The documentation of QA/QC activities and their implementation using internal checklists and summarised in relevant public material (e.g. the IIR).
- **Complete**: and include all relevant (anthropogenic) emission/removal activities, using representative data for the national territory for socio-economic assumptions and policies and measures for all required years, categories, gases and scenarios.
- **Consistent**: across trends in emissions/removals for all years (especially where applicable between the historic and projected estimates) and that there is internal consistency in aggregation of emissions/removals. Where possible, the same methodologies are used for the base year and all subsequent years and consistent data sets are used to estimate emissions or removals from sources or sinks.
- **Comparable**: with reported emission/removal estimates compiled for other countries through use of the latest reporting templates and nomenclature consistent with reporting requirements. Using the correct NFR or IPCC category level and consistent units for expressing mass of emissions/removals by gas., split between EU ETS and non EU ETS sources, scenarios, units for parameters and of input parameters with EU assumptions (e.g. energy prices, carbon price, population etc.).
- **Accurate**: ensuring the most accurate methods are used in the application of methods, minimising the uncertainty in assumptions and in use of data sources used for the estimates and inclusion of national and EU wide assumptions.

The overall aim of the inventory QA/QC system is to meet the above objectives, and to minimise the risk of errors in the UK inventory data such that emission estimates are not knowingly over- or under-estimated as far as can reasonably be judged.

The inventory QA/QC system also reflects that quality is one of three often competing attributes for a given project scope. These are quality (for which comprehensive QA/QC is crucial), time, and resources. Noting that the complete set of UK GHGI and AQPI estimates contain a large number of large and small contributors to emissions/removals, ***key category analysis*** is used to prioritise the most important categories (i.e. the highest-emitting source categories in the UK and/or the most uncertain sources). More resources and time are typically directed towards method development, compilation, reporting and associated QA/QC activities for these key source categories, with simpler methods and less rigorous approaches typically applied to lower-emitting / more certain (non-key) source categories.

1.6.3 Roles and Responsibilities

The QA/QC plan sets out specific responsibilities for the different QA (review) and QC (data controls, checking) activities and to different roles within the inventory compilation and reporting team. These are embedded within compilation and processing spreadsheets and databases. Training and project

[16] 2006 IPCC Guidelines for National Greenhouse Gas Inventories: http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[17] EMEP/EEA air pollutant emission inventory guidebook – 2016: http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

management communication across the inventory agency ensures that these responsibilities are clear, with specific tasks and checks signed-off at appropriate stages throughout the inventory process.

The following responsibilities are outlined in the UK inventory QA/QC plan:

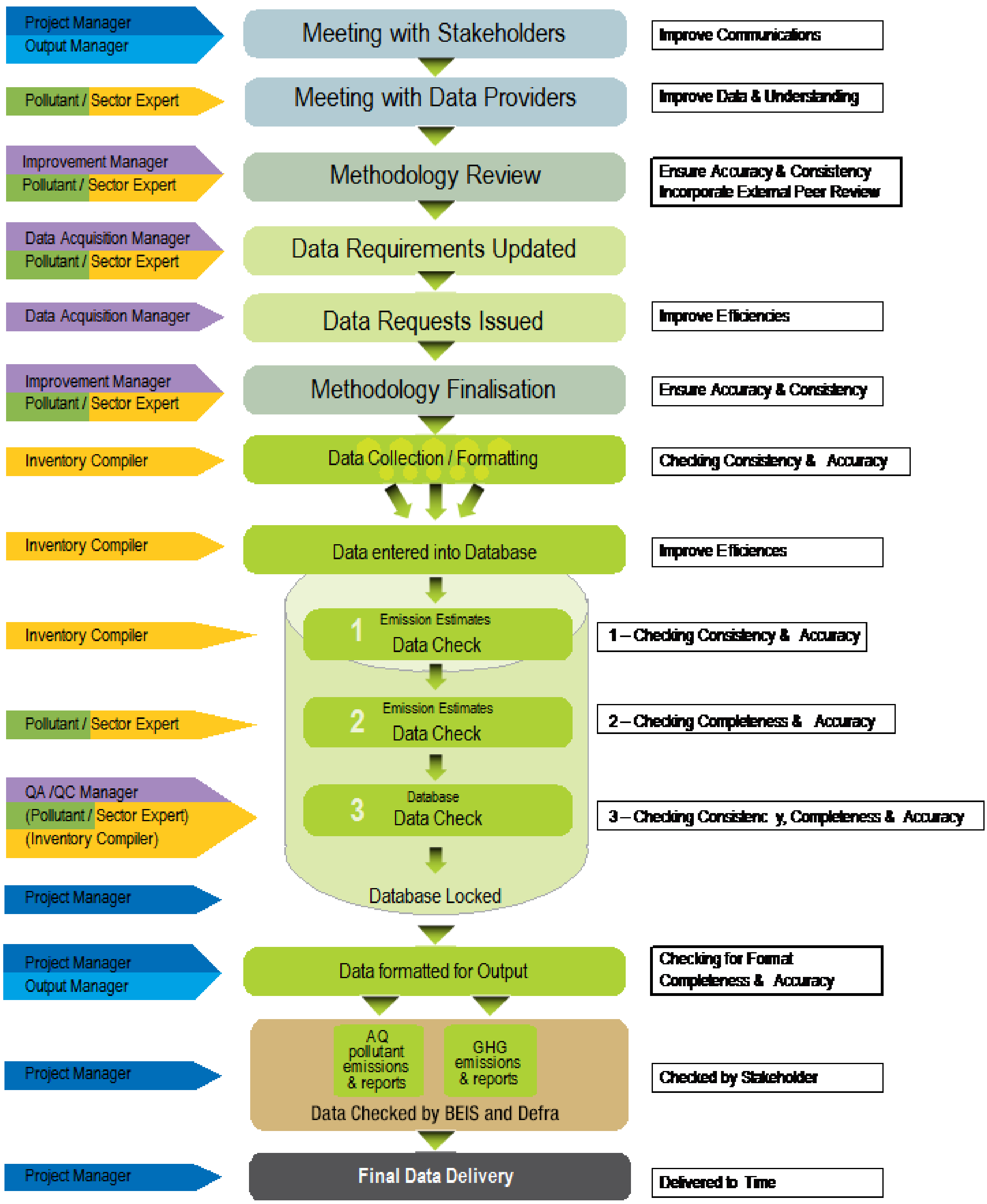
- **QA/QC Manager**: Co-ordinates all QA/QC activities and manages contributions from data suppliers, sector experts and independent experts and undertakes cross cutting QA/QC activities. Maintains the QA/QC plan, co-ordinates action across the team to: set quality objectives, communicate and implement QA/QC activities, identify training and development needs (individual, systematic).
- **Technical Directors / Knowledge Leaders**: Lead the technical development and implementation of the NAEI programme, supporting the QA manager and Project management team in delivering the project to meet technical requirements of international reporting as well as UK-specific and other output quality expectations. Manage periodic review and perform final checking activities on data and report submissions.
- **Project Manager**: Manage project finances and manage/attend project meetings, communicating project tasks and requirements to the team. Manage team resources and support QA Manager, Technical Director and Knowledge Leaders in identifying and resolving resource limitations (e.g. skills gaps, continuity planning).
- **Sector Experts**: Perform sector-specific and/or output-specific QA/QC activities and report to the QA/QC Manager. Sector Experts should also collaborate with data suppliers and other key stakeholders to review data quality (input data and outputs), perform quality checks on supplied information, assess and report on uncertainties associated with NAEI outputs. Identify improvement requirements for their tasks / sectors and promote / implement cross-cutting QAQC improvements by sharing best practice and engaging in team communication activities.
- **External Review Experts**: Provide expert/peer review of emission estimates / methods for specific sectors and report to the QA/QC Manager.

The QA/QC plan sets out a detailed timeline for QA/QC checks. The timeline is designed to fit in with compilation and reporting requirements for all UK GHG and Air Pollutant reporting commitments.

1.6.4 Implementation of the QA/QC Plan

Figure 1-9 gives an overview of the inventory compilation process and associated QA/QC activities. The process is based on the "plan, action, monitor and review" improvement cycle. The important QA/QC elements throughout the cycle are presented for each step.

Figure 1-9 QA/QC Activities throughout the Inventory Cycle

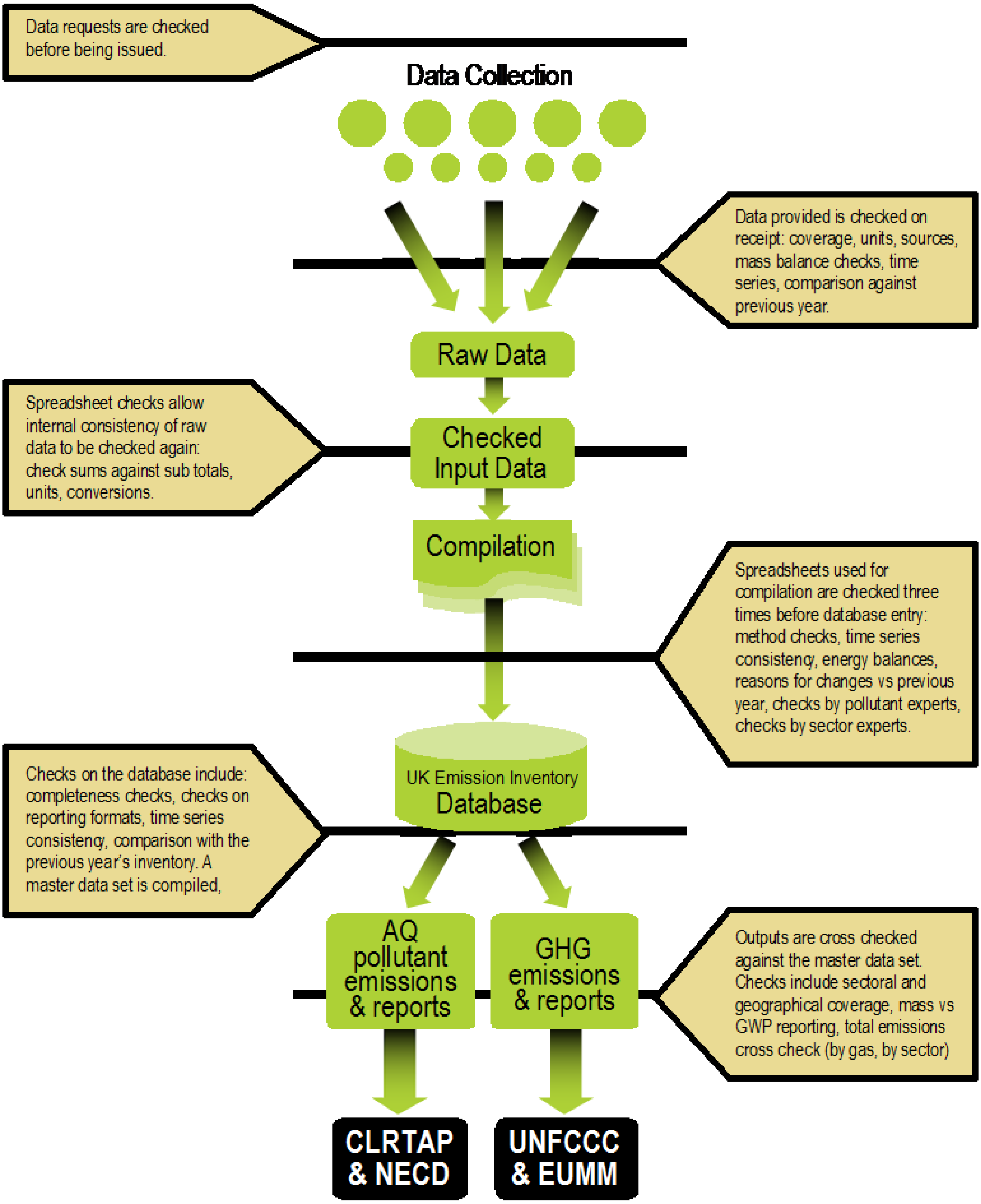


1.6.4.1 Quality Control and Documentation

The NAEI Quality Control (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle and illustrates the process of data checks used within the UK inventory compilation cycle. The horizontal bars symbolise ‘gates’ through which data does not pass until it meets the quality criteria and the appropriate checks have been performed. The key activities that are undertaken and documented to check the estimates include:

1. **Comparison of input data with other independent datasets** (if available).e.g. some datasets can be used to check inventories and their trends. For example, production-based emission estimates are compared with sales data to check that the trends and values are reasonable.
2. **Analysis of internal inventory energy balances** and other statistics assumptions against National Statistics input data (e.g. DUKES and ONS).
3. **Completeness checks**. The database is checked for completeness and consistency of entry across the different pollutants and gases. For example, combustion sources are checked for inclusion of all relevant pollutants and the database checked for any missing estimates and appropriate use of notation keys.
4. **Version checks**. The current database is cross-checked with the database that it is replacing. Any changes to the data must be explained by methodology changes or revision of source data.
5. **Time series checks**. The time series of emissions are checked for step changes. Any unusual features are checked and explained.
6. **Sector checks**. All sources are checked to ensure correct allocation into the NFR 2014-2 and CRF categories. Implied Emission Factors (IEFs) are checked against previous estimates and the IEF trends are analysed to identify and explain any step-changes.
7. **Unit checks**. Units of each emission are taken from the data in the compilation spreadsheets, but these are also checked.

Figure 1-10 Quality checks throughout the UK inventory compilation process



Checking and documentation is facilitated by specific custom data storage and handling systems alongside procedures developed for the NAEI compilation that include:

1. **<u>A database of contacts (the "contacts database")</u>** Containing uniquely referenced data suppliers and data users, detailed data requirement specifications (including requirements for supplier QA/QC and uncertainty information) and data supplied to and delivered from the AQPI. This database tracks all data sources and suppliers used for the estimation of emissions with unique references allocated to datasets through the inventory compilation process. The

contacts database also tracks all outputs from the AQPI including formal submissions and data supplied in response to informal and ad-hoc data requests.

2. **Individual data processing tools** are used to prepare the majority of source data into suitable activity data and emission factors for UK emissions estimates. These data processing tools (spreadsheets and Database models) include ***QC procedures, summaries and source data referencing within them***. The QC procedures include embedded (in the tools) ***sector specific checks*** (e.g., energy/mass balance and default emission factor checks for country specific emission factors, and implied emission factor checking). The QC procedures, within each tool/spreadsheet, include ***calculation input/output checking*** cells and flags to identify calculation errors. ***The QC summary*** sheets in each tool/spreadsheet provides an intuitive mechanism for documenting and summarising all checking undertaken on a model. It includes links to QC activities that need to be performed, flags for the QC activities, their status and sign off; details of source data; key assumptions, methods, data processing activities and progress; the scope of activities, gases and years included; relationships with other processing spreadsheets (where inter-dependencies exist); records of authorship; version control and checking. All relevant ***cells in the data processing spreadsheets are colour coded*** for ease of reference indicating whether the cells are calculation cells, output cells, checking cells or data input cells. All input cells carry a reference to the unique data source and data supplier held in the contacts database so all source data can be traced back to its originator and date of supply. ***All spreadsheets are subject to second-person checking*** prior to data uploading to the NAEI database.

3. **A core database (NAEI database) of Activity Data and Emission Factors** with embedded tier 1 QC routines (as defined at the start of Section 1.6) and data source and data processing referencing. The database provides the quality assured data source of emission/removal estimates used for reporting (including Common Reporting Format (CRF) population), responding to ad-hoc queries or deriving other downstream estimates (e.g. emissions by Devolved Administration and emissions by Local Authority). The detailed Activity Data and Emission Factor components for each estimate are held within the central database and include all sources, activities, gases/pollutants (AQPI and GHGI) and years. The majority of data in the database are imported directly from the individual data processing tools/spreadsheets (described above). ***Data transparency:*** All data points in the database carry a reference that pinpoints either the upstream data processing tools used to derive the data, the external data source and supplier or both. It also includes details of the date entered, the person uploading the data, its units (to ensure correct calculation), and a revision or recalculation code (which ensures that recalculations of historic data can be easily traced and summarised in reports). ***Automated data import routines*** used to populate the database minimise transcription errors and errors resulting from importing data that still itself contains errors even after previous checking. This process extracts output data from the upstream data processing tools/spreadsheets and can be controlled by the Inventory Agency via a data import dashboard. The automated system ensures that data is only uploaded to the database once it meets specified QA/QC criteria of data checking, completion and consistency. A number of ***detailed QC checking queries***[18] are embedded within the database that support the annual QA activities defined in the QA/QC Plan and include:
    a. Checks with previous submissions for changes due to recalculations or errors at a detailed level, (A designated auditor identifies sources where there have been significant changes or new sources. Inventory compilers are then required to explain these changes to satisfy the auditor).
    b. Assessment of trends and time series consistency for selected key sources.
    c. Mass balance checks to ensure that the total fuel consumptions in the AQPI and GHGI are in accordance with those published in the official UK Energy Statistics in DUKES;
    d. Other activity data checks (e.g. production and consumption with official national statistics).
    e. Implied Emission Factor checks (assessing trends in IEF and comparison with previous submissions).
    f. A consistency check between NFR 2014-2 output and IPCC CRF formatted output.

[18] A full list is included in the QA/QC plan.

4. **Data extraction checking routines and procedures:** Data exported from the NAEI database and entered into reporting tools (e.g. the CRF Reporter tool and for Air Quality reporting into the UNECE reporting templates) are finally checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to submission. This includes interrogating the output datasets and comparing this against a series of queries from the NAEI database to compare both emissions and activity data.

5. **Official annual reports to UNFCCC and UNECE** provide full documentation of inventory estimation methodologies, data sources and assumptions by source sector, key data sources and significant revisions to methods and historic data, where appropriate. In addition the annual reports include details of planned prioritised improvements identified by the Inventory Agency and agreed by the National Inventory Steering Committee (a cross-Government body), and from Expert and Peer Reviews. Any data presented in reports are checked against accompanying submission datasets and the NAEI database.

6. **Archiving**: At the end of each reporting cycle, all the database files, spreadsheets, on line manuals, electronic source data, records of communications, paper source data, output files representing all calculations for the full time series are frozen and archived on a central server. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on secure servers that are regularly backed up. Paper information is archived in a Roller Racking system with a simple electronic database of all items references in the archive.
    - The agriculture inventory (compiled by Rothamsted Research, North Wyke) is backed up on a daily basis on their network storage system. This system is mirrored with the Rothamsted Research Harpenden site, comprising an offsite backup.
    - At CEH, all data and information relating to the LULUCF inventory is stored on a networked drive (accessible only by the project team) which is backed up daily by CEH computer support. There is a separate folder for each inventory year and at the end of an inventory cycle the final versions of all datasets remain unchanged for back reference if required. In addition to this the model code used within CEH for inventory compilation is stored in a subversion repository to ensure a clear record of all amendments and iterations.

1.6.5 Quality Assurance and Verification

Quality Assurance and verification activities provide an objective, independent review of inventory source data, methods and assumptions. These activities are primarily conducted to assess compliance with reporting requirements (e.g. comparing UK inventory methods against international guidelines) and also to identify areas for future inventory improvement. QA and verification activities include:

1. Assessment of improvements against recommendations and the Inventory Improvement Programme lists of required improvements.
2. Official annual review of changes to estimates and trends, prior to submission, by stakeholders supplying key datasets and by UK government departments responsible for the inventory reporting.
3. Peer/Expert review of methods, assumptions and data sources for new / revised estimates and on a periodic basis for key categories to determine whether methods should be improved due to the availability of new datasets and assumptions (focussing on key categories).
4. Documentation of recalculations and changes to the estimates.
5. Verification analysis (e.g. comparison of trends with trends in ambient measurements).

This section describes a number of specific QA activities and procedures.

1.6.5.1 External Peer Review

The inventory agency may draw upon a team of air quality and emissions experts (from outside of the core NAEI team) in order to conduct periodic peer reviews or validation on sections of the inventory. These peer review experts are typically knowledge leaders from the emissions inventory, AQ modelling and research communities who use inventory data as part of their wider studies. Individual reviews may be commissioned, but also many of the peer review team conduct studies funded from other sources which give direct feedback on the robustness of the emissions inventory estimates.

In addition, the UK Government and Devolved Administrations' Air Quality Expert Group (AQEG) regularly utilises and analyses NAEI data whilst assessing policy and science questions related to air quality. AQEG are the Expert Committee to Defra that provides independent scientific advice on air quality. Specifically AQEG gives advice on levels, sources and characteristics of air pollutants in the UK and as such regularly utilises and scrutinises AQPI data. A senior member of the inventory agency is a member of the AQEG and is able to feed back comments, advice and any issues associated with the use of AQPI data to the inventory team.

1.6.5.2 Bilateral reviews

The UK also undertakes bilateral and external peer reviews which are managed as part of the UK inventory improvement programme. Bilateral reviews are initiated with other countries as a means to learn from good practice of other countries as well as to provide independent expertise to review estimates. The UK has participated in a number of bilateral exchanges and the current contract makes allowances for biennial bilateral reviews (see Table 1-10).

Table 1-10 Summary of Recent Inventory Reviews

Review description	Summary
2016: Stage 3 UNECE Review	In depth review of the UK AQPI inventory submitted under the UNECE LTRAP Convention and EU National Emissions Ceilings Directive. The review was coordinated by the EMEP emission centre CEIP acting as review secretariat. This review has concentrated on SO_2, NO_x, NMVOC, NH_3 plus PM_{10} and $PM_{2.5}$ for the time series years 1990-2014 reflecting current priorities from the EMEP Steering Body and the Task Force on Emission Inventories and Projections (TFEIP). Heavy metals and POPs have been reviewed to the extent possible. Recommendations made in this recent Stage 3 review will be considered in future improvement programme.
2015: Bilateral review of the Energy and Industrial Process Sectors	Bilateral review with Denmark, focusing on the energy balance, refineries, Reference Approach, mobile and fugitive sources and industrial processes. The recommendations from this review will feed into the UK inventory improvement programme.
2015: Multi-lateral review on QAQC.	Hosted by Germany and including QA experts from UK, Denmark, France and the Netherlands, the review compared Member State approaches to QAQC, reviewing the requirements of the 2006 IPCC Guidelines, to identify common approaches, areas of uncertainty and interpretation of the Guidelines. The aim was to exchange good practice and identify where the GLs were open to interpretation in order to derive a common approach for EU Member States.
2006 - 2015: Annual UNFCCC review	Annual review by the UNFCCC expert review team. Reviews highlight reporting issues of transparency, completeness, consistency, comparability or accuracy that need to be resolved by the UK. *These reviews are focussed on the GHG inventory rather than the AQPI inventory, but nevertheless identify areas for improvement that apply across all of the UK inventory programme.*
2014: Bilateral review of the energy and waste sectors	Bilateral review with Germany, focusing on the energy balance, iron and steel, refineries, the chemical industry and waste and biofuels. The recommendations from this review fed into the UK inventory improvement programme.

Review description	Summary
2012: Peer review of all except Sector 5. Conducted by EC Technical Expert Review Team	The review focussed on non LULUCF sectors and provided a report for each Member State (including the UK) highlighting recommendations for improvements as well as documentation of any revised estimates as a result of the review. The UK made 3 minor revisions as recommended by this review for lime production and burning of biomass for energy to address underestimates, and for Dairy Cattle to address an over estimate. The review also presented another 20 recommendations for the UK to consider.
2008: Bilateral review of Agriculture (4) with the French inventory team	The objectives of the review were to develop emissions inventory capacity in collaboration with France, and to provide elements of expert peer review to meet quality assurance requirements under national inventory systems e.g. Article 5, paragraph 1, of the Kyoto Protocol and European Union Monitoring Mechanism (EUMM) e.g. 280/2004/EC. Specific activities undertaken included sharing good practice between the UK and France and the development of ideas for efficient future technical collaboration.

1.6.5.3 Stakeholder Consultation and User Feedback

The inventory agency consults with a wide range of stakeholders in order to ensure that the UK inventory uses the best available data and research, interprets information from data providers correctly and improves outputs to address user requirements.

The inventory data are used by a wide range of UK air quality researchers and decision-makers including users of data for air pollution modelling and air quality review and assessment work undertaken by local authorities; these users provide regular feedback regarding possible improvements to source-specific or spatially-resolved air quality emission estimates. The inventory agency also manages an annual programme of stakeholder engagement meetings and engages in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data. The stakeholder engagement plan encompasses a programme of face to face meetings with data providers, research organisations, Government Department and Agencies, regulators and academia, as well as numerous emails and phone calls each year. The programme of meetings, calls and emails is aimed at raising the profile of the NAEI work programme and identifying new research that may lead to new data for the NAEI, but also importantly it enables targeted discussions to seek resolution of inventory improvements or to obtain data clarifications (e.g. regarding the scope or quality of source data provided to the inventory agency). Regular and important stakeholder consultations include:

<u>Department for Business, Energy & Industrial Strategy (BEIS)</u>

- The inventory agency met with the BEIS energy statistics team that produces the Digest of UK Energy Statistics to discuss what changes (to both activity and methodology) were expected in the 2016 publication of the statistics, and to clarify some outstanding queries. Subsequently, improvements to the inventory activity data were identified and implemented for the 2017 submission, including:
    - Derivation of a consistent time series of activity data for wood use in the residential and industrial sectors; the BEIS team had derived revised activity data for 2013 onwards and therefore an extrapolation of the revised DUKES methodology was derived for earlier years in the time series;
    - Improved understanding of the scope of reported data within the UK energy statistics on renewables, biomass/biofuels and fossil and bio-carbon sources in waste-derived fuels. This has led to several revisions in the assumptions applied to generate emission estimates, including revision of the NCVs applied to activity data to derive emission estimates from combustion of biomass in several sectors.

  - Improved understanding of the data sources and uncertainties associated with the DUKES data for commodities such as lubricants, leading to a change in approach to reconciling sector-specific lubricant estimates with overall UK demand statistics.
- Consultation with the BEIS Offshore Inspectorate to request clarifications on the scope of EEMS reported data for several individual installations, to ensure correct interpretation of the available data.

Environmental Regulators

- Meetings, teleconferences and emails with sector experts and emission inventory analysts from the environmental regulatory agencies in the UK (Environment Agency - EA, National Resources Wales - NRW, Scottish Environment Protection Agency - SEPA and Northern Ireland Environment Agency - NIEA) and plant operators. These were undertaken to address source-specific emission factor uncertainties and obtain up to date information regarding site-specific activities, abatement and changes to plant design or scope of reporting.
- As in previous years we have contacted environmental regulators to clarify discrepancies between the Pollution Inventory (PI) and EU ETS, and other data sources, including to work through PI/SPRI data clarifications for the 2017 submission

Other data providers

- Consultation with gas network operators regarding data reporting discrepancies for the gas supply sector across recent years, and to obtain new estimates of leakage from the UK gas transmission system including from gas storage installations following changes to storage capacity in recent years.
- Consultation with the UK Solid Fuel Association to seek any new data on fuel sales, fuel composition and type, and the main sectors into which SFA members sell their products.
- Consultation with industry contacts in the waste management sector and within Defra to identify and assess the usefulness of new activity data on commercial and industrial waste disposed to landfill, for inclusion within the UK landfill model.
- Consultation with non-ferrous metal operators to obtain new information to help improve estimates of petroleum coke use by the sector.
- Consultation with the British Aerosols Manufacturers Association (BAMA) to obtain new data on non-MDI aerosol emissions and to seek insights into F-gas market responses to the EU F-gas Regulations.

1.6.5.4 Verification

Defra has an ongoing air pollution mapping and dispersion modelling programme which compares emissions inventory data with ambient concentrations measured at an extensive network of air pollution sites. These activities compare emissions with ambient concentrations and deposition estimates and provide some independent verification activities for air quality pollutants. The UK's inventory programme has included verification activities undertaken each year involving experts from the air pollution science and modelling communities who use specific inventory information to analyse and interpret ambient measurements. The activities usually focus on specific sources or pollutants and require use of the spatially resolved inventory. In recent years, the focus has been on road transport emissions where time-series trends in emissions or pollutant ratios have been compared with trends and ratios in roadside concentrations. These have been used to highlight discrepancies in the trends for NO_x (as NO_2) emissions from road transport, suggesting problems with the factors used for recent Euro standard diesel cars.

Further long-term research is carried out by universities funded through UK's research councils. This research also uses inventory information to interpret observations of air pollution concentrations measured at specific locations, sometimes close to sources, or from tall towers where urban flux measurements are made and compared with inventory data. An example of such research is the London Clearflo project. A member of the inventory agency is represented on Defra's Air Quality Expert Group (AQEG) where there are opportunities to bring important research findings and inventory information together and discussed in relation to important air quality policy issues. The work of AQEG helps to highlight important verification issues and enables Defra to prioritise future research on emissions, measurements and inventory improvements.

1.6.5.5 Inventory Improvement Programme

New information needs to be regularly assessed to ensure the inventory is accurate and up-to-date. The AQPI and GHGI estimates are updated annually and incorporate as many improvements to methods, data and assumptions as possible. This annual revision of the full time-series ensures that the inventory reflects the latest scientific understanding of emission sources and removals, and that a consistent estimation methodology is used across the full time-series. Continuous improvement of the inventory is delivered through a process of review of inventory data followed by a programme of targeted research, data gathering and/or revisions to methods and data sources. Improved understanding of the science and policy relating to GHGI and AQPI is also greatly enhanced through participation in related international activities. The improvement programme is managed through maintenance of an on-going "live" list of comments, improvements and problems that the inventory team find at any time of the inventory cycle or through external review or international activities. Internal, external and international review findings as well as uncertainty analysis provide the means for justifying and prioritising improvements. Defra are responsible for improvements to the AQPI and BEIS for the GHGI. Improvements on activity data that improve both AQ and GHG emissions are jointly owned but led by one or other of the departments. Specific activities that feed into the improvement programme include:

- Participation in technical national and international projects, workshops, conferences and meetings (including TFEIP/CLRTAP meetings, EU projects, working groups and guidance writing, UNFCCC negotiations, provision of expertise to the UNFCCC and UNECE inventory review, expert participation in the European Topic Centre on Air and Climate Mitigation).
- On-going data collection and inventory compilation.
- Stakeholder consultation including specific improvement feedback from the wider user community including users of data for modelling and Local Authority review and assessment work.
- Assessment of results from the annual uncertainty assessments.
- Recommendations from external and internal reviews.
- Potential issues identified through inventory verification projects.

In recent years, the improvement programme implemented a number of specific consultations, bilateral reviews, research projects and analysis to improve the inventory estimates reporting for the NAEI. These include:

- **Biological treatment of waste (2016)**. This work involved a review of ammonia emission factors for anaerobic digestion, as well as a review of activity data for anaerobic digestion and Mechanical Biological Treatment (MBT).
- **Road transport emission factors for NO_x (2016)** were updated with the latest version of factors in the 2016 updated version of the EMEP/EEA Guidebook (2016) and also in consultation with the COPERT model development team at Emisia.
- **A programme of stakeholder consultation** with trade associations, process operators and regulators to resolve specific issues such as verification/updating of individual assumptions used in methodologies, gap filling etc. (see above).
- **Analysis of EU ETS data (every year)** to assess sector-specific fuel use and fuel quality, to compare and challenge the UK energy statistics, identifying potential gaps or inconsistencies in sector allocations, to resolve through dialogue with the BEIS energy statistics team;
- **Iron and Steel sector estimates (2014-15)**. Consultation with BEIS DUKES, ISSB and Tata Steel led to improved data access for detailed activity and emissions data from integrated steelworks and improved reconciliation of industry energy data against the UK energy balance in DUKES. The research has led to a number of activity data corrections and re-allocations, where the industry information helped to identify mis-allocations or gaps in the DUKES data. The research also enabled greater resolution of data reported through EU ETS, leading to improved understanding of fuel use and emissions within the individual sources across the integrated works. This has led to a number of minor revisions to source estimates alongside a large improvement in data quality through improved completeness, accuracy, time-series consistency and transparency.

- **NO_x and PM_{10} emissions from small regulated industrial processes and commercial plant (2015)**: Improvement of the methodology for PM_{10} and NO_x emissions from small-scale combustion processes including those in the commercial sectors, to use the EMEP-EEA Guidebook factors.
- **Review of emission factors for small combustion plant**, particularly for pollutants such as NO_x as NO_2, CO, PM_{10} & POPs.
- **NMVOC emissions from adhesives use and cleaning solvents (2015, ongoing):** Improvement of the methodology for estimation of NMVOC emissions from adhesives use and cleaning solvents, paying particular attention to improving the estimation of solvent abatement and providing more detailed sectoral breakdowns.
- **Feedstock vs combustion of Other Petroleum Gas (OPG) (2013, 2014, 2015):** The inventory agency consulted with the BEIS DUKES team, EU ETS regulators, site-specific regulatory contacts (Site Inspectors, Process Engineers), and directly with plant operators to assess the source and scale of the emissions. Through this research, new activity data for chemical and petrochemical industry use of OPG was estimated across the time series (reported under 1A2c). As in previous years, data discrepancies between DUKES and EU ETS for the refinery sector were noted and resolved through consultation with the BEIS DUKES team, EU ETS regulators and checked against data provided by the refinery sector trade association, UKPIA;
- **Coke oven coke, shipping fuel use and bunker definitions (2014):** Additional consultation with the BEIS DUKES team clarified data management within the UK energy statistics compilation system for coke oven coke, shipping fuel use and bunker definitions, to ensure correct use of DUKES data within the NAEI;
- **Onshore oil and gas terminals and offshore installations (2014, 2015):** Consultation with the BEIS Offshore Inspectorate, oil and gas sector contractors and individual site operators resolved data gaps and inconsistencies within reported emissions data for onshore oil and gas terminals and offshore installations. These resolved differences including discrepancies from the EU ETS and EEMS emission reporting systems;
- **Road traffic data (2014, 2015):** Specific consultation with the Department for Transport Traffic Statistics team has secured the provision of anonymised Automatic Number Plate Recognition data to compliment vehicle counts and potential new data on vehicle speeds;
- **Rail (2014)**: Consultation with the Department for Transport has secured improved data from their new Rail Emissions Model for updating the rail emissions inventory.
- **Wastewater treatment and sewage sludge treatment and disposal (2014, 2015):** Consultation with Defra and the water industry regulator (OFWAT), the Environment Agency and water and sewerage companies in the UK has led to improvements in activity data and emissions data provision for waste water treatment and sewage sludge treatment and disposal. The inventory agency periodically meets with Carbon Managers from most of the UK water companies via the UK Water Industry Research forum and has procured activity and emissions data from more water companies to improve the completeness of estimates in the latest inventory.;
- **Incineration and Landfill (2014, 2015):** Research with the EA and Defra has progressed our understanding of the data availability for landfill methane flaring and use in gas engines. Several research tasks in recent years have led to significant improvement in the UK data for landfill gas capture and utilisation from a wide range of landfill sites.
- **Natural gas distribution (2014, 2015):** Consultation with natural gas distribution network operating companies, BEIS and Energy UK to: (i) obtain new data on the estimated gas leakage from the transmission system to improve inventory transparency, (ii) a review of the time series of gas leakage through the distribution network, and (iii) to obtain data on actual (rather than weather-corrected) annual gas demand through all of the regional distribution networks, in order to improve the accuracy of the aggregated UK estimates for natural gas composition;
- **Limestone and dolomite use (2014):** Consultation with the Mineral Products Association, British Glass and the British Geological Survey to review data inconsistencies on national activity data for limestone and dolomite use, access sector-specific production statistics and therefore to derive improved activity data for several industry sectors;

- **Renewable energy consumption (including biomass) (2014, 2015):** Consultation with the team that compiles the RESTATS database, which informs the DUKES renewable energy statistics for the UK, to compare the scope and data sources that underpin the national statistics on biomass and biofuels against data provided directly by industry-specific publications and datasets.
- **Coal Mine Methane (2014):** Consultation with colliery operators and UK Coal, combined with review of annual reports on coal mine methane use in the UK have led to a small revision in the estimates of methane recovery and emissions in recent years. Previously the inventory estimates were based on data from mines that accounted for around 80% of UK production, and this consultation enabled a more complete, representative UK dataset to be used in the inventory;
- **Devolved Administration solid and liquid fuels (2013, 2015):** A review of energy data reporting from across the UK sought new data sources for solid and liquid fuel use, aiming to identify information that are sectorally and/or geographically resolved, in order to help inform improvements to the UK sector allocations and also the Devolved Administration inventory totals. This research was revisited in 2015 and included consultation and review of reports published by Her Majesty's Revenue and Customs, and in the 2013 research also wider consultation with oil brokers, local councils, the Climate Change Agreements (a national policy reporting mechanism operated by BEIS), the National Housing Model, Welsh Government research into gas network expansion and fuel poverty;
- **Off-road machinery activities (2014):** A review was undertaken with stakeholders to get a better understanding of the population, usage and engine size for certain types of machinery used in construction which led to a revision in the amount of fuel consumption by these sources.

1.6.5.6 Capacity Building and Knowledge Sharing

The UK actively participates in capacity building and knowledge sharing activities with other countries. The list below highlights some recent examples of these activities. The focus has mainly been on the GHG Inventory, which has in turn helped the AQ Inventory.

1. Study tour by representatives of the Israeli Ministry of Environmental Protection and Central Bureau of Statistics, who compile the GHG inventory for Israel.
2. Knowledge sharing with Chinese energy statisticians on GHG emissions trading and statistics.
3. Capacity building activities in South Africa in the agricultural sector.
4. Knowledge sharing with the Romanian GHG inventory team during December 2011 to support the improvement of energy sector reporting.
5. Knowledge sharing with the Chinese Energy Research Institute regarding the UK experience of integrating facility-level data into the national inventory and outlining all of the QA procedures that govern energy and emissions data from facility to sector to national level within the UK, to support their efforts in developing a national system of data management to account for GHG emissions, working from provincial and facility-level data.
6. Capacity building in Spain – invited presentation of the UK agricultural inventory improvements and further conversations with Spanish government representatives.
7. Knowledge sharing with Russian and French inventory teams.
8. CEH participation in twice yearly knowledge sharing with European LULUCF inventory compilers at EU Joint Research Council LULUCF meetings.
9. Knowledge sharing with and technical assistance to the Vietnam inventory team to help develop the national inventory system.
10. Capacity building workshop with Balkan EU accession countries on National System development.
11. Study visit by delegation from the Chinese National Center for Climate Change Strategy and International Cooperation (NCSC) as part of their week-long visit to the UK arranged by BEIS. Ricardo hosted representatives from NCSC, BEIS and Welsh Government, presenting on compilation and usage of national, devolved, local and city inventories.

1.6.6 Treatment of Confidentiality

Much of the data necessary to compile the UK inventory are publicly available. However, some of the industrial production data are commercially sensitive, such as cement production and adipic acid production. For these sectors, whilst emissions data are reported openly, the activity data are not reported in the NFR14 templates.

Detailed EU ETS data are also supplied by the regulators to the Inventory Agency, which allows further analysis of the data to develop new emission factors or to cross check fuel use data with other sources. This detailed data set is not publically available, and therefore information obtained from the analysis of this data is suitably aggregated before it can be explicitly reported in the NFR 2014-2 templates or the IIR.

The UK Informative Inventory Reports from the 2008 IIR onwards[19], and estimates of emissions of air quality pollutants, are all publicly available on the web; see http://naei.defra.gov.uk/

1.6.7 Uncertainty Assessments

An uncertainty analysis for national estimates of NAEI pollutants has been undertaken using both the Tier 1 uncertainty aggregation method, and a more complex and comprehensive Monte-Carlo analysis, as described in chapter 5 of EMEP (2016).

The Tier 1 methodology investigates the impact of the assumed uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. Uncertainties are assessed for the NECD and Gothenburg Protocol base year (2005) and the most recently reported year by source sector and by pollutant.

Results from both the Tier 1 methodology and the Monte-Carlo analysis are presented in Chapter 1.7. These results are used to plan the programme of inventory improvement.

1.7 Uncertainty Evaluation

According to the 2006 IPCC guidelines, “An uncertainty analysis should be seen, first and foremost, as a means to help prioritise national efforts to reduce the uncertainty of inventories in the future, and guide decisions on methodological choice”. Therefore, uncertainty information is not intended to dispute the validity of the inventory estimates, but to provide an indication of where improvements may be best made. The EMEP/EEA 2013 guidebook requires Member States to undertake an uncertainty assessment of the national totals of each pollutant reported under the CLRTAP.

Evaluation of uncertainty is undertaken by a Tier 1 uncertainty aggregation assessment as indicated in Section 1.6.7. Uncertainty estimates are shown in Table 1-11. These estimated uncertainties are one of the indicators used to guide the NAEI improvement programme, which aims to reduce uncertainties in the NAEI. More information on the analysis for some of the key pollutants are given in the subsequent sections including details on a sectoral basis for each of these pollutants (given in Table 1-13 to Table 1-20).

[19] Earlier versions of the IIR can be found on EIONET (http://cdr.eionet.europa.eu/gb)

Table 1-11 Uncertainty of the Emission Inventories for a sample of key air quality pollutants

Pollutant	Emissions[a]			Estimated Uncertainty[b]		
	2005	2015	Trend	2005	2015	Trend[c]
PM_{10}	166	145	-12.7%	46%	47%	22%
$PM_{2.5}$	113	105	-7.1%	30%	49%	25%
SO_x (as SO_2)	711	236	-67%	6.7%	12%	2.8%
NO_x (as NO_2)	1608	918	-43%	6.3%	7.1%	3.2%
NMVOC	1174	835	-29%	12%	17%	14%
NH_3	307	293	-4.6%	27%	27%	8.5%
Pb	0.11	0.07	-40%	35%	29%	17%
B[a]p[4]	5790	7532	30%	340%	430%	150%

[a] kg for B[a]p and kt otherwise
[b] the range of +- the percentages given represents a 95% confidence interval. Because the Tier 1 approach used does not account for asymmetric distributions these values can be greater than 100%, this does not indicate that emissions could be negative, but that the values are very uncertain and a skewed distribution is expected.
[c] This is the 95% confidence interval from the central estimate of the trend, e.g. if the trend in emissions is a decrease of 50% and the trend uncertainty is 5%, then the 95% confidence interval would be a decrease of between 45 and 55%.
[4] B[a]p is benzo(a)pyrene

This Tier 1 assessment has been undertaken for several key pollutants - analysis of a more comprehensive list of pollutants will be considered if future resources allowed. Table 1-12 presents a summary of uncertainties determined previously using a Tier 2 Monte Carlo approach.

The uncertainty ranges derived previously are not comparable with those from the current Tier 1 methodology. This is because there have been changes to the inventories since the figures in Table 1-12 were derived, and because the assumptions used in the current uncertainty analysis have been improved since the earlier uncertainty analysis. The uncertainties shown in Table 1-12 are presented to indicate the relative uncertainty of pollutant inventories i.e. the results suggest that the inventory for CO (-20% to +30%) is slightly less uncertain than the inventory for HCl (-30% to +>50%) etc.

The uncertainty figures derived from the Tier 1 uncertainty analysis are all higher than the figures derived previously from the Tier 2 Monte Carlo analysis e.g. SO_x (as SO_2) was +/- 4%, NMVOC was +/- 10%, ammonia was +/- 20%. No analysis has been undertaken using the Tier 1 methodology with the same inventory data as used for the Tier 2 approach (2012 NAEI data). It is therefore not possible to conclude how much the observed increase in inventory uncertainty is due to changes in methodologies and how much is due to changes in the inventory data itself.

Whilst the Tier 1 method has generated significantly different estimates of uncertainty for some pollutants (SO_x (as SO_2), NMVOC, B[a]P in particular), the ranking of pollutants is generally similar to that obtained previously.

Table 1-12 Uncertainty of the Emission Inventories determined previously using a Tier 2 Monte Carlo approach for pollutants covered under the NAEI, but not covered by the recent Tier 1 assessment.

Pollutant	Estimated Uncertainty (%)
Carbon monoxide	-20 to +30
Benzene	-20 to +30
1,3-butadiene	-20 to +30
$PM_{1.0}$	-20 to +50
$PM_{0.1}$	-20 to +50
Black Carbon	-20 to +50
Black smoke	-30 to +50
Hydrogen chloride Hydrogen fluoride[a]	-30 to +>50 -30 to +>50
Arsenic	+/- >50
Cadmium	-30 to +>50
Chromium	-50 to +>50
Copper	+/- >50
Mercury	-30 to +50

Pollutant	Estimated Uncertainty (%)
Nickel	-40 to + >50
Selenium	-30 to +40
Vanadium	-30 to +30
Zinc	-40 to + >50
Beryllium	+/- >50
Manganese	+/- >50
PCDD/PCDFs	+/- >50
Polychlorinated biphenyls	+/- >50
Pentachlorophenol	+/- >50
Hexachlorocyclohexane	+/- >50
Hexachlorobenzene	+/- >50
Short-chain chlorinated paraffins	+/- >50
Pentabromodiphenyl ether	+/- >50
Polychlorinated naphthalenes	not estimated

[a] Assumed to be same as for hydrogen chloride (see text below for discussion)

1.7.1 Ammonia

Ammonia emission estimates are more uncertain than those for SO_x (as SO_2), NO_x (as NO_2) and NMVOC largely due to the nature of the ammonia inventory, which is dominated by a small number of major agricultural sources. In particular, the emission source 'agricultural soils' introduces over 25% uncertainty to the national total on its own. Emissions from animal husbandry are also very uncertain and depend on animal type, age, weight, diet, housing systems, waste management and storage techniques. This large number of impacting factors makes interpretation of experimental data difficult and emission estimates uncertain (DOE, 1994). Emission estimates for non-agricultural sources such as LULUCF are also highly uncertain, although these sources are less significant than agriculture. Unlike the case of NO_x (as NO_2) and NMVOC, a few uncertain sources dominate the inventory for NH_3 and there is limited potential for error compensation.

Table 1-13 Assessment of Ammonia uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	17.7	99%	5.7%	9.37	62%	2.0%	4.0%
1B	0.22	38%	0.0%	0.13	37%	0.0%	0.0%
2A	0.51	31%	0.1%	0.33	31%	0.0%	0.0%
2B	4.03	63%	0.8%	1.26	66%	0.3%	0.5%
2C	0.00	91%	0.0%	0.00	91%	0.0%	0.0%
2D	1.21	140%	0.6%	1.21	150%	0.6%	0.4%
2G	0.27	50%	0.0%	0.19	50%	0.0%	0.0%
2H	0.87	130%	0.4%	0.63	130%	0.3%	0.1%
3B	119	11%	4.1%	107	11%	4.1%	5.5%
3D	131	60%	25%	130	59%	26%	3.8%
5A	5.10	62%	1.0%	1.47	62%	0.3%	0.7%
5C	0.03	66%	0.0%	0.02	72%	0.0%	0.0%
5B	3.57	55%	0.6%	6.98	47%	1.1%	1.5%
5D	5.33	95%	1.6%	5.64	92%	1.8%	0.4%
5E	0.27	50%	0.0%	9.07	50%	1.5%	2.1%
6A	17.8	87%	5.0%	18.9	84%	5.4%	2.1%
Total	**307**	**27%**	**27%**	**293**	**27%**	**27%**	**8.5%**

1.7.2 Carbon monoxide

Carbon monoxide emissions occur almost exclusively from combustion of fuels, particularly by road transport. Emission estimates for road transport are moderately uncertain, as measurements are quite limited on some vehicle types and emissions highly variable between vehicles and for different traffic situations.

Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. Emission estimates from small and medium-sized installations are derived from emission factors based on relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in emission data for major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_X (as NO_2) and SO_X (as SO_2) which are also emitted mainly from major combustion processes. Unlike the case of NO_X (as NO_2) and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

1.7.3 Nitrogen oxides

Uncertainty of NO_x (as NO_2) emission estimates are driven by uncertainty in emissions from fuel combustion (sector 1A). The estimates for 1A are subject to relatively low uncertainty compared with the estimates for other sectors, but because 1A dominates the inventory so much, the higher uncertainties for the other sectors make very little impact on the overall uncertainty. Sources within 1A that drive the uncertainty include:

- Road transport: contributes about 1/3 of national NO_X (as NO_2) emissions in both 2005 and the most recent year. There is a high level of confidence in the activity data, and hence uncertainty is driven by uncertainty in the emission factors of vehicles. The emission factors vary widely depending on vehicle type, catalyst technology and driving conditions amongst other factors. There is some uncertainty in choosing how the emission factors are applied to UK data, but also in the emission factors themselves, which are based on measurements that had significant variation even when keeping the conditions constant.

- Off-road machinery: While this is a relatively small source (compared to road transport or power generation), the emission factors have similar issues to that of road transport. Additionally, there is no reliable source of data for the activity for this source, and the uncertainty in the activity data is considered to be significant.

The estimates for large stationary combustion plant are assumed to be significantly less uncertain than the estimates for mobile sources or small stationary combustion. The large combustion plant consist of a large number of sites for which independent emission estimates are available, and these emission sources are broadly of similar size, with none dominating. This leads to a large potential for error compensation, where an underestimate in emissions for one site or sector is very likely to be compensated by an overestimate in emissions in another site or sector. Many of the larger point- sources make up the bulk of the UK estimates, and these are commonly derived from continuous emission measurement data and hence are regarded to be good quality.

Table 1-14 Assessment of Nitrogen Oxides uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	1600	6.3%	6.3%	913	7.1%	7.1%	3.2%
1B	3.15	35%	0.1%	2.16	38%	0.1%	0.0%
2B	1.02	39%	0.0%	0.85	50%	0.0%	0.0%
2C	1.57	22%	0.0%	0.83	22%	0.0%	0.0%
5C	1.52	29%	0.0%	1.30	29%	0.0%	0.0%
6A	0.32	92%	0.0%	0.13	89%	0.0%	0.0%
Total	**1608**	**6.3%**	**6.3%**	**918**	**7.1%**	**7.1%**	**3.2%**

1.7.4 Non-Methane Volatile Organic Compounds

The NMVOC inventory is more uncertain than those for SO_X (as SO_2) and NO_X (as NO_2). This is due in part to the difficulty in obtaining good emission factors or emission estimates for many sectors (e.g. for solvent use, industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. Given the broad range of independent sources of NMVOCs, as with NO_X (as NO_2), there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI. Compared with many of the other pollutants analysed, the uncertainty in the NMVOC inventory is quite variable with time, and this reflects the fact that the NMVOC inventory was subject to a lot of improvement work in the 1990s and early 2000s, resulting in the acquisition of much data, whereas much less data have been obtained since leading to an increase in emission uncertainty.

Table 1-15 Assessment of NMVOC uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	278	18%	4.3%	114	33%	4.5%	3.3%
1B	263	17%	3.8%	145	16%	2.7%	1.1%
2A	2.01	44%	0.1%	0.85	41%	0.0%	0.0%
2B	40.4	54%	1.9%	14.3	49%	0.8%	0.7%
2C	1.64	39%	0.1%	1.39	40%	0.1%	0.1%
2D	398	15%	5.2%	356	22%	9.5%	8.5%
2H	77.7	72%	4.8%	96.1	72%	8.3%	2.7%
2I	0.23	71%	0.0%	0.15	71%	0.0%	0.0%
3B	102	79%	6.9%	102	78%	9.6%	9.6%
5A	6.18	34%	0.2%	0.96	34%	0.0%	0.1%
5C	3.67	72%	0.2%	3.64	72%	0.3%	0.2%
6A	1.97	78%	0.1%	1.03	72%	0.1%	0.1%
Total	**1174**	**12%**	**12%**	**835**	**17%**	**17%**	**14%**

1.7.5 Particulate Matter Estimates

The emission inventory for PM_{10} is subject to high uncertainty. This stems from uncertainties in the emission factors themselves, and the activity data with which they are combined to quantify the emissions. For many source categories, emissions data and/or emission factors are available for total particulate matter only and emissions of PM_{10} must be estimated based on assumptions about the size distribution of particle emissions from that source. This adds a further level of uncertainty for estimates of PM_{10} and, in some cases to an even greater extent, $PM_{2.5}$ and other fine particulate matter.

Many sources of particulate matter are diffuse or fugitive in nature e.g. emissions from coke ovens, metal processing, or quarries. These emissions are difficult to measure and in some cases it is likely that no entirely satisfactory measurements have ever been made, so emission estimates for these fugitive sources are particularly uncertain.

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction. All parts of the inventory would need to be improved before the overall uncertainty in PM could be reduced to the levels seen in the inventories for SO_X (as SO_2), NO_X (as NO_2) or NMVOC.

Interestingly the overall uncertainty for $PM_{2.5}$ is lower than for PM_{10} in 2005, despite having the same or higher uncertainty parameters for all sources than PM_{10} ($PM_{2.5}$ emissions are generally estimated by assuming a fraction of PM_{10} is $PM_{2.5}$, so there is additional uncertainty introduced in this fraction). This is because the sources that have particularly high uncertainty generally have an assumed coarser profile of particulate emissions (i.e. less particles small enough to be $PM_{2.5}$). This is particularly notable when you observe that fuel combustion (sector 1A), which has a relatively low uncertainty, makes up less than 2/3 of total PM_{10} emissions, but over 75% of $PM_{2.5}$ emissions for 2005. This is in contrast to emissions from the much more uncertain mineral industry, which represents 14% of PM_{10} but only 4% of $PM_{2.5}$ total emissions in 2005. The gap between $PM_{2.5}$ and PM_{10} closes in the most recent year primarily because of the increase in the significance of the uncertain estimate of domestic wood burning emissions.

Table 1-16 Assessment of PM_{10} uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	106	31%	19%	97.0	53%	35%	18%
1B	2.21	62%	0.8%	2.10	62%	0.9%	0.1%
2A	22.6	290%	39%	13.2	290%	26%	12%
2B	0.74	43%	0.2%	0.33	43%	0.1%	0.1%
2C	4.97	82%	2.5%	6.62	99%	4.5%	2.7%
2D	5.48	62%	2.0%	4.71	63%	2.0%	1.2%
2G	0.97	50%	0.3%	0.42	50%	0.1%	0.2%
2H	1.86	500%	5.5%	1.31	500%	4.4%	1.0%
2I	1.17	71%	0.5%	0.75	71%	0.4%	0.5%
3B	10.9	110%	7.5%	10.3	120%	8.3%	0.9%
3D	4.45	290%	7.8%	4.70	290%	9.4%	1.4%
5A	0.01	62%	0.0%	0.00	62%	0.0%	0.0%
5C	1.91	380%	4.4%	1.92	390%	5.1%	1.3%
6A	2.95	150%	2.6%	2.15	96%	1.4%	1.4%
Total	**166**	**46%**	**46%**	**145**	**47%**	**47%**	**22%**

Table 1-17 Assessment of $PM_{2.5}$ uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	90.6	35%	28%	85.8	59%	48%	24%
1B	1.46	40%	0.5%	1.41	39%	0.5%	0.5%
2A	4.72	140%	5.7%	2.60	150%	3.7%	2.2%
2B	0.50	39%	0.2%	0.22	41%	0.1%	0.1%
2C	3.49	100%	3.1%	4.04	110%	4.2%	2.6%
2D	2.29	110%	2.1%	2.03	110%	2.1%	0.9%
2G	0.50	50%	0.2%	0.22	50%	0.1%	0.1%
2H	0.56	500%	2.4%	0.39	500%	1.9%	0.5%
2I	0.93	71%	0.6%	0.60	71%	0.4%	0.5%
3B	3.39	160%	4.7%	3.19	160%	4.8%	0.4%
3D	0.60	50%	0.3%	0.63	50%	0.3%	0.4%
5A	0.00	62%	0.0%	0.00	62%	0.0%	0.0%
5C	1.71	400%	6.0%	1.72	400%	6.6%	1.7%
6A	2.70	150%	3.5%	1.95	98%	1.8%	2.1%
Total	**113**	**30%**	**30%**	**105**	**49%**	**49%**	**25%**

1.7.7 Sulphur Dioxide

Sulphur dioxide emissions are related largely to the level of sulphur in fuels. Hence, the inventory, which is based upon comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture, industry and domestic sectors, contains accurate emission estimates for the most important sources.

It should be noted, however, that the uncertainty in emissions in the most recent year is significantly higher than the uncertainty in 2005 emissions. Over the last 20 years, regulations have been tightened to control the sulphur content of various fuels and SO_x (as SO_2) emissions also have to be reported by large emitters such as power stations, refineries and steelworks. As a result, it has been possible to reduce the uncertainty in the assumptions relating to the sulphur content of many fuels, and more confidence in the emission estimates for many sectors. However, the contribution of those fuels and sectors to the national total has reduced over time. The result is that fuels burnt by sectors for which there is less data (e.g. petroleum coke and coal used as a domestic fuel) now dominate the estimate of total sulphur emissions, and as these sources have a much higher uncertainty they drive up the overall uncertainty.

Table 1-18 Assessment of SO_x (as SO_2) uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	670	6.9%	6.5%	222	12%	12%	2.7%
1B	8.33	10%	0.1%	5.34	9.4%	0.2%	0.1%
2A	17.3	51%	1.2%	4.03	51%	0.9%	0.4%
2B	7.25	30%	0.3%	1.73	51%	0.4%	0.1%
2C	7.44	40%	0.4%	2.11	28%	0.3%	0.1%
5C	0.89	57%	0.1%	0.77	57%	0.2%	0.0%
Total	**711**	**6.7%**	**6.7%**	**236**	**12%**	**12%**	**2.8%**

1.7.8 Heavy Metals

Among the metal inventories, those for selenium, vanadium and lead are currently judged as least uncertain, followed by the inventories for cadmium, mercury, nickel, manganese and zinc. Those for chromium, arsenic, copper, beryllium and tin are the most uncertain. This ranking of the inventories reflects the relative contributions made by sources that can be estimated with more certainty, such as emissions from fuel combustion (very well characterised activity data, although determining the metal content of the fuel can be challenging) and chemicals manufacture. This is in contrast to the contributions made by sources for which estimates are very uncertain, such as burning of impregnated wood.

Below is the detailed assessment for lead. Many of the other heavy metals are expected to have a similar order of magnitude uncertainty to lead and some of the same relative uncertainties between sectors. Most of the metals emissions estimates are based on similar data and methodologies, and they all share certain important emission sources such as the combustion of coal and oils, and metal production processes. However, some of the metals do have specific sources from which emissions of that one metal are particularly abundant e.g. mercury emissions from crematoria, or selenium emissions from glassmaking. These unique features of each metal inventory mean that the uncertainty in the lead inventory can only be indicative of other heavy metal uncertainties.

Table 1-19 Assessment of lead uncertainty

NFR14 Code	2005			2015			
	Emissions (t)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (t)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	37.1	29%	9.9%	24.5	30%	11%	8.4%
1B	2.40	100%	2.3%	1.94	130%	3.9%	0.6%
2A	0.74	38%	0.3%	0.43	68%	0.4%	0.3%
2B	13.7	52%	6.5%	3.73	49%	2.8%	4.6%
2C	52.6	69%	33%	31.3	54%	26%	14%
2I	2.54	71%	1.6%	3.06	71%	3.3%	2.8%
5C	0.17	65%	0.1%	0.13	78%	0.2%	0.1%
Total	**109**	**35%**	**35%**	**65.1**	**29%**	**29%**	**17%**

1.7.9 Persistent Organic Pollutants

Inventories for persistent organic pollutants (POPs) are more uncertain than those for gaseous pollutants, PM_{10}, and metals. This is largely due to the paucity of emission factor measurements on which to base emission estimates and the complexity of dealing with POPs as families of congeners (PCDD/PCDFs, PCBs, PAHs). The issue is further exacerbated by a lack of good activity data for some important sources, for example small scale waste burning. The inventories for polychlorinated biphenyls and hexachlorobenzene are less uncertain than those for other persistent organic pollutants, however the overall uncertainty is still high.

Below is the detailed assessment for benzo[a]pyrene. In general, it is expected that the other PAH emissions estimates would be at least as uncertain and in some cases much more uncertain. Benzo[a]pyrene uncertainty estimates are not indicative of uncertainties in PCDD/PCDF emissions; independent PCDD/PCDF uncertainties will be prioritised in future work.

Table 1-20 Assessment of Benzo[a]pyrene uncertainty

NFR14 Code	2005			2015			
	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Emissions (kt)	Combined uncertainty for sector	Combined uncertainty as % of total national emissions	Uncertainty introduced into the trend in total national emissions
1A	4508	430%	340%	7006	470%	430%	140%
1B	75.6	91%	1.2%	92.5	91%	1.1%	0.1%
2B	17.9	92%	0.3%	8.68	120%	0.1%	0.2%
2C	161	27%	0.7%	102	36%	0.5%	1.0%
2D	10.5	130%	0.2%	8.09	130%	0.1%	0.1%
2G	10.3	50%	0.1%	7.47	50%	0.0%	0.1%
2I	23.4	140%	0.6%	19.2	140%	0.4%	0.3%
5C	645	490%	55%	29.2	370%	1.4%	69%
6A	338	140%	7.9%	260	85%	2.9%	7.9%
Total	**5790**	**340%**	**340%**	**7532**	**430%**	**430%**	**150%**

1.8 Assessment of Completeness

The NAEI uses a range of internationally agreed notation keys to indicate where there are methodological or data gaps in the inventories of pollutants, and where emissions are estimated but included elsewhere in the inventory instead of under the expected source category. The correct use of these notation keys ensures the NAEI is reported in a transparent manner, and facilitates the assessment of the completeness of the NAEI.

1.8.1 Not Estimated

The UK inventory does not currently estimate NMVOC from 2A5a (Quarrying and mining of minerals other than coal), 2a5b (Construction and demolition) and 2D3c (Asphalt roofing) due to lack of raw data. Activity data are not available for these sources but they are expected to be minor activities and emissions small as a result. However, these sectors will be kept until review in case suitable data should become available. SO_x (as SO_2) from 1B1a (Fugitive emission from solid fuels: Coal mining and handling) and NH_3 from 5C1bv (Cremation) are also marked as not estimated, however, no emission factors are given for either in the 2016 version of the EMEP/EEA Guidebook and so the notation key in both cases will be changed for the next inventory version to NA, in line with the guidance in the 2016 Guidebook that emission factors for these pollutants are not applicable.

Estimates forbenzo(b) fluoranthene, benzo(k) fluoranthene and Indeno (1,2,3-cd) pyrene from 5C1bv (Cremation) will be provided in future submission. At the 2016 Stage 3 in-depth review[20], it was recommended that the UK include NO_x emissions from 3B (Manure management) and 3D (agricultural soils), as well as NMVOCs from 3De (Cultivated crops). All are currently not estimated. These recommendations will be considered in the future improvement programme.

1.8.2 Included Elsewhere

Emissions of sources that are unspecified within the NFR14 disaggregation for a specific sector are reported as IE. Table 1-21 lists all sources included in these categories.

Table 1-21 Explanation to the Notation key IE

NFR14 code	Substance(s)	Included in NFR14 code
1A3ei	All	1A1c
1A4aii	All	1A4ai
1A5a	All	1A5b
1B1c	All	1B1b
1B2aiv	SO_x (as SO_2)	1B2ai
1B2av	SO_x (as SO_2)	1B2ai
2A5c	PM	2A5a & 2H3
2B10b	All (except NMVOCs)	2B10a
2C2	All	1A2a, 2C1 and 2A3
3B4d	NMVOC	3B2
3B4f	NH_3	3B4e
3B4giii	NMVOC	3B4gii
5C1bi	All	5C1a

1.8.3 Other Notation Keys

“NA” (not applicable), and “NO” (not occurring) notation keys are used where appropriate.

[20] http://www.ceip.at/fileadmin/inhalte/emep/pdf/2016_s3/UK-ReviewReport-2016.pdf

2 Explanation of Key Trends

2.1 UK Emission Trends for key sources

This chapter discusses the latest emission estimates for selected pollutants, and analyses the trends within six major emission source categories for each pollutant. The pollutants considered are the NECD pollutants (SO_x as SO_2, NO_x as NO_2, NMVOC, and NH_3) and additionally PM_{10}, $PM_{2.5}$, CO, PCDD/PCDF, PAHs, HCB, and a range of metals. Emissions of $PM_{2.5}$ are presented because emission reduction commitments are included in the revised Gothenburg protocol. The emission source categories considered are power generation, industrial combustion, residential, public and commercial sector combustion, industrial processes, transport, agriculture, and finally, waste – these six categories cover a high proportion of UK emissions of the pollutants covered by this chapter. The discussion for each source category concentrates on those pollutants where emissions are substantial from the source, or where there have been large changes in emissions or in the trend in emissions over time. The text highlights where there have been significant changes in emissions between 1990 and the latest reported inventory year. A wide range of legislation and activities have affected emissions of these pollutants, and these are listed and discussed. The chapter starts with a general discussion of the trends in emissions of NECD pollutants, and then moves on to discuss the emissions and trends for each of the six major source categories.

The percentage changes presented in this chapter are calculated from emission estimates held at full precision within a database and so they may differ slightly from percentages that could be calculated from the rounded figures presented in this report.

Further information and analysis on the emission trends of all pollutants reported under the CLRTAP are available on the NAEI website (http://naei.defra.gov.uk/). The website also provides access to more detailed NAEI data, including emission factors and emission maps for key pollutants.

The geographical coverage of the emissions reported to the CLRTAP is the United Kingdom and Gibraltar.

2.1.1 Trends in the NECD set of Pollutants

Figure 2-1 through Figure 2-4 show the time series of UK emissions of, NO_x as NO_2, SO_x (as SO_2), NMVOC, and NH_3 respectively from 1990 to 2015. Emissions of NO_x as NO_2, SO_x (as SO_2) and NMVOC have declined substantially since 1990, however the rate of decline has decreased in recent years for all three pollutants but particularly for SO_x and NMVOC. Emissions of NH_3 increased between 1990 and 1997 and then declined slowly between 1997 and 2013, before increasing again in 2014 and 2015.

Figure 2-1 Total UK emissions of NO_x (as NO_2) for 1990 – 2015

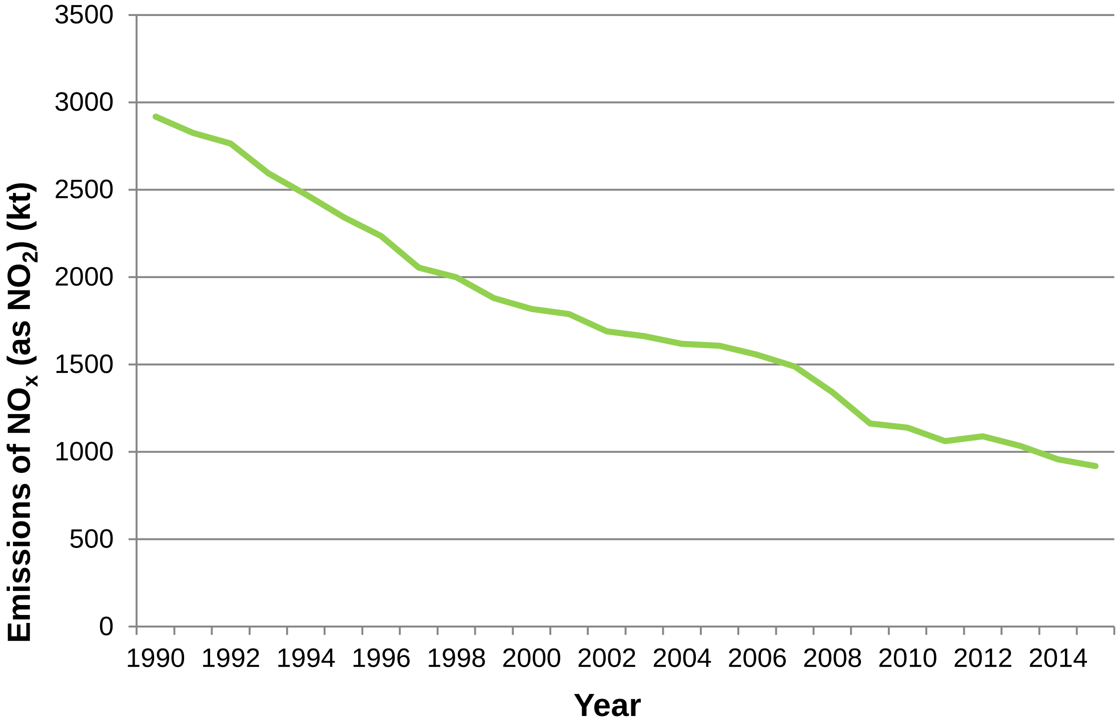


Figure 2-2 Total UK emissions of SO_x (as SO_2) for 1990 – 2015

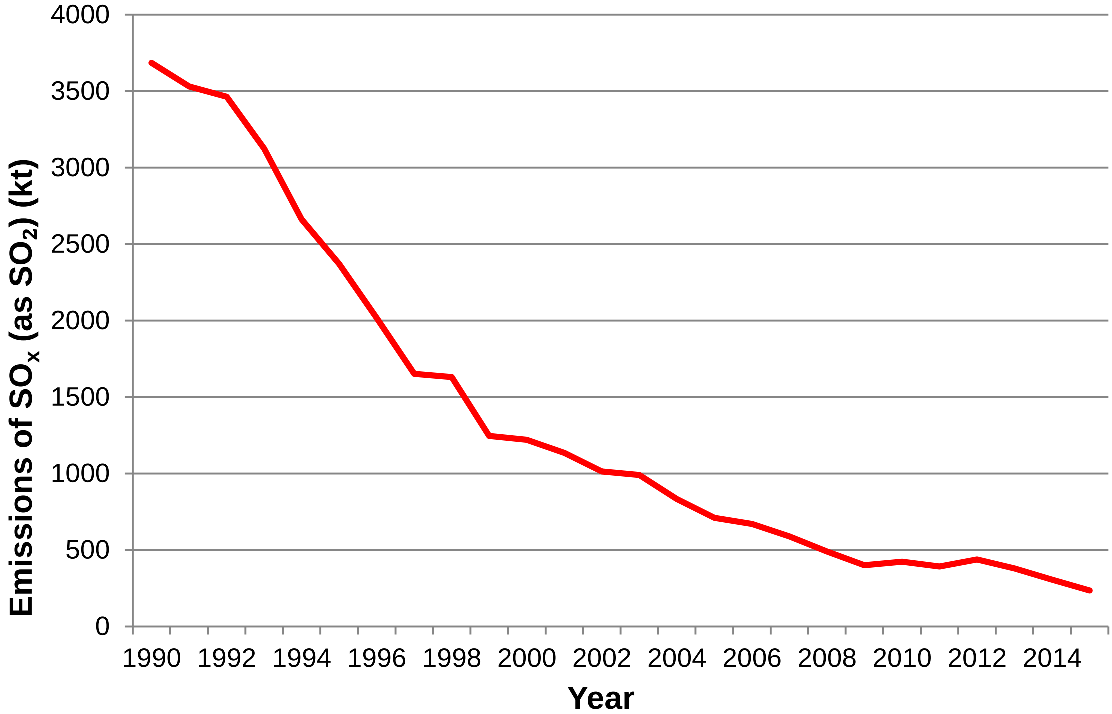


Figure 2-3 Total UK emissions of NMVOC for 1990 – 2015

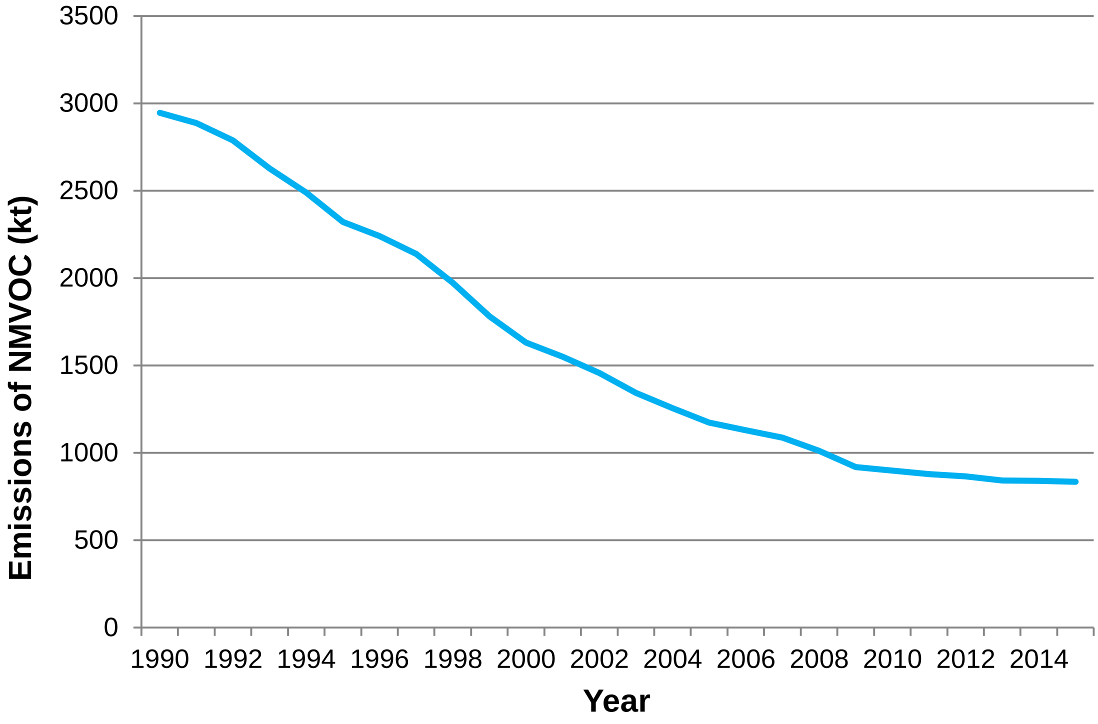


Figure 2-4 Total UK emissions of NH_3 for 1990 – 2015

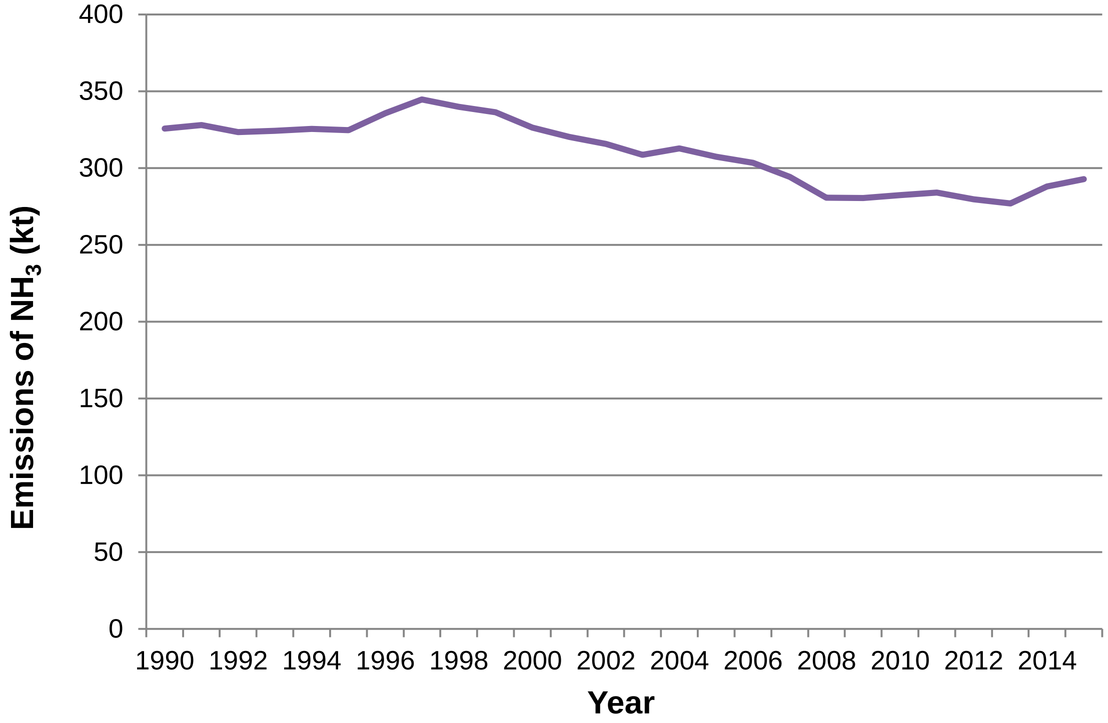


Table 2-1 shows the percentage changes in the emissions of NECD pollutants since 1990, and summarises the key factors and legislation responsible for the reductions in emissions. The impacts of these factors and legislation are discussed in greater detail, according to source, in the sections below this table.

Table 2-1 Changes in emissions of NECD pollutants since 1990

Pollutant	% reduction between 1990 & 2015	Key factors and legislation driving the decline in emissions
SO_x (as SO_2)	94%	• UK National Air Quality Strategy • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • Directive on industrial emissions 2010/75/EU (IED) • **UK Pollution Prevention and Control (PPC) regulations** • Large combustion plant directive (LCPD, 2001/80/EC) • **Limiting sulphur emissions from the combustion of certain liquid fuels by controlling the sulphur contents of certain liquid fuels (Directive 1999/32/EC)** • LRTAP convention which includes measures to combat the effects of SO_2 • **Reductions in the quantities of coal burnt** • Introduction of CCGT power stations • Implementation of flue gas desulphurisation at some power stations • Annex VI of the MARPOL agreement for ship emissions, augmented by the Sulphur Content of Marine Fuels Directive 2005/33/EC and the introduction of Sulphur Emission Control Areas
NO_x (as NO_2)	69%	• UK National Air Quality Strategy • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • Directive on industrial emissions 2010/75/EU (IED) • UK Pollution Prevention and Control (PPC) regulations • New air quality directive (Directive 2008/50/EC) • Implementation of the large combustion plant directive (LCPD, 2001/80/EC) • Series of Euro standards to limit vehicle tailpipe emissions, e.g. Euro 5 standards in Regulation (EC) No 715/2007 and previous Directives • Implementation of various stages of the EU Non-Road Mobile Machinery Directives 97/68/EC and subsequent amendments • LRTAP convention which includes measures to combat the effects of NO_x as NO_2 • Reductions in the quantities of solid and liquid fuels burnt • Improvements in combustion technology of solid, liquid and gaseous fuels leading to reductions in emissions, most notably trends in the power sector to fit low-NO_x burners, increase the use of nuclear and CCGT generation in the UK fuel mix, and retrofitting coal-fired power stations with Boosted Over-Fire Air systems to reduce NO_x formation.
NMVOC	72%	• UK Pollution Prevention and Control (PPC) regulations • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • **Directive on industrial emissions 2010/75/EU (IED)** • **Solvents Directive (99/13/EC)** • New air quality directive (Directive 2008/50/EC) • Series of Euro standards to limit vehicle tailpipe emissions, e.g. Euro 5 standards in Regulation (EC) No 715/2007 and previous Directives • EU Fuel Quality Directive 98/70/EC limiting vapour pressure of petrol to reduce evaporative emissions • Implementation of various stages of the EU Non-Road Mobile Machinery Directives 97/68/EC and subsequent amendments • Reductions in the quantity of petrol consumed • **LRTAP convention which includes measures to combat the effects of NMVOCs**

Pollutant	% reduction between 1990 & 2015	Key factors and legislation driving the decline in emissions
NH_3	10%	• UK Pollution Prevention and Control (PPC) regulations • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • **Directive on industrial emissions 2010/75/EU (IED)** • Water pollution by discharges of certain dangerous substances (Directive 76/464/EEC) • **Revised Gothenburg UN/ECE Protocol to abate acidification, eutrophication and ground level ozone (ECE/EB.AIR/122/Add.1, decisions 2013/3 and 2013/4)** • LRTAP convention which includes measures to combat the effects of NH_3

2.1.2 Power Generation

Power generation (NFR14 1A1a) was a key source for emissions of SO_x (as SO_2), NO_x (as NO_2), CO, TSP, PM_{10}, $PM_{2.5}$, Pb, Hg, Cd, and HCB in 2015. However, there has been a substantial reduction in the magnitude of emissions from this source between 1990 and 2015 for all of these pollutants apart for HCB (see Table 2-2). Emissions of HCB have increased significantly between 1990 and 2015 due to the sharp increase in municipal solid waste (MSW) used to generate electricity.

Table 2-2 Power Stations: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
CO	1A1a	4%	-47%
NO_x (as NO_2)	1A1a	20%	-76%
TSP	1A1a	3%	-94%
PM_{10}	1A1a	3%	-93%
$PM_{2.5}$	1A1a	3%	-91%
Hg	1A1a	25%	-87%
Cd	1A1a	4%	-97%
Pb	1A1a	5%	-98%
SO_x (as SO_2)	1A1a	38%	-97%
HCB	1A1a	64%	1149%

Figure 2-5 and Figure 2-6 show the emissions of a range of pollutants emitted from power stations between 1990 and 2015. The emissions for all the pollutants show substantial declines across the time series. Note that both charts use two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions. The emissions in Figure 2-5 are presented in kilotonnes and those in Figure 2-6 are presented in tonnes.

Figure 2-5 Total UK Emissions of SO_x (as SO_2), NO_x (as NO_2), CO, PM_{10}, $PM_{2.5}$ and TSP from Power Stations (1990-2015)

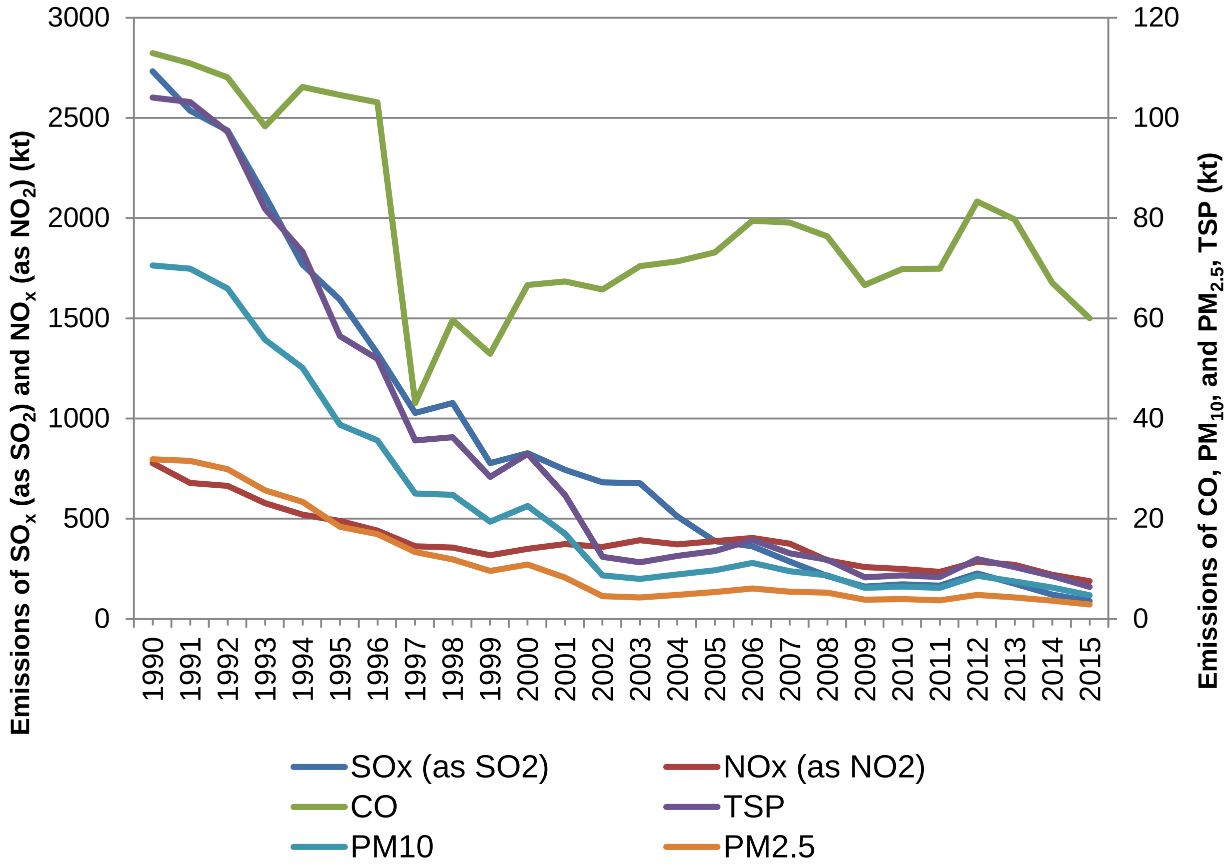
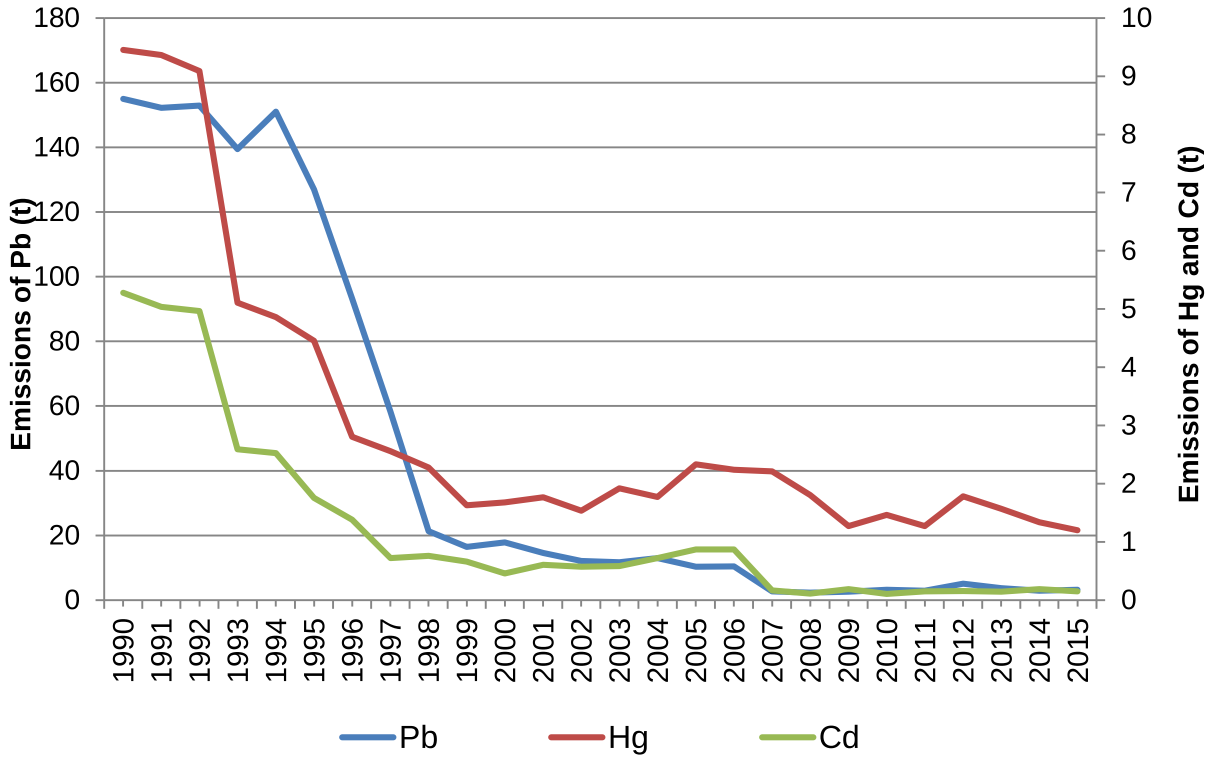


Figure 2-6 Total UK Emissions of Pb, Cd and Hg from Power Stations (1990-2015)



Since 1988, electricity generators have adopted a programme of progressively fitting low NO_x burners to their 500 MWe (megawatt electric) or larger coal fired units, and since 2007 a programme of fitting over-fire-air burners has further reduced NO_x (as NO_2) emissions from the sector. Since 1990, the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas have further reduced NO_x emissions. The emissions from the low NO_x turbines used are much lower than those of pulverised coal fired plant even when low NO_x burners are fitted at coal plant. Moreover, CCGTs are more efficient than conventional coal and oil stations and have negligible SO_x (as SO_2) emissions; this has accelerated the decline of SO_x (as SO_2) emissions. The reduction of particulate emissions is also due to this switch from coal to natural gas and nuclear power electricity generation, as well as improvement in the performance of particulate abatement plants at coal-fired power stations. The installation of flue gas desulphurisation at Drax and Ratcliffe and other power stations has reduced SO_x (as SO_2) and particulate emissions further.

Emissions of CO have not followed the same pattern as other pollutants and this reflects the assumption in the NAEI that CO emission rates (emission factors) in the early 1990s were similar to those in the late 1990s (there being very few reported emissions in the data sources for the early years). The reduction in emissions is therefore less pronounced for CO than for other pollutants, where changes in abatement led to lower emission rates over time.

2.1.3 Industrial Combustion

This category covers the use of fuels in combustion in crude oil refineries and other processes that manufacture or process fuels (NFR14 codes 1A1b & 1A1c) and combustion in industry (NFR14 codes 1A2a-1A2g). This category was a key source for emissions of SO_x (as SO_2), NO_x (as NO_2), CO, TSP, PM_{10}, $PM_{2.5}$, Pb, Hg, Cd, and PCDD/PCDF in 2015. There has been a substantial reduction in the magnitude of emissions from this source category between 1990 and 2015 for all of these pollutants, as well as for NMVOC, although emissions in some sub-categories have increased.

Table 2-3 Industrial Combustion: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
SO_x (as SO_2)	1A1b Petroleum refining	13%	-77%
NO_x (as NO_2)	1A1c Manufacture of solid fuels and other energy industries	6%	31%
CO	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	13%	7%
NO_x (as NO_2)	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	4%	-70%
TSP	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	2%	-74%
PM_{10}	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	2%	-74%
$PM_{2.5}$	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	3%	-74%
CO	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	5%	17%
NO_x (as NO_2)	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	7%	-39%
TSP	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	7%	25%
PM_{10}	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	9%	24%
$PM_{2.5}$	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	12%	25%
Hg	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	13%	-25%

Pollutant	NFR14 Code	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
Cd	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	25%	12%
Pb	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	14%	-42%
PCDD/PCDF	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	14%	53%
SO_x (as SO_2)	1A2gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	11%	-80%

The industrial combustion category covers both stationary plant and off-road vehicles and mobile machinery and these combustion processes burn a wide range of fuels in a wide range of combustion devices. In general, the trends since 1990 have been decreasing use of solid and liquid fossil fuels, fairly constant use of natural gas, and increasing use of waste-derived fuels, and biofuels such as biogas and biomass. The main fossil fuels used are coal (74% reduction in usage between 1990 and 2015), fuel oil (92% reduction), gas oil (48% reduction) and natural gas (1% reduction). The most important non-fossil fuels are wood & other solid biomass (4-fold increase in use between 1990 and 2015).

Figure 2-7 and Figure 2-8 show the emissions of a range of pollutants from the combined industrial combustion sectors between 1990 and 2015. The changes in fuel consumption by the sector are a major factor driving reductions in emissions of many pollutants. Coal and fuel oil contain significant levels of sulphur and metals and so their use can result in emissions of SO_2 and metals. Natural gas contains no metals and negligible quantities of sulphur and light oils such as kerosene and diesel contain relatively low levels of metals and sulphur, so the large reductions in the consumption of coal and fuel oil have resulted in big reductions in emissions of SO_2 and metals. Solid and liquid fuels also typically emit more NO_x or particulate matter (TPM, PM_{10}, $PM_{2.5}$) than a similar quantity of natural gas, so emissions of these pollutants have also fallen significantly. Emissions of CO and NMVOC have not reduced to the same extent and this reflects the fact that combustion of coal and fuel oil are not the major source of these two pollutants within the industrial combustion category. Instead, most of the CO emissions are from sinter plant at steelworks and from off-road vehicles & mobile machinery, with the latter source also being the main source of NMVOC. Emissions of CO from off-road vehicles and mobile machinery have changed little since 1990 while emissions from sinter plant have decreased by 46%. Emissions of CO from mobile machinery are dominated by small petrol units such as portable generators which are not subject to the emission regulations that apply to larger units. Emissions of NMVOC from off-road vehicles and mobile machinery have decreased by about 40% due to the penetration of units with diesel engines that comply with tighter regulation under the EU Non-Road Mobile Machinery (NRMM) emission Directive. Emission rates for CO & NMVOC have decreased over time in the case of larger plant burning gas oil and diesel oil, resulting in the decrease for NMVOC. Most of the CO though, is from small petrol driven units, and the emission rates for this type of unit have not changed. Since the consumption of petrol in these small units has increased between 1990 and 2015, there is an overall increase in CO emissions.

Figure 2-7 UK Emissions of CO, SO_x as SO_2, NO_x (as NO_2), NMVOC, TSP, PM_{10} and $PM_{2.5}$ from the Industrial Combustion Sectors (1990-2015)

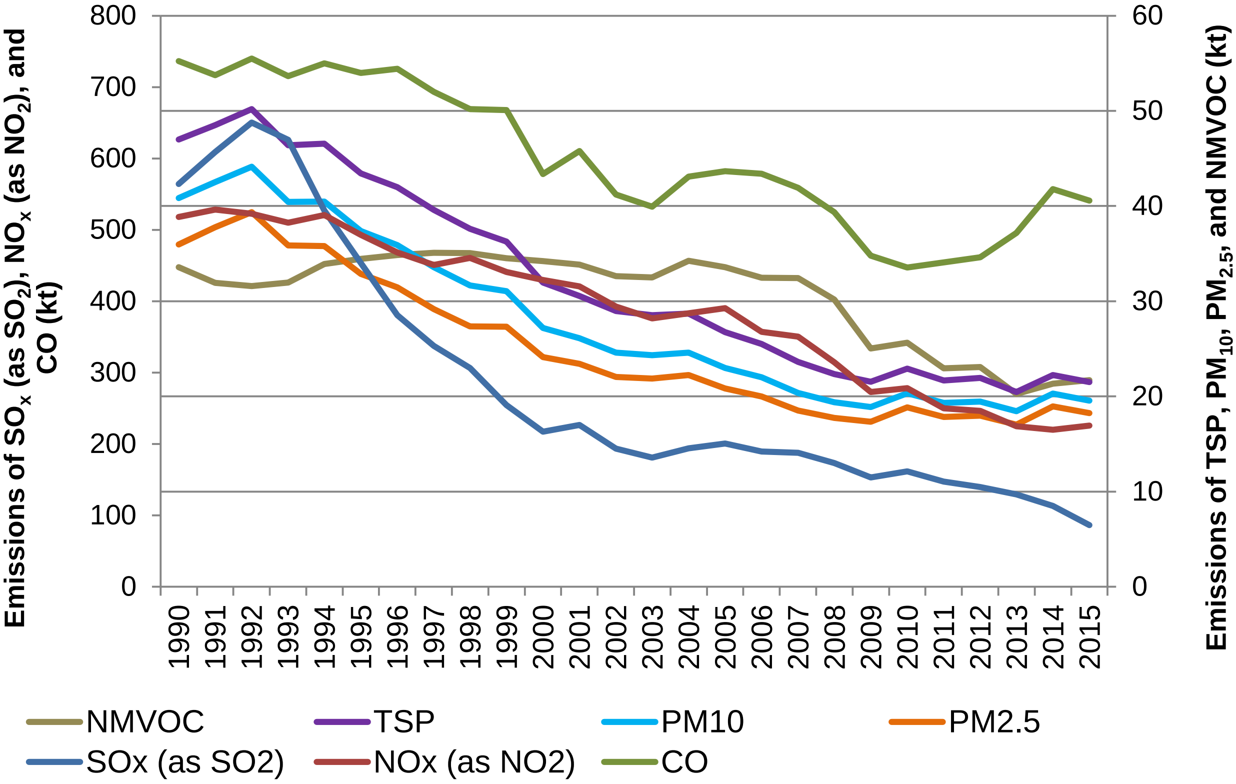
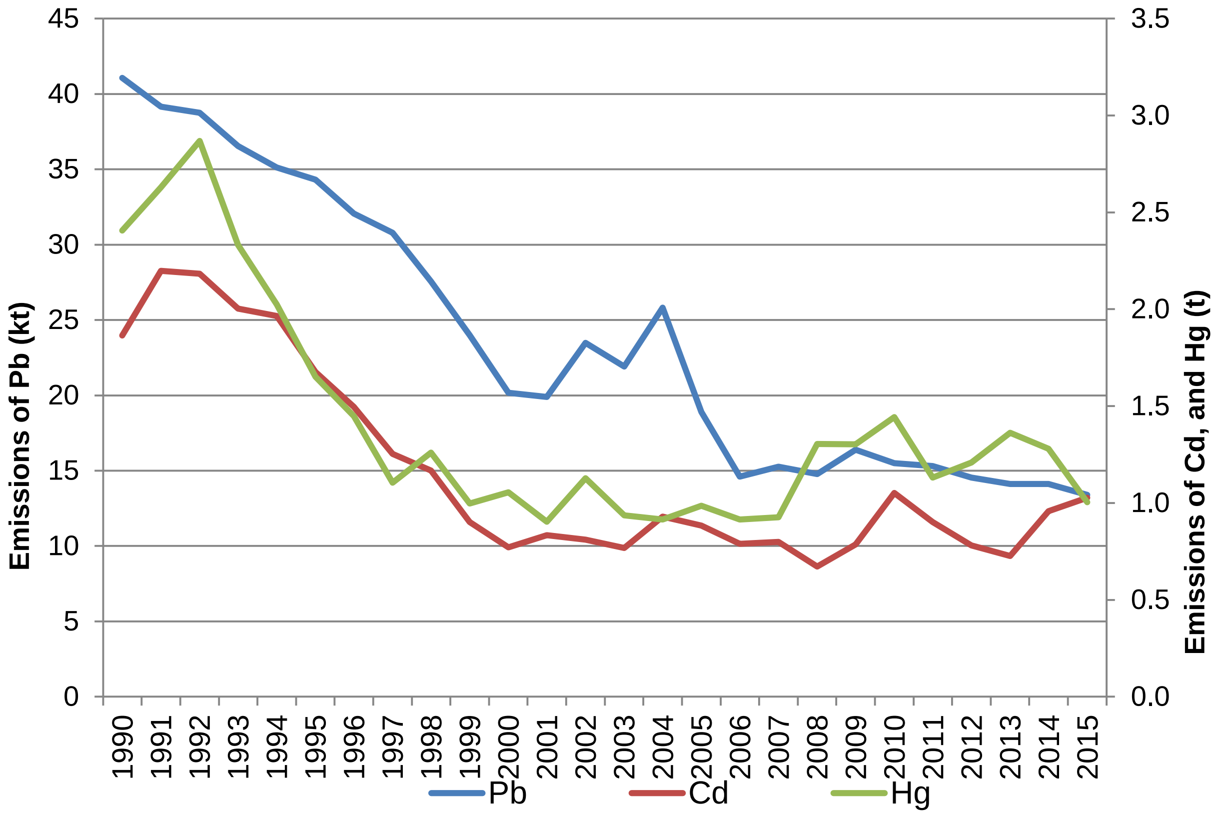


Figure 2-8 UK Emissions of Pb, Hg and Cd from the Industrial Combustion Sectors (1990-2015)



2.1.4 Residential, Public and Commercial Sectors

This category covers the use of fuels by the residential sector and by the public and commercial sectors. For most pollutants, emissions in this category are dominated by those from residential combustion, which was a key source for emissions of SO_x (as SO_2), NO_x (as NO_2), NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, Hg, Cd, Pb, and POPs (PCDD/PCDF and PAHs) emissions during 2015. However, there has been a substantial reduction in the magnitude of emissions for many of these pollutants between 1990 and 2015 (see Table 2-4). Emissions of other pollutants have either increased (for example PAHs) or remained fairly constant (for example, TSP, PM_{10}, and $PM_{2.5}$). These different trends reflect the different contributions that solid mineral and biomass fuels make to emissions of each pollutant, since trends in consumption are very different for those two fuel types. The use of coal and other solid mineral fuels as domestic fuels has decreased significantly since 1990, whereas the consumption of wood has increased significantly. Emissions of PAHs and particulate matter are particularly significant from wood combustion and so, for the residential sector as a whole, emissions of these pollutants have not reduced in the way that has happened for many other pollutants.

Table 2-4 Residential: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
CO	1A4bi	24%	-57%
NO_x (as NO_2)	1A4bi	4%	-62%
NMVOC	1A4bi	5%	-30%
TSP	1A4bi	23%	-2%
PM_{10}	1A4bi	31%	1%
$PM_{2.5}$	1A4bi	42%	0%
Hg	1A4bi	4%	-72%
Cd	1A4bi	28%	193%
Pb	1A4bi	7%	-75%
PCDD/PCDF	1A4bi	28%	-61%
SO_x (as SO_2)	1A4bi	15%	-67%
PAHs	1A4bi	87%	41%
CO	1A4bii	4%	-1%

Figure 2-9 and Figure 2-10 show the emissions of a range of pollutants from the combined residential, public and commercial sectors between 1990 and 2015. As for residential combustion alone, the emissions for some pollutants show substantial declines across the time series, whereas emissions of other pollutants have remained fairly constant or even increased. Note that both charts use two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions. The emissions in Figure 2-9 are presented in kilotonnes and those in Figure 2-10 are presented in tonnes.

Figure 2-9 UK Emissions of CO, SO_x as SO_2, NO_x (as NO_2), NMVOC, PM_{10} and $PM_{2.5}$ from the Residential, Public and Commercial Sectors (1990-2015)

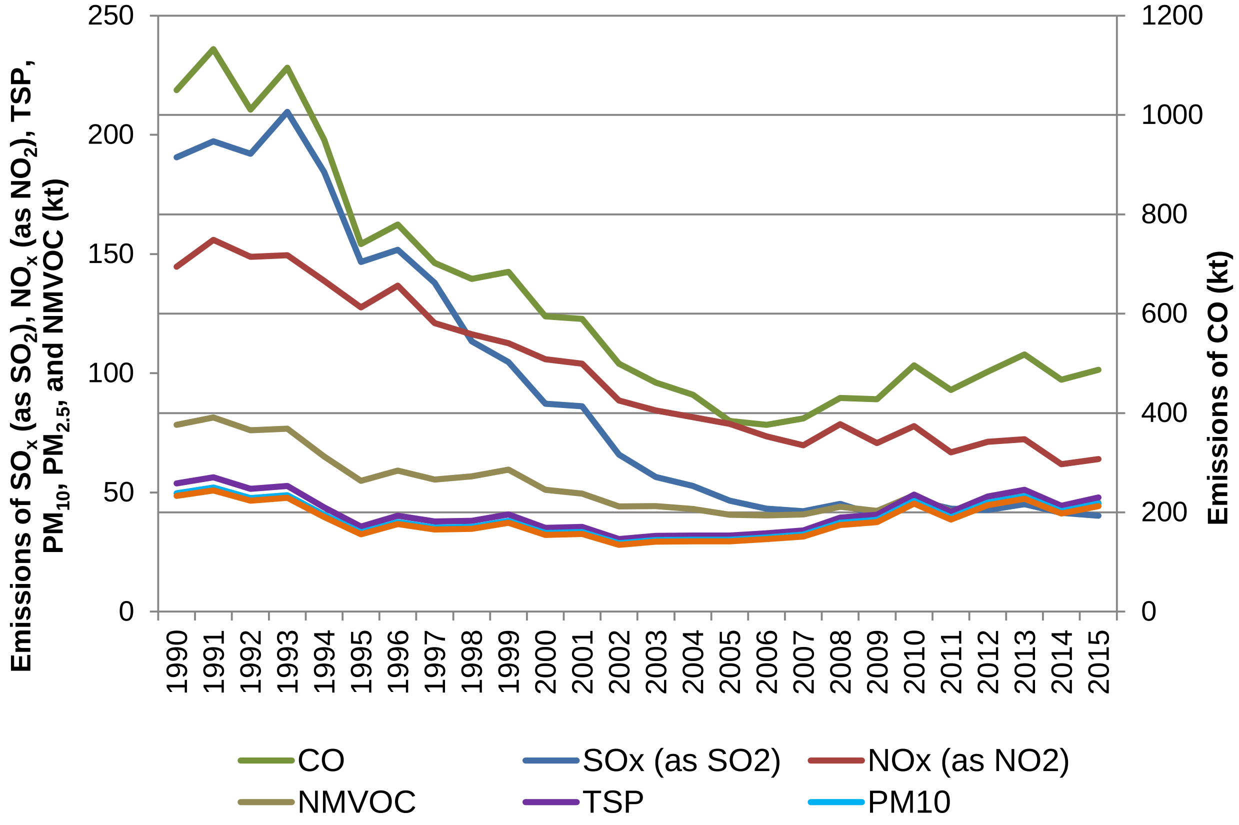
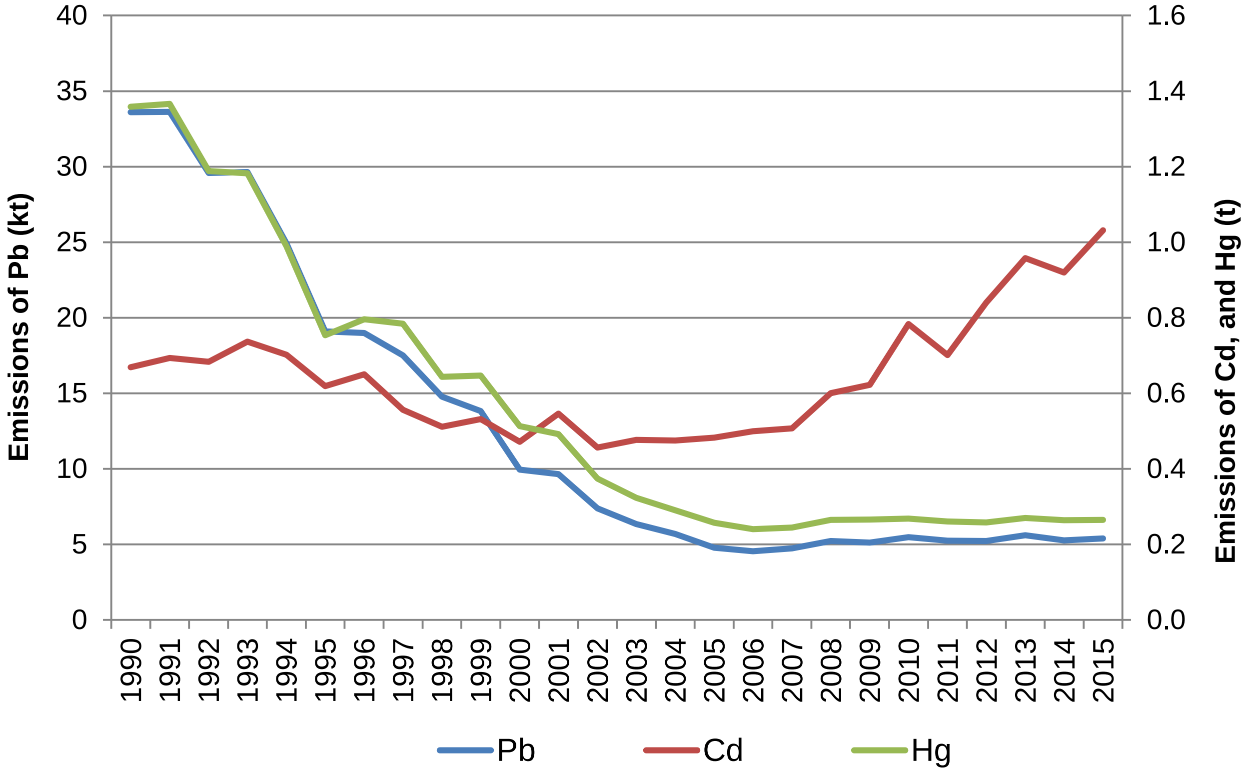


Figure 2-10 UK Emissions of Pb, Hg and Cd from the Residential, Public and Commercial Sectors (1990-2015)



There have been reductions in emissions of many pollutants from this sector, mainly because of a decline in the use of solid mineral fuels – residential, public, and commercial sector use of coal in 2015 was approximately 12% of the consumption in 1990. As previously mentioned, in the case of the residential sector the impact of declining use of solid mineral fuels has been moderated somewhat by increasing use of wood fuel. In the case of the commercial and public sectors, however, most energy requirements are now met by natural gas and electricity and so emissions of all pollutants have fallen. The combined emission figures for domestic, commercial and public sector combustion are, for most pollutants, dominated by the contribution from the residential sector and so Figures 2-7 and 2-8 largely reiterate the messages given in Table 2-3. Emissions of NO_x (as NO_2), SO_x (as SO_2), CO, NMVOC, Hg & Pb have fallen significantly, while emissions of other pollutants such as PM_{10}, and Cd have remained fairly constant or increased. The difference is that for the first group of pollutants, coal used as a domestic fuel emits significantly more per tonne burnt than wood used for the same purpose, whereas for the second group, the levels of emission from the two fuels are either similar or higher for wood.

2.1.5 Industrial Processes

Quarrying and construction (2A5a and 2A5b respectively) are key source categories for TSP and PM_{10}. Trends in emissions from both categories are downwards due to decreasing sectoral activity.

The food and drink industry (2H2) is a key source category for NMVOC emissions; comprising 12% of the total NMVOC emission in 2015 (see Table 2-5). The largest source is whisky maturation although animal feed manufacture, fat and oil processing, barley malting and bread baking are also important. The emission trends with time are primarily driven by production in these sectors, with significant growth in Scotch whisky production, and slower growth or decreasing production for many other foods and beverages.

The chemical industry (2B10a) is a key source category for mercury and lead. Mercury emissions are predominantly from manufacture of chlorine using mercury cell technology. The production is chlorine by this technology has decreased over time, and emissions have fallen as well. Emission reductions will also have been due to increasing emission controls, but because we only have emissions data for these processes, it is not possible to determine the separate impacts of changes in production and reductions in emission rates. Lead emissions arise mainly from the production of alkyl-lead fuel additives, but the banning of the use of these additives in most countries in recent decades has very significantly reduced demand for them, and emissions from their production have fallen.

Iron and steel production (2C1) and foundries (2C7c) are important sources of Cd, CO, PCDD/F, Hg, Pb, and PM. Emissions of all of the aforementioned pollutants have decreased between 1990 and 2015, most significantly so for foundries where the estimates are based on the assumptions that emissions were uncontrolled during the early part of the time series and that abatement now ensures much lower emission rates. Emissions from steelmaking have not fallen consistently over the period: instead there have been periods when emissions have increased from year to year. Emissions decreased throughout the 1990s, at least in part because of the closure of many production sites. Emissions of many pollutants then increased in the period 2002-2008; these increases coinciding with increases in steel production. Emissions then tended to decrease again in 2008-2011, due to a sharp fall in demand in steel which led to decreased production and the mothballing of one large works. Between 2011 and 2014, production of steel increased again as demand recovered, and emissions of many pollutants also increased. In 2015, the Teesside steelworks closed and steel production and emissions fell again. The trends are not identical for each pollutant, and even differ slightly for closely related pollutants such as TSP, PM_{10} and $PM_{2.5}$. Different emission sources within steelworks make different contributions to emissions of fine and coarse dust, and in recent years, for example, emissions from sintering and stockpiles have increased slightly more than emissions from other dust sources. Because emissions from these two sources are assumed to contain relatively high levels of coarse dust, this is the main reason why the upward trend in emissions is more pronounced for TSP than for PM_{10} or $PM_{2.5}$.

Emissions of mercury from steelmaking are 11% lower in 2015 than they were in 1990. This pollutant is emitted mainly from the manufacture of steel in electric arc furnaces and the emissions reported by some operators of these furnaces in recent years have been higher than levels reported in the 1990s. Emissions across the time-series fluctuate with frequent peaks and troughs. This may reflect a highly variable mercury content of the scrap metal melted in the furnaces, or perhaps instead indicate that the raw emissions data, taken from the PI and similar sources and used as the basis of the NAEI estimates are highly uncertain.

Industrial coatings and decorative paints (2D3d) and printing (2D3h) are key sources for NMVOC and PM, though consumption of coatings and inks have declined over time and this, combined with increasing control of NMVOC emissions from industrial coating & printing processes and regulation of solvent content of DIY paints, has led to a downward trend in emissions. NMVOC emissions from solvent use in consumer products such as aerosols, detergents and fragrances, on the other hand, are estimated to have increased slightly, in line with increasing population. Emissions from other solvent use (2D3i) have decreased mainly due to changes in the use of wood preservatives with abatement of emissions or use of alternative preservatives.

Lead emissions from wood processing (2I) are estimated on the basis of emissions reported by the operators to regulators. The emissions vary significantly from year to year, suggesting that either the waste wood burnt by these processes has a highly variable lead content, or that the quantities of waste wood burnt vary significantly from year to year. The source of the lead emission was not fully understood when this source was added to the inventory but is now known to be the combustion of recovered waste wood. Emissions would therefore be more accurately reported in 1A2, and they will be transferred in the next version of the inventory.

Figure 2-11 and Figure 2-12 show the emissions of a range of pollutants emitted from the iron and steel industry between 1990 and 2015. The emissions for all the pollutants show substantial declines across the time series. Note that both charts use two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions.

Table 2-5 Industrial Processes: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code and Name	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
TSP	2A5a Quarrying and mining of minerals other than coal	6%	-47%
PM_{10}	2A5a Quarrying and mining of minerals other than coal	4%	-47%
TSP	2A5b Construction and demolition	8%	-69%
PM_{10}	2A5b Construction and demolition	3%	-69%
Hg	2B10a Chemical industry: Other (please specify in the IIR)	6%	-96%
Pb	2B10a Chemical industry: Other (please specify in the IIR)	6%	-96%
CO	2C1 Iron and steel production	5%	-37%
TSP	2C1 Iron and steel production	5%	-2%
PM_{10}	2C1 Iron and steel production	4%	-14%
$PM_{2.5}$	2C1 Iron and steel production	3%	-28%
Hg	2C1 Iron and steel production	10%	-11%
Cd	2C1 Iron and steel production	18%	-56%
Pb	2C1 Iron and steel production	41%	-56%
PCDD/PCDF	2C1 Iron and steel production	12%	-61%
Hg	2C7c Other metal production (please specify in the IIR)	4%	-96%

Pollutant	**NFR14 Code and Name**	**% of total emissions for the given pollutant in 2015**	**% change in emissions between 1990 and 2015**
Pb	2C7c Other metal production (please specify in the IIR)	5%	-96%
NMVOC	2D3a Domestic solvent use including fungicides	18%	15%
NMVOC	2D3d Coating applications	13%	-64%
TSP	2D3d Coating applications	2%	-45%
PM_{10}	2D3d Coating applications	3%	-45%
$PM_{2.5}$	2D3d Coating applications	2%	-39%
NMVOC	2D3h Printing	2%	-68%
NMVOC	2D3i Other solvent use (please specify in the IIR)	6%	-29%
NMVOC	2H2 Food and beverages industry	12%	32%
Pb	2I Wood processing	5%	-26%

Figure 2-11 UK Emissions of CO, TSP, PM_{10} and $PM_{2.5}$ from Iron & Steel Production (1990-2015)

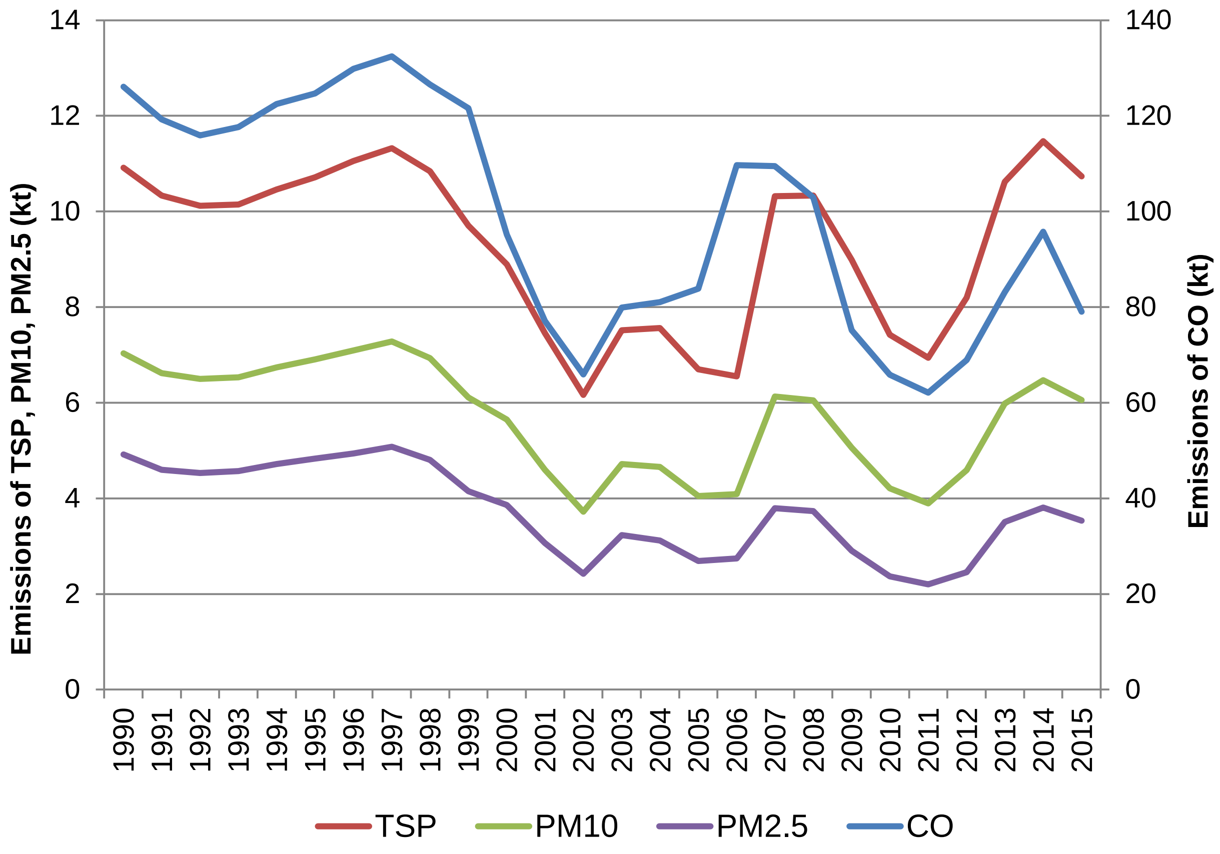
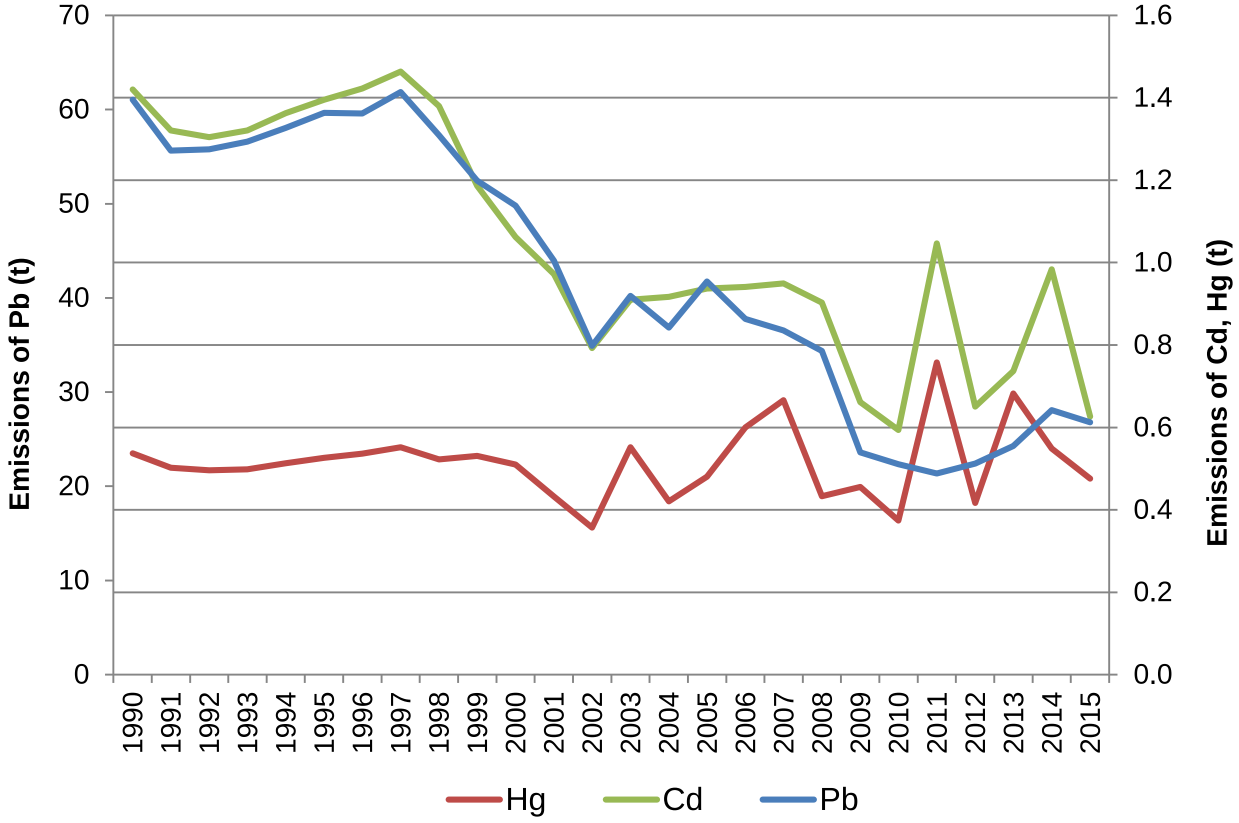


Figure 2-12 UK Emissions of Pb, Cd and Hg from Iron & Steel Production (1990-2015)



2.1.6 Transport

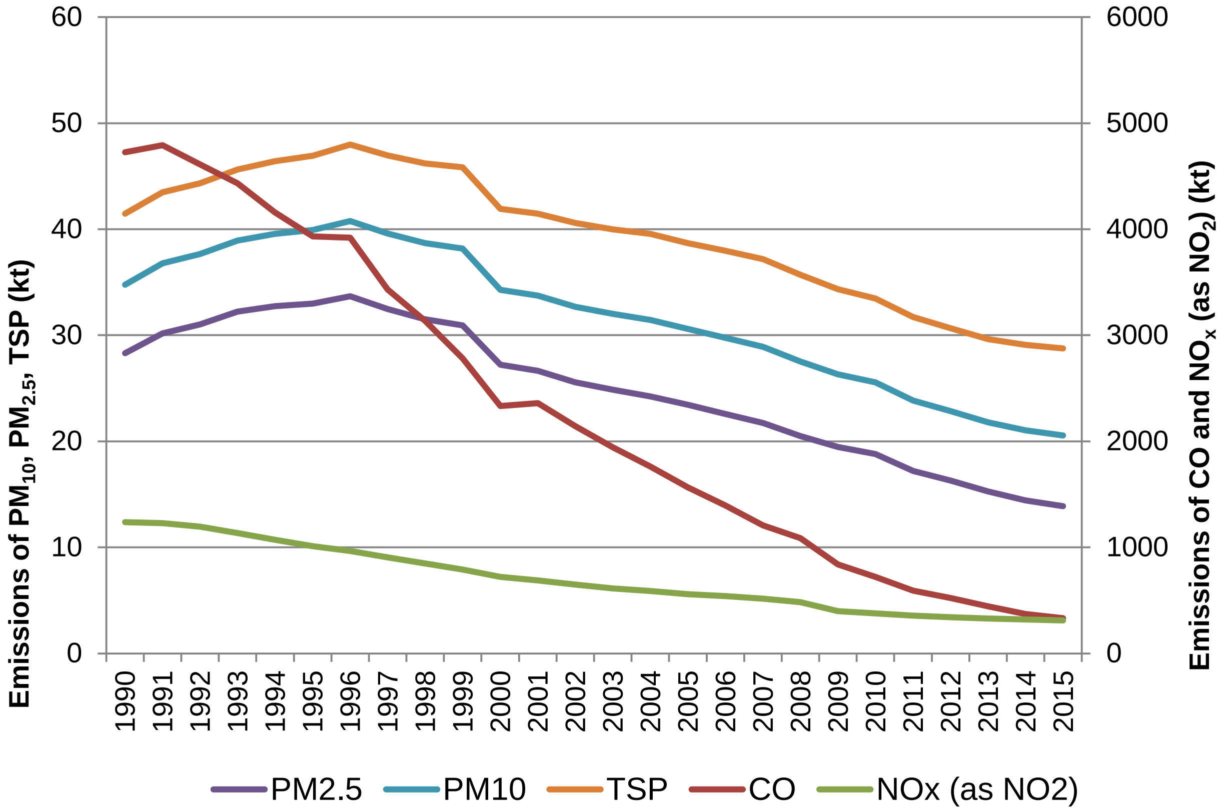
The transport sector is a key source of NO_x (as NO_2), CO, PM_{10}, $PM_{2.5}$, TSP, and Cd emissions in the UK; see Table 2-6.

Table 2-6 Transport: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
CO	1A3bi Road transport: Passenger cars	15%	-93%
NO_x (as NO_2)	1A3bi Road transport: Passenger cars	16%	-83%
PM_{10}	1A3bi Road transport: Passenger cars	2%	-44%
$PM_{2.5}$	1A3bi Road transport: Passenger cars	3%	-44%
Cd	1A3bi Road transport: Passenger cars	6%	-11%
NO_x (as NO_2)	1A3bii Road transport: Light duty vehicles	10%	-13%
$PM_{2.5}$	1A3bii Road transport: Light duty vehicles	2%	-66%
NO_x (as NO_2)	1A3biii Road transport: Heavy duty vehicles and buses	8%	-75%
TSP	1A3bvi Road transport: Automobile tyre and brake wear	6%	21%
PM_{10}	1A3bvi Road transport: Automobile tyre and brake wear	6%	20%
$PM_{2.5}$	1A3bvi Road transport: Automobile tyre and brake wear	5%	22%
TSP	1A3bvii Road transport: Automobile road abrasion	5%	21%
PM_{10}	1A3bvii Road transport: Automobile road abrasion	3%	21%
$PM_{2.5}$	1A3bvii Road transport: Automobile road abrasion	3%	21%
NO_x (as NO_2)	1A3c Railways	4%	59%
NO_x (as NO_2)	1A3dii National navigation (shipping)	4%	-12%
PM_{10}	1A3dii National navigation (shipping)	2%	-40%
$PM_{2.5}$	1A3dii National navigation (shipping)	2%	-40%

Figure 2-13 shows the emissions of a range of pollutants emitted from the road transport sector (1A3b) between 1990 and 2015. Note that this chart uses two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions.

Figure 2-13 Total UK Emissions of CO, NO_x (as NO_2), PM_{10} and $PM_{2.5}$ from Road Transport (1990-2015)



Road traffic activity has grown over the time-series but there has been a decline in emissions for a number of reasons. Since 1992, the requirement for new petrol cars to be fitted with three-way catalysts has reduced emissions of NO_x (as NO_2), CO, and NMVOC.

The further tightening up of emission standards on petrol cars and all types of new diesel vehicles over the last decade has also contributed to the reduction in NO_x (as NO_2) emissions. Recent evidence has shown however that Euro 4 and 5 and LGVs diesel cars exceed their type approval limit for NO_x (as NO_2) in real-world operation by significant amounts meaning that there has been little change in emission factors across the range of Euro standards for diesel cars and LGVs. This has been reflected in the emissions factors provided in the recent European COPERT 5 source of emission factors adopted for the inventory this year, with the factors for Euro 5 diesel LGVs showing significant increases compared with factors previously used in the inventory and with only modest reduction in NO_x factors occurring for new Euro 6 diesel cars entering the fleet for the first time in 2015. Fuel switching from petrol cars to diesel cars has reduced CO and NMVOC emissions and limited the reduction in NO_x emissions.

Diesel engine vehicles emit a greater mass of particulate matter per vehicle kilometre than petrol engine vehicle. However, since around 1992, however, emissions from diesel vehicles (on a per vehicle kilometre travelled basis) have been decreasing due to the penetration of new vehicles meeting tighter PM emission regulations ("Euro standards" for diesel vehicles were first introduced in 1992). This has more than offset the increase in diesel vehicle activity so that overall PM_{10} emissions from road transport have been falling. Emissions of PM from non-exhaust sources such as tyre and brake wear and road abrasion are not regulated and so have been increasing over the time series with growth in traffic and are now becoming a more important source of traffic-related PM emissions compared with exhaust emissions.

Further detailed information on Transport is provided in Chapter 3.3.

2.1.7 Agriculture

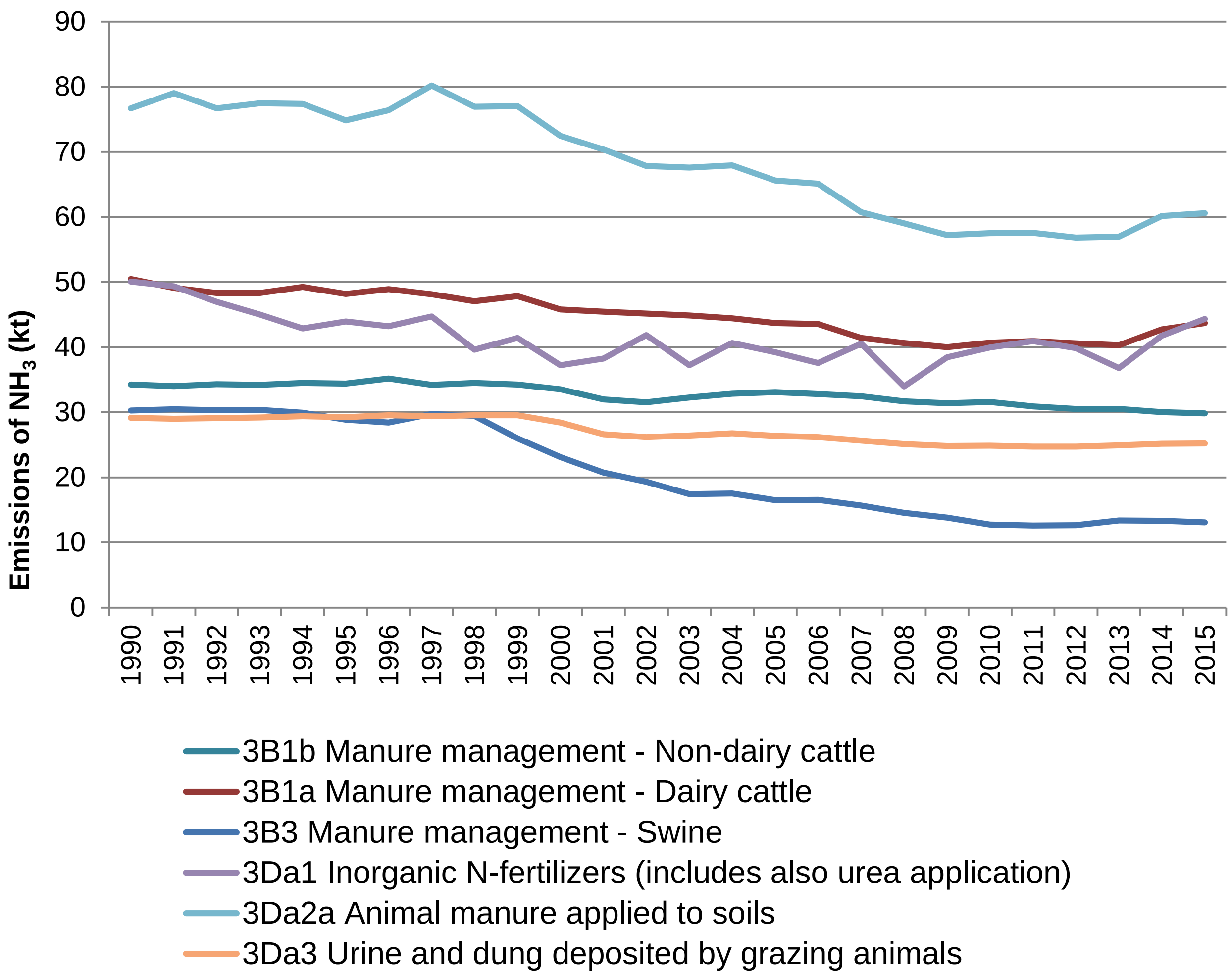
The agriculture sector is a key source of HCB, NH_3, NMVOC, PM_{10}, and TSP in the UK; see Table 2-7.

Table 2-7 Agriculture: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code and Name	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
NMVOC	3B1a Manure management - Dairy cattle	4%	-7%
TSP	3B1a Manure management - Dairy cattle	2%	-27%
PM_{10}	3B1a Manure management - Dairy cattle	1%	-27%
NH_3	3B1a Manure management - Dairy cattle	15%	-13%
NMVOC	3B1b Manure management - Non-dairy cattle	6%	-6%
TSP	3B1b Manure management - Non-dairy cattle	2%	-14%
NH_3	3B1b Manure management - Non-dairy cattle	10%	-13%
NH_3	3B3 Manure management - Swine	4%	-57%
TSP	3B4gi Manure management - Laying hens	5%	-4%
TSP	3B4gii Manure management - Broilers	2%	45%
PM_{10}	3B4gii Manure management - Broilers	1%	45%
NH_3	3Da1 Inorganic N-fertilizers (includes also urea application)	15%	-12%
NH_3	3Da2a Animal manure applied to soils	21%	-21%
NH_3	3Da3 Urine and dung deposited by grazing animals	9%	-13%
TSP	3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	4%	-13%
PM_{10}	3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products	3%	-13%
HCB	3Df Use of pesticides	33%	-92%

Figure 2-14 shows the emissions of NH_3 emitted from the key source categories in the agriculture sector between 1990 and 2015.

Figure 2-14 UK Emissions of NH_3 from Key Sources in Agriculture (1990-2015)



Agricultural sources with emissions from livestock and their wastes (NFR14 3B) are the major source of NH_3 emissions, contributing 37% of total emissions in 2015. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. Emissions of NH_3 from agricultural livestock were relatively steady prior to 1999. After that, emissions have decreased with time until 2014, when emissions increased relative to 2013. These trends are driven predominantly by the trends in animal numbers. In addition, there has been a decline in fertiliser use (NFR14 3Da1), which also caused a decrease in emissions although emissions have increased from 2013 to 2015 due to increased usage of urea-based fertilisers which are associated with much higher ammonia emission factors. Total NH_3 emissions from agriculture in 2015 represent a decrease of 19% on the 1990 emissions.

Dairy (3B1a) and non-dairy cattle (3B1b) are key sources for NH_3 and NMVOC. Estimates of PM_{10}, $PM_{2.5}$ and TSP emissions from agricultural livestock have been calculated in the current inventory using default emission factors, published in the 2016 update of the EMEP/EEA Emission Inventory Guidebook. PM and TSP emissions from broilers (3B4gii) have increased in line with an increase in broiler numbers between 1990 and 2015 (Misselbrook et al, 2016).

2.1.8 Waste

Emissions from the waste sector have a negligible effect on overall UK emissions for most pollutants. Waste is, however, a key source for Hg and PCDD/PCDF; see Table 2-8.

Table 2-8 Waste: Sector share of UK emissions total in 2015 and Trends from 1990 to 2015

Pollutant	NFR14 Code and Name	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
Hg	5A Biological treatment of waste - Solid waste disposal on land	7%	-43%
Hg	5C1bv Cremation	13%	18%
PCDD/PCDF	5C2 Open burning of waste	7%	-78%

Emissions from cremations (5C1bv) are a key source for Hg. The number of cremations has increased by 5% from 1990 to 2015. The Hg emission factor changes from year to year, reflecting changes in dental health over the years. People were slightly more likely to still have their own teeth (complete with any mercury fillings) at the time of death in 2015 than was the case in 1990 and so the mercury emission factor was therefore 12% higher in 2015 relative to 1990.

Emissions from solid waste disposal on land (5A) are a key source for Hg. The emissions trend shown in Table 2-8 is influenced by the fact that there has, since 1990, been a reduction in the mercury content of devices such as batteries and electrical equipment that are disposed of at landfill.

Emissions from open burning of waste (5C2) are a key source for PCDD/PCDF. The emissions trend shown in Table 2-8 is mainly influenced by the fact that there has been an increase in recycling activities meaning less burning of the industrial wastes which would give rise to PCDD/PCDF emissions.

2.2 Summary of Trends

A summary table of all the key sources and their contributions to overall pollutant emissions is provided in Table 2-9 below along with the tier methodology used.

Table 2-9 Key Sources: 2015 Significance and Trends, 1990-2015

Pollutant	NFR14 Code	Tier methodology[a]	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
Cd	1A4bi	2	28%	193%
	1A2gviii	1	25%	12%
	2C1	3	18%	-56%
	1A3bi	3	6%	-11%
	1A1a	3	4%	-97%
CO	1A4bi	2	24%	-57%
	1A3bi	3	15%	-93%
	1A2gvii	3	13%	7%
	1A2a	1	11%	-47%
	2C1	3	5%	-37%
	1A2gviii	1	5%	17%
	1A4bii	3	4%	-1%
	1A1a	3	4%	-47%
PCDD/PCDF	1A4bi	2	28%	-61%
	1A2gviii	1	14%	53%
	2C1	3	12%	-61%
	6A	2	11%	-65%
	1A4ci	1	9%	192%
	5C2	2	7%	-78%
HCB	1A1a	1	64%	1149%
	3Df	2	33%	-92%
Hg	1A1a	3	25%	-87%
	1A2gviii	1	13%	-25%
	5C1bv	3	13%	18%
	2C1	3	10%	-11%
	5A	3	7%	-43%
	2B10a	3	6%	-96%
	2C7c	3	4%	-96%
	1A4bi	2	4%	-72%

Pollutant	NFR14 Code	Tier methodology[a]	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
NH_3	3Da2a	3	21%	-21%
	3Da1	3	15%	-12%
	3B1a	3	15%	-13%
	3B1b	3	10%	-13%
	3Da3	2	9%	-13%
	6A[b]	2 and 3	6%	43%
	3B3	3	4%	-57%
NO_x (as NO_2)	1A1a	3	20%	-76%
	1A3bi	3	16%	-83%
	1A3bii	3	10%	-13%
	1A3biii	3	8%	-75%
	1A2gviii	1	7%	-39%
	1A1c	3	6%	31%
	1A3dii	3	4%	-12%
	1A3c	2	4%	59%
	1A4bi	2	4%	-62%
	1A2gvii	3	4%	-70%
PAHs	1A4bi	2	87%	41%
Pb	2C1	3	41%	-56%
	1A2gviii	1	14%	-42%
	1A4bi	2	7%	-75%
	2B10a	3	6%	-96%
	1A1a	3	5%	-98%
	2I	3	5%	-26%
	2C7c	3	5%	-96%
PM_{10}	1A4bi	2	31%	1%
	1A2gviii	1	9%	24%
	1A3bvi	2	6%	20%
	2C1	3	4%	-14%
	2A5a	2	4%	-47%
	1A3bvii	2	3%	21%
	2A5b	1	3%	-69%
	1A1a	3	3%	-93%

Pollutant	**NFR14 Code**	**Tier methodology[a]**	**% of total emissions for the given pollutant in 2015**	**% change in emissions between 1990 and 2015**
	3Dc	2	3%	-13%
	2D3d	2	3%	-45%
	1A3bi	3	2%	-44%
	1A2gvii	3	2%	-74%
	1A3dii	3	2%	-40%
	6A	1, 2 and 3	1%	-34%
	3B4gii	2	1%	45%
	3B1a	2	1%	-27%
$PM_{2.5}$	1A4bi	2	42%	0%
	1A2gviii	1	12%	25%
	1A3bvi	2	5%	22%
	2C1	2	3%	-28%
	1A3bi	3	3%	-44%
	1A1a	2	3%	-91%
	1A2gvii	3	3%	-74%
	1A3bvii	2	3%	21%
	1A3dii	3	2%	-40%
	6A	1, 2 and 3	2%	-35%
	2D3d	2	2%	-39%
	1A3bii	3	2%	-66%
SO_x (as SO_2)	1A1a	3	38%	-97%
	1A4bi	2	15%	-67%
	1A1b	3	13%	-77%
	1A2gviii	1	11%	-80%
	1A2a	1	5%	-58%
TSP	1A4bi	2	23%	-2%
	2A5b	1	8%	-69%
	1A2gviii	1	7%	25%
	1A3bvi	2	6%	21%
	2A5a	2	6%	-47%
	2C1	2	5%	-2%
	1A3bvii	2	5%	21%
	3B4gi	2	5%	-4%

Pollutant	NFR14 Code	Tier methodology[a]	% of total emissions for the given pollutant in 2015	% change in emissions between 1990 and 2015
	3Dc	2	4%	-13%
	1A1a	2	3%	-94%
	3B1a	2	2%	-27%
	2D3d	2	2%	-45%
	3B4gii	2	2%	45%
	1A2gvii	3	2%	-74%
	3B1b	2	2%	-14%
NMVOCs	2D3a	2	18%	15%
	2D3d	2 and 3	13%	-64%
	2H2	1 and 2	12%	32%
	2D3i	Country Specific and 3	6%	-29%
	3B1b	2	6%	-6%
	1A4bi	2	5%	-30%
	1B2ai	2 and 3	4%	-86%
	3B1a	2	4%	-7%
	1B2c	2 and 3	4%	-33%
	1B2b	2 and 3	3%	-41%
	1B2av	2	3%	-81%
	1B2aiv	2	2%	-80%
	2D3h	2 and 3	2%	-68%

[a] Many of the estimates at the NRF14 code level are aggregates of emission estimates at a more detailed level and a variety of tiers may be used at this more detailed level. The tiers given in this table are indicative only and refer to the tier or tiers used for the larger part of the emission estimate for that NFR14 code.

[b] NH_3 emissions under NFR14 6A include emission from horses not used in the agriculture sector (e.g. horses used by the military, police and other professions, and horses kept as pet

3 NFR14 1: Energy

3.1 NFR14 1A1: Combustion in the Energy Industries

Table 3-1 Mapping of NFR14 Source Categories to NAEI Source Categories: Combustion in the Energy Industries

NFR14 Category (1A1)	Pollutant coverage	NAEI Source category
1 A 1 a Public Electricity and Heat Production	All CLRTAP pollutants	Power stations
		Public sector combustion (sewage gas)
		Miscellaneous industrial/commercial combustion (landfill gas, MSW only)[21]
1 A 1 b Petroleum refining	All CLRTAP pollutants *(except NH_3, HCB and PCBs)*	Refineries – fuel combustion
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	All CLRTAP pollutants *(except HCB)*	Coke production
		Collieries – fuel combustion
		Gas production (downstream gas)[22]
		Gas separation plant
		Upstream gas production
		Nuclear fuel production
		Upstream oil production
		Solid smokeless fuel production
		Town gas manufacture

Table 3-2 Summary of Emission Estimation Methods for NAEI Source Categories in NFR14 Category 1A1

NAEI Source Category	Method	Activity Data	Emission Factors
Power stations	UK model	BEIS energy statistics, EU ETS, operators	Major fuels: Operator-reported emissions data under IED/E-PRTR. Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research)
Miscellaneous industrial/commercial combustion	AD x EF	BEIS energy statistics, EU ETS	MSW: Operator-reported emissions data under IED/E-PRTR. LFG: default factors (USEPA, EMEP-EEA, UK-specific research)
Public sector combustion	AD x EF	BEIS energy statistics	Sewage gas: default factors (USEPA, EMEP-EEA, UK-specific research)
Refineries	AD x EF	BEIS energy statistics, EU ETS	Operator-reported emissions data under IED/E-PRTR, UKPIA; default factors

[21] Emissions from public sector and miscellaneous / commercial sources are only reported in 1A1a where MSW, sewage gas & landfill gas are burned to produce heat or electricity.
[22] Activity and emissions reported in the UK inventory for the downstream gas sector includes the gas use at compressors operating the UK gas distribution network. Data are not available specific to the pipeline gas compressors; only aggregate downstream gas industry data are available. Hence all emissions are reported within the 1A1c NFR14 category, rather than any emissions allocated to 1A3e Pipeline Compressors.

NAEI Source Category	Method	Activity Data	Emission Factors
			(USEPA, EMEP-EEA, UK-specific research)
Coke production	UK model	BEIS energy statistics, EU ETS, ISSB	Major fuels: Operator-reported emissions data under IED/E-PRTR, Tata Steel, SSI Steel Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research)
Collieries – fuel combustion	AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, UK-specific research)
Gas production (downstream gas)	AD x EF	BEIS energy statistics, EU ETS	Default factors (USEPA, EMEP-EEA, UK-specific research)
Gas separation plant	AD x EF	BEIS energy statistics, EEMS, EU ETS	EEMS and IED/E-PRTR annual reporting by operators, UKOOA research, EMEP-EEA
Upstream gas production	AD x EF	BEIS energy statistics, EEMS, EU ETS	EEMS and IED/E-PRTR annual reporting by operators, UKOOA / other UK-specific research, USEPA PM_{10} factor
Nuclear fuel production	AD x EF	BEIS energy statistics	Default factors (USEPA, UK-specific research)
Upstream oil production	AD x EF	BEIS energy statistics, EEMS, EU ETS	EEMS and IED/E-PRTR annual reporting by operators, UKOOA / other UK-specific research, USEPA PM_{10} factor
Solid smokeless fuel production	AD x EF	BEIS energy statistics, EU ETS	Default factors (USEPA, UK-specific research e.g. HMIP)
Town gas manufacture	AD x EF	BEIS energy statistics	Default factors (USEPA, UK-specific research)

3.1.1 Classification of activities and sources

The NAEI utilises official UK energy statistics published annually in the Digest of UK Energy Statistics (BEIS, 2016), hereafter abbreviated to DUKES. The source categories and fuel types used in the NAEI therefore reflect those used in DUKES.

Table 3-1 relates the detailed NAEI source categories to the equivalent NFR14 source categories. In most cases, it is possible to obtain a precise mapping of an NAEI source category to a NFR14 source category; however, there are some instances where the scope of NAEI and NFR14 categories is different to a significant degree. Instances of this are discussed below. The NAEI source categories are the level at which emission estimates are derived, but reporting would not normally be at this detailed level, the NFR14 system being used instead for submission under the CLRTAP.

Table 3-3 lists the fuels used in the inventory. In two instances, fuels listed in DUKES are combined in the NAEI: propane and butane are combined as ‘liquefied petroleum gas’ (LPG), and ethane and ‘other petroleum gases’ are combined as the NAEI fuel ‘other petroleum gases’ (OPG).

Table 3-3 Fuel types used in the NAEI

Fuel type	Fuel name	Comments
Crude-oil based fuels	Aviation Spirit	
	Aviation Turbine Fuel (ATF)	Includes fuel that is correctly termed jet gasoline. Also known as kerosene
	Burning Oil	
	Fuel Oil	
	Gas Oil/ DERV	
	Liquefied Petroleum Gas (LPG)	DUKES uses the terms “propane” and “butane”
	Naphtha	
	Orimulsion®	An emulsion of bitumen in water
	Other Petroleum Gas (OPG)	DUKES uses the terms “ethane” and “other petroleum gases”
	Petrol	
	Petroleum Coke	Covers ‘green’ coke used as a fuel and catalyst coke.
	Refinery Miscellaneous	
	Vaporising oil	Not used as a fuel since 1978
Coal-based fuels	Anthracite	
	Coal	
	Slurry	Coal-water slurry. Not included separately in DUKES.
	Coke	Coke oven coke, includes coke breeze
	Solid Smokeless Fuel (SSF)	
	Coke Oven Gas	
	Blast Furnace Gas	Includes basic oxygen furnace gas
Gas	Natural Gas	
	Sour Gas	Unrefined gas used by offshore installations and one power station. Not included separately in DUKES.
	Colliery Methane	
	Town Gas	Not used as a fuel since 1988
Biomass	Wood	
	Straw	
	Poultry Litter	Includes meat & bone meal.
	Landfill Gas	
	Sewage Gas	
	Liquid bio-fuels	Liquid bio-fuels used at power stations
	Biogas	Methane generated via anaerobic digestion other than from landfill or sewage plants.
	Biomass	Solid biomass other than wood, used as a fuel by industry
Wastes	Municipal Solid Waste	
	Scrap Tyres	Not identified separately in DUKES.
	Waste Oil/ Lubricants	Not identified separately in DUKES.
	Waste Solvents	

Almost all of the NFR14 source categories listed in Table 3-1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR14 sector.

3.1.2 General approach for 1A1

The methodology for NFR14 1A1 is based mainly on the use of emissions data reported by process operators to regulators. These data are contained within the Pollution Inventory (PI), covering England, the Welsh Emissions Inventory (WEI), the Scottish Pollutant Release Inventory (SPRI), Northern Ireland’s Pollution Inventory (NIPI), and the Environmental Emissions Monitoring System (EEMS)[23] for upstream oil and gas installations situated offshore.
The PI data are available from www.environment-agency.gov.uk,

[23] www.gov.uk/oil-and-gas-eems-database

SPRI data can be viewed at
http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx,

The NIPI is not available online but is supplied directly to the UK inventory agency by the Northern Ireland Environment Agency (NIEA). The EEMS dataset is supplied to the UK inventory agency by the Department of Business, Energy & Industrial Strategy Offshore Inspectorate, which is the regulatory authority for upstream oil and gas installations.

The emissions reported in the PI, WEI, SPRI and NIPI are available as total emissions of each relevant pollutant for each regulated process, rather than being split down by source type or fuel used. For example, emissions data for an integrated steelworks are given as a single figure, rather than separate data for coke ovens, sinter plant, boilers, furnaces etc. In addition, emissions from use of coke oven gas as a fuel, for example, are not separated from emissions from use of fuel oil as a fuel. The EEMS dataset does provide some breakdown of emissions by source for the upstream oil and gas sector, as separate emission estimates by pollutant, by installation are provided for sources including: fuel combustion, flaring, venting, process emissions, fugitive releases and oil loading / unloading activities.

To derive UK source emission estimates based on the use of these regulatory pollution inventories, it is therefore sometimes necessary to split the reported emissions data by fuel and/or sub-source. Where emissions from high-emitting industries are reported across several NFR14 categories (such as the steelworks example mentioned above, or for refineries) the UK inventory agency has developed reporting templates that plant operators or trade association contacts complete, through consultation, in order to provide a more accurate breakdown of emissions by source. For less significant source sectors, the estimated split of emissions by sub-source is derived based either on periodic consultation with regulatory and industry contacts, or through expert judgement of the Ricardo Energy & Environment inventory team.

Fuel use data are primarily obtained from DUKES, with some deviations where alternative data are believed to be more reliable. In recent years, energy data for energy-intensive industry sectors from the EU Emissions Trading System (EU ETS) are used to revise energy data for some industry sectors such as power stations. The EU ETS data are provided by process operators and verified by accredited verifiers. The data set covers all UK plant within certain sectors: all refineries, major power producers, steelworks, and cement & lime kilns are included, for example. EU ETS-based energy data are therefore considered to be very reliable. There are very few instances where these alternative data sources for energy indicate a difference to the overall UK energy balance presented in DUKES; in most of these cases, because the EU ETS data are believed to be accurate the differences are therefore assumed to be due to a sector mis-allocation in the energy balance. Hence where there is a deviation from the DUKES data for one sector, an equal and opposite amendment to the energy allocation of another source is made (usually for “unclassified industry” in 1A2g) in order to retain overall consistency with the demand totals in the UK energy balance for that fuel. Further information on these modifications to energy data are given in the next section.

Emissions of some pollutants are estimated using literature emission factors and activity data from DUKES, rather than PI/WEI/SPRI/NIPI/EEMS data. This is particularly true of pollutants such as NMVOC, benzene, 1,3-butadiene, metals and POPs, where the level of emissions reporting in the regulators’ datasets is much lower than is the case for NO_x (as NO_2), for example. Many operators do not have to provide emissions data for these pollutants because these emissions are below minimum thresholds for reporting. Therefore, there are far fewer operator-reported data available for use in deriving country-specific emission factors; any such factors derived from a small dataset may not be representative and therefore literature factors are used in the UK inventories for these pollutants. The sectors and pollutants where literature factors are used due to limited operator-reported emissions data are typically minor contributors to UK emission totals.

The following sections give more details of the methodology. Detailed emission factors are available at http://naei.defra.gov.uk/data_warehouse.php.

3.1.3 Fuel consumption data

Fuel consumption data used in the UK inventories are primarily taken directly from DUKES, but there are a small number of instances where alternative energy use estimates are used in preference, and hence where the NAEI energy data deviate from those presented in DUKES[24]. This is done for two reasons:

- For some emission sources, DUKES data are not considered as accurate as energy data available from alternative sources such as the EU ETS;
- In some cases, DUKES does not present energy data at a sufficiently detailed level to enable inventory reporting for specific source categories. For example, DUKES does not provide any split of gas oil use in industry between mobile and stationary sources, where very different technologies are utilised and hence very different emission factors are applicable.

The most important of these deviations are as follows:

- DUKES data for the quantity of fuel oil consumed by power stations is much lower than the quantity reported by process operators to the NAEI team and more recently, quantities reported under the EU Emissions Trading System (EU ETS). In part, this is due to the use of recovered waste oils, which is reported as ‘fuel oil’ in the EU ETS data, but even when this is taken into account, the DUKES figures are still considered too low. The operators’ data are used in the NAEI and split into consumption of ‘waste oil’ and ‘fuel oil’. This split is determined by the independent estimates that are made for use of waste oils as a power station fuel (see below). Overall consistency between NAEI and DUKES for fuel oil is maintained by reducing the NAEI estimate for fuel oil consumed by the industrial sector compared with the figure in DUKES.

- Similarly, DUKES data for consumption of gas oil in power stations is also lower than data for recent years taken from EU ETS. As with fuel oil, a re-allocation of gas oil is made so that the NAEI is consistent with the EU ETS data for power stations, but also consistent with overall demand for gas oil, given in DUKES. The EU ETS data also shows that small quantities of burning oil are used at power stations, but DUKES does not include any data. The NAEI includes a similar re-allocation to that used for fuel oil and gas oil.

- DUKES does not include a full time series of consumption of petroleum coke as a fuel. Data are provided for:
  - the burning of catalyst coke at refineries in all years;
  - petroleum coke burnt at power stations for 2007 onwards;

  UK inventory activity data includes estimates of petroleum coke burnt by power stations (based on data from industry sources and the EU ETS) which differ slightly from the data given in DUKES. Furthermore, activity data for refinery use of petroleum coke for 2005-2010, 2013 and 2015 that are based on EU ETS data, rather than DUKES, because the ETS figures exceed those given in DUKES, and are regarded as more reliable. In the case of petroleum coke, it is not always possible to reconcile the NAEI estimates of total UK demand for petroleum coke with the data given in DUKES, because the NAEI values for all sectors are based on more detailed data sources than DUKES. The NAEI figure for total use of petroleum coke (including non-energy uses) is, as a result, higher than the DUKES demand figures for 1990-1991, 1999, 2001, 2005-2007 and 2015.

- Since 2002, DUKES has not included any energy use of gases derived from natural gas liquids (LPG and OPG) that are burned in plant associated with gas separation processes at oil terminals, as these data are no longer routinely provided to BEIS by oil companies. Through the EU ETS and EEMS, however, the use of OPG (mainly ethane) as a fuel at these sites is reported to the environmental regulatory agencies. The EU ETS provides data for this source-activity from 2005 onwards, whereas the EEMS dataset provides data from 1998 until some of the

[24] Detailed fuel reconciliation tables and explanations for deviations from UK energy statistics in compiling the UK emission inventories are presented in Annex 4 of the UK’s National Inventory Report for submission of GHG emission estimates to the UNFCCC. The activity data that underpin GHG and AQ emission estimates are identical as the UK inventories are compiled and reported via a common database, within the National Atmospheric Emissions Inventory programme.

terminals ceased reporting to EEMS (in 2010). The EEMS data are used therefore to estimate the OPG use in these terminals from 2003 onwards, with EU ETS data used to ensure completeness from 2010 onwards.

- The activity data for gas use in the upstream oil and gas sector is under-reported in DUKES prior to 2001. From 2001 onwards, a new reporting system, ‘Petroleum Production Reporting System’ (PPRS), was used to compile the DUKES data on gas use from upstream exploration and production. The long-term trends Table 4.2 in DUKES shows that “own gas use” by the industry increased by 20% between 2000 and 2001, but this step change is not a real reflection of increased activity but rather in the gap in DUKES gas statistics prior to PPRS, which is mainly due to non-reporting of gas use by gas terminals. The EEMS data provides activity data and emissions from own gas use at oil and gas terminals from 1998 onwards, and the trade association, UK Oil and Gas, has provided estimates for industry-wide activity and emissions for earlier years. These EEMS and UK Oil and Gas activity data are used in preference to the DUKES data for up to 2001, impacting on emission estimates in 1A1c.

- DUKES data for refinery use of OPG is significantly lower than that reported within the EU ETS. Analysis of the total reported emissions data from EU ETS (from 2005 onwards) from the activity data reported in DUKES and from the installation operators directly to the UK Petroleum Industries Association indicates that the gap in UK energy balance data is evident from 2004 onwards. Therefore, in deriving estimates for the UK inventories, the OPG activity is aligned with the data presented by the trade association (UKPIA) for 2004 and EU ETS from 2005 onwards.

- In the UK energy commodity balance tables presented in DUKES 2014, the DECC energy statistics team revised the energy / non-energy allocation for several petroleum-based fuels: propane, butane, naphtha, gas oil, petroleum coke. These revisions were based on re-analysis of the available data reported by fuel suppliers and HMRC, but the revisions to DUKES were only applied from 2008 onwards. Therefore, in order to ensure a consistent time series of activity data and emissions in the UK inventories, the Ricardo Energy & Environment team has derived (in consultation with the DECC energy statistics team) a revised time series for these commodities back to 1990, i.e. deviating from the published DUKES fuel activity totals for 1990-2007.

3.1.4 Methodology for power stations (NFR14 1A1a)

NFR14 Sector 1A1a is a key source for NO_x (as NO_2), SO_x (as SO_2), CO, TSP, PM_{10}, $PM_{2.5}$, Cd, Pb, Hg and HCB.

The electricity generation sector is characterised by a relatively small number of industrial sites. The main fossil fuels used are bituminous coal and natural gas. Approximately 29 Mt of coal were burnt at 13 power stations during 2015, while approximately 6,300 Mtherms of natural gas were consumed at 41 large power stations and 7 small (<50MWth) regional stations (almost all gas plants are Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at one large facility, and gas oil or burning oil was used as the primary fuel by four large and nine small power stations; in most cases of gas oil and burning oil use, it is used primarily as a start-up or support fuel, for coal-fired or gas-fired power stations.

One of the gas-fired power stations has on occasions burnt small quantities of sour gas as well as natural gas, larger quantities being burnt in the 1990s. Several UK coal-fired power stations have trialled use of petroleum coke in the past, and it continues to be used as a partial substitute for coal at a number of sites. In the past, UK power stations have also burnt scrap tyres, Orimulsion, and coal slurry, but none of these fuels has been used in the UK in recent years.

Biofuels are burnt at an increasing number of power generation sites to help electricity generators meet Government targets for renewable energy production. Four established sites use poultry litter as the main fuel, two burn straw, and another eight burn wood or other biomass. Many coal-fired power stations have increased the use of biofuels such as short-rotation coppice and biomass-based liquid fuels to supplement the use of fossil fuels.

Electricity and/or heat is also generated at 36 Energy from Waste (EfW) plants in the UK. All UK mainland incinerators have generated electricity and/or heat since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery, and emissions from those sites is reported under NFR14 5C1a. The waste incinerator on the Scilly Isles may not recover heat or generate electricity, but it is very small, and separate activity data are not available so it is reported under 1A1 together with all other UK incinerators, rather than separately under 5C1a.

Landfill gas and sewage gas are also burnt to generate electricity. At the end of 2015, there were 633 sites utilising landfill gas or sewage gas to generate electricity. The UK also had 351 sites where anaerobic digestion (AD) of wastes from farming, food production or other industries produces biogas used to generate electricity. These AD sites are assumed in the UK inventory to be autogenerators rather than power stations, and emissions are currently reported in 1A2gviii (in keeping with the approach for other fuels where an accurate split into 1A2a-1A2g cannot be made).

Nearly all UK power stations burning fossil fuels are required to report emissions in the various regulators' inventories: the Pollution Inventory (PI), the Welsh Emissions Inventory (WEI), the Scottish Pollutant Release Inventory (SPRI), and Northern Ireland's Pollution Inventory (NIPI). The only exceptions are a number of very small power stations, typically providing electricity to island communities, which burn burning oil or diesel oil. Emissions from these non-reporting sites are relatively insignificant in the UK context, and emissions are estimated based on activity data from EU ETS or based on plant capacity information. Emission estimates for the sector are therefore largely based on the emission data reported for individual sites:

UK emission = Σ Reported Site Emissions

There are a few instances of sites not reporting emissions of some pollutants, generally because those emissions are trivial, or because a site is closed down partway through a year and therefore does not submit an emissions report. In these instances, either reported activity data or plant capacity data are used to extrapolate emissions to cover any non-reporting sites; data gap-filling by extrapolation does not add significantly to emission totals, as the non-reporting sites are usually smaller, lower-emitting sites. For example, in the case of NO_x as NO_2 in 2015, reported emissions make up 99.4% of the total UK estimate, whilst the remaining 0.6% is estimated for sites where no reported data are available.

The methodology is complicated by stations burning more than one fuel; as far as possible the UK inventory estimates are allocated to individual fuels. Therefore, for power stations, reported emissions are allocated across the different fuels burnt at each station. Plant-specific fuel use data are available either directly from operators, or obtained from EU ETS data held by UK regulators, or estimated from carbon emissions in a few cases where no other data are available. The allocation of reported emissions of a given pollutant across fuels is then achieved as follows:

1) Emissions from the use of each fuel at each power station are calculated using the reported fuel use data and a set of literature-based emission factors to give 'default emission estimates'.
2) For each power station, the 'default emission estimates' for the various fuels are summed, and the percentage contribution that each fuel makes to this total is calculated.
3) The reported emission for each power station is then allocated across fuels by assuming each fuel contributes the same percentage of emissions as in the case of the 'default emission estimates'.

The approach described above is used for most pollutants. However, in the case of emissions of persistent organic pollutants (POPs), reporting of emissions in the regulators' inventories is limited and/or highly variable. Therefore, for emission estimates of POPs the PI/SPRI/NIPI data are disregarded and emissions are calculated from literature emission factors and activity statistics.

Emissions data for NMVOC and metals are quite scarce in the PI/WEI/SPRI/NIPI data sets, and therefore the emission factors generated using these data can show large year-on-year variations, particularly for power stations using burning oil, gas oil and poultry litter. These are relatively small plant and emissions of NMVOC and metals are often below the reporting thresholds for the regulators' inventories. However, these are also small-scale operations and so emissions are very small compared with UK emissions as a whole. The variation in emission factors for these sites does not therefore lead to significant year-on-year variation in the total UK emission. The general approach described above is used for power stations burning coal, oils, natural gas and biomass as their primary fuel.

Emissions from EfW plants and MSW incinerators are also based on operator-reported data within the PI, WEI and SPRI: there are currently no sites in Northern Ireland. All reported emissions are allocated only to the combustion of the MSW, with no account being taken of any fossil fuels used to support combustion, as there are no data available on the use of fossil fuels at these sites. This methodological simplification will result in a minor inconsistency in the inventory, but its impact on UK estimates is small and it is not regarded as a priority for revision.

Emissions data are available back to 1988 in the case of NO_x (as NO_2) and SO_x as SO_2 from major fossil-fuel powered stations. For NO_x (as NO_2), emission factors from Stewart & Walker (1997) are used for the years prior to 1989, while in the case of SO_x as SO_2, factors for 1970-1987 are based on information provided by coal suppliers. The emission factors for NO_x (as NO_2) & SO_x (as SO_2) back to 1990 and for other pollutants back to 1997 are reviewed each year so that any changes in reported emissions, activity data, or underlying assumptions, are taken into account in recalculations. The emission factors for the remaining years in the time series (1970-1989 for NO_x (as NO_2) and SO_x (as SO_2), 1970-1996 for most other pollutants) are based on a combination of the use of emissions data published by operators or supplied by regulators; use of UK-based literature emission factors; use of UK-specific fuel composition data; and use of emission factors derived from later UK emissions data.

Emissions data for EfW plant are available from the early 1990s onwards. Emission factors derived from the reported data in the early part of the time series are quite variable. Outlier emission factors are discarded as unreliable, and the estimates are associated with higher uncertainty than estimates from recent years. Gaps in the time-series, and emissions factors prior to the 1990s are filled either by extrapolating back emission factors from emissions data in later years, or by using literature factors.

Emissions of NO_x as NO_2 and SO_x as SO_2 from landfill gas engines and NO_x as NO_2 from sewage gas engines are based on emission factors derived using UK data or based on emission limit values for UK processes. Emissions of other pollutants from landfill gas and sewage gas engines are based on literature emission factors from AP-42 (US EPA, 2009). Several landfill gas and sewage gas sites have started to report emissions in the regulators' inventories in recent years. These data are not currently used to derive UK-specific factors, as the scope of reported installations is small and may not be representative. Furthermore, the scope of emissions reported by the sites that do report includes other emission sources (e.g. flaring) and hence source-specific estimates for the power generation source cannot be derived.

The NO_x (as NO_2) emission factor for engines burning landfill gas and sewage gas is based on engines being typically 3MW and complying with the regulatory emission limit values appropriate for this size of plant. The SO_x as SO_2 emission factor for landfill gas engines is based on monitoring results for seven landfill gas engines (reported in Gregory, 2002).

Table 3-4 UK Power Generation Emission Estimation Methodology by Pollutant

Fuels	Pollutant	Methodology
Coal & fuel oil (including use of Orimulsion and petroleum coke and co-firing of biomass)	NO_x (as NO_2)	1990-2015: O 1989: O/M 1970-1988: L
	SO_x as SO_2	1990-2015: O 1988-1989: O/M 1970-1987: F
	HCl (coal only)	1993-2015: O 1992: O/M 1970-1991: E
	Pb	1997-2015: O

Fuels	Pollutant	Methodology
		1990-1996: O/M 1970-1989: E
	CO, NMVOC, other metals, PM_{10}, HF	1997-2015: O 1993-1996: O/M 1970-1992: E
Sour gas	NO_x (as NO_2), SO_x as SO_2	1992:2015: O 1970-1991: not occurring
	CO	1997:2015: O 1992-1996: L 1970-1991: not occurring
	VOC, PM_{10}	1997:2015: O 1992-1996: O/M 1970-1991: not occurring
Coal slurry	NO_x (as NO_2), SO_x as SO_2	1994:2015: O 1970-1993: not estimated separately, included with estimates for coal
	CO, NMVOC, HCl, metals, PM_{10}	1994:2015: O 1994-1996: O/M 1970-1993: not estimated separately, included with estimates for coal
Natural gas	NO_x (as NO_2)	1997-2015: O 1992-1996: O/M 1970-1991: E
	SO_x as SO_2	1997-2015: O 1993-1996: O/M 1970-1992: not estimated
	CO	1997-2015: O 1993-1996: O/M 1970-1992: E
	NMVOC, Hg, PM_{10}	1997-2015: O 1996: O/M 1970-1995: E
Gas oil	NO_x (as NO_2)	1997-2015: O 1994-1996: O/M 1970-1993: L
	SO_x as SO_2	1997-2015: O 1994-1996: O/M 1970-1993: F
	CO	1997-2015: O 1996: O/M 1970-1995: L
	NMVOC, metals, PM_{10}	1997-2015: O 1970-1996: L
Poultry litter	All	1997-2015: O 1992-1996: O/M 1970-1991: not occurring
Straw	All	2000-2015: O 1970-1999: not occurring
Landfill/sewage gas	All	1970-2015: L
All fuels	$PM_{2.5}$	1970-2015: M (PM)

Key:
E – extrapolated from earliest factor based on operators' data
F – based on fuel composition data supplied by fuel suppliers
L – literature emission factor
O – based on operators' emissions data
O/M – combination of operators' emissions data and modelling using technology-specific literature emission factors
M – modelling using technology-specific literature emission factors
M (PM) – Modelled by combining PM_{10} emission estimates with $PM_{2.5}$ / PM_{10} ratios derived from emission factors for those pollutants, given in the EMEP/EEA 2016 Guidebook

3.1.5 Methodology for Refineries (NFR14 1A1b)

NFR14 Sector 1A1b is a key source for SO_x as (SO_2).

The UK had eight oil refineries at the start of 2015, although two of these are small specialist refineries employing simple processes such as distillation to produce solvents or bitumen only. The remaining six complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstock, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke.

The crude oils processed, the refining techniques, and the product mix will differ from one refinery to another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

All of these sites are required to report emissions to either the PI, WEI, or SPRI. Additional data for CO, NO_x (as NO_2), SO_x as SO_2, and PM_{10} are supplied annually by process operators via the United Kingdom Petroleum Industry Association (UKPIA, 2016). These data split the emissions[25] for the complex refineries into those from large combustion plants (burning fuel oil and OPG) and those from processes (predominantly catalyst regeneration involving the burning of petroleum coke); separate estimates of emissions of NMVOCs are also provided from refinery process sources such as flares, tankage, spillages, process fugitives, drains/effluent, road/rail loading. Emission estimates for the sector are based on the emission data reported for individual sites:

UK Emission = Σ Reported Site Emissions

The UKPIA data used in the NAEI extend back to 1999, and data for English and Welsh sites are available in the PI & WEI for the years 1998-2015. Data for Scotland's refineries are reported in the SPRI for the years 2002 and 2004-2015. Emissions data for NO_x (as NO_2) and SO_x as SO_2 from the large combustion plant present on refinery sites is available back to 1990. Thus, emission factors are generally based on reported data back to 1990 for NO_x (as NO_2) and SO_x (as SO_2), and back to 1998 for other pollutants. While emission factors for earlier years are generated by extrapolation from 1990 data for NO_x (as NO_2) and SO_x as SO_2, and 1998 data for other pollutants.

In recent years in the UK, there have been a number of changes within the refinery sector, including several closures and also several sites where ownership of the refinery and supporting plant (such as boilers and CHP plant) have changed through mergers, acquisitions and divestments. This has made the tracking of the scope of installations in the refinery sector more challenging, and it is evident that reported data on energy use and emissions has (for some sites) become more inconsistent over time. As a result, the inventory agency has been working with the BEIS energy statistics team to reconcile the EU ETS and DUKES data for the sector, to close out any differences in energy data (especially for petcoke and OPG). In the compilation of the 1990-2014 air quality pollutant inventories, therefore, the inventory agency has reviewed the emissions data reported over recent years via the PI/WEI/SPRI, EU ETS and from UKPIA, to identify and resolve any reporting inconsistencies as far as possible. This has led to a small number of revisions to the UK emission estimates for the sector.

For the years covered by reported data, there are instances of individual sites not reporting emissions of some pollutants, generally because those emissions are trivial or because a site has closed down partway through a year and therefore does not submit an emissions report. However, DUKES has data on the capacity of each individual plant, so it is possible to extrapolate the emissions data to cover non-reporting sites as well. This extrapolation of data does not add significantly to emission totals. For example, for the 2011 and 2012 datasets, the Coryton refinery had closed in Q2 of 2012 and therefore did not return any detailed emissions data via UKPIA. The emission estimates for Coryton in the UK inventory are therefore aligned with Pollution Inventory data, and source allocation of emissions is based on historic data and is somewhat more uncertain than for other refineries.

[25] The refinery category 1A1b is used for all fuel combustion related to refineries whether used to generate electricity, power or heat, and thus covers boilers, furnaces, engines, CHP etc. as well as the removal of coke deposits from catalysts in the regeneration sections of cat crackers.

The methodology for the refinery sector is complicated by the fact that more than one fuel is burnt, but the NAEI needs to record emissions from each fuel separately if possible. For crude oil refineries, reported emissions are either allocated to a single fuel (e.g. metal emissions are allocated to combustion of fuel oil) or else split across several fuels in the same manner used for power stations. Emissions of CO, NO_x (as NO_2), SO_x (as SO_2), and PM_{10} from catalyst regeneration involving the burning of petroleum coke are calculated directly from the data provided by UKPIA.

The approach described above is used for most pollutants, however in the case of emissions of persistent organic pollutants, reporting of emissions in the PI and SPRI is limited and/or highly variable, and therefore emissions are calculated from literature emission factors and activity statistics.

Activity data for the refinery sector are predominantly taken directly from UK energy statistics (BEIS, 2016); however, the EU ETS data on energy use and emissions indicate an under-report in OPG use at UK refineries within the energy statistics, and there is close consistency between EU ETS and UKPIA emissions totals for carbon dioxide. Therefore, the EU ETS activity data for OPG are used in preference to BEIS data, with amendments to the DUKES statistics back to 2004 inclusive. (See also Section 3.1.3 above for further information.)

3.1.6 Methodology for other energy industries (NFR14 1A1c)

NFR14 Sector 1A1c is a key source for NO_x (as NO_2). The sector covers emissions from production of manufactured fuels (coke, other solid smokeless fuels (SSF), town gas), coal extraction, oil and gas exploration and production, and gas distribution.

Coke and Smokeless Solid Fuel Production

Most UK coke is produced at coke ovens associated with integrated steelworks, although independent coke manufacturers have also existed in the period covered by the inventory. At the end of 2015, there were just three coke ovens at steelworks following the closure of two other coke ovens associated with the Teesside steelworks in 2015 and closure of the last independent coke oven in late 2014. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes regulated under IED/E-PRTR are included in the inventory since only these give rise to significant emissions. Currently, there are two such sites. Town gas was manufactured from coal, but has not been consumed in the UK since 1988, after the closure of the last coal gas plants in the UK in 1987.

Table 3-5 UK Coke Ovens and SSF Manufacturing Plant in Operation, 1970-2015

Process type	Period	No of plant
Coke ovens	2015	3
	2004-2014	6
	2003	7
	1993-2002	9
	1991-1992	10
	1970-1990	Insufficient data
Solid smokeless fuel manufacture	2006-2015	2
	2000-2005	3
	1997-1999	4
	1996	5
	1991-1995	6
	1970-1990	Insufficient data

All of these sites are required to report emissions in the PI or WEI. Emission estimates for the sector are based on the emission data reported for individual sites:

UK Emission = Σ Reported Site Emissions

There are instances of sites not reporting emissions of some pollutants, generally because those emissions are below the reporting threshold. However, estimates can be made of the capacity of each individual plant, so it is possible to extrapolate the emissions data to cover non-reporting sites as well. This extrapolation of data does not add significantly to emission totals.

The methodology for this sector is complicated by the fact that more than one fuel is burnt, but the NAEI needs to record emissions from each fuel separately if possible. For coke ovens, emissions from process sources can also be very significant, and the approach taken to allocate reported emissions to fuels varies from pollutant to pollutant.

The first approach is used for NO_x (as NO_2), where emissions are expected to occur mainly from combustion of coke oven gas (the main fuel used), with very minor contributions from the use of other fuels (blast furnace gas, colliery methane, natural gas) and fugitive emissions from the coke oven. The approach relies upon the use of literature emission factors to estimate emissions from the minor sources. These emission estimates for the minor sources are then subtracted from the reported emissions data, with the remainder being allocated as the emissions from the coke oven gas.

Emissions of other pollutants will either be significant both from combustion and process-related sources, or will predominantly occur from process sources. In the case of SO_x as SO_2, emissions data are split between coke oven gas combustion and process sources using a ratio based on actual emissions data for these sources for the mid-1990s. For CO, NMVOC, PM_{10}, metals, B[a]P and PCDD/PCDFs, we have no detailed source- and fuel-specific emissions data on which to base a split and so all of the reported site emissions are allocated to a non-fuel specific source category covering both types of emissions. These emissions are reported under NFR14 Sector 1B1b.

Processes manufacturing SSF are relatively small compared with coke ovens, and so reporting of emissions is very limited in the Pollution Inventory due to reporting thresholds, with only CO, NO_x and PM_{10} reported on a regular basis. The reported emissions for these pollutants are allocated to a non-fuel specific source category. Emissions of other pollutants are estimated using literature emission factors, primarily taken from the EMEP-EEA Guidebook (EMEP, 2016) or earlier versions of the (EMEP-CORINAIR) guidebook, and several UK research reference sources from the early 1990s. These emissions are reported under NFR14 Sector 1B1b.

Gas Production (Downstream Gas)

Emissions from fuel use in the downstream gas production industry are primarily from gas use at compressor stations on the UK transmission and distribution network, downstream of the gas terminals where gas is injected to the UK pipeline network. For most years, the activity data for this source are taken directly from DUKES; however, the EU ETS reporting system also provides activity data for gas use in compressor stations since 2005, and in some years the EU ETS data exceeds the gas allocation in DUKES. Therefore, in the UK inventory we use the DUKES data unless EU ETS data are higher; where we use the higher EU ETS data, we re-allocate the difference from other sources in the inventory (1A2g, unclassified industry) in order that the overall UK gas balance in the inventory is consistent with UK energy statistics.

Default emission factors are applied, taken primarily from USEPA AP-42, the EMEP-EEA 2016 Guidebook and from UK industry research where it is available.

Upstream Oil and Gas Exploration and Production (E&P) Sources

The UK inventory includes emissions from all of the upstream oil and gas E&P sources, with emissions allocated to NFR14 source category 1A1c from all fuel combustion-related activities at offshore and onshore oil and gas platforms and floating production and storage vessels, as well as from combustion sources at onshore terminals.

Offshore oil and gas facilities are regulated by the BEIS Offshore Inspectorate, whilst onshore facilities are regulated under the IED/EPR by the Environment Agency, NRW, and SEPA.

Annual emission estimates from all such facilities are reported via the Environmental Emissions Monitoring System (EEMS) from 1998 to 2010; offshore facilities still report to EEMS, whilst for onshore terminals this reporting is now voluntary, as it is regarded as duplication of mandatory reporting under the IED/EPR. For combustion of gas, gas oil and fuel oil, the EEMS dataset includes activity data and emission estimates for NO_x (as NO_2), SO_x (as SO_2), CO, NMVOC and GHGs (CO_2, N_2O and CH_4).

The activity data for the emission estimates are taken from DUKES, except in instances where the data from EU ETS and EEMS reporting systems indicate that the UK energy statistics are under-reporting the activity (see Section 3.1.3 above).

Emission factors are derived based on the EEMS and IED EPR operator reported data, with data for prior to 1998 based on periodic studies by the trade association, UK Oil and Gas including a revision of time series estimates provided in December 2005. Emission estimates of PM_{10} from use of gas oil and natural gas by oil & gas production facilities are derived using default factors from USEPA AP-42, while PM_{10} factors for process gas used as fuels at terminals are taken from the EMEP-EEA 2016 Guidebook.

Other 1A1c Sources
Other emission sources reported under 1A1c include fuels used at collieries and fuels used at sites processing nuclear fuels. Emissions from these sources are relatively low in the UK inventory context. The emission estimation methodology in all cases uses the UK energy statistics activity data and applies default emission factors from USEPA AP-42, the EMEP-EEA 2016 Guidebook or from UK industry research.

3.1.7 Source specific QA/QC and verification

The QA/QC procedure for this sector is covered by the general QA/QC of the NAEI in Section 1.6; however, specific additional QA/QC exists for 1A1.

The core publication for Activity Data is the annual BEIS publication *The Digest of UK Energy Statistics* which is produced in accordance with QA/QC requirements stipulated within the UK Government's National Statistics Code of Practice, and as such is subject to regular QA audits and reviews.

Where emissions data are provided by plant operators to the UK environmental regulatory agencies (i.e. the Environment Agency, NRW, SEPA and NIEA) and reported via their respective inventories of pollutant releases (i.e. the PI, WEI, SPRI and NIPI) the data is subject to audit and review within established regulator QA systems. In England, the operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations. Similar systems are being developed or in use by NRW, SEPA and NIEA, with some routine checking procedures already in place.

Further, limited review of the data is undertaken by the UK inventory team in order to identify any major outliers. The PI, WEI, SPRI & NIPI contain well in excess of 100,000 individual emissions data points covering thousands of sites, and at many sites emissions show significant year on year changes. Such variations can be due to factors such as changes in production rates, commissioning of new plant or closure of old plant within processes, changes in feedstocks or products, fitting of abatement or failure of those systems, etc. Finally, operators may change the basis on which they estimate their emissions, e.g. using measurements rather than calculating emission estimates from literature emission factors. The inventory team is not in a position to be aware of the influence of all these factors, therefore we have assumed that most year-on-year variations in emissions data are a reflection of real changes in emissions, and only reject emissions data in a small number of cases where the reliability of the data seems to be particularly in doubt. Conclusions from our reviews are periodically fed back to the regulators. Specific data inconsistencies are sometimes queried directly with the PI, WEI, SPRI & NIPI teams, Site Inspectors or other technical experts within the regulatory agencies, to seek to resolve data-reporting errors and to ensure the use of appropriate data within UK inventory outputs.

3.1.8 Recalculations in NFR14 1A1

There have been no particularly significant recalculations since the 2016 submission in NFR14 1A1. The most notable of the recalculations are:

- A revision to the way in which emissions reported for crude oil refineries are allocated to the numerous fuels burnt at those sites. The new approach uses default emission factors from the 2016 EMEP/EEA Guidebook to establish a likely split. Overall emissions for 1A1b are not changed to any significant degree – only the allocation to each fuel
- Literature factors used for various relatively minor sources have been reviewed and some changes made. The impact of these changes is trivial and the most significant, where factors from the 2016 EMEP/EEA Guidebook have been used instead of USEPA factors for oil & gas terminals results in an overall change to the PM_{10} & $PM_{2.5}$ inventories of less than 0.05%
- Recalculations to the wood activity data time-series due to revisions in DUKES calorific values for wood; this has very little impact on emissions for the majority of pollutants as wood is a minor fuel for this source
- 2014 estimates of MSW used in power stations is up by 30% due to recalculations in DUKES estimates of MSW used for autogeneration. Again, this has very little impact on overall emissions from 1A1 since those are dependent upon emissions data reported by the operators, which has not changed.

3.1.9 Planned Improvements in NFR14 1A1

Most of the emission estimates for 1A1 are generated from site-specific emissions data supplied by process operators for inclusion in regulators' inventories. The NAEI estimates are therefore only as good as the estimates supplied by the process operators. We do not have any details of how these operators derive their estimates, so it is impossible to be sure how reliable the figures are, however as described elsewhere, the data in the regulators' inventories is subject to thorough QA/QC, and the level of reporting is very high with all significant sites within 1A1 reporting data. We therefore regard the emission estimates for 1A1 to be generally of high quality. Note, however, that this relates to the emission totals only – the operators do not provide emissions data split by fuel or process, so all disaggregation by fuel etc. is based on assumption, and therefore much more uncertain. The presumption of a high level of overall quality in the emission estimates for 1A1 mean that this category is not regarded as a high priority for any major improvements.

Some sub-sectors within 1A1 consist mostly of a handful of smaller sites (for example power stations using gas oil or biomass as the primary fuel are almost all very small). Because of their small size, most of these sites do not emit sufficiently large quantities of air pollutants to require emission reporting. Therefore, for these smaller sites, we have to make assumptions and extrapolate data, in order to derive emission estimates. The resulting emission estimates are therefore more uncertain, and tend to vary significantly from year to year due to the limited and variable input data. It should be stressed though that these more uncertain sub-sectors are, since they consist of a small number of small sites, insignificant emission sources compared with the UK as a whole, and so are not a priority for improvement.

3.2 NFR14 1A2: Manufacturing Industries and Construction

Table 3-6 Mapping of NFR14 Source Categories to NAEI Source Categories: Stationary Combustion

NFR14 Category (1A2)	Pollutant coverage	NAEI Source category
1 A 2 a Iron and Steel	All CLRTAP pollutants (except HCB)	Blast furnaces
		Iron and steel - combustion plant
1 A 2 b Non-ferrous metals	All CLRTAP pollutants	Non-ferrous metal (combustion)
		Autogenerators (coal)
1 A 2 c Chemicals	All CLRTAP pollutants	Ammonia production - combustion
		Chemicals (combustion)
1 A 2 d Pulp, Paper and Print	All CLRTAP pollutants	Pulp, paper & print (combustion)
1 A 2 e Food processing, beverages and tobacco	All CLRTAP pollutants	Food & drink, tobacco (combustion)
1 A 2 f Stationary combustion in manufacturing industries and construction: Other	All CLRTAP pollutants	Cement - non-decarbonising
		Cement production - combustion
		Industrial engines
		Lime production - non decarbonising
		Other industrial combustion
1 A 2 gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	All CLRTAP pollutants	Industrial off-road mobile machinery
1 A 2 gviii Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	All CLRTAP pollutants	Autogenerators
		Other industrial combustion

Table 3-7 Summary of Emission Estimation Methods for NAEI Source Categories in NFR14 Category 1A2

NAEI Source Category	Method	Activity Data	Emission Factors
Blast furnaces	UK model for integrated works	BEIS energy statistics, EU ETS, ISSB	Operator-reported emissions data under IED/E-PRTR, plant-specific data from Tata Steel. Default factors (EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Iron and steel - combustion plant	UK model for integrated works; AD x EF	BEIS energy statistics, EU ETS, ISSB	Operator-reported emissions data under IED/E-PRTR, plant-specific data from Tata Steel. Default factors (EMEP-EEA, USEPA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Non-ferrous metal (combustion)	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Ammonia production - combustion	AD x EF	BEIS energy statistics, operator data on natural gas use for feedstock and combustion.	Operator data on annual NO_x emissions from combustion sources, Default factors (USEPA) for other pollutants.
Chemicals (combustion)	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics, EU ETS	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.

NAEI Source Category	Method	Activity Data	Emission Factors
Pulp, paper & print (combustion)	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Food & drink, tobacco (combustion)	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Autogenerators	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Operator-reported emissions data under IED/E-PRTR. Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Cement - non-decarbonising	AD x EF	Mineral Products Association clinker production data, EU ETS	IED/E-PRTR annual reporting by operators, EFs derived via inventory agency model to allocate emissions across fuel combustion, non-decarbonising and process sources (i.e. between 1A2f and 2A1).
Cement production - combustion	AD x EF	Mineral Products Association fuel use data, EU ETS	IED/E-PRTR annual reporting by operators, default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Industrial engines	AD x EF	BEIS energy statistics	Default factor for SO_2: Passant et al. (2004)
Lime production - non decarbonising	AD x EF	EU ETS data, with extrapolation across time-series using IED/E-PRTR emissions data and production estimates from British Geological Survey.	IED/E-PRTR annual reporting by operators, default factors (USEPA, EMEP-EEA, HMIP, UK-specific research).
Other industrial combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics (modified to accommodate other data sources such as MPA, EU ETS). EU ETS data (OPG).	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Industrial off-road mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	Default factors (EMEP-EEA, USEPA, UK-specific research)

3.2.1 Classification of activities and sources

As with NFR14 sector 1A1, the source categories and fuel types used in the NAEI reflect those used in DUKES, although with some differences in detail. Fuels used in the inventory have already been listed in Table 3-3, whilst Table 3-6 relates the detailed NAEI source categories to the equivalent NFR14 source categories for 1A2. The NAEI source categories are the level at which emission estimates are derived, but reporting would not normally be at this detailed level, the NFR14 system being used instead for submission under the CLRTAP. All of the subsectors of 1A2 consist of a mixture of large and small plant, but the precise number of industrial combustion processes is not known.

In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR14 source category. However, there are a few instances where the scope of NAEI and NFR14 categories is different because the NAEI source category is used for reporting both combustion and process-related emissions. These are ‘Cement - non-decarbonising’ and ‘Lime production - non decarbonising’, used to report emissions from cement clinker production and lime kilns respectively, and reported under 1A2f.

In these cases, estimates are based on emissions data reported by operators which do not differentiate between combustion and process-related emissions (see Section 3.2.4) and so mapping of the NAEI source categories to a single NFR14 code is necessary.

Emissions for combustion in manufacturing industries and construction are disaggregated on an industry sector basis to categories 1A2a to 1A2g in the case of the most significant fuels - coal, fuel oil, gas oil and natural gas. Data on the sectoral split of consumption for other fuels are insufficient to allow a similar disaggregation, and so all emissions from use of these fuels is allocated to 1A2g. One minor exception to this is for OPG, where fuel use is split between 1A2c and 1A2g. The chemical industry sector use of OPG is estimated from EU ETS and other site-specific data, while data for 1A2g are taken from DUKES. Details of the methods used to disaggregate fuel data are given in Section 3.2.3. Autogeneration using coal is reported in 1A2b since most of the coal burnt is used at a single site which provided electricity for use at an aluminium smelter. Autogeneration using other fuels is reported in 1A2gviii.

Almost all of the NFR14 source categories listed in Table 3-6 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR14 sector.

3.2.2 General approach for 1A2

NFR14 Sector 1A2a is a key source for CO and SO_x (as SO_2), 1A2gvii is a key source for CO, NO_x (as NO_2), TSP, PM_{10} and $PM_{2.5}$, 1A2gviii is a key source for SO_x (as SO_2), NO_x (as NO_2), CO, TSP, $PM_{2.5}$ and PM_{10}, Cd, Pb, Hg and PCDD/PCDFs.

As well as the separate emission estimates made for the various industry sectors, for the chemical industry, emissions are estimated separately for ammonia and methanol production plant because gas consumption data are available as a result of the need to estimate non-energy use of natural gas by the chemical industry.

Emission estimates are generally based on literature emission factors, mostly taken from the EMEP/EEA Emission Inventory Guidebook. Emissions of CO and NO_x (as NO_2) from OPG use in 1A2c, NO_x from furnaces used in methanol and ammonia production, and emissions of most pollutants from coal-fired autogeneration in 1A2b are, however, based on reported emissions data.

Emissions are also estimated separately for cement and lime kilns because these sectors are characterised by a small number of large plant, all of which report emissions data in the PI, WEI, SPRI and NIPI. These reported emissions data form the basis of the emission estimates. Emissions from burning of gases to heat the air used in blast furnaces are also calculated from reported data in the case of NO_x (as NO_2) although for other pollutant emissions, an approach based on use of literature factors has been adopted. Other NAEI source categories are a mixture of large and small plants and a bottom-up approach utilizing reported emissions is not possible. In these cases, therefore, literature emission factors, taken mainly from the EMEP/EEA Emission Inventory Guidebook, are used together with activity data taken from DUKES.

3.2.3 Fuel consumption data

Fuel consumption data are predominantly taken from DUKES. However, there are some sources within the inventory where the NAEI energy data deviates from the detailed statistics given in DUKES. This is done for two reasons:

- Some of the detailed data contained in DUKES is not considered as accurate as data available from alternative sources;
- DUKES does not include data for a specific source, or data in DUKES is not available in sufficient detail.

The most important of these deviations in 1A2 are as follows:

1) The NAEI emission estimates for cement kilns and lime kilns are based on specific fuel use data for those sectors, which are therefore split-out from the wider industrial fuel use data. Fuel use

data for cement kilns are provided by the Mineral Products Association (MPA, 2016), and are also available from the EU ETS. The EU ETS data provides the basis for the inventory agency annual estimates of fuel used at lime kilns.

2) Gas oil is used in large quantities as a fuel for off-road vehicles and mobile machinery. These devices are not treated as a separate category in DUKES and the fuel they use is included in the DUKES data for agriculture, industry, public administration, railways, and industry. The inventory, however, must include emissions from these off-road vehicles and mobile machinery as separate categories to the use of gas oil in stationary combustion equipment. The inventory agency therefore generates independent estimates of gas oil use for off-road vehicles and mobile machinery from estimates of the numbers of each type of vehicle/machinery in use, and their fuel consumption characteristics. Emission estimates are also made independent of DUKES for other sectors including power stations, railways, and agricultural machinery. Estimates are then made of gas oil use in stationary combustion plant using EU ETS data. Since the EU ETS only covers larger sites, the consumption of gas oil given in the EU ETS is factored up to account for all stationary plant, by assuming a similar split between EU ETS and non-ETS usage as is the case for natural gas. This approach was adopted since gas oil is mostly used as a secondary fuel at sites burning natural gas as the primary fuel. Finally, overall consistency with UK consumption of gas oil, as given in DUKES, is maintained by summing the NAEI estimates of gas oil usage, comparing with the DUKES totals, and then adjusting the NAEI estimates for gas oil used for off-road vehicles as necessary to ensure that the NAEI total matches that given in DUKES.

3) Petroleum-based products used for non-energy applications can be recovered at the end of their working life and used as fuels. Waste lubricants, waste solvents, waste-products from chemicals manufacture, and waste plastics can all be used in this way. DUKES does not include the use of these products for energy but consumption of waste lubricants and waste oils are estimated by the inventory agency for inclusion in the NAEI. The EU ETS presents data for a number of chemical and petrochemical manufacturing plant where process off-gases that are derived from petroleum feedstock materials (primarily ethane, LPG and naphtha) are burned in the plant boilers. The use of these fuels is not reported within DUKES, as the feedstock provided to the installations are reported as “non- energy use”. Therefore, in the UK inventories emission estimates are based on reported EU ETS activity data for these installations (for 2005 to 2015), with estimates for 2004 and earlier based on overall installation reported data to regulators (if available) and plant capacity data for instances where there are no operator-reported data.

4) DUKES does not include a full time series of consumption of petroleum coke as a fuel. Data are provided for petroleum coke burnt by unclassified industry from 2008. Prior to that, all petroleum coke (other than that burnt in refineries) is reported in DUKES as being used for non-energy applications. Petroleum coke is, however, known to have been used as a fuel in cement kilns and elsewhere in industry. Therefore, we include our own estimates for petroleum coke use as fuel in NFR14 1A2. In the case of petroleum coke, it is not always possible to reconcile the NAEI estimates of total UK demand for petroleum coke as a fuel, with the data given in DUKES, since the NAEI total exceeds the DUKES figure in some years. The NAEI figures are retained however, because they are based on more detailed data sources than DUKES, and are considered more reliable.

5) In the UK energy commodity balance tables presented in DUKES 2014, the BEIS energy statistics team revised the energy / non-energy allocation for several petroleum-based fuels: propane, butane, naphtha, gas oil, petroleum coke. These revisions were based on re-analysis of the available data reported by fuel suppliers and HMRC, but the revisions to DUKES were only applied from 2008 onwards. Therefore, in order to ensure a consistent time series of activity data and emissions in the UK inventories, the Ricardo Energy & Environment team has derived (in consultation with the BEIS energy statistics team) a revised time series for these commodities back to 1990, i.e. deviating from the published DUKES fuel activity totals for 1990-2007.

6) Emissions for manufacturing industries and construction are disaggregated by industrial sector for separate reporting to categories 1A2a to 1A2g for coal, fuel oil, gas oil and natural gas. Full details of the methods used to generate the activity data are given below.

3.2.3.1 Coal

Fuel use in NFR14 sector 1A2f only covers the consumption in cement kilns and lime kilns, for which Ricardo Energy & Environment make estimates based on data from the MPA and EU ETS, as outlined above. For fuel use in the rest of 1A2, DUKES contains data on the use of coal by subsector for the whole of the period 1990-2015, although there are some changes to the format of data over this time series. The data for the period 1997-2000 indicates large step changes in the use of coal by some sectors, including a shortfall in coal allocated to the mineral industry between 1997 and 1999, compared with the independent estimates for fuels used for cement and lime production.

We have reviewed data including the fuel use estimates provided by the cement industry; clinker production data, site closures and new sites construction, site capacity, the choices of fuel available to the cement industry and IPC permit documents indicating the choice of fuels in the early to mid-1990s. This evidence is consistent with a gradually changing cement industry as opposed to the step changes seen in the time series compiled from the DUKES data between 1997 and 2000. Therefore, the independently-derived estimates for coal used by the cement sector are used in preference to the DUKES time series, with equal and opposite deviations made for the rest of the 1A2 sources in order to maintain the overall balance of coal use reported in the industry sector. Although the lime sector has not been reviewed in detail, there were no plant closures over that period and there is no evidence to support any major changes in that industry either. In this case independently-derived estimates for the lime sector are again used. It is probable that other users within the mineral products sector will also burn coal e.g. a number of brickworks. A comparison of the DUKES data for 1996 and 2000 and the independently-derived data for cement and lime production suggest that these other processes used substantial amounts of coal in those years. However, in the absence of further data, we have not attempted to generate coal consumption estimates for brickworks and other mineral processes for the years 1997-1999.

In summary, therefore, for the period 1990-1996, fuel consumption data taken directly from DUKES have been used for sectors 1A2a to 1A2e and 1A2g. DUKES data are also used from 2000 onwards. In the intervening years, the DUKES industry sector totals only have been used, together with figures for 1A2f, which are consistent with the independent cement and lime industry emissions data. Estimates for 1A2b to 1A2e, and 1A2g are then derived from the difference between the DUKES industry totals and the independent cement and lime data, with the split between the five industry sub-sectors being based on a linear interpolation between the splits in 1996 and 2000.

3.2.3.2 Natural Gas

As with coal, separate estimates are made for fuels used in cement and lime kilns and those estimates constitute the data for 1A2f. Fuel consumption data for 1A2a to 1A2e are taken directly from DUKES. 1A2g then makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES. 1A2g is also used as a balance, in cases where we have deviated elsewhere from DUKES and then need to make adjustments elsewhere in order to maintain overall consistency with DUKES. For example, the natural gas use allocation in the inventory in NFR14 1A1c for gas compressors is estimated based on data reported by operators under EU ETS. The data from EU ETS exceeds the allocation for this source within DUKES, and therefore some natural gas is re-allocated from 1A2g to 1A1c, retaining the overall UK gas demand total, but rectifying the evident under-report for 1A1c.

3.2.3.3 Fuel Oil

Fuel consumption data for 1A2a to 1A2e are taken directly from DUKES. 1A2g makes up the rest of the industry sector after re-allocations to 1A1a (see Section 3.1.3), and the UK demand figure for fuel oil in the NAEI is consistent with that in DUKES.

3.2.3.4 Gas Oil

Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. DUKES provides a breakdown of gas oil consumption in different industry and other sectors but is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

The independent estimates of industrial gas oil use that are made by the inventory agency are disaggregated across 1A2b to 1A2e and 1A2g using detailed sector-level data from DUKES.

3.2.4 Methodology for cement & lime kilns

The UK had 11 sites producing cement clinker during 2015. The main fuels used are coal and petroleum coke, together with a wide range of waste-derived fuels. However, use of petroleum coke is declining and use of waste-derived fuels is increasing. Lime was produced at 14 UK sites during 2015, however two of these sites produce lime for use on-site in the manufacture of soda ash via the Solvay process, so emissions from those two plant are reported under 2B7. Four of the remaining 12 sites produce lime for use on-site in sugar manufacturing, and two other sites produce dolomitic limes. Lime kilns use either natural gas, anthracite or coal as the main fuel.

All cement and lime kilns are required to report emissions in the PI, WEI, SPRI, or NIPI, hence emission estimates for the sector can be based on the emission data reported for the sites:

UK Emission = Σ Reported Site Emissions

There are instances of sites not reporting emissions of some pollutants, generally because those emissions are trivial, or because a site closed down partway through a year and therefore did not submit an emissions report. However, good data are generally available on the capacity of each individual plant, so it is possible to extrapolate the emissions data to cover non-reporting sites. This extrapolation of data does not add significantly to emission totals.

Each UK cement works typically burns a wide range of fuels, with pollutant emissions derived from each of the fuels and process emission sources also. It would be impractical to allocate emissions to each of these numerous sources, therefore all emissions are reported using a single, non-fuel specific source category. All lime kilns burn either a single fuel such as natural gas or, in a few cases, burn a range of fuels (similar to cement kilns), so reported emissions of CO and NO_x (as NO_2) are allocated to a single source-category for each facility, based on the main fuel burnt at each site. Note that in the case of coal this leads to quite variable emission factors, due to the fact that some of the kilns that burn coal also burn varying amounts of other fuels. As a result, the trends in emissions do not always mirror the trends in coal burnt. PM_{10} is also emitted from process sources at lime kilns, as well as from fuel combustion, so this pollutant is reported using a non-fuel specific source category.

3.2.5 Methodology for blast furnaces

Emissions data for the period 2000-2014 are supplied by the process operators (Tata Steel, 2015; SSI, 2015). In the case of NO_x (as NO_2), emissions are allocated to the 'hot stoves' which burn blast furnace gas, coke oven gas, and natural gas to heat the blast air, and emission factors calculated using gas consumption data given in DUKES. The same emission factor is assumed to be applicable for each type of gas. For other pollutants, reported emissions are allocated to a non-fuel specific source category which is reported under NFR14 category 2C1.

Due to difficulties in the iron and steel industry during 2016 we were unable to collect the data that we normally would from operators. In the absence of this data, Pollution Inventory (EA, 2016) data for 2015 emissions have been used in conjunction with the previously reported detailed data from operators to extrapolate emissions estimates for 2015.

For the period 1998-1999, emissions data are available from the PI; however, they do not distinguish between emissions from the various sources on each steelmaking site (combustion plant, blast furnaces, sinter plant etc.). Therefore, the detailed emission breakdown for 2000, supplied by the process operator, has been used to generate source-specific emissions data for 1998 and 1999, which are then allocated to fuels as normal.

Emission factors calculated from the 1998 emissions data are also used for the earlier part of the time-series, despite the Pollution Inventory containing some emissions data for some years. The 1998 factors are used in preference because of the limited number of pollutants which are reported in earlier years, and because some of the emissions that are reported prior to 1998 are very much lower than the emissions reported in subsequent years. The inventory agency is not aware of any other evidence to suggest that emissions in earlier years would be significantly lower than from 1998 onwards (e.g. steel production and fuel consumption were higher in the earlier years). Therefore, the emissions data from the earlier years of the time series have been disregarded, and a conservative approach to estimating emissions (i.e. using factors derived from 1998 onwards) has been adopted.

3.2.6 Methodology for industrial combustion

As previously described, consumption of coal, fuel oil, gas oil and natural gas is estimated separately for 1A2a through to 1A2g. With a few exceptions such as blast furnaces and cement kilns discussed above, the emission factors used are the same for the different sub-categories of industrial fuel. In the case of other fuels such as coke oven coke, LPG, and burning oil, all industrial fuel use is reported in 1A2g, so there is no need to even consider using different factors for different industrial sub-sectors. The 1A2g sector is also sub-divided into combustion in stationary plant (1A2gviii) and combustion in off-road vehicles and mobile machinery (1A2gvii), although the methodology for the latter sector is described with other transport-related sources, in section 3.3.7.

Emission estimates for CO, NO_x (as NO_2) and PM_{10} from the combustion of coal, coke oven coke, fuel oil, gas oil, burning oil and natural gas are largely based on the use of Tier 1 EMEP/EEA Emission Inventory Guidebook default factors. This approach is straightforward and transparent, but is subject to high uncertainty. The Guidebook does provide Tier 2 emission factors for certain combustion processes but these are mainly furnaces and kilns, and in many cases relate to industries that are of minor significance in the UK (for example, primary production of non-ferrous metals). In any case, UK energy data are not available at a sufficiently detailed level to allow the use of any of the Tier 2 factors, except for cement and lime where UK-specific emissions data are available and used instead.

In the case of SO_x (as SO_2), emission factors for coal and oils are derived from data on typical sulphur contents of the fuels, with information being provided by fuel suppliers. The factors for coal have become more uncertain over time, due to a shift away from UK-mined coal (for which it is relatively easy to get data on sulphur contents), to imported coal (for which we cannot get good data).

For other pollutants, the approach has always been to use a single, literature-based emission factor for each fuel. Emission factors are mostly taken from the EMEP/EEA Guidebook, with the US EPA compilation of emission factors (AP-42) also used extensively.

In the case of coal-fired autogeneration, one plant is responsible for practically all of the fuel used nationally, and so emissions from that sector alone are calculated using emission factors derived from the emissions reported in the PI for that plant, and an estimate of coal consumption at that plant derived from the reported emissions of CO_2.

3.2.7 Source specific QA/QC and verification

The QA/QC procedure for this sector is covered by the general QA/QC of the NAEI in Section 1.6, with specific additional QA/QC for 1A2 outlined here.

Allocations of fuel use are primarily derived from BEIS publications that are subject to established QA/QC requirements, as required for all UK National Statistics. For specific industry sectors (iron & steel, cement, lime, autogeneration) the quality of these data are also checked by the Inventory Agency through comparison against operator-supplied activity and emissions information and energy use data obtained from the EU Emissions Trading System. As discussed above, there are instances where such information has led to amendments to the fuel allocations reported by BEIS (through fuel re-allocations between sectors).

Some emission estimates for 1A2 rely upon emissions data reported in the PI, SPRI and NIPI. Section 3.1.7 discusses QA/QC issues regarding these data.

3.2.7.1 Recalculations in NFR14 1A2

The most significant recalculations since the 2016 submission in NFR14 1A2 are:

- Revisions to the emission factors used for industrial combustion of wood and other biomass, with default factors from the 2016 EMEP/EEA Guidebook now being used in preference to UK data. That UK data related to a single plant, and was possibly not particularly representative of UK plant in general, so the use of a Guidebook default is considered more defensible. UK emissions of PM_{10} & $PM_{2.5}$ are 4% and 5% higher respectively as a result of the change.
- A revision to estimates for petroleum coke used as an industrial fuel leads to increases in UK emissions of SO_2, PM_{10} & $PM_{2.5}$ of 1%, 0.2% & 0.3% respectively.
- Ammonia emission estimates have been added for industrial combustion of biomass other than wood. This source was not included in the 2014 version of the inventory but estimates have now been made assuming the same emission factor as for industrial combustion of wood. UK emissions of ammonia rise in 2014 by 0.3% as a result.
- Revisions to the DUKES gas oil balance for 2013 and 2014, which in particular has impacted on other industrial combustion (1A2g) because this source is used to bring the NAEI activity in line with the DUKES totals. Emissions from combustion of gas oil are, however, trivial, and the recalculations have very little impact on emission totals.
- Revisions to the DUKES fuel oil balance for 2013 and 2014, which in particular has impacted chemical industry fuel use (1A2c), although the impact on emissions is trivial.
- Revisions to the DUKES coal balance for 2013 and 2014, which in particular has impacted chemical and non-ferrous metals industry fuel use (1A2c, 1A2b). Overall impacts are small for NO_X but UK emissions of SO_2 are about 1.5% lower as a result and PM_{10} & $PM_{2.5}$ are 0.2% and 0.3% lower.
- Reallocation of waste lubricants burnt as a fuel by industry to 1A2 from 2D. The activity data used have also been revised downward slightly, with the result that UK emissions of SO_2 fall by 0.2%.
- Reallocation of some natural gas used in the chemical industry between 1990 and 2001 to being stored in methanol
- Recalculations to the wood activity data time-series due to revisions in DUKES calorific values for wood

3.2.8 Planned Improvements in NFR14 1A2

With a few exceptions, the emission estimates for 1A2 are derived using literature emission factors. This ensures that the UK inventory approach is transparent and, through the use of EMEP/EEA Guidebook defaults, based on inventory good practice. However, this approach cannot take into account UK-specific or site-specific factors such as differences in abatement levels, fuel composition, or combustion appliance design compared with the 'typical' situation which the default factors represent. As a result, emission estimates for 1A2 are relatively uncertain. Ideally, emission estimates should be able to accurately reflect the types of combustion appliances in use in the UK and take into account the level of abatement of emissions (and also the changes in these over time). In practice the data do not exist that would allow this to be done. So while emission estimates are highly uncertain, it is currently not possible to identify any options for significantly improving emission estimates.

3.3 NFR14 1A3: Transport

Table 3-8 Mapping of NFR14 Source Categories to NAEI Source Categories: Transport.

NFR14 Category (1A3)	Pollutant coverage	NAEI Source category	Source of Emission Factors
1 A 3 a i(i) International Aviation (LTO)	All CLRTAP pollutants *(except NH_3 and all POPs)*	Aircraft - international take-off and landing	UK literature sources
		Aircraft engines	
		Overseas Territories Aviation - Gibraltar	
1 A 3 a ii (i) Civil Aviation (Domestic, LTO)		Aircraft - domestic take-off and landing	
		Aircraft between UK and Gibraltar - TOL	
1 A 3 b i Road transport: Passenger cars	All CLRTAP pollutants *(except PCBs)*	Petrol cars with and without catalytic converter (cold start, urban, rural and motorway driving)	UK factors or factors from COPERT 5 and EMEP inventory guidebooks
		Diesel cars (cold start, urban, rural and motorway driving)	
		Road vehicle engines (lubricating oil)	
1 A 3 b ii Road transport: Light duty trucks		Petrol LGVs with and without catalytic converter (cold start, urban, rural and motorway driving)	
		Diesel LGVs (cold start, urban, rural and motorway driving)	
1 A 3 b iii Road transport: Heavy duty vehicles		Buses and coaches (urban, rural and motorway driving)	
		HGV articulated (urban, rural and motorway driving)	
		HGV rigid (urban, rural and motorway driving)	
1 A 3 b iv Road transport: Mopeds & motorcycles		Mopeds (<50cc 2st) - urban driving	
		Motorcycle (>50cc 2st) - urban driving	
		Motorcycle (>50cc 4st) – urban, rural and motorway driving	
1 A 3 b v Road transport: Gasoline evaporation	NMVOCs	Petrol cars and LGVs, mopeds and motorcycles (<50cc 2st and >50cc 4st)	
1 A 3 b vi Road transport: Automobile tyre and brake wear	Particulate Matter, Cd, Cr, Cu, Ni and Zn	All Cars, LGVs, HGV rigid and articulated, buses and coaches, mopeds and motorcycles (urban, rural and motorway driving)	
1 A 3 b vii Road transport: Automobile road abrasion	Particulate Matter	All Cars, LGVs, HGV rigid and articulated, buses and coaches, mopeds and motorcycles (urban, rural and motorway driving)	
1 A 3 c Railways	All CLRTAP pollutants including PCDD/PCDFs *(except PAHs, HCB and PCBs)*	Rail - coal	UK factors
		Railways - freight	
		Railways - intercity	
		Railways - regional	

NFR14 Category (1A3)	Pollutant coverage	NAEI Source category	Source of Emission Factors
1A3dii National navigation (Shipping)	All CLRTAP pollutants *(except PCBs)*	Marine engines	UK factors and EMEP inventory guidebooks
		Shipping – coastal	
		Inland waterways	
1A3eii Other (please specify in the IIR)	All CLRTAP pollutants *(except NH_3, HCB and PCBs)*	Aircraft - support vehicles	UK Literature sources, EMEP Guidebook
1A4bii Non-road mobile sources and machinery	All CLRTAP pollutants *(except NH_3 HCB and PCBs)*	Domestic house and garden mobile machinery	EMEP inventory guidebooks
1A4cii Non-road mobile sources	All CLRTAP pollutants *(except NH_3 HCB and PCBs)*	Agricultural mobile machinery	EMEP inventory guidebooks
1A4ciii Non-road mobile sources	All CLRTAP pollutants *(except PCBs)*	Fishing	UK factors and EMEP inventory guidebooks
1 A 5 b Other, Mobile (Including military)	All CLRTAP pollutants *(except HCB and PCBs)*	Aircraft - military	UK Literature sources, EMEP Guidebook
		Shipping - naval	

This covers category 1A3. Other types of mobile machinery and non-road transport are also included in this table and described in this chapter under NFR14 categories 1A2, 1A4 and 1A5.

3.3.1 Classification of activities and sources

Fuel types used in the NAEI for transport sources are the same as those used for stationary combustion sources and are listed in Table 3-3. The detailed NAEI source categories used in the inventory for transport are presented in Table 3-8 above according to the NFR14 source categorisation.

Almost all of the NFR14 source categories listed in Table 3-8 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR14 sector.

3.3.2 Aviation

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation, but only emissions related to landing and take-off (LTO) are included in the national total. Emissions from international and domestic cruise are recorded as a memo item, and are not included in national totals. Emissions from both the landing and take-off (LTO) phase and the cruise phase are estimated. The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

The aviation estimation method in the UK inventory is a complex UK-specific model that uses detailed flight records and plane-specific, engine-specific estimates for pollutant emissions throughout the different stages of LTO and cruise cycles. An overview of the method is presented below; for a more detailed description of the UK aviation method please see Watterson *et al* 2004.

The UK aviation method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport, and so complies with the IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. The method reflects differences between airports and the aircraft that use them, and emissions from additional sources (such as aircraft auxiliary power units) are also included.

This method utilises data from a range of airport emission inventories compiled in the last few years by the Ricardo Energy & Environment aviation team, including:

- ✓ the RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT); and
- ✓ the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by the airports. Emissions of NO_x (as NO_2) and fuel use from the Heathrow inventory are used to verify the inventory results.

In 2006, the Department for Transport (DfT) published its report "Project for the Sustainable Development of Heathrow" (PSDH). This laid out recommendations for the improvement of emission inventories at Heathrow. The PSDH recommendations included methodological changes, which have been introduced into the NAEI. For departures, the PSDH recommended revised thrust setting at take-off and climb-out as well as revised cut-back heights, whilst for arrivals the PSDH recommended revised reverse thrust setting and durations along with revised landing-roll times. These recommendations are integrated in full within the UK inventory method, for all UK flights. Other recommendations that are reflected in the UK inventory method include: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; approach thrusts and times; taxiing thrust and times; engine deterioration and Auxiliary Power Unit (APU) emission indices and running times.

The UK inventory includes all flights to and from the overseas territories, irrespective of origin or destination. Flights between the UK and overseas territories are included as part of the domestic aviation[26]. In addition, flights to and from oilrigs are included in the inventory.

Improvements to the UK aviation method in recent years include:

- The 1990-2012 inventory incorporated data from local London airport inventories (2008 onwards) so that aircraft engine mixes; times in mode and thrust settings are consistent with the latest fleet and performance data. Furthermore, international flights with an intermediate stop at a domestic airport were reclassified as having a domestic leg and an international leg.

- The 1990-2013 inventory incorporated revised cruise emissions in line with the updated EMEP-EEA air pollutant emission inventory guidebook. Errors had been corrected in the assumptions regarding climb thrust settings and engine bypass ratios.

- The 1990-2014 inventory incorporated improvements in the assignment of aircraft to EMEP-EEA cruise categories; and updated assumptions regarding the APU types fitted to aircraft.

- The 1990-2015 inventory incorporates minor revisions to the following:
    - assignment of aircraft to EMEP-EEA cruise categories
    - assumptions regarding the APU types fitted to aircraft
    - surrogate aircraft data used in calculation of LTO cycle emissions

Separate estimates are made for emissions from the LTO cycle and the cruise phase for both domestic and international aviation. For the LTO phase, fuel consumed and emissions per LTO cycle are based on detailed airport studies and engine-specific emission factors (from the ICAO database). For the cruise phase, fuel use and emissions are estimated using distances (based on great circles) travelled from each airport for a set of representative aircraft.

The inventory emission trends for the sector present a noticeable reduction in domestic emissions from 2005 to 2006 despite a modest increase in aircraft movements. This is attributable to the propagation

[26] Gibraltar is the only UK Overseas Territory included under the CLRTAP. There are no UK Crown Dependencies included under the CLRTAP.

of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in domestic emissions, which is attributable to both a modest decrease in aircraft movements and kilometres flown and the propagation of more modern aircraft into the fleet. In 2008, and again in 2009 and 2010, there are reductions in both emissions and aircraft movements, in line with the economic downturn. The impact of the economic recovery is seen in the international movements from 2011. However, domestic movements and emissions have continued to decline.

3.3.2.1 Emission Reporting Categories for Civil Aviation

Table 3-9 below shows the emissions included in the emission totals for the domestic and international civil aviation categories currently under the UNFCCC, the EU NECD and the CLRTAP. Note the reporting requirements to the CLRTAP have altered recently – the table contains the most recent reporting requirements.

Table 3-9 Components of Emissions Included in Reported Emissions from Civil Aviation

	EU NECD	LRTAP Convention	EU-MM/UNFCCC
Domestic aviation (landing and take-off cycle [LTO])	Included in national total	Included in national total	Included in national total
Domestic aviation (cruise)	Not included in national total	Not included in national total	Included in national total
International aviation (LTO)	Included in national total	Included in national total	Not included in national total
International aviation (cruise)	Not included in national total	Not included in national total	Not included in national total

Notes
Emissions from the LTO cycle include emissions within a 1000 m ceiling of landing

3.3.2.2 Aircraft Movement Data (Activity Data)

The methods used to estimate emissions from aviation require the following activity data:

- **Aircraft movements and distances travelled**

Detailed activity data are provided by the UK Civil Aviation Authority (CAA). These data include aircraft movements broken down by: airport; aircraft type; whether the flight is international or domestic; and, the next/last POC (port of call) from which sector lengths (great circle) are calculated. The data covered all Air Transport Movements (ATMs) excluding air-taxi.

Fights between the UK and overseas territories are considered international in the CAA aircraft movement data, but these have been reclassified as domestic aviation.

International flights with an intermediate stop at a domestic airport are considered international in the CAA aircraft movement data. However, these have been reclassified as having a domestic leg and an international leg.

The CAA also compiles summary statistics at reporting airports, which include air-taxi and non-ATMs.

The CAA data are supplemented with data from overseas territories, supplied by DfT.

A summary of aircraft movement data is given in Table 3-10. Fights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Turbine Fuel and Aviation Spirit**

Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DUKES (BEIS, 2016). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of Aviation Turbine Fuel and Aviation Spirit by the Military**

Historically, total consumption by military aviation has been given in ONS (1995) and MOD (2005) and was assumed to be aviation turbine fuel. A revised, but consistent time series of military aviation fuel was provided by the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2009 and 2010) covering each financial year from 2003/04 to 2009/10. These data also included estimates of aviation spirit and turbine fuel classed as “Casual Uplift”, with the latter being drawn from commercial airfields world-wide and assumed not to be included in DUKES. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). These data no longer separately identified aviation spirit or turbine fuel classed as "Casual Uplift", so all fuel was assumed to be aviation turbine fuel and included in DUKES. In 2013 the MoD provided revised data for 2010/11 onwards that did separately identify aviation spirit. However, these data still did not identify "Casual Uplift", so all fuel was assumed to be included in DUKES.

Adjustments were made to the data to derive figures on a calendar year basis.

Table 3-10 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	460.5	377.0	652.0	116.4
1995	530.9	365.3	849.0	118.3
2000	704.3	407.2	1190.7	145.2
2005	800.5	488.2	1447.6	178.7
2010	734.0	393.9	1395.1	146.4
2011	769.2	381.2	1465.2	141.6
2012	765.7	365.2	1444.6	137.5
2013	786.6	360.9	1471.1	134.4
2014	809.9	347.1	1524.0	130.2
2015	821.7	356.0	1565.8	135.0

Notes
Gm Giga metres, or 10^9 metres
Estimated emissions from aviation are based on data provided by the CAA and, for overseas territories, the DfT.
Gm flown calculated from total flight distances for departures from UK and overseas territories airports.

3.3.2.3 Emission factors used

The following emission factors are used to estimate emissions from aviation. Emissions factors for SO_x (as SO_2) and metals are derived from the contents of sulphur and metals in aviation fuels (UKPIA, 2015). These contents are reviewed, and revised as necessary, each year. Full details of the emission factors used are given in Watterson *et al*. (2004).

Table 3-11 Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2015 (kg/t)

Fuel	SO_x as SO_2 (kg/t)
Aviation Turbine Fuel	1.6
Aviation Spirit	1.6

For the LTO-cycle calculations, emissions per LTO cycle are required for each of a number of representative aircraft types. Emission factors for the LTO cycle of aircraft operation are calculated from the International Civil Aviation Organization (ICAO) database. The cruise emissions are taken from CORINAIR data (which are themselves developed from the same original ICAO dataset). Average factors for aviation representative of the fleet in 2015 are shown in Table 3-12.

Table 3-12 Average Emission Factors for Civil and Military Aviation for 2015 (kt/Mt)

	Fuel	NO_x (as NO_2)	CO	NMVOC
Civil aviation				
Domestic LTO	AS	4.36	40.52	5.98
Domestic Cruise	AS	1.58	1228.38	10.22
Domestic LTO	ATF	12.44	9.07	1.73
Domestic Cruise	ATF	15.05	6.47	0.69
International LTO	AS	3.96	221.94	7.88
International Cruise	AS	1.47	1219.75	10.20
International LTO	ATF	13.65	9.25	1.15
International Cruise	ATF	17.09	1.30	0.14
Military aviation				
Military aviation	AS	8.50	8.20	1.00
Military aviation	ATF	8.50	8.20	1.00

Notes
AS – Aviation Spirit
ATF – Aviation Turbine Fuel
Use of all aviation spirit assigned to the LTO cycle

3.3.2.4 Method used to estimate emissions from the LTO cycle – civil aviation – domestic and international

The contribution to aircraft exhaust emissions (in kg) arising from a given mode of aircraft operation (see list below) is given by the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second) and the emission factor for the pollutant of interest (kg pollutant per kg fuel).

The annual emissions total for each mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year. The time in each mode of operation for each type of airport and aircraft has been taken from individual airport studies. The time in mode is multiplied by an emission rate (the product of fuel flow rate and emission factor) at the appropriate engine thrust setting in order to estimate emissions for each phase of the aircraft flight. The sum of the emissions from all the modes provides the total emissions for a particular aircraft journey. The modes considered are:

- Taxi-out;
- Hold;
- Take-off Roll (start of roll to wheels-off);
- Initial-climb (wheels-off to 450 m altitude);
- Climb-out (450 m to 1000 m altitude);
- Approach (from 1000 m altitude);
- Landing-roll;
- Taxi-in;
- APU use after arrival; and
- Auxiliary Power Unit (APU) use prior to departure.

Departure movements comprise the following LTO modes: taxi-out, hold, take-off roll, initial-climb, climb-out and APU use prior to departure. Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

3.3.2.5 Method used to estimate emissions in the cruise – civil aviation – domestic and international

Cruise emissions are only calculated for aircraft departures from UK airports (emissions therefore associated with the departure airport), which gives a total fuel consumption compatible with recorded deliveries of aviation fuel to the UK. This procedure prevents double counting of emissions allocated to international aviation.

3.3.2.6 Estimating emissions

EMEP/EEA air pollutant emission inventory guidebook (2016) provides fuel consumption and emissions of non-GHGs (NO_x (as NO_2), HC and CO) for a number of aircraft modes in the cruise. The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data are assigned to a generic type in the Guidebook.

A linear regression is applied to these data to give emissions (and fuel consumption) as a function of distance:

$$E_{Cruise_{d,g,p}} = m_{g,p} \times d + c_{g,p}$$

Where:

$E_{Cruise_{d,g,p}}$	is the emissions in cruise of pollutant p for generic aircraft type g and flight distance d (kg)
d	is the flight distance
g	is the generic aircraft type
p	is the pollutant (or fuel consumption)
$m_{g,p}$	is the slope of regression for generic aircraft type g and pollutant p (kg / km)
$c_{g,p}$	is the intercept of regression for generic aircraft type g and pollutant p (kg)

Emissions of SO_x as SO_2 and metals are derived from estimates of fuels consumed in the cruise (see equation above) multiplied by the sulphur and metals contents of the aviation fuels for a given year.

3.3.2.7 Overview of method to estimate emission from military aviation

LTO data are not available for military aircraft movements, so a simple approach is used to estimate emissions from military aviation. A first estimate of military emissions is made using military fuel consumption data and IPCC (1997a) and EMEP/ CORINAIR (1999) cruise defaults. The EMEP/ CORINAIR (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons and casual uplift at civilian airports.

Emissions from military aircraft are reported under NFR14 category 1A5 Other.

3.3.2.8 Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the BEIS publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. The aviation fuel consumptions presented in DUKES include the use of both civil and military fuel, and the military fuel use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil aviation fuel consumption is used in the fuel reconciliation. Emissions from flights originating from the overseas territories have been excluded from the fuel reconciliation process as the fuel associated with these flights is not included in DUKES. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

3.3.3 Road Transport (1A3b)

3.3.3.1 Overview

3.3.3.1.1 Summary of methodology

A Tier 3 methodology is used for calculating exhaust emissions from passenger cars (1A3bi), light goods vehicles (1A3bii), heavy duty vehicles including buses and coaches (1A3biii), and motorcycles (1A3biv). A Tier 2 methodology is used for calculating evaporative emissions (1A3bv) from petrol vehicles. Non-exhaust emissions from tyre and brake wear (1A3bvi) and road abrasion (1A3bvii) are also calculated based on a Tier 2 methodology.

3.3.3.1.2 Summary of emission factors

The emission factors are mainly taken from COPERT 4.11.4 and COPERT 5 (Emisia, 2016), including new factors for NO_x emissions from diesel cars and LGVs, and EMEP (2013).

3.3.3.1.3 Summary of activity data

Traffic activity data in billion vehicle km by vehicle type are provided by DfT and total fuel sales for petrol and diesel are provided in the Digest of UK Energy Statistics (DUKES). Vehicle licensing statistics and on-road Automatic Number Plate Recognition data provided by DfT are used to further break down the vehicle km travelled by fuel type and vehicle year of first registration.

3.3.3.2 Fuel sold vs fuel used

The UK inventory for road transport emissions of key air pollutants as submitted to the NECD and CLRTAP is currently based on fuel consumption derived from kilometres driven rather than fuel sales. Paragraph 23 of the revised Guidelines on Reporting (ECE/EB.AIR/125)[27] and references under the revised NEC Directive (2016/2284/EU)[28] allow the UK to report emissions on the basis of fuel used or kilometres driven only.

The UK has a number of reasons for deciding to report emissions on a fuel used basis. Information on total fuel sales is available on a national scale, but is not broken down by vehicle type or road and area type. Emissions of air pollutants are not directly related to amounts of fuel consumed as they depend on vehicle characteristics, exhaust after treatment technology and vehicle speed or drive cycle in a manner different to the way fuel consumption responds to these factors. The availability of high quality traffic data for different vehicle types on different roads covering the whole road network, combined with fleet composition data and other vehicle behaviour and usage trends makes the use of COPERT-type methodologies a logical choice for estimating emissions in the UK. That methodology is one based on kilometres driven.

This approach also makes it possible to develop a robust inventory, which transport and air quality policy makers can relate to national statistics on transport and measures to control traffic and emissions. This direct link to transport statistics and policies would be lost with the adjustments that would be necessary on a vehicle by vehicle basis to bring consistency with national fuel sales. The UK's projections on emissions from road transport are based on the UK's forecasts on traffic levels on an area-type basis (not on fuel sales) and the inventory projections are a benchmark against which different transport and technical measures can be assessed. This has been crucial for UK air quality policy development and would not be feasible from an inventory based on fuel sales. Using a kilometres driven approach also allows the UK to produce spatially resolved inventories for road transport at 1x1km resolution, which are widely used for national and local air quality assessments.

[27] http://www.ceip.at/fileadmin/inhalte/emep/2014_Guidelines/ece.eb.air.125_ADVANCE_VERSION_reporting_guidelines_2013.pdf
[28] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG&toc=OJ:L:2016:344:TOC

The UK does estimate fuel consumption from kilometres driven and g/km factors and compares these each year with national fuel sales figures, as discussed in the following sections. The agreement is within 16% for both petrol and diesel consumption across the 1990-2015 time-series, but the agreement tends to be better in the more recent part of the time-series. In principle, the UK could develop a fuel sales-based inventory for air pollutants, but this would lead to trends in emissions on a vehicle type basis that would be more difficult to interpret by policy makers from established vehicular activity statistics. It is the UK's view that as it would still require an inventory based on fuel consumed for the reasons outlined above, reporting a second inventory based on fuel sales would create confusion. This has already been experienced in the context of CO_2 emissions which for UNFCCC reporting are based on fuel sales. However, the argument for a carbon inventory based on fuels sales can be understood in the context of the country selling the fuel being responsible for the impact it causes on global climate change.

Thus, the UK's emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or from a combination of drive related emission factors and road traffic data.

3.3.3.3 Fuel-based emissions

Emissions of sulphur dioxide (SO_x as SO_2) from road transport are calculated from the consumption of petrol and diesel fuels and the sulphur content of the fuels consumed. Emissions of metals are also calculated from fuel consumption and fuel-based emission factors.

Fuel consumption by road transport

Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics (DUKES) published by BEIS and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES (emissions from the Crown Dependencies are calculated elsewhere).

In 2015, 12.08 Mtonnes of petrol and 23.66 Mtonnes of diesel fuel (DERV) were consumed in the UK. Petrol consumption has decreased while diesel consumption has increased compared with consumption in 2014. It was estimated that of this, 3.3% of petrol was consumed by inland waterways, and off-road vehicles and machinery. Some 0.5% of this was used in the Crown Dependencies, leaving 11.62 Mtonnes of petrol consumed by road vehicles in the UK in 2015. An estimated 1.7% of road diesel was used by inland waterways and off-road vehicles and machinery (the bulk of these use gas oil), and 0.2% used in the Crown Dependencies, leaving 23.21 Mtonnes of diesel consumed by road vehicles in the UK in 2015.

According to figures in DUKES (BEIS, 2016), 0.082 Mtonnes of LPG were used for transport in 2015, a small decrease from 0.088 Mtonnes the previous year.

Since 2005, there has been a rapid growth in consumption of biofuels in the UK. These are not included in the totals presented above for petrol and diesel which according to BEIS refer only to mineral-based fuels (fossil fuels). According to statistics in DUKES and from HMRC (2016), 0.63 Mtonnes bioethanol and 0.60 Mtonnes biodiesel were consumed in the UK in 2015. On a volume basis, this represents about 4.6% of all petrol and 2.3% of all diesel sold in the UK, respectively. This is a small decrease in bioethanol consumption compared with 2014, and a more significant decrease in biodiesel consumption compared with 2014. On an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.38 Mtonnes of mineral-based petrol (about 3.1% of total petrol that would have been consumed) and 0.52 Mtonnes of mineral-based diesel (about 2.2% of total diesel that would have been consumed), respectively.

To distribute fuel consumption, hence emissions, between different vehicle types, a combination of data sources and approaches were used making best use of all available information.

Fuel consumption factors for petrol and diesel vehicles

The source of fuel consumption factors for all vehicle types is the fuel consumption-speed relationships given in COPERT 4v11 and the EMEP/EEA Emissions Inventory Guidebook (2013). This provides a method for passenger cars which applies a year-dependent 'real-world' correction to the average type-approval CO_2 factor weighted by new car sales in the UK from 2005-2015. The new car average type-approval CO_2 factors for cars in different engine size bands were provided by the Society of Motor Manufacturers and Traders (SMMT, 2016). The real-world uplift uses empirically-derived equations in the Guidebook that take account of average engine capacity and vehicle mass.

Using the Guidebook factors with fleet composition data and average speeds on different road types (Section 3.3.3.4), fleet average fuel consumption factors for each main vehicle category are shown in Table 3-13 for years 1990-2015.

Table 3-13 UK Fleet-averaged fuel consumption factors for road vehicles (in g fuel/km)

g fuel/km	1990	1995	2000	2005	2010	2014	2015
Petrol cars	56.3	55.8	54.8	54.9	54.0	51.7	50.9
Diesel cars	55.0	53.4	53.6	53.6	54.1	51.2	51.1
LGVs	77.9	78.7	77.6	74.9	74.7	72.8	72.1
HGVs	210	205	194	207	211	216	215
Buses and coaches	292	293	268	267	262	256	255
Mopeds and motorcycles	36.2	37.0	38.0	36.9	35.9	34.9	34.9

Fuel reconciliation and normalisation

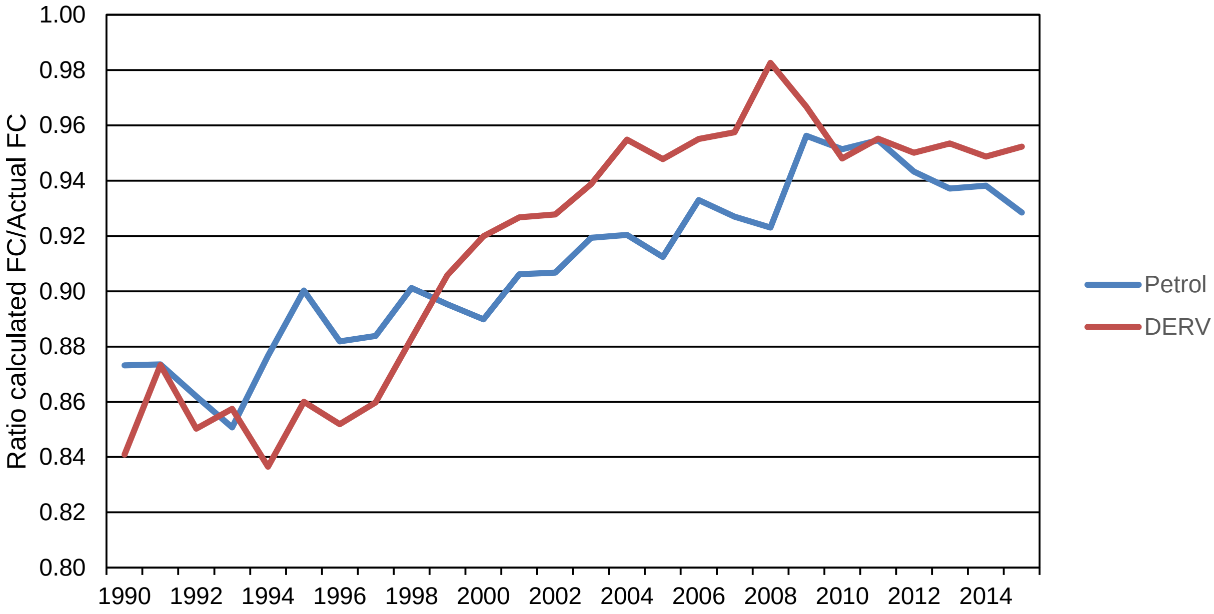
A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data. The "bottom-up" calculated estimates of petrol and diesel consumption are then compared with BEIS figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies.

The bottom-up estimated fuel consumption differs from the DUKES-based figures and so it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total consumption of petrol and diesel equals the DUKES-based figures. This is to comply with the UNFCCC reporting system which requires emissions of CO_2 to be based on fuel sales.

Figure 3-1 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. In all years, the bottom-up method tends to underestimate fuel consumption. The maximum deviation from DUKES is 16% (for DERV, in 1990) however the ratio tends towards 1 up to 2009, indicating better agreement with fuel sales data in recent years than in the earlier part of the time-series. In 2015, the bottom-up method underestimates petrol and diesel consumption by 7.1% and 4.8% respectively.

The normalisation process introduces uncertainties into the fuel consumption estimates for individual vehicle classes even though the totals for road transport are known with high accuracy. Petrol fuel consumption calculated for each vehicle type was scaled up by the same proportions to make the total consumption align with DUKES. The same procedure was used to scale up diesel consumption by each vehicle type. Passenger cars consume the vast majority of petrol, so one would expect that DUKES provides a relatively accurate description of the trends in fuel consumption by petrol cars. This suggests the gap in the early part of the inventory time-series between DUKES and bottom-up estimates is due to inaccuracies in the estimation of fuel consumption by passenger cars during the 1990s.

Figure 3-1 Ratio of calculated consumption of petrol and diesel fuel based on traffic movement and fuel consumption factors summed for different vehicle types to the DUKES figures for these fuels based on fuel sales in the UK.



Emissions from LPG consumption

Few vehicles in the UK run on LPG. There are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG was 0.2% of the total amount of petrol and diesel consumed by road transport in 2015, and vehicle licensing data suggest 0.2% of all light duty vehicles ran on LPG in 2015.

Emissions from natural gas consumption

The UK inventory does not currently estimate emissions from vehicles running on natural gas. The number of such vehicles in the UK is extremely small, with most believed to be running in captive fleets on a trial basis in a few areas. Estimates are not made as there are no separate figures from BEIS on the amount of natural gas used by road transport, nor are there useable data on the total numbers and types of vehicles equipped to run on natural gas from vehicle licensing sources. The small amount of gas that is used in the road transport sector would currently be allocated to other sources in DUKES.

Fuel-based emission factors

SO_2

Emission factors for SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for SO_2 vary annually as the sulphur-content of fuels change, and are shown in Table 3-14 for 2015 fuels based on data from UKPIA (2016).

Table 3-14 Fuel-Based SO_2 2015 Emission Factor for Road Transport (kg/tonne fuel)

Fuel	SO_2[a]
Petrol	0.010
Diesel	0.014

a 2015 emission factor calculated from UKPIA (2016) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2015

Metals
Emission factors for metals are based on the EMEP/EEA emissions inventory guidebook for road transport (EMEP, 2013). The guidebook factors cover the combined effect of the trace amounts of metals in the fuel itself and in lubricating oil and from engine wear. The exception is for lead emissions from petrol where UK-specific factors are used. The factors used are given in Table 3-15.

Table 3-15 Emission factors used in the UK inventory for road transport

Metal	Fuel	Emission Factor (t/Mt)
Cr	DERV	0.03
Cr	Petrol	0.016
As	DERV	0.0001
As	Petrol	0.0003
Cd	DERV	0.0087
Cd	Petrol	0.0108
Cu	DERV	0.0212
Cu	Petrol	0.042
Hg	DERV	0.0053
Hg	Petrol	0.0087
Ni	DERV	0.0088
Ni	Petrol	0.013
Pb	DERV	0.05
Se	DERV	0.0001
Se	Petrol	0.0002
Zn	DERV	1.74
Zn	Petrol	2.16
V	DERV	12.7
Mn	DERV	0.04
Be	DERV	0.144
Sn	DERV	0.304

The Guidebook does not provide factors for the metals V, Mn, Be and Sn, so for these metals UK specific factors are used.

In order to retain a consistent time-series in lead emissions from petrol consumption, UK-specific emission factors continued to be used based on the lead content of leaded petrol (used up until 2000) and unleaded petrol. These figures were provided by the UK petroleum industry. The factor for unleaded petrol is 54 µg/kg fuel which is higher than the value of 33 µg/kg fuel given by the 2016 EMEP/EEA Guidebook. The factors for leaded petrol up until 2000 are year-dependent. Following the Guidebook, the lead emission factors are used in conjunction with a scaling factor of 0.75 to account for the fact that only 75% of the lead in the fuel is emitted to air. Emissions of SO_x (as SO_2) and metals are broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants.

3.3.3.4 Traffic-based emissions

Emissions of the pollutants NMVOCs, NO_x (as NO_2), CO, PM, NH_3 and other air pollutants are calculated from measured emission factors expressed in g/km and road traffic statistics from the Department for Transport. The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven under test cycles with different average speeds. The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications on the UK road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of diesel- and petrol-fuelled vehicles on the road and in terms of the fraction of vehicles on the road made to the different emission regulations that applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet in each year.

Emissions from motor vehicles fall into several different categories, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions, evaporative emissions of NMVOCs, and tyre wear, brake wear and road abrasion emissions of PM_{10} and $PM_{2.5}$.

Hot exhaust emissions
Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, the type of fuel, the driving style or traffic situation of the vehicle on a journey and the emission regulations which applied when the vehicle was first registered as this defines the type of technology the vehicle is equipped with that affects emissions.

For a particular vehicle, the driving style or traffic situation over a journey is the key factor that determines the amount of pollutant emitted over a given distance. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). A similar conclusion was reached in the review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see TRL Report PPR355 at https://www.gov.uk/government/publications/road-vehicle-emission-factors-2009 . Emission factors for average speeds on the road network are then combined with the national road traffic data.

Vehicle and fuel type
Emissions are calculated for vehicles of the following types:

- Petrol cars;
- Diesel cars;
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Articulated Heavy Goods Vehicles (GVW ≥ 3.5 tonnes);
- Buses and coaches; and
- Motorcycles.

Total emission rates are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads.

Vehicle kilometres by road type
Hot exhaust emission factors are dependent on average vehicle speed and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on rural roads and higher speed motorways/dual carriageways and many different types of urban roads with different average speeds. The emission results are combined to yield emissions on each of these main road types:

- Urban;
- Rural single carriageway; and
- Motorway/dual carriageway.

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2016a). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2015 inventory, taking into account any revisions to historic data. The vkm data are derived by DfT from analysis of national traffic census data involving automatic and manual traffic counts. Additional information discussed later are used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2015a). This gave a time-series of vehicle km data from 2008 to 2014. To create a time-series of vehicle km data for 1990 to 2007, the vehicle km data from DRDNI (2013) was used. The data was scaled up or down based on the ratio of the data for 2008 between DRDNI (2015) and DRDNI (2013) for the given vehicle type and road type considered. Data for 2015 were not available in time for the current inventory compilation and thus they were extrapolated from 2014 vehicle km data for Northern Ireland based on the traffic growth rates between 2014 and 2015 in Great Britain. Motorcycle vehicle km data were not available from the DRDNI and so they were derived based on the ratio of motorcycles registered in Northern Ireland relative to Great Britain each year. The ratios were then applied to the motorcycle vehicle km activity data for Great Britain. Additional information is provided by DRDNI about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by DRDNI of licensing data (DRDNI, 2015).

The Northern Ireland data have been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2015. Table 3-16 shows the UK vehicle kilometres data from 1990 to 2010 (at five year intervals) and for the most recent years (2014, 2015).

Table 3-16 UK vehicle km by road vehicles

Billion vkm		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**
Petrol cars	urban	142.2	137.9	135.1	119.9	99.4	89.8	89.3
	rural	140.9	133.9	134.1	127.2	109.0	95.9	93.5
	m-way	49.3	48.4	53.0	48.9	41.7	35.1	34.3
Diesel cars	urban	5.8	17.2	26.1	40.8	54.0	64.6	65.2
	rural	6.1	17.9	28.3	47.5	65.8	82.7	88.3
	m-way	2.8	8.5	14.7	25.2	33.6	43.8	46.0
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.3	1.0	1.0
	rural	11.4	8.3	5.0	2.3	1.6	1.3	1.3
	m-way	3.9	3.2	2.0	0.9	0.6	0.6	0.6
Diesel LGVs	urban	5.8	10.2	15.6	21.2	22.7	24.7	25.3
	rural	6.0	11.4	18.8	25.9	29.5	32.1	33.9
	m-way	2.0	4.3	7.4	10.4	11.4	13.9	14.7
Rigid HGVs	urban	4.5	3.7	3.9	4.0	3.2	3.0	2.9
	rural	7.1	6.8	7.2	7.5	6.6	6.1	6.3
	m-way	3.7	3.7	4.2	4.2	4.1	3.6	3.9
Artic HGVs	urban	1.1	1.1	1.1	1.1	0.8	0.8	0.9
	rural	4.4	4.7	5.2	5.4	5.1	5.1	5.3
	m-way	4.7	6.0	7.4	7.9	7.5	8.1	8.4
Buses	urban	2.4	2.9	3.0	3.2	3.1	2.8	2.6
	rural	1.7	1.5	1.7	1.5	1.6	1.4	1.4
	m-way	0.6	0.5	0.5	0.5	0.5	0.4	0.4
M/cycle	urban	3.3	1.9	2.3	2.9	2.5	2.2	2.2
	rural	2.0	1.6	2.0	2.2	1.8	2.0	2.0
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Total		**423.3**	**443.8**	**482.9**	**512.9**	**507.9**	**521.4**	**529.9**

Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009a) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008a) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned. Table 3-17 shows the speeds used in the inventory for light duty vehicles, HGVs and buses.

Table 3-17 Average Traffic Speeds in Great Britain

Road Type		Cars & LGV (kph)	HGV (kph)	Buses (kph)
Urban Roads				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Conurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	30
	Motorways	97	82	82
Urban	Major principal roads	36	36	32
	Major trunk roads	53	52	32
	Minor roads	35	34	29
	Motorways	97	82	82
Rural Roads				
Rural single carriageway	Major roads	77	72	71
	Minor roads	61	62	62
Rural dual carriageway		111	90	93
Rural motorway		113	90	95

Vehicle fleet composition: by age, size, technology and fuel type

Vehicle kilometre data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. Automatic Number Plate Recognition (ANPR) data provided by DfT (2016, personal communication) are used to define the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) at over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for years 2007 to 2011, 2013 and 2015. Since 2011, measurements are made biennially. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

The ANPR data are primarily used to define the fleet composition on different road types for the whole of Great Britain (GB), rather than in specific regions. However, Devolved Administration (DA)-country specific vehicle licensing data (hereafter referred as DVLA data) are used to define the variation in some aspects of the vehicle fleet composition between DA country. The ANPR data are used in two aspects to define:

- Petrol and diesel mix in the car fleet on different road types (urban, rural and motorway).

- Variations in age and Euro standard mix on different road types

As the ANPR data are only available between 2007 and 2011 and for 2013 and 2015, it was necessary to estimate the road-type variations in the fleet for years before the ANPR became available otherwise a step-change would be introduced in the emission time-series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel vehicles as indicated by the DfT Vehicle Licensing Statistics. The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. For Northern Ireland, there were only four years of ANPR data (2010, 2011, 2013, and 2015) with reasonable number of observations being recorded. However, they did not show consistent trend or major difference in the proportion of diesel cars observed on different road types, and that the proportion was similar to that implied by the licensing data. As a result, it is assumed that there is no preferential use of diesel cars in Northern Ireland and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI. This leads to the vehicle km data for petrol and diesel cars on different road types in the UK shown in Table 3-16.

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have entailed the successive introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems.

Table 3-18 shows the regulations that have come into force up to 2015 for each vehicle type. The date into service is taken to be roughly the mid-point of the Directive's implementation dates for Type-Approval and New Registrations.

Table 3-18 Vehicles types and regulation classes

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
Cars	Petrol	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/7/1992
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
		EC 715/2007 (Euro 6)	1/4/2015
	Diesel	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/1/1993
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
		EC 715/2007 (Euro 6)	1/4/2015
LGVs	Petrol	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
	Diesel	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
HGVs and buses	Diesel (All types)	Pre-1988	
		88/77/EEC (Pre-Euro I)	1/10/1988
		91/542/EEC (Euro I)	1/10/1993
		91/542/EEC (Euro II)	1/10/1996
		99/96/EC (Euro III)	1/10/2001
		99/96/EC (Euro IV)	1/10/2006
		99/96/EC (Euro V)	1/10/2008
		EC 595/2009 (Euro VI)	1/7/2013
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st)	
		97/24/EC: all sizes (Euro 1)	1/1/2000
		2002/51/EC (Euro 2)	1/7/2004
		2002/51/EC (Euro 3)	1/1/2007

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The ANPR data provided direct evidence on the age mix of vehicles on the road and how this varied on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2011, 2013, and 2015, so it was important to consider how the trends observed in these limited years of ANPR data availability could be applied to earlier years. This was done by developing a pollutant and vehicle specific scaling factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with that obtained from the licensing and older mileage with age data. The fleet-adjustment scaling factors were averaged over the 2007-2011 period and were extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types have no effect on emissions. An overall year-, vehicle-, road- and pollutant-specific factor is then applied to GB average emission factors calculated from the vehicle fleet turnover model across the whole time-series to account for the variations in fleet profiles according to vehicle usage as evidenced from the ANPR data.

As no ANPR data were available for 2012, the average of the fleet-adjustment scaling factors for 2011 and 2013 was applied to the emission factors derived for the fleet in 2012 according to licensing data. As no ANPR data was available for 2014, the average of the fleet-adjustment scaling factors for 2013 and 2015 was applied to the emission factors derived for the fleet in 2014 according to licensing data.

For some pollutants, the emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The vehicle licensing statistics have shown that there has been a growing trend in the sales of bigger and smaller engine-sized cars in recent years, in particular for diesel cars at the expense of medium-sized cars. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, 2016c). In addition, the relative mileage done by different size of vehicles was factored into the ratios, to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2016b).

For other vehicle categories, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover eight different size classes of rigid HGVs, six different weight classes of artic HGVs, five different weight classes of buses and coaches and six different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types was obtained from vehicle licensing statistics (DfT, 2016c), or else provided by direct communication with officials in DfT, and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles.

DfT Road Freight Statistics (DfT, 2016d) provided a time series of vehicle km (2000-2014) travelled by different HGV weight classes based on the Continuing Survey of Road Goods Transport (CSRGT). The data show that there has been a gradual reduction in traffic activity for the rigid HGVs below 17 tonnes across the time-series, while there has been an increase in traffic activity for rigid HGVs over 17 tonnes over the period 2000 to 2008, after which there is a slight decrease in activity to 2014. Data for 2015 was not available and so the vehicle size mix for 2014 was applied to 2015. For artic HGVs, the dominant group continues to be those over 33 tonnes, and traffic activity from the below 33 tonnes category have been decreasing over time. This information has been used to allocate HGV vehicle km between different weight classes, although further assumptions have to be made as the inventory uses a more detailed breakdown of weight classes than those defined in the Road Freight Statistics.

Only limited information on the sizes of buses and coaches by weight exists; based on analysis of local bus operator information, it was assumed that 72% of all bus and coach km on urban and rural roads are done by buses, the remaining 28% by coaches, while on motorways all the bus and coach km are done by coaches.

Assumptions on the split in vehicle km for buses outside London by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t. For London buses, the split is defined by the fleet composition provided by Transport for London (TfL, 2016).

For motorcycles, the whole time series of vkm for 2-stroke and 4 stroke motorcycles by different engine sizes are based on a detailed review of motorcycle sales, population and lifetime by engine size. It was also assumed that mopeds (<50cc) operate only in urban areas, while only larger >750cc, 4-stroke motorcycles are used on motorways. Otherwise, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions estimated to be in the fleet. Research on the motorcycle fleet indicated that 2-stroke motorcycles are confined to the <150cc class.

Assumptions made about the proportion of failing catalysts in the petrol car fleet

A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008, only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT there is evidence that a high proportion of replacement catalysts before 2009 were not Type Approved and did not restore the emission performance of the vehicle to its original level (DfT, 2009b). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore, a change in the successful repair rate is taken into account for petrol LDVs adhering to Euro 3 standards from 20% prior to mid-2009 to 100% after 2009.

Voluntary measures and retrofits to reduce emissions
The inventory also takes account of the early introduction of certain emission standards and additional voluntary measures such as incentives for HGVs to upgrade engines and retrofit with particle traps to reduce emissions from road vehicles in the UK fleet. This was based on advice from officials in DfT.

Emissions from HGVs, buses, LGVs and black cabs (taxis) in London
The inventory pays particular attention to the unique features of the HGV and bus fleets in London. This is primarily so as to be able to account for measures taken to reduce emissions and improve air quality in London.

The effect of the Low Emission Zone (LEZ) on PM emissions from HGVs and buses from 2008 is taken into account by using a different Euro standard mix for HGVs within the LEZ area. To be compliant, vehicles must meet Euro III standards or above from 2008, but this is only in respect of PM emissions. With respect to other pollutant emissions, the London fleet of HGVs and buses (except TfL's buses) are assumed to be the same as the national fleet.

The specific features of the fleet of buses operated by Transport for London (TfL) were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used and it is assumed that approximately 78-87% of all bus km in London are done by TfL buses, the remainder being done by non-TfL buses having the composition of the national bus fleet, except from 2008 onwards where the fleet is modified to be compliant with the LEZ.

The inventory takes into account the introduction of the next phase of the London LEZ in January 2012 which requires the minimum of Euro 3 PM standards for larger vans and minibuses.

Information from TfL was also used to disaggregate the car vkm data between passenger cars and black cab taxis. This was important to take into account the high share of diesel powered light duty vehicles in areas of inner and central London where black cabs make up a high proportion of the traffic flow and the consequences this has on NO_x and PM emissions. Emission factors for London black cabs were assumed to be the same as a diesel LGVs. The measures introduced by TfL requiring a minimum of Euro 3 PM standards for black cabs in London are included.

Fuel quality
In January 2000, European Council Directive 98/70/EC came into effect relating to the quality of petrol and diesel fuels. This introduced tighter standards on a number of fuel properties affecting emissions. The principal changes in UK market fuels were the sulphur content and density of diesel and the sulphur and benzene content of petrol. The volatility of summer blends of petrol was also reduced, affecting evaporative losses. During 2000-2004, virtually all the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level sulphur content was not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2004, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

The introduction of road fuels with sulphur content less than 10ppm from January 2009 is taken into account according to Directive 2009/30/EC.

Hot Emission Factors
The emission factors for different pollutants are now taken from COPERT 5 and EMEP/EEA Emissions Inventory Guidebooks (2013 version with September 2014 update).

Regulated pollutants NO_x, CO, NMVOCs, $PM_{10/2.5}$

For NO_x (as NO_2), a notable change is the implementation of COPERT 5 NO_x (as NO_2) emission factors for Euro 5 diesel LGVs, reflecting more recent evidence on the real-world performance of these vehicles. These emission factors are higher than those used in COPERT 4v11, leading to an increase in estimated NO_x (as NO_2) emissions from diesel LGVs from 2011, relative to the previous submission. The latest factors for NO_x emissions from Euro 6 diesel cars (first introduced in 2015) were also adopted from COPERT 5.

COPERT 5 provides separate emission functions for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NO_x control. According to European Automobile Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available (it is not expected that the UK situation will vary from this European average).

NMVOC emissions are calculated from total hydrocarbon (THC) emission factors. THC emissions include CH_4. Therefore, NMVOC emissions are derived by subtracting CH_4 emissions from the THC emissions.

The COPERT NO_x, THC, CO and PM emission factors are represented as equations relating emission factor in g/km to average speed. These baseline emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors (for NO_x, CO and THC) to take account of degradation in emissions with accumulated mileage. The detailed methodology of emission degradation is provided in the 2013 EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013).

Scaling factors are also provided to take into account the effects of fuel quality since some of the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT NO_x, PM, CO and THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in Table 3-19. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

Various other assumptions and adjustments were applied to the emission factors, as follows.

The emission factors used for NMVOCs, NO_x (as NO_2), CO and PM are already adjusted to take account of improvements in fuel quality for conventional petrol and diesel, mainly due to reductions in the fuel sulphur content of refinery fuels. An additional correction was also made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels were based on the figures from HMRC (2016) and it was assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Account was taken of some heavy duty vehicles in the fleet being retrofitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO, and NMVOC emissions beyond that required by Directives. Emissions from some Euro II buses and HGVs were scaled down according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles.

Table 3-19 shows implied emission factors for each main vehicle category and pollutant for the UK fleet from 1990-2015. These are weighted according to the mix of Euro classes and technologies in the fleet each year as well as the proportion of kilometres travelled at different speeds and therefore with different emission factors. Implied emission factors over the whole time-series are also shown in Figure 3-2 to Figure 3-6. Because of minor revisions to the mix of Euro classes and technologies in the fleet each year as well as the proportion of kilometres travelled at different speeds, these implied emission factors are slightly different to the previous submission, even where emission factors by Euro class have not changed.

Table 3-19 UK fleet averaged hot exhaust emission factors for road transport

Pollutant	Source	Units	1990	1995	2000	2005	2010	2014	2015
CO	Petrol cars	g/km	7.3	5.7	3.0	1.9	0.93	0.61	0.56
	DERV cars		0.55	0.41	0.26	0.11	0.069	0.047	0.046
	LGVs		11	7.0	3.0	0.99	0.55	0.31	0.26
	HGVs		2.0	1.8	1.5	1.4	1.1	0.85	0.68
	Buses and coaches		3.5	3.3	1.9	1.5	1.3	1.3	1.2
	Mopeds and motorcycles		20	20	19	14	8.9	6.4	5.7
NO_x (as NO_2)	Petrol cars	g/km	2.5	1.8	0.99	0.54	0.21	0.11	0.10
	DERV cars		0.64	0.66	0.68	0.73	0.64	0.61	0.59
	LGVs		2.6	2.1	1.5	1.1	0.89	1.1	1.2
	HGVs		8.7	7.7	6.5	5.7	4.1	2.4	1.8
	Buses and coaches		12	11	9.5	8.3	6.7	5.1	4.4
	Mopeds and motorcycles		0.30	0.32	0.32	0.29	0.24	0.22	0.21
NMVOC	Petrol cars	mg/km	1100	821	405	206	72	36	32
	DERV cars		98	60	40	23	13	9.3	8.8
	LGVs		874	568	269	109	54	37	35
	HGVs		574	458	283	182	93	50	42
	Buses and coaches		1225	1112	596	320	161	97	83
	Mopeds and motorcycles		2514	2267	1948	1354	862	617	562
PM_{10}	Petrol cars	mg/km	5.7	4.2	2.4	1.7	1.2	1.1	1.1
	DERV cars		193	122	68	37	23	12	11
	LGVs		108	142	98	69	46	25	21
	HGVs		337	291	178	121	68	37	29
	Buses and coaches		544	515	261	152	89	61	52
	Mopeds and motorcycles		41	36	30	21	14	10	9.4
NH_3	Petrol cars	mg/km	1.7	20.9	66.7	49.4	36.7	21.2	18.4
	DERV cars		0.87	0.87	0.88	0.88	0.94	1.3	1.8
	LGVs		1.4	2.2	5.8	4.3	3.1	2.2	2.1
	HGVs		3.0	3.0	3.0	3.0	4.6	7.8	8.3
	Buses and coaches		3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Mopeds and motorcycles		1.9	1.9	1.9	1.9	1.9	2.0	2.0
B[a]p	Petrol cars	µg/km	0.48	0.43	0.31	0.21	0.16	0.14	0.14
	DERV cars		2.9	1.4	0.80	0.37	0.22	0.17	0.16
	LGVs		1.8	2.1	1.3	0.70	0.41	0.29	0.27
	HGVs		1.5	1.3	0.72	0.44	0.30	0.20	0.17
	Buses and coaches		2.6	2.3	1.3	0.75	0.51	0.37	0.33
	Mopeds and motorcycles		2.8	2.8	2.8	2.9	2.9	2.9	2.9

Figure 3-2 UK fleet averaged CO hot exhaust emission factors for road transport

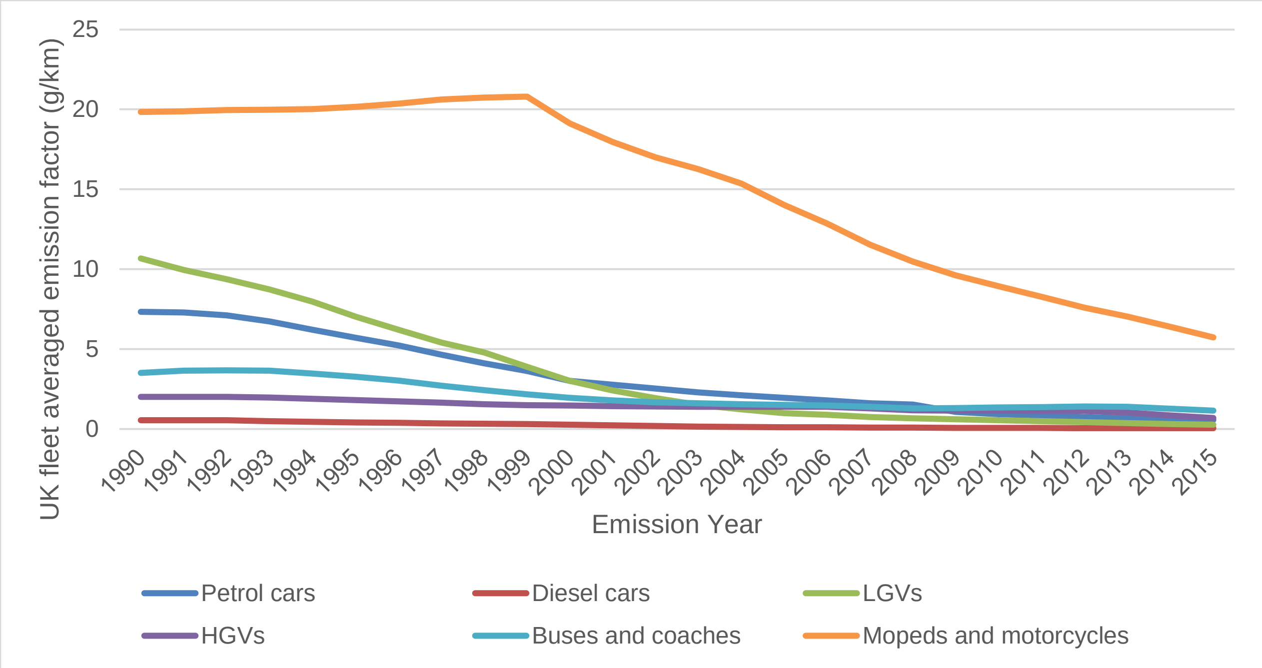


Figure 3-3 UK fleet averaged NO_x (as NO_2) hot exhaust emission factors for road transport

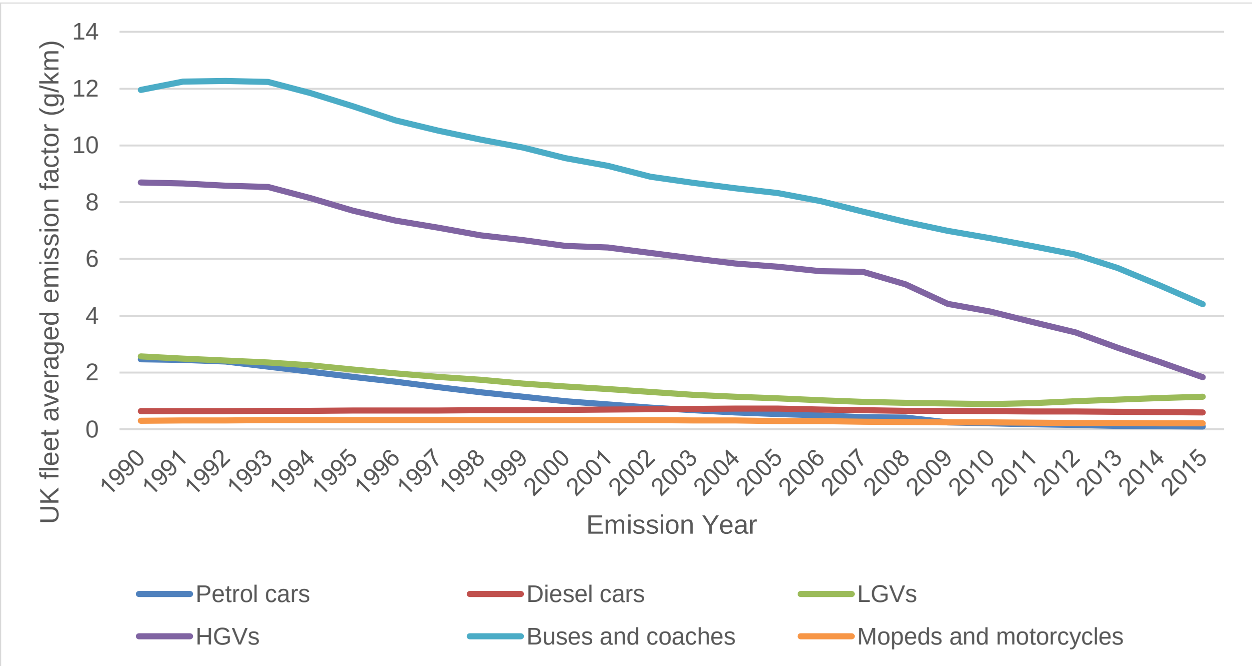


Figure 3-4 UK fleet averaged NMVOC hot exhaust emission factors for road transport

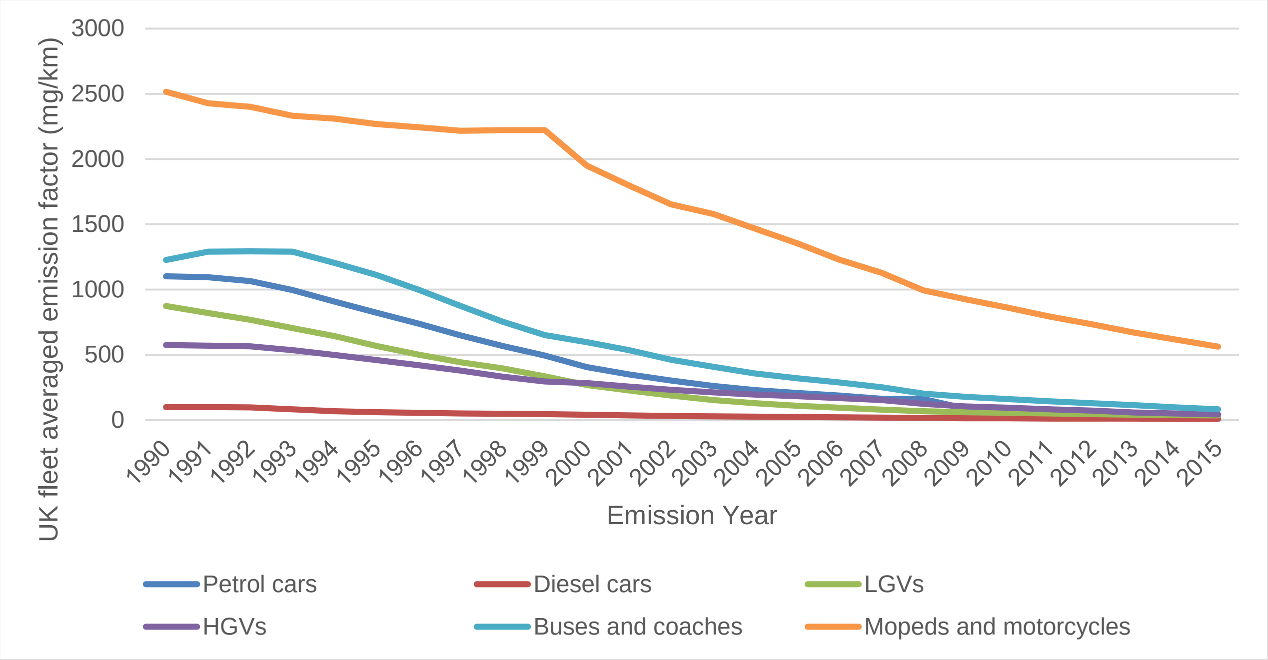


Figure 3-5 UK fleet averaged PM_{10} hot exhaust emission factors for road transport

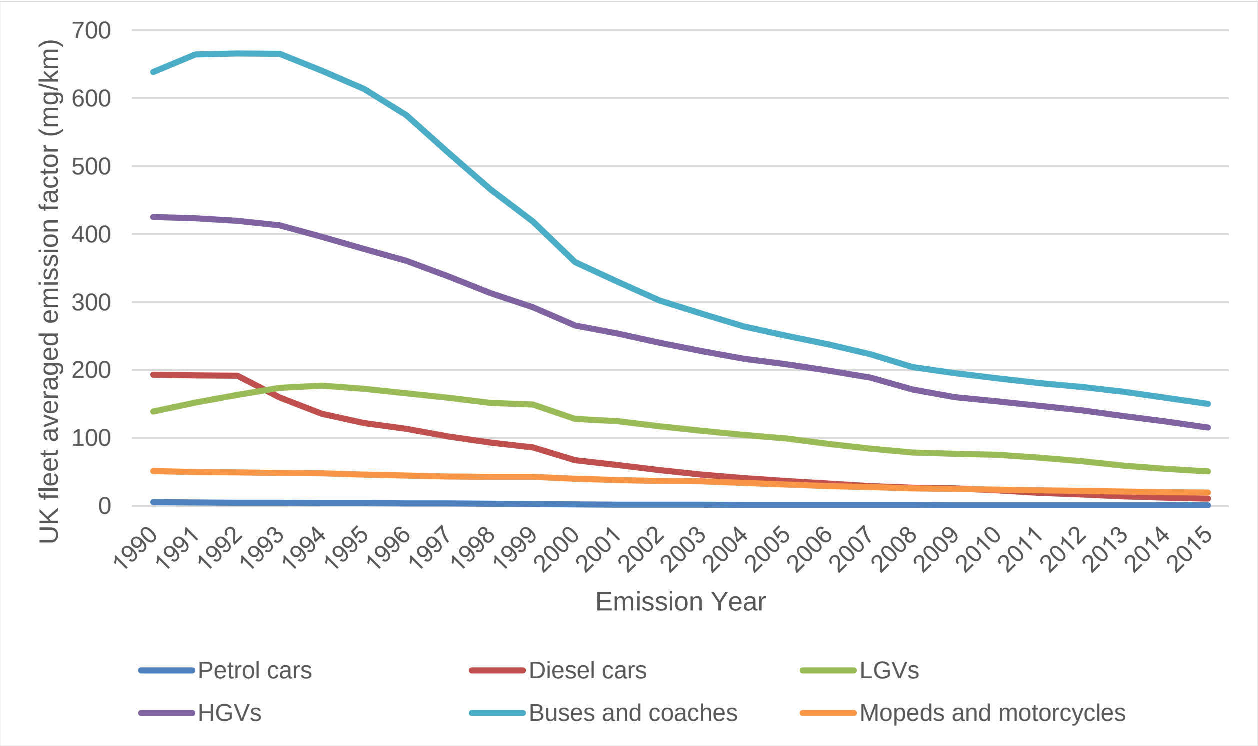
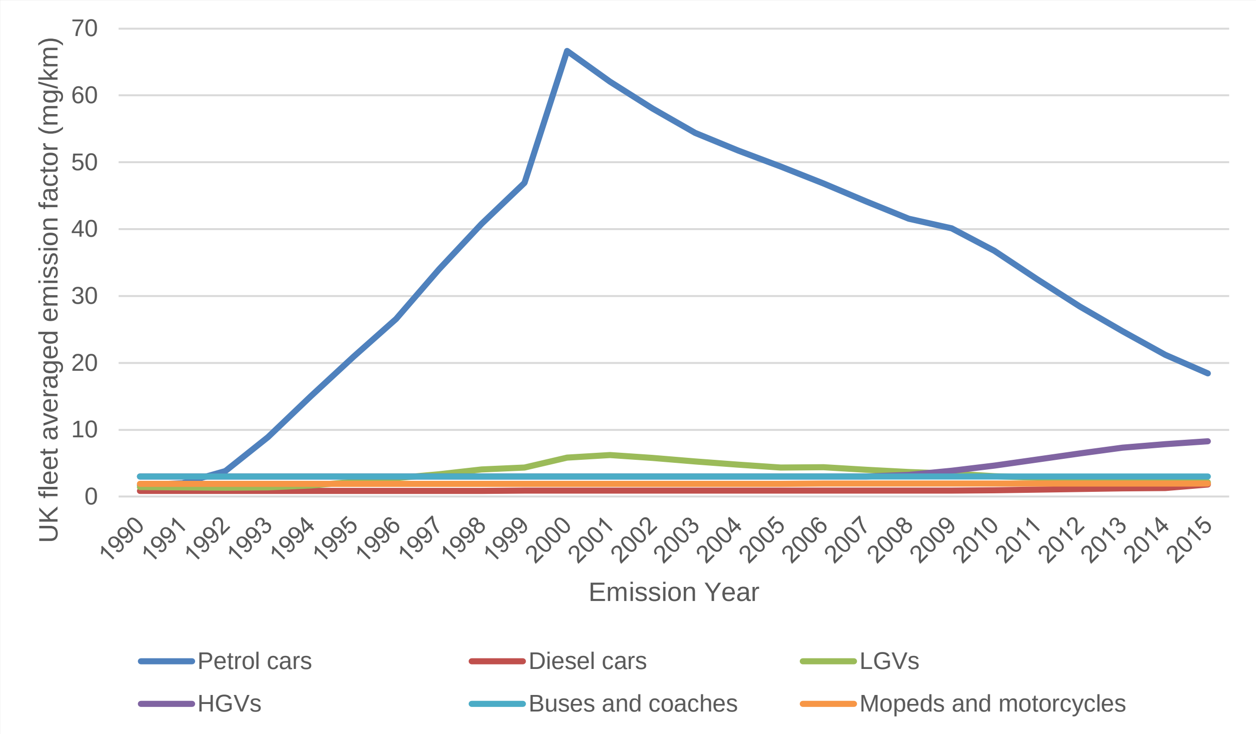


Figure 3-6 UK fleet averaged NH_3 hot exhaust emission factors for road transport



Non-regulated pollutants: NH_3, PAHs, **PCDD/PCDFs, PCBs, HCB**
Ammonia emissions from combustion sources are usually small, but significant levels can be emitted from road vehicles equipped with catalyst devices to control NO_x emissions. Nitrous oxides (N_2O), and ammonia emissions are an unintended by-product of the NO_x reduction process on the catalyst and were more pronounced for early generation petrol cars with catalysts (Euro 1 and 2). Factors for later petrol vehicle Euro standards and for diesel vehicles are much lower.

The emission factors for NH_3 for all vehicle types are based on the recommendation of the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013) and the COPERT 5 source.

For NH_3 emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content. The factors for diesel vehicles and motorcycles make no distinction between different Euro standards and road types and bulk emission factors are provided.

Table 3-19 and Figure 3-6 show the implied emission factors for NH_3 for each main vehicle category in the UK fleet from 1990-2015.

Polyaromatic hydrocarbons (PAHs) are emitted from exhausts as a result of incomplete combustion. The NAEI focuses on 16 PAH compounds that have been designated by the USEPA as compounds of interest using a suggested procedure for reporting test measurement results (USEPA, 1988). Road transport emission factors for these 16 compounds were developed through a combination of expert judgement and factors from various compilations. A thorough review of the DfT/TRL emission factors, available at https://www.gov.uk/government/publications/road-vehicle-emission-factors-2009 , was initially undertaken. Single emission factors were given for a number of PAHs, including the 16 USEPA species, for all driving conditions. Where possible, information from the database of emission measurements was used, however in the absence of such data, COPERT 4 emission factors were used. The factors were provided in g/km, and independent of speed (Boulter et al, 2009). The review indicated that data from additional sources should be reviewed, and as a result the NAEI emission factors have been derived from the following data sources or combination of sources:

- DfT/TRL emission factors (Boulter et al, 2009);
- EMEP/EEA emission inventory guidebook 2009, updated June 2010 (EMEP, 2009); and
- Expert judgement.

The expert judgement focused on how PAH emission factors change with Euro standard and technologies using trends shown by other pollutants as proxy. Consideration was largely based on whether the PAH species was volatile or condensed phase and either trends in NMVOC or PM emissions, respectively, were taken as proxy. The aim was to develop an internally consistent set of factors for each PAH species across the vehicle types and Euro classes.

Emission factors have been specified by vehicle type and Euro standard for all 16 PAHs. As an example, Table 3-19 shows the implied emission factors for benzo[a]pyrene for each main vehicle category for the UK fleet from 1990-2015.

Emission factors for PCDD/PCDFs are based on the EMEP/EEA Emissions Inventory Guidebook. The inventory also includes emission factors for PCBs and HCB, consistent with those in the EMEP/EEA Emissions Inventory Guidebook. However, the factors for petrol vehicles before 2000 were scaled up to take into account the much higher emissions from vehicles using leaded petrol. This assumption has been made in previous versions of the UK inventory and is consistent with information in the European dioxin inventory (http://ec.europa.eu/environment/archives/dioxin/pdf/stage1/road_transport.pdf).

Pollutant speciation

A number of pollutants covered by the inventory are actually groups of discrete chemical species and emissions are reported as the sum of its components. Of key interest to road transport is the speciation in emissions of the groups of compounds represented as NO_x, NMVOCs and PM.

Nitrogen oxides are emitted in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). The fraction emitted directly as NO_2 (f-NO_2) is of particular interest for air quality modelling and the inventory is required to provide estimates of the fraction emitted as NO_2 for different vehicle categories. Values of f-NO_2 are given in the EMEP/EEA Emissions Inventory Guidebook (2013) for different vehicle types and Euro standards. Based on these and the turnover in the fleet, the fleet-averaged values of f-NO_2 for each main vehicle class have been calculated and whilst not reported in the inventory, factors for the UK fleet are available on the UK's inventory website at http://naei.defra.gov.uk/data/ef-transport . This source is annually updated as new factors from COPERT or the Guidebook emerge; the set currently available were developed from fleet information and factors available in June 2016.

Particulate matter is emitted from vehicles in various mass ranges. PM emissions from vehicle exhausts fall almost entirely in the PM_{10} mass range. Emissions of $PM_{2.5}$ and smaller mass ranges can be estimated from the fraction of $PM_{2.5}$ in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given elsewhere in this report for different sources. Using information from the DfT/TRL emission factor review and EMEP/EEA Emissions Inventory Guidebook (2013), the fraction of PM_{10} emitted as $PM_{2.5}$ is assumed to be 0.95 for all vehicle exhaust emissions.

NMVOCs are emitted in many different chemical forms. Because of their different chemical reactivity in the atmosphere, the formation of ozone and secondary organic aerosols depends on the mix of NMVOCs emitted and the chemical speciation of emissions differs for different sources. The speciation of NMVOCs emitted from vehicle exhausts is taken from EMEP (2013).

3.3.3.5 Cold-Start Emissions

Cold start emissions are the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature. The excess emissions occur from petrol and diesel vehicles because of the lower efficiency of the engine and the additional fuel used when it is cold, but more significantly for petrol cars, because the three-way catalyst does not function properly and reduce emissions from the tailpipe until it has reached its normal operating temperature.

Cold start emissions are calculated following the recommendations made by TRL in a review of alternative methodologies carried out on behalf of DfT (Boulter and Latham, 2009). The main conclusion was that the inventory approach ought to take into account new data and modelling approaches developed in the ARTEMIS programme and COPERT 4 (EMEP, 2007). However, it was also acknowledged that such an update can only be undertaken once the ARTEMIS model and/or COPERT 4 have been finalised and that at the time of their study it was not possible to give definitive emission factors for all vehicle categories.

Boulter and Latham (2009) also stated that it is possible that the incorporation of emission factors from different sources would increase the overall complexity of the UK inventory model, as each set of emission factors relates to a specific methodology. It was therefore necessary to check on progress made on completing the ARTEMIS and COPERT 4 methodologies and assess their complexities and input data requirements for national scale modelling.

The conclusion from this assessment of alternative methodologies was that neither ARTEMIS nor a new COPERT 4 was sufficiently well-developed for national scale modelling and that COPERT 4 referred to in the EMEP/EEA Emissions Inventory Guidebooks still utilises the approach in COPERT III (EEA, 2000). COPERT III was developed in 2000 and is quite detailed in terms of vehicle classes and uses up-to-date information including scaling factors for more recent Euro standards reflecting the faster warm-up times of catalysts on petrol cars. COPERT III is a trip-based methodology which uses the proportion of distance travelled on each trip with the engine cold and a ratio of cold/hot emission factor. Both of these are dependent on ambient temperature. Different cold/hot emission factor ratios are used for different vehicle types, Euro standards, technologies and pollutants.

Cold start emissions are calculated from the formula:

$$E_{cold} = \beta \, . \, E_{hot} \, . \, (e^{cold}/e^{hot} - 1)$$

where

E_{hot} = hot exhaust emissions from the vehicle type
β = fraction of kilometres driven with cold engines
e^{cold}/e^{hot} = ratio of cold to hot emissions for the particular pollutant and vehicle type

The parameters β and e^{cold}/e^{hot} are both dependent on ambient temperature and β is also dependent on driving behaviour in particular the average trip length, as this determines the time available for the engine and catalyst to warm up. The equations relating e^{cold}/e^{hot} to ambient temperature for each pollutant and vehicle type were taken from COPERT III and were used with monthly average temperatures for central England based on historic trends in UK Met Office data.

The factor β is related to ambient temperature and average trip length by the following equation taken from COPERT III:

$$\beta = 0.6474 - 0.02545 \, . \, l_{trip} - (0.00974 - 0.000385 \, . \, l_{trip}) \, . \, t_a$$

where

l_{trip} = average trip length
t_a = average temperature

The method is sensitive to the choice of average trip length in the calculation. A review of average trip lengths was made, including those from the National Travel Survey, which highlighted the variability in average trip lengths available (DfT, 2007b). A key issue seems to be what the definition of a trip is according to motorist surveys. The mid-point seems to be a value of 10 km given for the UK in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013), so this figure was adopted.

The COPERT III method provides pollutant-specific reduction factors for β to take account of the effects of Euro 2 to Euro 4 technologies in reducing cold start emissions relative to Euro 1.

This methodology was used to estimate annual UK cold start emissions of NO_x (as NO_2), PM, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for each Euro standard of petrol cars. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

Cold start emissions of NH_3 were estimated using a method provided by the COPERT 4 methodology for the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013). The method is simpler in the sense that it uses a mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up., i.e. under “cold urban” conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle’s accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for NH_3 emissions from light duty vehicles are shown in Table 3-20, calculated for zero cumulative mileage and <30ppm S fuel. There are no cold start factors for HGVs and buses.

Table 3-20 Cold Start Emission Factors for NH_3 (in mg/km)

mg/km	Petrol cars and LGVs
Pre-Euro 1	2.0
Euro 1	38.3
Euro 2	43.5
Euro 3	4.4
Euro 4	4.4
Euro 5	12.7
Euro 6	12.7

All the cold start emissions are assumed to apply to urban driving.

3.3.3.6 Evaporative Emissions (1A3bv)

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The methodology for estimating evaporative emissions is based on the COPERT 4 simple approach from the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2007). This is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory, as concluded from a review by Stewart *et al*. (2009) and recommendations of a review carried out by TRL under contract to DfT (Latham and Boulter 2009).

There are three different mechanisms by which gasoline fuel evaporates from vehicles:

i) Diurnal Loss
This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through “tank breathing” will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

ii) Hot Soak Loss
This represents evaporation from the fuel delivery system when a hot engine is turned off and the vehicle is stationary. It arises from transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Carburettor float bowls contribute significantly to hot soak losses.

iii) Running Loss
These are evaporative losses that occur while the vehicle is in motion.

These emissions depend to varying degrees on ambient temperatures, volatility of the fuel, the size of vehicle, type of fuel system (carburettor or fuel injection and whether it uses a fuel return system) and whether the vehicle is equipped with a carbon canister for evaporative emission control. Since Euro 1 standards were introduced in the early 1990s, evaporative emissions from petrol cars and vans have been controlled by the fitting of carbon canisters to capture the fuel vapours which are then purged and returned to the engine manifold thus preventing their release to air. Evaporative emissions were particularly high from vehicles using carburettor fuel intake systems and these have been largely replaced by fuel injection systems on more modern vehicles which have further reduced evaporative losses.

COPERT 4 provides a method and emission factors for estimating evaporative emissions for detailed vehicle categories and technologies and also has the benefit of including factors for motorcycles. The vehicle classes are compatible with those available and currently used by the inventory in the calculation of exhaust emissions, although approximations and assumptions have been necessary to further divide vehicles into technology classes according to the type of fuel control systems used on cars (carburettor and fuel return systems) and carbon canisters fitted to motorcycles, given the absence of any statistics or other information available on these technologies relevant to the UK fleet. It has also not been possible to take into account the failure of VOC-control systems because of lack of data on failure rates and emission levels that occur on failure. The COPERT 4 method uses temperature and trip dependent emission factors, and it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure.

The application of the method for the UK inventory required the following input data and assumptions.

The number of petrol cars in the small, medium and large engine size range was required and was taken from national licensing statistics. All Euro 1+ vehicles are assumed to be equipped with carbon canister controls. However, the method provides different emission factors for different sizes of canisters. The numbers of vehicles in the UK equipped with different sized canisters is not available, but the EMEP/EEA Emissions Inventory Guidebook provides a table that correlates size of carbon canister with Euro emission class. Hence an assignment of the appropriate COPERT 4 evaporative emission factor can be made to Euro class in the UK fleet.

The method also requires additional information on the number of cars with carburettor and/or fuel return systems. Both these systems lead to higher emissions, the latter because fuel vapour being returned to the fuel tank is warm and therefore heats the fuel in the tank. Data are not available in the UK on the number of cars running with either of these systems, but it was assumed that all pre-Euro 1 cars would be with carburettor and that all Euro 1 onward cars would use fuel injection, but with fuel return systems, hence having high emission factors. The latter is a conservative assumption as some modern cars with fuel injection might be using returnless fuel systems and hence have lower emissions, but it was not possible to know this as there is no association with the car’s Euro class.

COPERT 4 provides different emission factors for six classes of motorcycles associated with engine cc, whether the engine operated as 2-stroke or 4-stroke and for the largest motorcycles, whether they were or were not equipped with a carbon canister. A review of the motorcycle fleet had been undertaken to yield most of the required information, but it was necessary to make a conservative assumption that no motorcycles are currently fitted with carbon canisters.

Trip information was required to estimate hot soak and running loss evaporative emissions. The information required is the number of trips made per vehicle per day and the proportion of trips finishing with a hot engine. The same trip lengths as used in the calculation of cold start emissions were used.

The COPERT 4 methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (2016), the COPERT 4 emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

The seasonal emission factors were applied based on the number of summer and winter days in each month. However, as the COPERT 4 emission factors are also classified by fuel vapour pressure, the number of summer and winter days in each month has been defined by whether the fuel sold in that month is either a winter or summer blend or a mixture of both. The information from UKPIA indicates the average vapour pressure of fuels sold in the UK in the summer, winter and also the transitional spring and autumn months. This information allows identification of summer and winter months for the purpose of assigning COPERT 4 evaporative emission factor (winter months have an average vapour pressure of 90 kPa or more and summer months have a vapour pressure of 70 kPa or less). In the transitional months (September, May), the equivalent number of winter and summer days in the month were calculated from the average vapour pressure for the month assuming a winter fuel vapour pressure of 90 kPa and a summer blend vapour pressure of 70 kPa. From this, weighted average evaporative emission factors could be derived for the month.

Further details of the methodology and tables of emission factors are given in the EMEP/EEA Emission Inventory Guidebook (EMEP, 2007).

An implied emission factor based on the population, composition of the fleet and trips made in 2015 is shown for petrol cars and motorcycles in Table 3-21. The units are in g per vehicle per day.

Table 3-21 Fleet-average emission factor for evaporative emissions of NMVOCs in 2015

g/vehicle.day	2015
Petrol cars	0.55
Motorcycles	1.59

3.3.3.7 Non-exhaust emissions of PM (1A3bvi and 1A3bvii)

Particulate matter is emitted from the mechanical wear of material used in vehicle tyres, brake linings and road surface.

Methods for calculating emissions from tyre and brake wear are provided in the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013) derived from a review of measurements by the UNECE Task Force on Emissions Inventories (http://vergina.eng.auth.gr/mech0/lat/PM10/). Emission factors are provided in g/km for different vehicle types with speed correction factors which imply higher emission factors at lower speeds. For heavy duty vehicles, a load correction factor is provided and tyre wear emissions depend on the number of axles. Further details are given in the AQEG (2005) report on PM.

Table 3-22 shows the PM_{10} emission factors (in mg/km) for tyre and brake wear for each main vehicle and road type based on the average speed data used in the inventory. There are no controls on emissions from tyre and brake wear, so the emission factors are independent of vehicle technology or Euro standard and are held constant each year. Emissions are calculated by combining emission factors with vehicle km data and are reported under NFR14 code 1A3bvi.

PM emissions from road abrasion are estimated based upon the emission factors and methodology provided by the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013). The emission factors are given in g/km for each main vehicle type and are constant for all years, with no road type dependence. The factors for PM_{10} (in mg/km) are shown in Table 3-23. The factors are combined with vehicle-km data to calculate the national emissions of PM from this source. Emissions from road abrasion are reported under 1A3bvii.

Table 3-22 Emission factors for PM_{10} from tyre and brake wear

mg PM_{10} /km		Tyre	Brake
Cars	Urban	8.7	11.7
	Rural	6.8	5.5
	Motorway	5.8	1.4
LGVs	Urban	13.8	18.2
	Rural	10.7	8.6
	Motorway	9.2	2.1
Rigid HGVs	Urban	20.7	51.0
	Rural	17.4	27.1
	Motorway	14.0	8.4
Artic HGVs	Urban	47.1	51.0
	Rural	38.2	27.1
	Motorway	31.5	8.4
Buses	Urban	21.2	53.6
	Rural	17.4	27.1
	Motorway	14.0	8.4
Motorcycles	Urban	3.7	5.8
	Rural	2.9	2.8
	Motorway	2.5	0.7

Table 3-23 Emission factors for PM_{10} from road abrasion

mg PM_{10}/km	Road abrasion
Cars	7.5
LGVs	7.5
HGVs	38.0
Buses	38.0
Motorcycles	3.0

Emissions of $PM_{2.5}$ and smaller mass ranges are estimated from the fraction of $PM_{2.5}$ in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given elsewhere in this report for different sources. Using information from the EMEP/EEA Emissions Inventory Guidebook (EMEP, 2013), the fraction of PM_{10} emitted as $PM_{2.5}$ for tyre wear, brake wear and road abrasion is shown in Table 3-24.

Table 3-24 Fraction of PM_{10} emitted as $PM_{2.5}$ for non-exhaust traffic emission sources

	$PM_{2.5}$ /PM_{10}
Tyre wear	0.7
Brake wear	0.4
Road abrasion	0.54

The particulate matter emitted from tyre and brake wear comprise various metal components. Based on information on the metal content of tyre material and brake linings, the metal emissions from tyre and brake wear are included in the inventory and calculated from the mass content of each metal component in the PM. Details on the metal emissions inventory are reported elsewhere.

3.3.4 Railways (1A3c)

A Tier 2 methodology is used for calculating emissions from Intercity, regional and freight diesel trains, as well as coal-fired heritage trains.

UK specific emission factors in g/vehicle (train) km are taken from the Department for Transport's Rail Emissions Model (REM) for different rail engine classes based on factors provided by WS Atkins Rail. From January 2012, the EU Fuel Quality Directive (2009/30/EC) required gas oil consumed in the railway sector to contain a maximum sulphur content of 10ppm. Prior to this, the sulphur content was obtained from UKPIA.

Gas oil consumption data was obtained from the Office of Rail and Road for passenger and freight trains for 2005-2014. This was combined with trends in train kilometres to estimate consumption for other years. Train km data from REM are used to provide the breakdown between train classes.

Details of Methodology
The UK inventory reports emissions from both stationary and mobile sources.

<u>Railways (stationary)</u>
The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported in Section 3.4. These emissions are based on fuel consumption data from BEIS (2016).

<u>Railways (mobile)</u>
Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity. In this sector, emissions are reported from gas oil and from coal used to power steam trains; the latter of which only contributes a small element.

Coal consumption data are obtained from DUKES. Estimates are made across the time-series from 1990-2015 and are believed to be due to consumption by heritage trains. For the air pollutants, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions from coal-fired steam trains.

The UK inventory reports emissions from trains that run on gas oil in three categories: freight, intercity and regional. These are reported under NFR14 code 1A3c Railways. Emission estimates are based on:

- Vehicle kilometres travelled and emission factors in grams per vehicle kilometre for passenger trains
- Train kilometres travelled and emission factors in grams per train kilometre for freight trains.

For Great Britain, vehicle kilometre data for intercity and regional trains are obtained from the UK's Department for Transport's Rail Emissions Model for 2009 to 2014 and then estimated for other years from train kilometre data from the Office of Rail and Road (ORR), National Rail Trends Yearbook (NRTY) and data portal. Train kilometre data for freight trains are obtained for all years from the Office of Rail and Road (ORR) National Rail Trends Yearbook (NRTY) and data portal.

Gas oil consumption by passenger and freight trains is obtained from the 2011 NRTY for the period 2005-2009 and from ORR's data portal for the years 2011 - 2014. No data are available for the years 1970 – 2004 and 2010, therefore fuel consumption for these years was estimated based on the trend in train kilometres. Consumption data is now available for 2015; however this data was published too late for inclusion in this year's inventory cycle, hence fuel consumption data for this year was also estimated based on the trend in train kilometres.

Fuel consumption by both passenger and freight rail has increased year on year alongside increases in freight / train kilometres travelled up to and including 2012; 2013 however saw a brief decline in activity across both passenger and rail activity, before increasing again in 2014. 2015 saw a decline in total train kilometres, which is reflected in the estimated fuel consumption.

For Northern Ireland, train kilometre data and fuel consumption data are provided by Translink, the operator of rail services in the region, and is calculated via the operator timetable.

Carbon and sulphur dioxide emissions are calculated using fuel-based emission factors and the total fuel consumed. Emissions of CO, NMVOC, NO_x (as NO_2) and PM are based on the vehicle / train kilometre estimates and emission factors for different train classes. The distribution of the train fleet by train class is determined based on:

- For passenger trains:
  - Vehicle train kilometres data for different train classes for 2009, 2010 and 2011 are derived from the Department for Transport's Rail Emissions Model. The fleet for other years is estimated based on the year of introduction of new engines and assuming that the new trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations,

- For freight trains:
  - Total billion tonne train kilometre data is taken from the NRTY and ORR. The breakdown by train class was obtained from the Department for Transport's Rail Emissions Model for 2009. The fleet for other years is estimated based on the year of introduction of new engines and assuming that the new freight trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations.

The emission factors shown in Table 3-25 are aggregate implied factors for trains running on gas oil in 2015, so that all factors are reported on the common basis of fuel consumption. These factors differ slightly to previous inventory versions, due to changes year on year in the composition of the rail fleet.

Table 3-25 Railway Emission Factors for 2015 (kt/Mt fuel)

	NO_x (as NO_2)	CO	NMVOC	SO_x (as SO_2)	PM_{10}
Freight	105.5	15.1	6.0	0.02	1.4
Intercity	41.6	8.6	3.0	0.02	3.4
Regional	46.9	9.1	2.4	0.02	1.4

The 2015 inventory now includes estimates of NH_3 emissions from railways. This is in response to recommendations from the 2016 CLRTAP Stage 3 Review of the UK inventory. An emission factor of 0.01kt/Mt fuel was taken from Tables 3.2-3.4 of the 1.A.3.c Railways chapter of the EMEP Emissions Inventory Guidebook (EMEP (2016)).

3.3.5 Navigation (1A3d, 1A4ciii, 1A5b)

The UK inventory provides emission estimates for domestic coastal shipping and inland waterways (1A3dii), fishing (1A4ciii), international marine bunkers (1A3di) and naval shipping (1A5b). International marine bunker emissions are reported as a Memo item and are not included in the UK national totals.

The method for estimating domestic coastal shipping is centred around a procedure developed by Entec (now AMEC Foster Wheeler) under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters. The method uses a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The approach represents a Tier 3 method for estimating emissions from domestic water-borne navigation in the CLRTAP Guidelines for national inventories.

Further Tier 3 approaches are used to estimate emissions from inland waterways, and other emissions away from UK waters for which the UK is responsible, including fishing activities and vessel movements between the UK and overseas territories. Emissions from military shipping are estimated from information provided by the MOD.

The balance in total marine fuel consumption is used to define emissions from international marine bunkers (1A3di) following a Tier 2 approach.

3.3.5.1 Overall Approach

Prior to the 2009 inventory (reported in 2011), emission estimates for coastal and international marine were based on total deliveries of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES). This led to very erratic time series trends in fuel consumption and emissions which bear little resemblance to other activity statistics associated with shipping such as port movement data. The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are understood to be an accurate representation of the total amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption.

The shipping inventory developed by Entec (2010) provides estimates of shipping for journeys that can be classified as domestic, for journeys departing from or arriving at UK ports on international journeys and for journeys passing through UK shipping waters, but not stopping at UK ports, nor using UK fuels. The detailed study covered movements in only one year, 2007, but Entec used proxy data to backcast movements and fuel consumption to 1990 and forward cast to 2009. A methodology consistent with that described by Entec (2010) has been used to forward cast to 2015.

Emissions from domestic coastal shipping estimated by Entec are included in national inventory totals (1A3dii). Other methods are used to estimate emissions from other navigation sources not covered by Entec that must be included in the UK totals. These are emissions from military shipping, inland waterways, fishing in waters outside the Entec study area and emissions from vessel movements between the UK and overseas territories.

To retain consistency with the total fuel consumption for navigation in DUKES, the balance between DUKES and the amount of fuel calculated for domestic navigation and other sources included in UK totals is assigned to international navigation and reported as a Memo item.

A summary of the overall approach indicating the sources of activity data and emission factors is shown in Table 3-26.

Table 3-26 Sources of activity data and emission factors for navigation

		Source	NFR14	Activity data – Source	Activity data – Base year	Activity data – Time-series	Emission factors
DUKES total marine fuel consumption (A)	Domestic (B)	Domestic coastal	1A3dii	Entec (2010) based on detailed vessel movement data (LMIU and AIS)	2007	DfT port movement data to scale from 2007 to other years	Entec (2010), EMEP/EEA Guidebook, UKPIA (2016)
		Fishing in UK sea territories	1A4ciii	Entec (2010) based on detailed vessel movement data	2007	MMO fish landing statistics to scale from 2007 to other years	Entec (2010), EMEP/EEA Guidebook, UKPIA (2016)
		Fishing in non-UK sea territories	1A4ciii	MMO data on fish landings by sea territory from 1994-2014 and estimates of fish landed per trip			Entec (2010), EMEP/EEA Guidebook, UKPIA (2016)
		Naval	1A5b	MoD data on fuel consumption by naval vessels			Assumed same as international shipping vessels using gas oil
		Shipping between UK and OTs	1A3dii	DfT Maritime Statistics and OT port authorities: number of sailings between UK and OT	2000-2015	Trends for years before 2000 based on trends in fuel consumption derived by Entec for international shipping and trends in DfT data on number of cruise passengers	Assumed same as international shipping vessels using fuel oil
		Inland waterways	1A3dii	Based on estimates of vessel population and usage estimates using data from various sources	2008	Statistics on expenditure on recreation (ONS), tourism (Visit England), port freight traffic (DfT), inland waterways goods lifted (DfT) used to scale from 2008	EMEP/EEA Guidebook, UKPIA (2016)
	International (C)		1A3di	Fuel consumption difference between DUKES total marine fuel consumption and domestic navigation calculated above (C=A-B)			Implied emission factor for international shipping from Entec (2010)

Details in the approach for each of these parts of the inventory for navigation are given in the following sections, including the methodologies for inland waterways, naval shipping, and fishing outside UK waters and shipping movements between the UK and Overseas Territories. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on shipping vessel movements are given in the Entec (2010) report.

3.3.5.2 Domestic Navigation

3.3.5.2.1 Coastal shipping (1A3dii)

The method used for calculating domestic shipping is based on a one-off assessment of activity data in 2007, followed by extrapolation using proxy data to generate the time series for individual sources up to 2015.

a) Activity data for 2007

Entec developed a gridded emissions inventory from ship movements within waters surrounding the UK including the North Sea, English Channel, Irish Sea and North East Atlantic. The study area was 200 nautical miles from the UK coastline and fuel consumption and emissions were resolved to a 5x5km grid and included emissions from vessels cruising at sea and manoeuvring and at berth in port.

The Entec inventory was based on individual vessel movements and characteristics data provided by Lloyd's Marine Intelligence Unit (LMIU) for the year 2007 supplemented by Automatic Identification System (AIS) data transmitted by vessels to shore with information about a ship's position and course. A major part of the Entec study was to consider vessel movements not captured in the LMIU database. These were known to include small vessels and those with multiple callings to the same port each day, such as cross-channel passenger ferries. To assess this, Entec carried out a detailed comparison between the LMIU data and DfT port statistics. The DfT port statistics (DfT, 2008b) are derived from primary LMIU data in combination with estimates from MDS-Transmodal for frequent sailings missing from the LMIU database. The DfT port data are reported as annual totals by port and ship type in Maritime Statistics and refer to movement of all sea-going vessels >100 Gross Tonnage (GT) involved in the movement of goods or passengers. In this comparison, special consideration was given to movements involving small vessels <500 tonnes, fishing vessels and movements from and to the same port. Missing from both data sources are movements by tugs, dredgers, research vessels and other vessels employed within the limit of the port or estuary as well as small pleasure craft.

The comparisons showed the extent by which the LMIU data underestimated port arrivals for each port most likely from missing vessels <300 GT with multiple callings each day. A more detailed analysis highlighted the particular movements underestimated in each port by the LMIU database and from this an estimate could be made as to the missing fuel consumption and emissions which needed to be incorporated into the final gridded inventory. The main outcome of the analysis was a series of scaling factors by which fuel consumption derived for the LMIU database (as described below) were uplifted for each vessel category involved in domestic and international movements.

The LMIU movement data included vessel type and speed. The vessel types were grouped into the following eight vessel categories:

- Bulk carrier
- Container ship
- General cargo
- Passenger
- Ro-Ro cargo
- Tanker
- Fishing
- Other

This categorisation marks the differences between engine and vessel operation between different vessel types and along with the vessel size gives an indication of the likely fuel used, whether fuel oil or marine diesel oil/gas oil (marine distillate).

Fuel consumption and emissions were calculated for each of these vessel categories for different operations. Vessel speeds were combined with distance travelled to determine the time spent at sea by each vessel. Entec undertook a detailed analysis of port callings where a significant proportion of emissions occur. The analysis considered time-in-mode for manoeuvring, hotelling in ports and loading and unloading operations.

The LMIU data were analysed to determine engine characteristics that influence fuel consumption and emissions for each vessel type. This included engine size, engine type and any installed abatement technology, together with fuel type, engine power and engine speed for both the main ship engine and auxiliary engines.

Fuel types were assigned depending on whether the vessel is travelling within or outside a Sulphur Emission Control Area (SECA). The area defined as a SECA was as defined in the Sulphur Content of Marine Fuels Directive (SCMFD) which came into force in July 2005 setting a maximum permissible sulphur content of marine fuels of 1.5%. Around the UK coast, the SECA came into effect in August 2007 covering the North Sea and English Channel and sulphur limits also apply for passenger vessels between EU ports from August 2006. For the purposes of the inventory, it was assumed that the sulphur limit applied to all vessels in the SECA for the full 2007 calendar year and on this basis all shipping fuel used within a SECA was either marine diesel oil (MDO) or marine gas oil (MGO).

For vessel movements outside the SECA, vessels were assumed to be using either residual fuel oil (with a higher sulphur content) or MGO or MDO. Entec made the allocation according to vessel type and whether the engine was the main ship engine or auxiliary engine. Details are given in Entec (2010).

The detailed Tier 3 approach used by Entec is able to distinguish fuel consumption and emissions between domestic movements from one UK port to another and UK international movements between a UK port and a port overseas. This enables the correct activities and emissions to be allocated to the NFR14 category 1A3dii Domestic Water-borne Navigation.

The Entec inventory excluded emissions and fuel consumption from military vessel movements which are not captured in the LMIU and DfT database. Naval shipping emissions are reported separately using fuel consumption data supplied by the MoD. The Entec study did not cover small tugs and service craft used in estuaries, private leisure craft and vessels used in UK rivers, lakes and canals. These were captured in the estimates for inland waterways described below.

Fishing was one of the vessel categories treated by Entec, so this enables emissions from fishing vessels to be reported separately under the NFR14 category 1A4ciii. However, Entec only covered emissions from fishing activities occurring within the UK waters study area extending 200 nautical miles from the UK coast. Emissions from UK fishing activities outside this area which must be included in the UK national totals were estimated by a different approach described later.

b) Time series trends in activity data

The LMIU data used by Entec only covered vessel movements during the 2007 calendar year. Applying the same approach to other years required considerable additional time and resources, so an alternative approach was used based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2015 from the 2007 base year emissions. The variables that were considered were:

- Trends in vessel movements over time affected by changes in the number of vessels and their size.
- Trends in fuel type in use over time reflecting the era before the introduction of SECAs which would have permitted higher sulphur content fuel to be used

The key consideration was the trend in vessel movements over time. For this, DfT’s annual published Maritime Statistics were used as proxies for activity rate changes which were taken to be indicators of fuel consumed. A range of time-series trends back to 1990 from the DfT statistics are available and appropriate data were assigned to different vessel categories, differentiating between international and domestic movements. Details are given in the Entec (2010) report, but in brief:

- All ports traffic data based on tonnes cargo for domestic and international movements was assigned as an indicator for the bulk carrier, general cargo and tanker vessel categories. Trends were available from 1990-2015.

- All ports main unitised statistics reported as number of units for domestic and international movements was assigned as an indicator for the container ship and Ro-Ro cargo vessel categories. Trends were available from 1990-2015.
- International and domestic sea passenger movements reported as number of passengers was assigned to the passenger vessel category

A time-series of tonnes fish landed in the UK provided in UK Sea Fisheries Statistics by the Marine Management Organisation was used for the domestic fishing vessels category (MMO, 2016).

The Entec (2010) report shows the trends in each of the relevant statistics relative to the 2007 base year level. Figure 13.1 in that report shows that before 2007, all statistics were showing a growth in the level of activity from 1990 with the exception of three. Since 2007, there has tended to be a downward trend in these activities that has continued to 2015.

It was assumed that 2007 heralded the introduction of marine gas oil and marine diesel oil consumption by vessels that had previously used residual fuel oil in the SECA around UK coasts. Thus in years between 1990-2006, all vessels except fishing and those in the ‘other’ category were assumed to be using fuel oil for their main engine. It was also assumed that passenger vessels outside the SECA started to use MDO in 2007 in order to comply with the SCMF Directive having previously been using fuel oil. Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007.

Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table 3-27 Assumed sulphur content of fuel for 2007

	Sulphur content of fuel (2007)
Marine gas oil	0.2%
Marine diesel oil	1.5%
Residual fuel oil	2.7%

Such figures were based on assumptions from CONCAWE and Entec (2005).

As described in the revised MARPOL Annex VI, the maximum permitted sulphur content of marine fuels for vessels operating in a SECA became 1.5% in 2007, reducing to 1% from 1 July 2010 and 0.1% from January 2015. The average sulphur content of Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) for domestic coastal shipping assumed by Entec was around 1% in 2007, i.e. below the 2010 limit for a SECA. Therefore, the overall sulphur content and SO_2 factors for consumption of gas oil (the average of MDO and MGO) was held constant from 2007-2014 at 1% and assumed to apply to all domestic vessels operating around the UK. The sulphur content and corresponding SO_2 factor was reduced to 0.1% in 2015 in line with the tighter limits that come into effect that year.

Fishing vessels were assumed by Entec to be using MGO with a sulphur content of 0.2% in 2007 and 0.1% from 2008 onwards.

Other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2015 time-series. Information from UKPIA and BEIS shows that fuel oil is still used for marine consumption. UKPIA indicate that two types of bunker fuel oil are supplied for consumption with different sulphur contents for use inside and outside SECAs. For domestic consumption of fuel oil, it is assumed that fuel oil meeting the SECA limits is used which according to UKPIA had a sulphur content of 1.3% in 2008 falling to 0.9% in 2011. The higher sulphur content fuel oil is assumed to be used for international shipping only. According to UKPIA, these range from 2.2% in 2008 to 1.3% sulphur in 2015. These are below the global MARPOL limit on sulphur content for marine fuels outside SECAs of 4.5% up to January 2012 and 3.5% since January 2012.

c) Emission factors

Entec calculated fuel consumption and emissions from g/kWh emission factors appropriate for the engine type and fuel type for operations “at sea” cruising, “at berth” when stationary in port and for “manoeuvring” while entering and leaving port. The 2007 emission factors and formulae used for calculating emissions are given in the Entec report. As well as the time spent cruising, in berth and manoeuvring, the formulae used the installed engine power and average load factor for the main ship engine and auxiliary engines.

The emission factors used by Entec come from amendments to an earlier set of emission factors compiled by Entec during a study for the European Commission (Entec, 2002, 2005). These largely originate from Lloyds Register Engineering Services and a study by IVL.

The Entec study considered only fuel consumption and CO_2 emissions and emissions of NO_x (as NO_2), SO_2, PM and NMVOCs.

Emission factors for SO_2 depend on the sulphur content of the fuel, as discussed earlier. A new method was introduced in the 2013 inventory compilation using information from the inventory mapping improvement programme on the share of gas oil used during berthing in ports and at sea inside and outside SECAs to feed into the national estimates of shipping emissions. This was to take into account that since January 2010, vessels at berth for over 2 hours must use fuels with a sulphur content less than 0.1%. The share of fuel used at berth and at sea was used to develop a weighted SO_2 factor for all gas oil used for domestic and international shipping. Fuel consumption information from the mapping is based on the spatial distribution of fuels used for different operations according to the Entec study.

For NO_x (as NO_2), the factors took into account limits on emissions from engines installed on ships constructed or converted after 1 January 2000, as required to meet the NO_x Technical Code of the MARPOL agreement. As the age of the engine is identified in the LMIU dataset, an average factor for engines in 2007 could be determined. For each year, an estimated engine replacement rate was used to estimate the proportion of pre- and post-2000 engines in the fleet and from this a weighted NO_x emission factor was derived. It was assumed that emission factors were constant in years before 2000.

Emission factors for PM taken from the Entec (2005) study for the European Commission were adjusted where necessary by Entec to take account of changes in sulphur content of fuel each year using relationships between PM emissions and fuel sulphur content taken from Lloyd’s Register. Factors for NMVOCs are unchanged from those in Entec (2005).

For pollutants not covered in the Entec (2010) study emission factors in units g/kg fuel were taken from the EMEP/EEA guidebook and are assumed to remain constant over the time-series.

The 2015 inventory now includes estimates of NH_3 emissions from shipping. There are no factors for NH_3 emissions from shipping in the EMEP/EEA Guidebook (2016). It was deemed reasonable to assume the emission factors would be the equivalent to those of a diesel railway train. That emission factor used is the Tier 2 NH_3 emission factor from Tables 3.2-3.4 of the 1.A.3.c Railways chapter (EMEP (2016)). This emission factor, in mass-based units, is 10 g/tonne fuel.

d) Summary of fuel consumption trends and implied emission factors

A summary of fuel consumption trends for coastal shipping and implied emission factors for 2015 are provided in Section 3.3.5.4.

3.3.5.2.2 Military shipping (1A5b)

Emissions from military shipping are reported separately under NFR14 code 1A5b. Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Maritime Analysis Group of the MoD (MoD, 2016). Data are provided on a financial year basis so adjustments were made to derive figures on a calendar year basis.

The time-series in fuel consumption from military shipping is included with that for coastal shipping in Section 3.3.5.4.

Implied emission factors derived for international shipping vessels running on marine distillate oil (MGO and MDO) from the Entec (2010) study were assumed to apply for military shipping vessels.

3.3.5.2.3 Emissions from Deep Sea Fishing in Sea Territories outside UK Waters (1A4ciii)

The Entec study covers only domestic emissions from fishing vessels that stay within UK waters (covering a sea area up to 200 nautical miles from the UK coast) and leaving from and returning to UK ports. Emissions are estimated separately for UK commercial fishing activities occurring in waters outside the Entec study area. These emissions should be included in the UK national totals.

A Tier 2 approach was used to estimate emissions from deep sea trawlers heading out of the UK waters, fishing and then returning to the UK.

a) Activity data

The Marine Management Organisation (MMO)[29] produces a report annually on the UK fishing industry entitled "*UK Sea Fisheries Statistics*"[30]. This is classed as a National Statistics Publication. This report gives the tonnes of fish landing into the UK and abroad by UK vessels by **area of capture**. The areas of capture are listed in terms of the ICES[31] sea area classification system. The sea areas covered by Entec are broadly the ICES areas IV, V, VI and VII. The approach considered activities outside these areas. According to the MMO reports, the other areas where the UK actively fishes are listed below:

- Barents Sea/Murman Coast (I)
- Norwegian Coast (IIa)
- Bear Island & Spitzbergen (IIb)
- Bay of Biscay (VIII)
- East Coast of Greenland (XIV)
- North Azores (XII)
- Other Areas

The MMO reports give tonnes of fish landed in the UK from each of these areas from 1994-2015 (see for example, Table 3.8 in the 2015 Fisheries statistics).

The approach involved calculating the fuel used by the fleet to reach and return from these "non-UK" sea areas and the fuel consumed whilst fishing in the areas.

To calculate the fuel used to reach and return from these non-UK ICES sea areas it is necessary to know:

- The number of vessel trips to non-UK ICES areas, based on average tonnes fish landed per trip
- The distance from a UK port to a point in the ICES sea area
- The average vessel speed in order to estimate the time taken to reach the sea area
- The typical engine power of the types of vessels used
- Time spent fishing in the sea areas

[29] The MMO is an executive non-departmental public body (NDPB) incorporating the work of the Marine and Fisheries Agency (MFA) and marine-related powers and specific functions previously associated with BEIS and the Department for Transport (DfT)

[30] https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics

[31] ICES is the International Council for the Exploration of the Sea. See for example http://www.fao.org/docrep/009/a0210e/a0210e12.jpg

Details of the methods and sources of information used to estimate these are given in the UK's National Inventory Report for Greenhouse Gas emissions and are not repeated here (Brown et al, 2016).

The time-series in fuel consumption by fishing in non-UK waters is included with that for fishing in domestic UK waters in Section 3.3.5.4.

b) Emission factors

A specific fuel consumption factor of 203 g/kWh was used to calculate total fuel consumption by UK vessels involved in fishing outside UK waters in conjunction with rated engine power, load factor and total travel time. The fuel consumption factor was taken from Table 3-4 in the EMEP/EEA Emissions Inventory Guidebook 2009 for a medium- and high-speed diesel engine using MDO/MGO.

All the fuel used for deep sea fishing in non-UK waters is assumed to be gas oil sourced in the UK. The emission factors are those used by Entec for fishing vessels in UK waters supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Implied emission factors for 2015 derived for all fishing vessels are shown in Section 3.3.5.4.

3.3.5.2.4 Emissions from Vessel Movements between the UK and Overseas Territories (1A3dii)

Emissions are estimated for vessel movements between the UK and Overseas Territories. These were not included in the Entec study, but need to be included in the UK national totals.

a) Activity data

There are no published data on the number and types of voyages between the UK and overseas territories (OTs). However, officials at the UK Department for Transport were able to interrogate their ports database which forms the basis of the less detailed information published in DfT's Maritime Statistics. This included information on freight shipping movements and passenger vessel movements. Additional information on passenger vessel movements were gathered from individual OT port authorities.

For freight shipping, the DfT were able to provide the number of trips made between a UK port and an OT port by each unique vessel recorded. The information provided the type of vessel and the departure and arrival port. Figures were provided for all years between 2000 and 2015.

The information on the type of vessel was used to define:

- The average cruise speed of the vessel
- The average main engine power (in kW), and
- The specific fuel consumption factor (g/kWh)

This information was taken from the EMEP (2013). Distances for each voyage were taken from http://www.portworld.com/map/. This has a tool to calculate route distance by specifying the departure and arrival ports.

Using the distance, average speed, engine power and fuel consumption factor it was possible to calculate the amount of fuel consumed for every voyage made.

DfT were unable to provide the detailed port data for years before 2000. The individual OT port authorities also did not have this information. The trends in fuel consumption calculated by Entec for all UK international shipping from 1990 to 2000 (based on less detailed UK port statistics) were used to define the trend in fuel consumption between the UK and OTs over these years.

For passenger vessels, the information held by OT port authorities indicated the only movements were by cruise ships (i.e. not ferries). Detailed movement data were held by the port authority of Gibraltar listing all voyages departing to or arriving from the UK back from 2003 to 2012. The DfT also held information on the number of UK port arrivals by cruise ships from the OTs, but only between 1999 and 2004. This is unpublished information and was provided via direct communication with DfT officials.

The data held by DfT showed the majority of sailings were from Gibraltar and the data were consistent with the information provided by the Gibraltar port authority. However, the DfT data also showed a total 3 arrivals from the Falkland Islands between 1999 and 2004.

This information was combined to show the total number of cruise ship movements between the UK and OTs from 1999 to 2015.

The same source of information as described above was used to define the distances travelled, cruise speed, engine power and fuel consumption factor to calculate total fuel consumption by cruise ships between the UK and each OT. The information for passenger ships was taken from the EMEP Guidebook.

No cruise ship information was available before 1999 from either DfT or the individual OT port authorities. Trends in the total number of passengers on cruises beginning or ending at UK ports between 1990 and 1999 published in DfT's Maritime Statistics (from Table 3.1(a) UK international short sea passenger movements, by port and port area: 1950 – 2009) were used to define the trend in fuel consumption by cruise ships between the UK and OTs over these years.

The total fuel consumed by vessels moving between the UK and each OT was calculated as the sum of all fuel consumed by freight and passenger vessels. This was calculated separately for movements from the UK to each OT and from each OT to the UK.

The time-series in fuel consumption from the UK to OTs is shown in Section 3.3.5.4.

b) Emission factors

All fuel used for voyages between the UK and OTs is assumed to be fuel oil. The emission factors used are average factors implied by Entec for all vessels involved in international voyages (see below) supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Implied emission factors for 2015 derived for vessels using fuel oil for international voyages including to/from the OTs are shown in Section 3.3.5.4.

3.3.5.2.5 Emissions from Inland Waterways (1A3dii)

The category 1A3dii Waterborne Navigation must include emissions from fuel used for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. These small vessels were not included in the Entec study.

The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts. The UK has no national fuel consumption statistics on the amount of fuel used by inland waterways in DUKES, but they are included in the overall marine fuel statistics. A Tier 3 bottom-up approach based on estimates of population and usage of different types of inland waterway vessels is used to estimate their emissions. In the UK, all emissions from inland waterways are included in domestic totals.

The methodology applied to derive emissions from the inland waterways sector uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP, 2007; EMEP, 2009). The inland waterways class is divided into four categories and sub-categories:

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    - recreational craft operating on inland waterways;
    - recreational craft operating on coastal waterways;

  - o workboats;
- Personal watercraft i.e. jet ski; and
- Inland goods carrying vessels.

Details of the approach used are given in the report by Walker et al (2011).

a) Activity data for 2008

A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

The methodology used to estimate the total amount of each fuel consumed by the inland waterways sector follows that described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009) where emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi$$

where:
E = mass of emissions of pollutant i or fuel consumed during inventory period,
N = source population (units),
HRS = annual hours of use,
HP = average rated horsepower,
LF = typical load factor,
EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker *et al.*, 2011). Some smaller vessels also run on petrol engines.

Walker at al. (2011) and Murrells *et al.* (2011) draw attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap.

b) Time series trends in activity data

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time series 1990 – 2015:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on “Recreation and culture”[32]. No data were available for this dataset after 2009, therefore a second dataset was used to estimate the activity from 2010: OECD. Stat data (Final consumption expenditure of household, UK, P31CP090: Recreation and culture)[33];

- Commercial passenger/tourist craft – Visit England, Visitor Attraction Trends in England 2015, Full Report (Page 14: "Total England Attractions")[34];

- Service craft (tugs etc.) – DfT Maritime Statistics, Port freight traffic. Table PORT0102 - All UK port freight traffic, foreign, coastwise and one-port by direction[35]; and

- Freight – DfT Waterborne Freight in the United Kingdom, Table DWF0101: Waterborne transport within the United Kingdom (Goods lifted - UK inland waters traffic - Non-seagoing traffic – Internal)[36]

One of these four proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate.

Table 3-28 shows the trend in fuel consumption by inland waterways from 1990-2015 developed for the inventory this year. More detail regarding the vessels and their fuel type can be found in the report by Walker *et al.,* 2011.

[32] http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html
[33] http://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE5
[34] http://www.visitengland.org/insight-statistics/major-tourism-surveys/attractions/Annual_Survey/
[35] https://www.gov.uk/government/statistical-data-sets/port01-uk-ports-and-traffic
[36] https://www.gov.uk/government/statistical-data-sets/dwf01-waterborne-transport

Table 3-28 Fuel consumption for inland waterways derived from inventory method

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1990	86.2	3.8	0.6	27.6	22.0	11.2
1991	86.5	3.4	0.6	28.8	22.6	11.7
1992	86.9	3.8	0.7	31.5	24.1	12.8
1993	88.4	4.1	0.7	34.3	25.5	13.9
1994	92.8	4.5	0.8	37.0	27.0	15.0
1995	94.2	4.2	0.9	39.8	28.5	16.1
1996	94.9	3.6	0.9	42.5	29.9	17.2
1997	95.2	3.1	1.0	45.3	31.1	18.3
1998	95.8	2.7	1.0	48.0	32.2	19.4
1999	95.5	2.7	1.1	50.7	33.6	20.5
2000	96.1	2.7	1.1	53.5	34.8	21.6
2001	94.5	2.7	1.2	56.2	35.9	22.8
2002	95.9	2.5	1.3	60.4	38.7	24.4
2003	96.5	2.0	1.4	64.6	41.0	26.1
2004	98.8	1.7	1.5	68.8	43.2	27.8
2005	100.2	2.2	1.6	72.9	45.2	29.5
2006	101.1	2.3	1.7	77.1	47.6	31.2
2007	101.7	2.1	1.7	81.3	49.9	32.9
2008	100.3	2.3	1.8	85.5	52.2	34.6
2009	94.6	2.1	1.9	89.6	54.8	36.3
2010	97.0	2.2	1.9	90.3	55.4	36.5
2011	99.0	2.2	1.9	90.2	55.7	36.5
2012	96.5	2.3	2.0	93.1	57.0	37.7
2013	98.4	3.3	2.0	93.4	57.7	37.8
2014	100.0	3.2	2.1	99.8	61.4	40.4
2015	99.8	3.2	2.3	105.6	64.3	42.7

c) Emission factors

The fuel-based emission factors used for all inland waterway vessels were taken from the EMEP Emissions Inventory Guidebook and implied factors for 2015 are presented later. The factors for SO_2 from vessels using gas oil took into account the introduction of the much tighter limits on the sulphur content of gas oil for use by inland waterway vessels, the limit reduced to 10ppm from January 2011.

The 2015 inventory now includes estimates of NH_3 emissions from inland waterways. There are no factors for NH_3 emissions from shipping in the EMEP/EEA Guidebook (2016). It was deemed reasonable to assume the emission factors would be the equivalent to those of a diesel railway train. That emission factor used is the Tier 2 NH_3 emission factor from Tables 3.2-3.4 of the 1.A.3.c Railways chapter (EMEP, 2016). This emission factor, in mass-based units, is 10 g/tonne fuel.

3.3.5.3 International Navigation (1A3di)

Emissions from international marine bunkers are calculated, but reported as a Memo item and not included in the UK totals.

a) Activity data

The study by Entec provided a time-series in fuel consumption and emissions from vessels involved in international movements, i.e. those arriving at UK ports from overseas and those leaving UK ports to voyage overseas. However, when adding the estimates of fuel consumption from international movements to fuel consumed by domestic movements (UK port-to-UK port), the sum is different to the total fuel supplied to international marine bunkers and consumed by national navigation in DUKES. This is illustrated in Table 3-29 which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil, after deducting the amount of fuel used for military. Note that DUKES makes no separation between marine diesel oil and marine gas oil, so the figures here and in the inventory for gas oil refer to the combined amounts for both these types of fuel.

Table 3-29 Total consumption of marine fuels (Mt fuel) for domestic and international shipping calculated by the Entec method compared with DUKES for 2007 (excludes military)

Mt fuel	Entec	DUKES
Gas oil	4.34	1.57
Fuel oil	1.00	2.04

The totals differ markedly. One reason for that is the Entec "international" category includes fuel consumed by vessels arriving at UK ports that purchased their fuel overseas and so would not be included in the DUKES marine bunkers supply. However, in reporting emissions from international shipping movements as a Memo item, the UK is only responsible for emissions from fuel supplied by the UK's bunker fuels market.

Another issue is the international bunker fuels market itself and how the figures in DUKES for marine bunkers relate to actual consumption by international shipping movements starting in the UK. International fuel bunkering may be affected by variations in international marine fuel prices such that it is conceivable that fuel tankering occurs to a greater or lesser extent each year. This may explain why the trend in total marine fuel consumption implied by DUKES since 1990 is more erratic than trends in shipping movements implied by port statistics.

All these factors can lead to potential differences in the total domestic plus international fuel consumption calculated from a method based on vessel movements from fuel statistics in DUKES. Moreover, BEIS acknowledged that there is uncertainty with refineries who submit data to DUKES as to where the fuel ultimately gets used, i.e. whether for domestic shipping activities or for international marine fuel bunkers. So not only could the total fuel consumed be different, but these uncertainties could allocate the incorrect amounts of the DUKES marine fuels to domestic (national navigation) and international (marine bunkers) consumption.

Under CLRTAP guidelines, the UK is only responsible for emissions from the fuel it supplies, whatever it is used for, but an accurate estimate is required of the amount of fuel used for domestic shipping consumption because emissions arising from this are accounted for in the UK inventory totals. Therefore, to retain overall consistency with national energy statistics and the requirements of inventory reporting under CLRTAP Guidelines an approach is used whereby the figures for domestic coastal shipping would be taken directly from the Entec method as described above, but the figures for international shipping would be based on the residual fuel consumption. This residual is the difference between the total fuel deliveries statistic in DUKES and the sum of the Entec figure for domestic coastal shipping plus other fuel used for domestic marine purposes sourced in the UK and included in the national totals. These include fuel used for military shipping, inland waterways, deep sea fishing in non-UK waters and fuel used to power vessels on trips from the UK to OTs, but not on the reverse trip.

Discussions with the DUKES team during a study on the allocation of gas oil across sectors (Murrells *et al.,* 2011) revealed that it is likely that gas oil supplied for inland waterway vessels by marinas and filling points along rivers is included in the DUKES figures for national navigation.

Thus for fuel consumption across the time series:

$$E = A - B - C - D - F - G$$

Where:
E is International shipping fuel consumption
A is total DUKES fuel consumption
B is domestic shipping fuel consumption derived from the Entec approach

C is naval fuel consumption
D is inland waterways fuel consumption
F is fishing vessels outside UK waters fuel consumption
G is shipping vessels travelling from the UK to overseas territories fuel consumption

This approach was used to estimate international shipping fuel consumption and emissions for all years back to 1990.

This implies that the total marine fuel consumption by all marine activities covered in the inventory is considered a “closed” system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic coastal shipping, fishing, naval and inland waterways, voyages to overseas territories, fishing outside UK waters) is consistent with the total amount of gas oil and fuel oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES, as can be seen in Table 3-30.

Table 3-30 Consumption of marine fuels by domestic and international shipping for 2007 (Mt)[a]. Excludes military.

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.55	0.94
	International	1.02	0.63
	Total	1.57	1.57
	% domestic	35%	60%
Fuel oil	Domestic	0.12	0.57
	International	1.92	1.47
	Total	2.04	2.04
	% domestic	6%	28%

[a] Consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic coastal movements and inventory estimates of inland waterway, fishing in non-UK waters and voyages from UK to OTs activities compared with figures from DUKES for 2007.

The DUKES figure for gas oil (international) have consumption by military vessels excluded.

A summary of fuel consumption trends for international navigation is provided in Section 3.3.5.4.

b) Emission factors

Emissions for international shipping (1A3di) were calculated by multiplying the residual fuel consumption calculated above with an implied emission factor for international vessel movements. The implied emission factors were derived from the Entec study by dividing the Entec emission estimates for international vessel movement by their associated fuel consumption for each fuel type. This effectively means the inventory does capture the types of vessels, engines, speeds and activities used for international movements in Entec’s inventory even though the overall movements, fuel consumption and hence emissions are different. The same factors were used for voyages between the UK and OTs (see above).

Implied emission factors for international navigation in 2015 are shown in Section 3.3.5.4.

3.3.5.4 Summary of all Activity Data Trends and Emission Factors for Navigation

3.3.5.4.1 Trends in Fuel Consumption

This section summarises the time-series in gas oil and fuel oil consumption for domestic coastal and military shipping, fishing, inland waterways and international shipping and voyages from the UK to the OTs since 1990. These all refer to fuel sourced in the UK, so the sum is consistent with total fuel consumption figures reported in DUKES. Fuel consumed in the OTs and for voyages from the OTs to the UK are not included in this table.

Table 3-31 Fuel consumption (Mtonnes) for UK marine derived from inventory method

	Gas oil				Fuel oil		
Mtonnes fuel	Domestic coastal and military	Fishing	Inland waterways	International bunkers	Domestic coastal and military	Voyages from UK to OTs	International bunkers
1990	0.61	0.032	0.09	1.59	0.35	0.007	1.13
1991	0.63	0.032	0.09	1.65	0.34	0.007	1.06
1992	0.59	0.032	0.09	1.67	0.34	0.007	1.09
1993	0.54	0.033	0.09	1.59	0.33	0.008	1.14
1994	0.52	0.033	0.10	1.52	0.35	0.008	0.94
1995	0.53	0.034	0.10	1.35	0.37	0.008	1.19
1996	0.54	0.045	0.10	1.56	0.37	0.008	1.25
1997	0.56	0.054	0.10	1.48	0.36	0.009	1.56
1998	0.45	0.051	0.10	1.78	0.37	0.010	1.41
1999	0.48	0.046	0.10	1.44	0.37	0.010	0.87
2000	0.46	0.043	0.10	1.45	0.35	0.010	0.62
2001	0.43	0.041	0.10	1.61	0.33	0.010	0.53
2002	0.41	0.039	0.10	1.20	0.35	0.008	0.45
2003	0.44	0.040	0.10	1.40	0.34	0.009	0.57
2004	0.47	0.039	0.10	1.31	0.34	0.009	0.93
2005	0.44	0.040	0.10	1.22	0.36	0.009	1.16
2006	0.43	0.052	0.10	1.64	0.34	0.009	1.47
2007	0.66	0.058	0.10	1.02	0.10	0.005	1.93
2008	0.65	0.106	0.10	0.99	0.10	0.010	2.45
2009	0.63	0.068	0.10	1.03	0.09	0.009	2.26
2010	0.61	0.090	0.10	0.94	0.09	0.011	1.84
2011	0.59	0.052	0.10	0.98	0.09	0.011	2.14
2012	0.54	0.056	0.10	1.11	0.08	0.009	1.54
2013	0.51	0.040	0.10	1.37	0.07	0.008	1.30
2014	0.48	0.047	0.10	1.67	0.08	0.010	1.06
2015	0.50	0.046	0.10	1.56	0.08	0.009	0.74

The method for estimating fuel consumption by domestic, fishing and international shipping prior to 1990 is based on the relative share of these movement types in 1990 itself which was assumed to remain constant in all previous years. The 1990 share was applied to the total fuel consumption figures given in DUKES for each year back to 1970 (after deducting consumption by military vessels).

3.3.5.4.2 Emission Factors

Table 3-32 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2015. The units are in g/kg fuel and are implied by the figures in the Entec study and fuel sulphur content.

Table 3-32 2015 Inventory Implied Emission Factors for Shipping

Fuel	Source	NO_x (as NO_2)	SO_x as SO_2	NMVOC	PM_{10}	CO	NH_3
		g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.4	2.0	2.82	1.95	7.4	0.01
	Fishing	58.0	2.0	2.04	1.32	7.4	0.01
	International	69.3	2.0	2.74	1.85	7.4	0.01
Fuel Oil	Domestic	70.6	2.0	3.52	6.56	7.4	0.01
	International	77.7	26.8	2.92	6.75	7.4	0.01

Table 3-33 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2015.

Table 3-33 2015 Inventory Emission Factors for Inland Waterway Vessels

Fuel	NO_x (as NO_2)	SO_x as SO_2	NMVOC	PM_{10}	CO	NH_3
	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.014	4.7	4.1	10.9	0.007
Gas Oil	42.5	0.015	4.7	4.1	10.9	0.007
Petrol	9	0.010	50	0.04	300	0.005

3.3.6 Other Emissions Associated with Transport Sectors (1A4)

Emissions associated with other transport sources are mapped to 1A4, Combustion in Residential/Commercial/Public sectors covered in Section 3.4. This includes stationary combustion emissions from the railway sector in 1A4a, including generating plant dedicated to railways. For most sources, the estimation procedure follows that of the base combustion module using BEIS reported fuel use data and emission factors from Section 0. The 1A4a Commercial and Institutional sector also contains emissions from stationary combustion at military installations, which should be reported under 1A5a Stationary.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. The estimation of emissions from off-road sources is discussed in Section 3.3.7. Emissions from fishing vessels are included in 1A4ciii and were described in the section on Navigation, Section 3.3.5.

3.3.7 Off-Road Machinery

Emissions from a variety of off-road mobile machinery sources are included in 1A2gvii, 1A4bii, 1A4cii, 1A4ciii and 1A3eii. These are for industrial and construction mobile machinery, domestic house and garden machinery, agricultural machinery and airport support machinery, respectively. Military aircraft and naval shipping are covered under 1A5b and have been previously described.

3.3.7.1 Estimation of Other Off-Road Sources (1A2gvii, 1A4bii, 1A4cii/iii, 1A3eii)

A Tier 3 methodology is used for calculating emissions from individual types of mobile machinery.

Machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from the EMEP Guidebook (2009). Emission factors for more modern machinery are based on engine or machinery-specific emission limits established in the EU Non-Road Mobile Machinery Directives.

Activity data are derived from bottom-up estimates from population and hours of use of equipment in 2004. Various proxy statistics are used as activity drivers for different groups of machinery types to estimate fuel consumption in other years.

Summary of activity data

Bottom-up estimates from population and hours of use of equipment in 2004. Various proxy statistics used as activity drivers for different groups of machinery types to estimate fuel consumption in other years.

Details of Methodology

Emissions are estimated for 77 different types of portable or mobile equipment powered by diesel or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers; aircraft support equipment. In the inventory they are grouped into four main categories:

- domestic house & garden
- agricultural power units (includes forestry)
- industrial off-road (includes construction and quarrying)
- aircraft support machinery.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery.

The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). Emissions are calculated using the following equation for each machinery class:

$$E_j = N_j \,.\, H_j \,.\, P_j \,.\, L_j \,.\, W_j.(1 + Y_j \,.\, a_j /2).\, e_j$$

where

E_j	=	Emission of pollutant from class j	(kg/y)
N_j	=	Population of class j.	
H_j	=	Annual usage of class j	(hours/year)
P_j	=	Average power rating of class j	(kW)
L_j	=	Load factor of class j	(-)
Y_j	=	Lifetime of class j	(years)
W_j	=	Engine design factor of class j	(-)
a_j	=	Age factor of class j	(y^{-1})
e_j	=	Emission factor of class j	(kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \,.\, H_j \,.\, e_{vj}$$

where

E_{vj}	=	Evaporative emission from class j	kg
evj	=	Evaporative emission factor for class j	kg/h

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by AEA on behalf of the Department for Transport (Netcen, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research Ltd (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *and Zierock* (1993, 1994) were also used.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from BEIS on how much fuel is consumed by mobile machinery separately from fuel used for stationary combustion by a particular industrial or commercial sector.

However, as part of the 2014 Inventory Improvement Programme a review was made of some of the activity data used in light of further evidence and information not available when the 2004 survey was carried out. The review did not consider all the different types of machinery, but focused on those that made a significant contribution to the overall total inventory for the sector. The activity parameters considered were population, lifetime, engine power, and hours of use per year. The engine size is important for several reasons including the fact that it defines the emission limits that apply to the machinery in question according to the EU Non-Road Mobile Machinery (NRMM) Directive. The main types of machinery where activity data were revised in the 2013 NAEI (submitted in 2015) relative to the original 2004 study were for airport support machinery, generator sets, rollers, cranes and tracked bulldozers and dumpers.

The above review only captured a small number of machinery types and provided updates for the core 2004 activity data. As in previous years, various activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2015. These drivers were applied to all machines, including those above which were the subject of the most recent review.

For industrial and construction machinery, a set of four drivers is used. Each of the individual machinery types is mapped to one of these four drivers depending on the typical industry sector in which the machinery type is usually used. The four categories and drivers used are described in Table 3-34.

For domestic house and garden machinery, historic and projected trends in number of households are used (CLG, 2016). For airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2016). For agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (BEIS, 2016) are used.

For the current inventory, minor revisions were made to some of the activity drivers used for house and garden machinery, agricultural machinery and industrial machinery.

Table 3-34 Activity drivers used for off-road machinery in the industry and construction sector.

Category	Driver source	Machinery types
Construction	ONS construction statistics. "Output in the Construction Industry.", http://www.ons.gov.uk/businessindustryandtrade/constructionindustry/datasets/outputintheconstructionindustry Table 2b – Value of construction output in Great Britain: non-seasonally adjusted. The value of all new work (i.e. excluding repair and maintenance work) at constant (2010) prices. The seasonally non-adjusted figures were used and scaled to ensure time series consistency.	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS (2016).	bore/drill rigs
		off highway trucks*
		crushing/processing equip
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	excavators
		loaders with pneumatic tyres
		bulldozers
		tracked loaders
		tracked bulldozers
		tractors/loaders
		crawler tractors
		off highway tractors
		dumpers /tenders
General Industry	Based on an average of growth indices for all industrial sectors, taken from data supplied by BEIS for use in energy and emissions projections.	generator sets 100-1000KW
		pumps
		air compressors
		gas compressors
		welding equip
		pressure washers
		aerial lifts
		forklifts*
		sweepers/ scrubbers
		other general industrial equip
		other material handling equip

Having calculated fuel consumption from a bottom-up method, the figures for diesel engine machinery were allocated between gas oil and road diesel. This was following a survey of fuelling practices of uses of off-road machinery where it was found that, particularly for small, non-commercial and domestic users who may only occasionally need to refuel, engines are filled with road diesel rather than gas oil. A further fuel reconciliation procedure was then followed for gas oil which took account of consumption from all sources, as described in Murrells et al (2011). If UK total consumption figures given in DUKES for gas oil exceeded that calculated for each source, the figure for gas oil consumption from industrial machinery was reduced to bring alignment with DUKES. The reason for making the reduction specifically to industrial and construction machinery use of gas oil rather than other sectors is because this source is considered to have the most uncertain estimates of activity due to the large and varied nature of machinery included.

As a consequence of this normalisation procedure, changes in fuel consumption and emissions for industrial machinery occur when revisions to the allocation of gas oil consumption to other sources are made.

Figure 3-7 and Figure 3-8 show the trend in total fuel consumption for the four main off-road categories since 2000. These include the combined consumption of gas oil, road diesel and petrol by each sector. The trend in consumption for the industry and construction machinery sector reflects the fuel reconciliation process used as well as the effect of activity drivers used which themselves are a reflection of economic conditions.

Figure 3-7 Fuel consumption by off-road machinery in kilotonnes fuel (2000-2015)

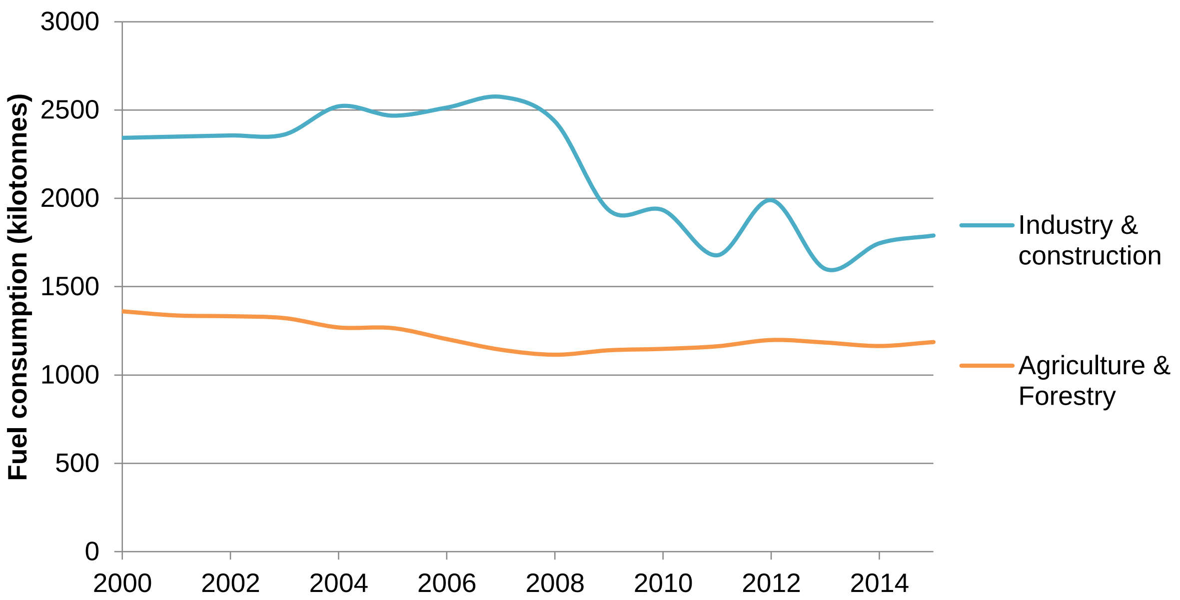
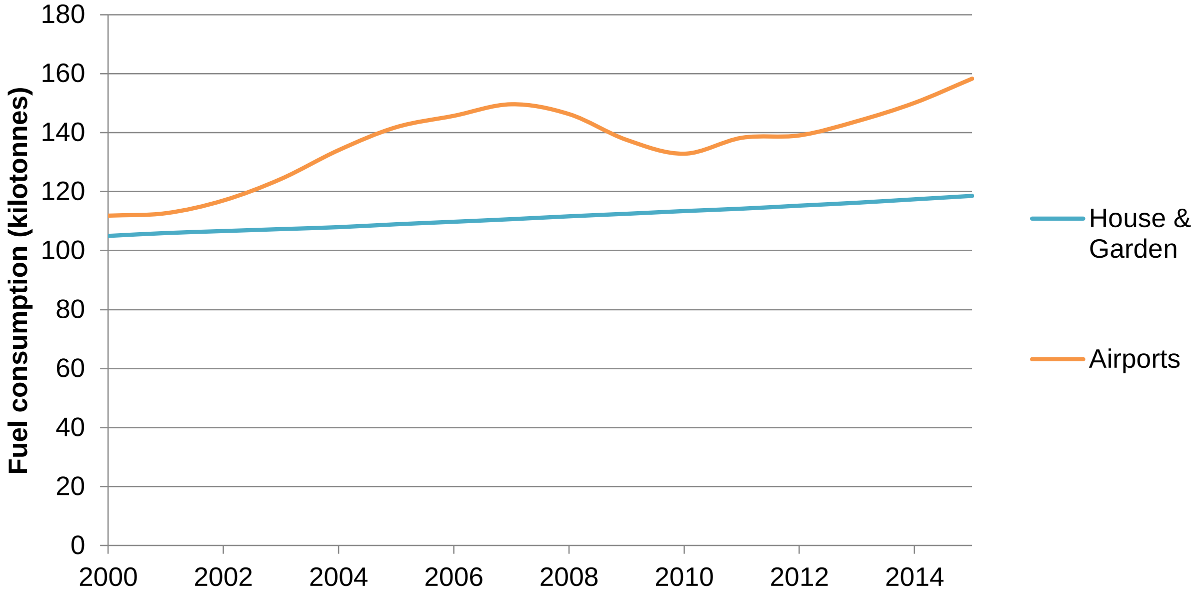


Figure 3-8 Fuel consumption by off-road machinery in kilotonnes fuel (2000-2015)



A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale) and hence emission standard. For older units, the emission factors used came mostly from EMEP (2009) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004b). For equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in terms of how they apply to different machinery types. Each of the 77 different machinery types was mapped to the relevant regulation in terms of implementation date and limit value.

The methodology follows the Tier 3 methodology described in the EMEP/EEA emission inventory guidebook (EMEP, 2013).

For the industrial and construction machinery, the fuel reconciliation process described above essentially overrides any changes in estimates of fuel consumption calculated from the bottom-up procedure arising from the 2014 review of activity data for some selected machinery types. However, this review still affects the emissions of air pollutants by leading to changes in implied emission factors for these machinery types, e.g. through revisions to the lifetime and emission limit value.

Aggregated emission factors for the four main off-road machinery categories by fuel type in 2015 are shown in Table 3-35.

The emission factors shown here for 2015 are generally similar to or slightly lower than the factors for 2014. A decrease is a consequence of the penetration of new machinery meeting the tighter emission regulations in the non-road mobile machinery fleet. The factors for SO_2 in 2015 reflect the sulphur content of fuels used, according to figures provided by UKPIA (2016).

Table 3-35 Aggregated Emission Factors for Off-Road Source Categories in 2015 (t/kt fuel)

Source	Fuel	CO	NO_x (as NO_2)	PM_{10}	SO_2[1]	NMVOC
Domestic House & Garden	DERV	4.3	48.0	1.7	0.014	2.6
Domestic House & Garden	Petrol	668	3.1	0.03	0.010	13.0
Agricultural Power Units	Gas oil	17.0	14.3	1.3	0.015	2.8
Agricultural Power Units	Petrol	716	1.4	0.03	0.010	249
Industrial Off-road	DERV	14.5	20.6	1.9	0.014	4.5
Industrial Off-road	Gas oil	14.5	20.6	1.9	0.015	4.5
Industrial Off-road	Petrol	1035	6.2	0.03	0.010	39.3
Aircraft Support	Gas oil	12.6	15.8	1.1	0.015	2.7

[1] Based on sulphur content of fuels in 2015 from UKPIA (2016). For gas oil, the SO_2 factor is based on the maximum permitted sulphur content of gas oil reduced to 10 ppm from 1 January 2011 for fuels used by off-road machinery according to the EU Fuel Quality Directive.

3.3.8 Recalculations in transport sources

Aviation (1A3a)

The main recalculations for aircraft sources were due to minor revisions to the following:

- assignment of aircraft to EMEP-EEA cruise categories
- assumptions regarding the APU types fitted to aircraft
- surrogate aircraft data used in calculation of LTO cycle emissions

Road transport (1A3b)

For CO, emission estimates have been significantly revised as the method for estimating CO emission degradation from cars and LGVs was improved to use the approach in the latest European COPERT emissions model. The effect of this methodology change varied between vehicle types and emission years, however it mostly led to a decrease in emissions. Another notable change is the implementation of COPERT 5 NO_x (as NO_2) emission factors for Euro 5 diesel LGVs, reflecting more recent evidence on the real-world performance of these vehicles. These emission factors are higher than those used in COPERT 4v11, leading to an increase in estimated NO_x (as NO_2) emissions from diesel LGVs from 2011, relative to the previous submission.

Other, smaller re-calculations occur for the following reasons:

- Updates to some of the vehicle km (from DfT) and fleet composition data for London (from TfL).
- Revisions to vehicle km data for Northern Ireland including the split between road types. This affected the whole time-series.

Rail (1A3c)

No recalculations were made for rail, but emissions of NH_3 from rail were included for the first time, following recommendations of the 2016 CLRTAP Stage 3 Review of the UK inventory

Navigation (1A3d)

Small re-calculations occur due to:

- The application of new mapping data that splits fuel consumption between different activities where S-content of fuel legislation has an impact (at berth, at sea etc.) for both SECA and non-SECA areas, used to determine a weighted SO_x (as SO_2) emission factor.

and revisions in fuel consumption data:

- Revision in DUKES marine gas oil consumption estimates. 2013 fuel consumption is 4.7% higher, and 2014 fuel consumption is 20.7% higher than the previous submission. This affects the estimate for international shipping emissions only (Memo item)
- Revision in DUKES marine fuel oil consumption estimates. 2013 fuel consumption is 0.05% higher, and 2014 fuel consumption is 0.15% higher. This affects the estimate for international shipping emissions only (Memo item)
- 5.6% decrease in the estimated activity in 2014 in the proxy statistics used to estimate the activity from freight vessels within the inland waterways sector.
- Minor recalculation in the proxy statistics used to estimate the activity from private leisure craft within the inland waterways sector. This includes a <1% decrease in 2010-2011, a 0.1% increase in 2012, and a 1-2% decrease in 2013-2014.
- Recalculations have occurred due to the removal of Bermuda from the list of OTs.

Emissions of NH_3 from navigation were included for the first time

Off-road machinery (1A2gvii, 1A4bii, 1A4cii/iii, 1A3eii)

The main re-calculation is due to changes in fuel consumption for industrial and construction mobile machinery affecting 1A2gvii arising from the re-allocation of changed gas oil activity data in DUKES. The changes to this sector are made to retain fuel mass balance with DUKES and are affected by changes made to other sectors using gas oil.

Minor re-calculations arise from:

- Revision to DUKES gas oil consumed in agriculture used as a driver for the agricultural machinery sector. The 2013 value is 86% of the previous value used and the 2014 value is 78% of the previous value used.
- Revisions to the combination of drivers for construction, construction/quarrying, and industry machinery (<1.5% change between 2004 and 2014). These included UK minerals yearbook and ONS construction statistics.

3.3.9 Planned improvements in transport sources

Most of the improvements in the transport sectors will depend on the availability of new or revised forms of activity data and emission factors and not all of these can be anticipated at this stage. Particularly for the road transport sector, the evidence to base changes in emission factors is a fast developing and changing area, particularly as new evidence on ‘real-world’ factors for NO_x emissions from modern diesel vehicles emerges.

The most significant change is planned for the shipping sector 1A3d as a consequence of an improvement programme currently in progress that will use detailed AIS vessel movement data captured around the UK coast for 2014. As well as enhancing activity data and emission factors for better spatial representation of the emissions, this work will also provide a better estimate of total UK domestic and international shipping emissions from a bottom-up activity-based method.

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

3.4 NFR14 1A4: Combustion in the Residential / Commercial / Public Sectors

Table 3-36 Mapping of NFR14 Source Categories to NAEI Source Categories: Residential / Commercial / Public Sectors

NFR14 Category (other 1A4)	Pollutant coverage	NAEI Source category
1 A 4 a i Commercial / institutional: Stationary	All CLRTAP pollutants	Miscellaneous industrial & commercial combustion
		Public sector combustion
		Railways - stationary combustion
1 A 4 b i Residential: Stationary plants	All CLRTAP pollutants	Domestic combustion
1 A 4 b ii Residential: Household and gardening (mobile)	All CLRTAP pollutants *(except HCB and PCBs)*	House and garden machinery
1 A 4 c i Agriculture/Forestry/Fishing: Stationary	All CLRTAP pollutants *(except HCB)*	Agriculture - stationary combustion
1 A 4 c ii Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	All CLRTAP pollutants *(except HCB and PCBs)*	Agricultural engines
		Agriculture - mobile machinery
1A 4 c iii Agriculture/Forestry/Fishing: National fishing	All CLRTAP pollutants *(except NH_3, HCB, PCBs)*	Fishing vessels

Table 3-37 Summary of Emission Estimation Methods for NAEI Source Categories in NFR14 Category 1A4

NAEI Source Category	Method	Activity Data	Emission Factors
Miscellaneous industrial & commercial combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Public sector combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Railways - stationary combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
Domestic combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, IPCC, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_x as SO_2.
House and garden machinery	See Section 3.3.7 on off-	Study on population and usage of	Factors from EMEP-EEA Guidebook combined with estimates of effect of

NAEI Source Category	Method	Activity Data	Emission Factors
	road machinery	machinery in 2004. Trends in activities for other years based on trends in household numbers. See Section 3.3.7	more recent NRMM emission regulations on more modern equipment. See 3.3.7. Fuel analysis (UKPIA) for SO_x as SO_2.
Agriculture - stationary combustion	UK model for activity allocation to unit type; AD x EF	BEIS energy statistics	Default factors (USEPA, EMEP-EEA, IPCC, HMIP, UK-specific research). Fuel analysis (UKPIA) for SO_x as SO_2.
Agricultural engines	AD x EF	Inventory agency estimate of fuel use by different mobile units	See 3.3.7. Default factors mainly from UK-specific research / analysis based on UK stock of combustion units, fuels and assumed utilisation. Fuel analysis (UKPIA) for SO_x as SO_2.
Agriculture - mobile machinery	See Section 3.3.7 on off-road machinery	Inventory agency estimate of fuel use by different mobile units. Study on population and usage of machinery in 2004. Trends in activities for other years based on DUKES trends in gas oil consumption by agriculture. See Section 3.3.7	Factors from EMEP-EEA Guidebook combined with estimates of effect of more recent NRMM emission regulations on more modern equipment. See 3.3.7. Fuel analysis (UKPIA) for SO_x as SO_2.
Fishing vessels	See Section 3.3.5 on navigation	Inventory agency estimate of fuel use across different shipping types, based on Entec 2010 study for year 2007 and use of trends in MMO fish landing statistics to estimate trends in fuel use in other years. See 3.3.5	See 3.3.5. Default factors mainly from UK-specific research / analysis, including the Entec 2010 study on marine shipping, EMEP-EEA Guidebook and fuel analysis (UKPIA) for SO_x as SO_2.

3.4.1 Classification of activities and sources

The NAEI utilises energy statistics published annually in the Digest of UK Energy Statistics (BEIS, 2016). The source categories and fuel types used in the NAEI therefore reflect those used in DUKES.

Table 3-3 lists the fuels used in the inventory. In two instances, fuels listed in DUKES are combined in the NAEI: propane and butane are combined as ‘liquefied petroleum gas’ (LPG), and ethane and ‘other petroleum gases’ are combined as the NAEI fuel ‘other petroleum gases’ (OPG).

Table 3-36 relates the detailed NAEI source categories to the equivalent NFR14 source categories for stationary combustion. Most NAEI sources can be mapped directly to an NFR14 (Nomenclature for Reporting) source category, but there are some instances where the scope of NAEI and NFR14 categories are notably different, and these are highlighted in the methodology descriptions below. The NAEI source categories are presented at the level at which the UK emission estimates are derived which is more detailed than that required for reporting; the NFR14 system is the reporting format used for submission of the UK inventories under the CLRTAP.

Almost all of the NFR14 source categories listed in Table 3-36 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR14 sector. The emission inventory methodology for the mobile sources listed in Table 3-36 is described elsewhere (Sections 3.3.5 and 3.3.7).

3.4.2 General approach for 1A4

NFR14 Sector 1A4bi is a key category for NO_x (as NO_2), TPM, $PM_{2.5}$, & PM_{10}, SO_x (as SO_2), NMVOC, CO, Pb, Cd, B[a]P, PAHs, Hg and PCDD/PCDFs. Sector 1A4ci is a key source only for PCDD/PCDFs.

The NAEI stationary source categories reported under 1A4 consist mainly of large numbers of very small plant with only a few large plant in the commercial and public sectors. Therefore, a bottom-up inventory approach utilizing reported emissions is not possible, and instead a top-down method using the UK activity data and literature emission factors is used extensively for 1A4.

3.4.3 Fuel consumption data

Fuel consumption data are primarily taken from DUKES, but for some emission sources the NAEI energy data deviates from the detailed statistics given in DUKES. This is done for one of two reasons:

- Some of the detailed data contained in DUKES is not considered as accurate as data available from alternative sources;
- DUKES does not include data for a specific source, or data in DUKES is not available in sufficient detail.

The most important of these deviations in 1A4 are as follows:

- DUKES does not include any energy uses of petroleum coke by this sector, and only includes very recent data for some sectors covered by 1A1 and 1A2. Instead, the remaining consumption of petroleum coke in DUKES is allocated to 'non-energy uses' in the commodity balance tables for petroleum products. The inventory agency therefore includes estimates of petroleum coke burnt by the domestic sector (1A4b), based on data provided by industry.
- Gas oil is used in large quantities as a fuel for off-road vehicles and mobile machinery. These devices are not treated as a separate category in DUKES and the fuel they use is included in the DUKES data for agriculture, industry, public administration, railways, and the commercial sector. The inventory agency generates independent estimates of gas oil use for off-road vehicles and mobile machinery, derived from estimates of the numbers of each type of vehicle/machinery in use, and the fuel consumption characteristics. See Section 3.3.7 for method description. Overall consistency with UK consumption of gas oil, as given in DUKES, is maintained by reducing NAEI estimates for gas oil consumed by the sectors listed above. Off-road vehicles and mobile machinery reported in 1A4 includes agricultural tractors and other machinery, and garden equipment such as lawn-mowers.

In the 2014 version of DUKES, petroleum coke was listed as an input to smokeless fuel manufacture for the first time. Data extended back to 2009 and, for those years, the data in DUKES relating to production of solid smokeless fuels must therefore be assumed to include that component of the smokeless fuel derived from the petroleum coke. Therefore, in the NAEI:

- For 1970-2008, the inventory agency uses the estimates of petroleum coke for the domestic sector as provided by industry;

- For 2009-2015, the inventory agency uses the industry data, but reduced by the amount of petroleum coke reported in DUKES as used in solid smokeless fuel manufacture.

3.4.4 Method for commercial, domestic and public sector combustion sources

Individual combustion plants range in scale from domestic appliances such as central heating boilers and open fires, up to a few combustion facilities with thermal inputs exceeding 50 MW_{th} used in the commercial or public sectors. Even in the latter two sectors, most combustion plant will be small, and because of this, it is not possible to derive bottom-up estimates. Emissions are estimated using an appropriate emission factor applied to national fuel consumption statistics taken from DUKES.

Similar to 1A2, the approach for commercial/public sector combustion using the major fuels (coal, coke oven coke, fuel oil, gas oil, burning oil, natural gas) uses Tier 1 default factors from the EMEP/EEA Emission Inventory Guidebook for CO, NO_X and PM_{10} and a mixture of EMEP/EEA, US EPA, IPCC and UK-specific factors for other pollutants and for minor fuels. Emission factors for SO_2 are based on UK-specific data on the sulphur content of coals and oils, provided by fuel suppliers. There are limited data on appliance population and fuel use to allow a higher Tier approach, however, work to support development and implementation of the Medium Combustion Plant Directive may allow a more detailed inventory in future.

Emissions from domestic combustion are estimated using literature, Tier 1 and, for wood, Tier 2 emission factors. Suitable factors are not always available for some minor fuels, and so emission factors for a similar fuel are used instead e.g. a factor reported in the literature for coke might be used for other manufactured smokeless fuels.

In the case of domestic combustion of coal and coal-based solid fuels, emission factors are derived that take into account the types of appliances used in the UK, applying emission factors for specific technologies from the EMEP/EEA Guidebook. The proportions of each type of appliance using each fuel are estimated, based primarily on information from the 2007 report '*Preparatory Study for Eco-design Requirements of EuPs, Lot 15: Solid fuel small combustion installations*'[37], with some more detailed splits utilising expert elicitation. No other data are available regarding the population of appliance types over time, and therefore the assumptions are held constant over the 1970-2015 timescale of the inventory. This method will be reviewed and improved as new data becomes available, with the aim that changes in appliance use over time will be reflected in the NAEI emission trends.

In the case of residential combustion of wood / biomass, DECC (now BEIS) conducted research during 2014-15 into the use of wood for residential heating. This led to a very significant increase in the estimated use of wood in the residential sector within the DUKES 2015 publication, compared to previous UK energy statistics. The BEIS research led to a new time series of activity data in DUKES, back-revising the residential wood use activity from 2008 onwards but did not revise the published data for earlier years. To ensure consistency in reported inventory emissions trends across the entire time-series, the inventory agency (in consultation with the BEIS energy statistics team) derived a new time series for residential wood use from 2007 back to 1990 to supplement the published revisions for 2008-2013.

These recalculations to the wood activity data have a significant impact on the emission estimates from the UK residential sector compared to previous inventories, most notably leading to a large increase in reported particulate matter from the sector. However, activity data for this source category remain highly uncertain; the accurate assessment of wood use in the residential sector is extremely difficult due to the lack of comprehensive fuel sales data for a fuel with a substantial component outside conventional fuel markets.

The BEIS research enables some improved assumptions regarding the use of wood within different appliance types through time. The inventory agency has consulted with industry experts to supplement

[37] Available here: http://www.eceee.org/ecodesign/products/solid-fuel-small-combustion-installations/ (website checked 30 January 2017).

the BEIS research information, aiming to ensure that the high growth in wood use in the residential sector in recent years is reflected as accurately as possible within the NAEI method.

Based on the BEIS research, most of the wood burned in 2014 was in non-automatic appliances including about half in open appliances. The BEIS survey data for 2014 has been applied to 2015. Although the BEIS survey was primarily a 'snapshot' it also included information on appliance age. Details on assumptions for fuel use and appliance population are provided in a report[38] but the key assumption is that for open and closed appliances the proportion of wood fuel used in open appliance from 1970-1990 compared to closed appliances was 3:1. Between 1990 and 2014 the ratio was interpolated between 3:1 (1990) and about 1:1 (2014 and 2015).

Since combustion on open fires is less controlled, and therefore typically emits higher levels of many pollutants, the assumptions made on appliance technologies have a significant impact on the emission estimates.

Although most of the emissions from wood combustion are calculated using a Tier 2 methodology, ammonia emissions are calculated at a Tier 1 level. Following review of the NAEI, the ammonia emission factors in the EMEP/EEA Guidebook were assessed and determined to be based on wildland fires and consequently highly uncertain. The decision was made to replace with a Tier 1 factor based on the original reference.

As with coal-based fuels, the methodology and assumptions for wood will be kept under review and improved should better data become available.

For domestic gas consumption, the NAEI also includes a modelled approach to estimate changes in appliance technologies. The method assumes that all gas is burnt in boilers, and that emission rates for new plant are constant over the following three periods:

- 1970-1989 70 g NO_x (as NO_2)/GJ
- 1990-2004 24 g NO_x (as NO_2)/GJ
- 2005-2015 19 g NO_x (as NO_2)/GJ

It is further assumed that all boilers have a 15 year lifetime and that an equal number are replaced each year, so that while all boilers in 1989 emit 70 g NO_x (as NO_2)/GJ, 1 in 15 of these boilers are replaced in 1990 with new boilers that emit 24 g NO_x (as NO_2)/GJ and that by 2004 all boilers emit 24 g NO_x (as NO_2)/GJ. The three emission factors chosen are, respectively i) the EMEP/EEA 2009 Guidebook default factor for domestic gas combustion; ii) a factor taken from the Ecodesign Directive preparatory studies on central heating boilers (Lot 1) and water heaters (Lot 2) and derived from the GEMIS database for gas boilers; and iii) the Class 5 standard for new boilers introduced in EN 483.

For residential combustion of oils, Tier 1 emission factors for CO, NO_x (as NO_2) and PM_{10} are taken from the EMEP/EEA Guidebook, whereas factors for SO_x (as SO_2) and metals are, like the factors for 1A2, based on UK-specific data on fuel composition.

3.4.5 Source specific QA/QC and verification

The QA/QC procedure for this sector is covered by the general QA/QC of the NAEI in Section 1.6.

3.4.6 Recalculations in NFR14 Sector 1A4

Revisions to estimates as compared with the previous submission include:

- Emission factors for many stationary combustion processes have been reviewed and key assumptions revised, particularly regarding the calorific value of fuels (notably of biomass fuels) and consideration of the technology and age mix of the appliances. Also, minor changes to

[38] Unpublished report - Air Quality Improvement Plan 2015: Residential Biomass Combustion, report ED 59801034 Issue 1.1 Date 05/01/2016 prepared by Ricardo Energy & Environment for Defra

activity data from DUKES. A particularly significant change is for particulate matter emissions from agricultural use of straw as fuel, where a very conservative factor for open burning of straw has been replaced with a default factor for biomass combustion from the 2016 EMEP/EEA Guidebook, leading to a reduction in both PM_{10} and $PM_{2.5}$ of approximately 6 ktonnes in 2014 (so a 4% reduction in the UK emission total for PM_{10} and a 5% reduction in the UK emission total for $PM_{2.5}$ in 2014).

- The methodology for residential combustion of wood has been improved to better model changes in use of different appliance types over time and the assumptions regarding calorific value of wood fuels have also been revised. Finally, the emission factor for ammonia has been revised. The overall change in UK emissions for 2014 from these changes is a decrease of 0.5% for ammonia but increases of 0.3% for NMVOC and 0.1% for $PM_{2.5}$.

3.4.7 Planned Improvements in NFR14 Sector 1A4

The methodology for stationary combustion in 1A4 is based exclusively on the use of literature emission factors, including factors from the EMEP/EEA Guidebook, and factors based on UK-specific data (for SO_x (as SO_2) and metals, for example). To some extent the factors take account of the types of combustion devices in use, for example those for NO_x (as NO_2) from the domestic combustion of gas, wood and coal, for particulate matter from wood and coal combustion, and NMVOC from wood combustion.

In the case of domestic wood and domestic gas combustion, the inventory methods aim to reflect the change in emission factors over time as lower-emitting technologies have penetrated the UK stock of combustion units. However, the methods are quite simplistic and suffer both from a lack of data on the market share of different technologies in the UK, and also a limited set of emission factors for different technologies. At present, the inventory does not include any assessment of changes in technology over time for domestic combustion of coal, nor for changes in combustion technology for any fuels in the case of commercial and public sector combustion.

The influence of technology is greatest in the domestic sector, where wood and solid mineral fuel open fires typically emit significantly more particulate matter and VOC, for example, than boilers. Technology will also have differing impacts on different pollutants e.g. little or no impact on SO_x (as SO_2) emissions, and most impact on particulate matter (and related pollutants such as metals, POPs, CO, NO_x (as NO_2) and NMVOC. As a result, emission estimates within 1A4 are most uncertain for those pollutants that are most affected by technology.

Domestic wood combustion is a major source of emissions of particulate matter and Benzo[a[pyrene and so the uncertainty of estimates for 1A4 is a key component of overall uncertainty in the UK inventory for PM species and PAH.

Emissions from 1A4 are also significant for NO_x (as NO_2), NMVOC, benzene, CO and some persistent organic pollutants, and therefore uncertainty in 1A4 is important for the UK inventory as a whole. The sector is therefore one where improvements in methodology are a priority. Unfortunately, the scarcity of data, already mentioned, means it is difficult to implement any major improvements to the inventory methodology.

The highest priority for improvement is to improve the information on the market shares of domestic wood burning appliances, and the further development of the methodology for domestic combustion of coal and smokeless fuels. Gas combustion is the dominant source of NO_x (as NO_2) emissions within 1A4, so further data on the use and performance of different technologies in both the residential and non-residential markets would be valuable. Currently, no specific improvements are planned, but the methods will be kept under review, and could be improved if new data becomes available.

3.5 NFR14 1B1 & 1B2: Fugitive Emissions from Fuels

Table 3-38 Mapping of NFR14 Source Categories to NAEI Source Categories: Fugitive Emissions from Fuels.

NFR14 Category	Pollutant coverage	Source
1 B 1 a Fugitive emission from solid fuels: Coal mining and handling	NMVOC	Deep-mined coal
		Open-cast coal
1 B 1 b Solid fuel transformation	All CLRTAP pollutants *(except Se, HCB)*	Charcoal production
		Coke production
		Iron and steel flaring
		Solid smokeless fuel production
1 B 2 a i Oil (Exploration, production, transport)	NO_x (as NO_2), NMVOC, SO_x (as SO_2) and CO	Upstream Oil Production - Offshore Oil Loading
		Upstream Oil Production - Offshore Well Testing
		Upstream Oil Production - Oil terminal storage
		Upstream Oil Production - Onshore Oil Loading
		Upstream Oil Production - process emissions
		Petroleum processes
1 B 2 a iv Oil (Refining / Storage)	NMVOC and NH_3	Refineries – drainage
		Refineries – general
		Refineries – process
		Refineries – tankage
1 B 2 a v Distribution of oil products	NMVOC	Petrol stations - petrol delivery
		Petrol stations - spillages
		Petrol stations - storage tanks
		Petrol stations - vehicle refuelling
		Petrol terminals - storage
		Petrol terminals - tanker loading
		Refineries - road/rail loading
		Sea going vessel loading
1 B 2 b Natural gas (exploration, production, processing, transmission, storage, distribution and other)	NO_x (as NO_2), NMVOC, SO_x (as SO_2) and CO	Upstream Gas Production - Gas terminal storage
		Upstream Gas Production - Offshore Well Testing
		Upstream Gas Production - process emissions
		Gasification processes
		Gas transmission network leakage
		Gas distribution network leakage
		Gas leakage at point of use
1 B 2 c Venting and flaring (oil, gas, combined oil and gas)	NO_x (as NO_2), NMVOC, SO_x (as SO_2) Particulate Matter, Black Carbon and CO	Upstream gas production - gas flaring
		Upstream gas production - gas venting
		Upstream oil production - gas flaring
		Upstream oil production - gas venting
		Refineries - flares
1 B 2 d Other fugitive emissions from energy production	NA (not applicable)	

Table 3-39 Summary of Emission Estimation Methods for NAEI Source Categories in NFR14 Category 1B

NAEI Source Category	Method	Activity Data	Emission Factors
Deep-mined coal	AD x EF	BEIS energy statistics	EMEP-EEA 2016
Open-cast coal	AD x EF	BEIS energy statistics	EMEP-EEA 2016
Charcoal production	AD x EF	FAOSTAT	Default factors (USEPA AP-42, EMEP-EEA 2013, IPCC 2006, IPCC 1996)
Coke production	UK I&S model, AD x EF	BEIS energy statistics, ISSB, EU ETS	Operator data reported under IED/E-PRTR, Tata Steel, SSI, default factors (USEPA, EIPPCB, EMEP-EEA 2013)
Iron and steel flaring	UK I&S model, AD x EF	BEIS energy statistics, EU ETS, Tata Steel	Operator data reported under IED/E-PRTR; Default factors (EMEP-EEA 2013, IPCC 2006, USEPA)
Solid smokeless fuel production	UK model for SSF production, AD x EF	BEIS energy statistics	Operator data reported under IED/E-PRTR, default factors (EMEP-EEA 2013, EIPPCB)
Upstream Gas Production - Gas terminal storage	Operator data, time series assumptions	EEMS, Oil and Gas UK, BEIS energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using BEIS oil and gas production statistics.
Upstream Gas Production - process emissions			
Upstream Oil Production - process emissions			
Upstream Oil Production - Oil terminal storage			
Upstream Gas Production - Offshore Well Testing	AD x EF	EEMS, Oil and Gas UK, BEIS energy statistics	Operator data reported under EEMS, with AD and emissions reported since 1998. Earlier emissions data and factors based on estimates from UK Oil and Gas, using BEIS oil and gas production statistics.
Upstream Oil Production - Offshore Well Testing			
Upstream Oil Production - Offshore Oil Loading			
Upstream Oil Production - Onshore Oil Loading			
Gasification processes	AD x EF	BEIS energy statistics	Operator reported emissions under IED/E-PRTR
Petroleum processes	Operator reported emissions	BEIS energy statistics	Operator reported emissions under IED/E-PRTR
Refineries – Drainage, General, Process, Tankage	Operator reported emissions	UKPIA, BEIS energy statistics	Operator reported emissions under IED/E-PRTR, UKPIA data for all refinery sources.
Petrol stations and terminals (all sources)	AD x EF	BEIS energy statistics	UK periodic research (IoP) and annual data on fuel vapour pressures (UKPIA), UK mean temperature data (Met Office), and abatement controls (IoP annual surveys).
Refineries – road / rail loading	Trade association estimates	BEIS energy statistics	UKPIA estimates based on petroleum consumption. Pre-1994 data scaled on energy statistics data for UK petrol use.
Sea-going vessel loading	AD x EF	BEIS energy statistics	UK periodic research (IoP) and annual data on fuel vapour pressures (UKPIA) and temperature data (Met Office).
Gas transmission network leakage	UK gas leakage model	National Grid, Northern Gas	

NAEI Source Category	Method	Activity Data	Emission Factors
Gas distribution network leakage		Networks, Scotia Gas, Airtricity, Wales and West Utilities	Annual gas compositional analysis by the GB gas network operators.
Gas leakage at point of use	UK model	BEIS energy statistics. Leakage % of total by end user sector based on assumptions on unit leakage, operational cycles of gas-fired heaters, boilers, cookers.	Annual gas compositional analysis by the GB gas network operators.
Upstream gas production - gas flaring	AD x EF	EEMS, Oil and Gas UK, BEIS energy statistics	Operator data reported under EEMS, with AD and emissions reported since 1998. Earlier emissions data and factors based on estimates from UK Oil and Gas, using BEIS oil and gas production statistics.
Upstream oil production - gas flaring			
Upstream gas production - gas venting	Operator data, time series assumptions	EEMS, Oil and Gas UK, BEIS energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using BEIS oil and gas production statistics.
Upstream oil production - gas venting			
Refineries - flares	Trade association estimates	UKPIA, BEIS energy statistics	Operator reported emissions under IED/E-PRTR, UKPIA data for all refinery sources.

3.5.1 Classification of activities and sources

The UK emission inventory estimates are derived from a range of methods, but in the 1B sector the key activity data are:

- fuel use production and consumption data from the Digest of UK Energy Statistics, including data on coal extraction, production of coke and other manufactured solid fuels, gas flaring and venting volumes at UK oil and gas production sites (BEIS, 2016);
- refinery activity and source emission estimates reported by refinery operators via the trade association (UKPIA, 2015);
- upstream oil & gas activity data from the EEMS reporting system managed by the BEIS Offshore Inspectorate (BEIS, 2016b); and
- natural gas leakage data provided annually by the gas supply network operators in the UK (National Grid, Northern Gas Networks, Scotia Gas, Airtricity, Wales and West Utilities; all 2016).

The most significant emission estimates in the 1B sector are calculated using operator-reported data from refineries and from the oil & gas exploration and production sector. Other emission estimates are derived from a combination of:

- periodic UK research;
- literature factors (where available, literature EFs are taken from the EMEP-EEA 2016 Guidebook, EMEP-EEA 2013 Guidebook, but in some instances from IPCC 2006 Guidelines, IPCC 1996 Guidelines, USEPA AP-42 and from publications from the EIPPCB);
- annual sampling and analysis, e.g. to determine natural gas composition;
- calculations that utilise fuel qualities and UK temperature data, e.g. to determine fugitive / tank breathing / evaporative losses.

3.5.2 NFR14 1B1: Fugitive emissions from solid fuels

1B1a Fugitive Emissions from Solid Fuels: Coal mining and handling

Coal seams contain a proportion of highly volatile material which is released during the extraction, and then the handling and storage of coal. This material is known as firedamp when emitted in coalmines and is primarily comprised of methane, although other compounds are present in minor quantities. During coal extraction, a number of processes are connected with firedamp emission release;

- developing access to the coal deposit and preparation for extraction;
- coal extraction and transport to the surface;
- coal processing, disposal, transport, and crushing before final use;
- deposit de-methaning before, during, and after its excavation;
- disposal of spoils from the coal extraction system.

The extraction of deep-mine coal is a more important source than open-cast coal mining for emitted NMVOCs. 85% of NMVOC emissions from this NFR14 sector are from deep-mine coal mining and handling. In 2015, this sector contributed 1.0% of the total UK NMVOC inventory.

The inventory draws emission factors upon the EMEP/EEA air pollutant emission inventory 2016 guidebook (EMEP, 2016) for both open-cast and deep-mined coal extraction. The uncertainty in emission factors for NMVOC is very high. The EMEP/EEA 2016 factors are calculated using methane emission factors and the species profile of the firedamp, which both carry high levels of uncertainty when considered in isolation.

Activity data is derived from UK energy statistics (BEIS, 2016), providing data on the tonnage of saleable coal produced from both deep-mine and open-cast sites. At open-cast sites, coal is upgraded to saleable form with some coal rejected in the form of coarse discards containing high mineral matter and also in the form of unrecoverable fines. Typically, around 20% of the weight of the raw coal feed is lost through these preparation processes, according to the 2006 IPCC guidelines (IPCC, 2006). Raw coal production is therefore estimated by increasing the amount of saleable coal by the fraction lost through washing.

1B1b Fugitive Emissions from Solid Fuels: Solid fuel transformation

The main source of emissions is coke production, which is a key category for NMVOCs and also a notable source for other pollutants such as lead (~2.9% of the total Pb inventory in 2015) and PAHs such as Benzo[a]pyrene (~0.9% of the total B[a]p inventory in 2015). The manufacture of other, patented solid fuels is a minor source in the UK inventory context.

Solid fuel transformations include the manufacture of coke oven coke, charcoal and other solid smokeless fuel (SSF); the sector also includes emissions from losses/flaring of coke oven gas at coke ovens and steelworks. Emissions can occur both from the combustion of fuels used to provide heat required for the transformations, but also from fugitive releases from the transformation process itself. Total emissions at UK coke ovens and certain SSF manufacturing sites are reported annually to the IED/E-PRTR pollution inventories of the regulatory agencies, but it is not possible to reliably split these emissions data into a combustion component and a fugitive component. Therefore, emissions are usually reported either under 1A1c or 1B1b and contain both types of emissions. For most pollutants, reporting is under 1B1b.

Coke production and iron and steel flaring emissions of all key pollutants are reported by operators within the IED/E-PRTR pollution inventories. For integrated steelworks, the breakdown of emissions from different sub-sources on the facility are provided to the inventory agency by plant operators. The data for coke oven emissions are used directly within the UK inventory. For many other pollutants where emissions from these sources are generally of lower significance, the inventory estimates draw upon emission factors from literature sources such as the EMEP/EEA guidebook (EMEP, 2013), BREF notes, US EPA AP-42 and industry-specific studies.

Operator-reporting of annual emissions under IED/E-PRTR is less comprehensive for other solid smokeless fuel production, therefore emissions in the UK inventory are generally estimated using literature factors and in some cases (e.g. SO_x as SO_2) using a mass balance approach.

As of 2015, all UK coke oven coke is produced at coke ovens associated with integrated steelworks, although for most of the period covered by the inventory there were independent coke ovens as well. Other solid smokeless fuels (SSF) can be manufactured in various ways but only those processes employing thermal techniques are included in the inventory since only these give rise to significant emissions. Currently, there are two sites manufacturing SSF using such processes.

All of these sites are required to report annual emission estimates to the UK environmental regulatory agencies under the terms of their IED/E-PRTR permits. Emission estimates for the sector can be based on the emission data reported for individual sites:

UK Emission = Σ Reported Site Emissions

There are instances of sites not reporting emissions of some pollutants where the annual estimate is below the reporting threshold under the terms of their regulatory permit. In these instances, the inventory agency derives estimates of the annual emissions based on surrogate information (typically the plant operating capacity) and extrapolating implied emission factors from other reporting plant in the sector, i.e. assuming that emissions per unit production from non-reporting plant are similar to those for other sites. This method to extrapolate data is typically only needed to cover smaller operating sites, and therefore does not add significantly to the UK emission inventory totals.

3.5.3 NFR14 1B2: Fugitive emissions from oil & gas industries

The following are all key source categories for NMVOC (only) in 2015:

- 1B2c (3.1% of the UK NMVOC inventory total). These are primarily from venting and flaring sources in upstream oil and gas exploration and production facilities, with a small contribution from refinery flaring activities. The emissions in 2015 are roughly a 50:50 split between flaring and venting sources; 1B2c emissions in 2015 from oil production far exceed that from gas production, by a factor of over 10;
- 1B2ai (3.9% of the UK NMVOC inventory total). These emissions are from fugitive releases of gases during oil loading and unloading at onshore and offshore facilities, as well as other upstream oil production process and fugitive releases, including from oil well testing. In 2015, the oil loading / unloading emissions account for around 87% of this NFR14 sector total;
- 1B2b (2.8% of the UK NMVOC inventory total). These emissions comprise all fugitive releases from upstream gas processing as well as from the downstream gas transmission and distribution networks and losses at the point of use (prior to ignition). By far the most significant source (approximately 97% of the NFR14 sector total in 2015) is the estimated fugitive losses from the downstream gas transmission and distribution networks;
- 1B2av (2.4% of the UK NMVOC inventory total). These emissions are from downstream oil distribution systems such as spillages, storage losses, and loading / unloading losses at petrol stations and intermediate petrol storage terminals. The most significant source are vehicle refuelling and loading/unloading of refined petroleum products into sea-going tankers for transfer or export;
- 1B2aiv (2.2% of the UK NMVOC inventory total). These are fugitive releases at refineries from components such as valves and flanges on process units, emissions from wastewater treatment systems and emissions from crude oil and product storage tanks.

There are no key source categories for any other pollutant in the 2015 UK inventories, however emissions from refinery processes and fugitive releases in oil distribution are key sources for non-CLRTAP pollutants such as benzene and 1,3-butadiene.

Most of the emissions from the extraction, transport and refining of crude oil, natural gas and related fuels are fugitive in nature: Rather than being released via a stack or vent, emissions occur in an uncontained manner, often as numerous individual small emissions. Typical examples are leakage of gases and volatile liquids from valves and flanges in oil & gas production facilities and refineries, and displacement of vapour-laden air during the transfer of volatile liquids between storage containers such as road tankers and stationary tanks. The magnitude of the emission from individual sources will depend upon many factors including the characteristics of the gas or liquid fuel, process technology in use, air temperature and other meteorological factors, the level of plant maintenance, and the use of abatement systems.

For these reasons it is generally impractical to estimate emissions using simple emission factors applied to some readily available national activity statistic. Instead, methodologies have been developed by industries which allow emission estimates to be derived using detailed process data and it is this type of approach which is used in the inventory for many sources. In most cases, the methodologies are used by process operators to generate emission estimates which are then supplied for use in the inventory. In other cases, where the methodologies are simpler, estimates are derived directly by the inventory agency.

The data sources and inventory methods applied to estimate emissions for each NFR14 sector are described below.

1B2ai Fugitive Emissions from Fuels, Oil - Exploration, Production, Transport

Emission estimates of all pollutants reported within the UK inventories are made based on operator-reported estimates where these are available (1998 onwards), and trade association (UK Oil and Gas) periodic research for earlier years. For upstream oil & gas production sites, since 1998 operators submit annual returns via the Environmental Emissions Monitoring System (EEMS) regulated by the BEIS Offshore Inspectorate, which includes emission estimates of NMVOC, CO_2, CH_4, CO, NO_x (as NO_2), SO_x (SO_2) and fluorinated gases reported by emission source and (where appropriate) fuel type. Under 1B2ai, emissions are reported from:

- processes (such as acid gas treatment or degassing of associated oil);
- oil loading at offshore platforms and storage units or from onshore terminals (in each case from storage tanks on the offshore installation or the terminal onto ships);
- fugitive releases (including tank storage emissions);
- emissions from well testing.

All upstream oil & gas production sites operate under license to BEIS, and the inventory estimates are therefore simply the sum of the EEMS site estimates. Each year the inventory agency conducts quality checking on the EEMS dataset, notably to check time series consistency and address any gaps or inconsistencies through consultation with the regulators at BEIS and the site operators where necessary. For the years prior to the EEMS data reporting system, the UK Oil and Gas trade association has provided industry-wide estimates within periodic publications and data submissions to the inventory agency (in 1995, 1998, 2005), for direct use within the inventory.

In addition to these offshore and terminal sites, there are some additional onshore sites involved in oil extraction from onshore fields in England that report their emissions annually under IED/E-PRTR to the Environment Agency. The emission estimates from these sites are added to those from sites regulated under EEMS and reported within 1B2ai.

1B2aiv Fugitive Emissions from Fuels: Refining and Storage

Emissions of NMVOC and speciated NMVOCs such as benzene and 1,3-butadiene arise from drainage, process and tankage sources on refinery sites, and these emissions are reported within NFR14 1B2aiv. Emissions of NMVOC occur at refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant components such as flanges and valves, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries.

The NMVOC emissions from all refineries are estimated annually and reported to the inventory agency via the UK Petroleum Industry Association (UKPIA, 2016), the trade association for the refinery sector. The UKPIA estimates are compiled by the refinery operators using agreed industry standard methods. The UK inventory estimates are the sum of the data reported from each of the refineries operating each year (6 sites remained in operation at the end of 2015). Annual estimates have been provided by UKPIA since 1993, with 1993 data assumed also to be applicable to all earlier years in the case of emissions from tankage and drainage systems. For process releases on the other hand, the 1993 emission has been extrapolated to earlier years in the time series in line with changes in production. In a few cases, where data for a particular site are not available for a particular year, data from the PI have been used instead.

1B2av Fugitive Emissions from Distribution of Oil Products

Petrol distribution begins at refineries where petrol may be loaded into rail or road vehicles. Petrol is then distributed either directly to petrol stations or via intermediate petrol terminals where it is stored prior to loading into road tankers for distribution to petrol stations. At petrol stations it is stored and then dispensed into the fuel tanks of road vehicles. Emissions of NMVOC occur from each storage stage and from each transfer stage.

Petrol distribution emissions are calculated using petrol sales data taken from the Digest of UK Energy Statistics and emission factors calculated using the UK Institute of Petroleum's protocol on estimation of emissions from petrol distribution. This protocol requires certain other data such as average temperatures, Reid Vapour Pressure (RVP) of petrol and details of the level of abatement in place.

Central England Temperature (CET) data, obtained from the Met Office, is used for the temperature data, while UKPIA supply RVP estimates for summer and winter blend petrol, and estimates of the level of control are based on statistics given in the Institute of Petroleum's annual petrol retail survey.

1B2b Fugitive Emissions from Natural Gas Transmission and Distribution

Emission estimates from the natural gas distribution network in the UK are provided by the gas network operators: National Grid, Scotia Gas, Northern Gas Networks, Wales and West, Airtricity. Natural gas compositional analysis is provided by the gas network operators and emissions of NMVOCs (as well as methane and carbon dioxide) from leaks are included within the UK emissions inventories. The estimates are derived from industry models that calculate the leakages from:

- Losses from high pressure (transmission) networks (National Grid, 2016);
- Losses from low pressure (distribution) networks (National Grid, Scotia Gas, Northern Gas Networks, Wales & West, Airtricity; all 2016); and
- Other losses, from above-ground installations and other sources (National Grid, Scotia Gas, Northern Gas Networks, Wales & West; all 2016).

Additional estimates of gas leakage at the point of use within heating, boiler and cooking appliances in the residential and commercial sectors are made using a combination of:

- Annual gas use in domestic and commercial sectors for heating, cooking (BEIS, 2016)
- Numbers of appliances in the UK in these sectors (Inventory agency estimate, 2016)
- Estimates of gas leakage prior to ignition and typical operational cycle times for different appliances, to determine an overall % of gas that is not burned (and assumed released to atmosphere) (Inventory agency estimate, 2016, based on UK energy efficiency research for recent Government programmes)

The emissions of NMVOC from these sources are then calculated thus:

Emission (t) = UK mean NMVOC concentration in gas (t/kt) x total gas leakage (kt)

The estimates for 1B2b also include emissions reported in the PI by operators at onshore installations extracting gas from onshore fields in England, although emissions are relatively trivial.

1B2c Oil and Natural Gas: Venting and Flaring

Emissions from gas flaring and venting at offshore oil & gas production sites and refineries are all included within 1B2c. The inventory estimation methodology is the same as for the sources outlined above in 1B2a. All upstream oil and gas production sites report annual emission estimates for these sources via the EEMS regulatory system to the BEIS Offshore Inspectorate (BEIS, 2015), whilst refinery flaring estimates are generated by operators and reported annually to the inventory agency via the refinery trade association (UKPIA, 2016). The NMVOC emission estimates in the UK inventories are simply the sum of the reported emissions data for the years where operator reporting is complete (1998 onwards), with industry-wide estimates from periodic studies for earlier years (UKOOA: 1995, 1998, 2005).

3.5.4 Source specific QA/QC and verification

This source category is covered by the general QA/QC of the NAEI in Section 1.6. However, specific, additional QA/QC exists for 1B2 and is described below.

1B2ai, 1B2c
Oil and Gas UK (formerly UKOOA) provides emission estimation guidance for all operators to assist in the completion of EEMS and EU ETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The emission estimates for the offshore industry are based on the BEIS-regulated EEMS dataset for 1998 onwards. Emission estimates for earlier years (i.e. pre-EEMS) are estimated based on industry studies (UKOOA 1995, 1998) which were revised and updated in 2005 (UKOOA, 2005); the approach to deriving emission estimates in the earlier years used oil and gas production data as a basis for back-calculating emission estimates from across the industry. EEMS data quality has improved over recent years through the development of the online reporting systems which have in-built quality checking functions (e.g. to check on completeness of operator reporting against an expected scope of source estimates for each installation). In addition, the inventory agency has also developed more quality checking routines, e.g. to compare EEMS emissions and activity data against EU ETS emissions and activity data, and to compare the implied emission factors for specific emission sources between sites (within year) and across the reporting time series for a given installation. Despite these improvements, however, the completeness and accuracy of emissions reported via the EEMS reporting system is still subject to uncertainty as reporting gaps for some sites are still evident and in some cases identical reported estimates are entered by operators from one year to the next; these data quality issues are typically associated with periodic emission sources where gathering activity data and emissions estimates are problematic (e.g. for health and safety reasons) such as process fugitives. The Inventory Agency continues to work with the regulatory agency, BEIS, to improve the completeness and accuracy of emission estimates from these sources.

The EEMS data are reviewed in detail each year by the Inventory Agency, to assess data consistency and completeness across the time series; this analysis seeks to reconcile data on energy and emissions reported to BEIS and the UK environmental regulatory agencies, comparing and aligning data from DUKES, EEMS and EU ETS.

1B2aiv, 1B2av
The emission estimates from refineries and from petrol distribution are all derived based on consistent methods across the time series using industry standard methods and UK-specific emission factors and models. Uncertainties arise primarily from the use of emission factors for different process designs and delivery systems, especially in the refinery storage, transfer and petrol distribution systems.

Quality checking and verification involves time-series consistency checks and periodic benchmarking against international emission factors for these sources.

1B2b
The emission estimates from leakage from the gas transmission and distribution network are based on UK industry models and annual activity data. Uncertainties stem predominantly from the assumptions within the industry model that derives mass leakage estimates based on input data such as network pipe replacement (plastic replacing old metal pipelines) and activities/incidents at above-ground installations; for these sources the NMVOC content of the gas released is known to a high degree of accuracy, but the mass emitted is based on industry calculations.

The estimates of emission from leakage at the point of use are based on the same gas compositional analysis as outlined above, combined with a series of assumptions regarding leakage from residential and commercial appliances. The same assumptions and factors are applied across the time series.

There is a high degree of uncertainty associated with the activity data for this source, but in the UK inventory context it is a minor source of uncertainty.

Quality checking and verification involves time-series consistency checks and periodic benchmarking against international emission factors for these sources. In addition, checks between datasets from the different UK network operators provides UK-wide consistency checking.

1B2a
Activity data for coal production in deep-mined and open-cast mines in the UK are quality-checked through comparison of data reported within DUKES and data reported directly by the UK Coal Authority, which provides regional and UK totals of coal production. The information provided directly by colliery operators regarding their methane recovery systems are also checked against the data published by BEIS on coal mine methane projects in the UK (which encompasses both operating and closed / abandoned mines with coal mine methane recovery systems).

3.5.5 Recalculations in NFR14 sectors 1B1 and 1B2

The only major recalculations in either NFR14 1B1 and 1B2 since the previous submission are:

- The introduction of estimates for NMVOC emissions from the mining and handling of coal, reported in NFR14 sector 1B1a. This is due to the publication of new emission factors in the EMEP/EEA 2016 air pollutant emission inventory guidebook (EMEP, 2016) and so improves completeness.
- Minor recalculations for the gas leakage from gas transmission due to updated data from gas transmission network operators.

3.5.6 Planned Improvements in Fugitive Emissions (NFR14 1B1 and 1B2)

No specific improvements are planned.

4 NFR14 2: Industrial Processes

Table 4-1 Mapping of NFR14 Source Categories to NAEI Source Categories: Industrial Processes (excluding solvent use).

NFR14 Category	Pollutant coverage	NAEI Source Category	Source of EFs
2 A 1 Cement Production	Particulate Matter	Slag clement production	Literature factor (USEPA AP-42)
2 A 3 Glass Production	Particulate Matter and NMVOC	Glass – container Glass – continuous filament glass fibre Glass – domestic Glass – flat Glass – frits Glass – glass wool Glass – special Glass - ballotini	Operator reporting under IED/E-PRTR & UK-specific factors / research for PM_{10} from glass sector
2 A 5 a Quarrying and mining of minerals other than coal	Particulate Matter, Pb and Zn	Dewatering of lead concentrates Quarrying	UK-specific factors
2 A 5 b Construction and demolition	Particulate Matter	Construction	EMEP/EEA Guidebook
2 A 6 Other mineral products	All CLRTAP pollutants *(except* NO_x (as NO_2), *PAHs, HCB and PCBs)*	Bitumen use	Literature factors, predominantly from USEPA AP-42 with some UK-specific reference sources for PCDD/PCDFs, metals.
		Other industry – asphalt manufacture	
		Cement & concrete batching	
		Brick manufacture – non Fletton	Literature factors (USEPA AP-42, HMIP)
		Brick manufacture – Fletton	Operator reporting under IED/E-PRTR & UK-specific factors / research for PCDD/PCDFs (HMIP).
		Coal tar and bitumen processes	
		Glazed ceramics	Literature factors (USEPA AP-42, HMIP)
		Refractories – chromite based	
		Refractories – non chromite based	
		Unglazed ceramics	
2 B 2 Nitric Acid Production	NO_x (as NO_2)	Nitric acid production	Operator-reported activity and emissions
2 B 6 Titanium dioxide production	CO, Particulate Matter	Titanium dioxide production	Operator-reported emissions
2 B 7 Soda ash production	CO, Particulate Matter	Soda ash Production	Operator-reported emissions
2 B 10 Other chemical industry	All CLRTAP pollutants *(except benzo[b] fluoranthene, Indeno(1,2,3-cd)pyrene and PCBs)*	Chemical industry – cadmium pigments and stabilizers	Literature factors (USEPA AP-42, HMIP, other UK references)
		Chemical industry – carbon tetrachloride	
		Chemical industry – halogenated chemicals	
		Chemical industry – pesticide production	
		Chemical industry – picloram production	

NFR14 Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Chemical industry – sodium pentachlorophenoxide	
		Chemical industry – trichloroethylene	
		Chemical industry – alkyl lead	Operator reporting under IED/E-PRTR & literature factors for PCDD/PCDFs (HMIP), PAHs and metals from some sources
		Chemical industry – ammonia based fertilizer	
		Chemical industry – ammonia use	
		Chemical industry – carbon black	
		Chemical industry – chloralkali process	
		Chemical industry – chromium chemicals	
		Chemical industry – general	
		Chemical industry – magnesia	
		Chemical industry – nitric acid use	
		Chemical industry – phosphate based fertilizers	
		Chemical industry – pigment manufacture	Operator reporting under IED/E-PRTR & literature factors for PCDD/PCDFs (HMIP), PAHs and metals from some sources
		Chemical industry – reforming	
		Chemical industry – sulphuric acid use	
		Chemical industry – tetrachloroethylene	
		Coal tar distillation	
		Solvent and oil recovery	
		Sulphuric acid production	
2 C 1 Iron and steel production	All CLRTAP pollutants *(except NH_3, HCB)*	Basic oxygen furnaces	Operator reporting under IED/E-PRTR, plus additional operator reporting and literature sources for metal emissions and NMVOCs (EEA/EMEP, IPCC, other industry research)
		Blast furnaces	
		Electric arc furnaces	
		Integrated steelworks – other processes	
		Integrated steelworks – stockpiles	
		Iron and steel – flaring	
		Sinter production	
		Cold rolling of steel	Literature factors (EMEP/EEA)
		Hot rolling of steel	
2 C 4 Magnesium production	PCDD/PCDFs	Magnesium alloying	Literature factors
2 C 3 Aluminium production	All CLRTAP pollutants *(except NMVOC, NH_3,Se and PCBs)*	Alumina production	Literature factors (UK research)
		Primary aluminium production - anode baking	Operator reporting under IED/E-PRTR, plus additional operator reporting and literature sources for metal emissions
		Primary aluminium production - general	
		Primary aluminium production - pre-baked anode process	

NFR14 Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Primary aluminium production - vertical stud Soderberg process	
		Secondary aluminium production	Operator reporting under IED/E-PRTR, literature sources for PCDD/PCDFs where no reported emissions (HMIP)
2 C 7 a Copper production	Particulate Matter, CO, Heavy Metals *(except Cr and Se)* and PCDD/ PCDFs	Copper alloy and semis production	
		Secondary copper production	
2 C 5 Lead production	SO_2, Particulate Matter, CO, Heavy Metals *(except Cr and Ni)* and PCDD/ PCDFs	Lead battery manufacture	
		Secondary lead production	
2 C 7 b Nickel production	Ni and PCDD/PCDFs	Nickel production	
2 C 6 Zinc production	Particulate Matter, CO, Heavy Metals *(except Se)* and PCDD/ PCDFs	Primary lead/zinc production	
		Zinc alloy and semis production	
		Zinc oxide production	
		Non-ferrous metal processes	Literature factors (EIPPCB, EMEP/EEA, HMIP, UK industry research)
		Hot-dip galvanising	
2 C 7 c Other metal production	NH_3, Particulate Matter, CO, Heavy Metals and PCDD/ PCDFs	Foundries	
		Other non-ferrous metal processes	Operator reporting under IED/E-PRTR
		Tin production	Literature factors (HMIP, UK industry research)
2 D 1 Pulp and Paper	NH_3	Paper production	
2 D 3 a Domestic solvent use	NMVOC	Agriculture – agrochemicals use	UK industry data (BAMA, Dyer)
		Aerosols - cosmetics and toiletries	
		Aerosols - household products	
		Aerosols - car care products	
		Non-aerosol products - automotive products	UK-specific and US emission factors (UK industry, USEPA)
		Non-aerosol products - cosmetics and toiletries	
		Non-aerosol products - domestic adhesives	
		Non-aerosol products - household products	
		Non-aerosol products - paint thinner	
2 D 3 b Road paving with asphalt	NMVOC, Particulate Matter, Benzo[a]Pyrene, PCDD/PCDFs	Bitumen use	UK industry data and country-specific factors
		Road dressings	
		Asphalt manufacture	
2 D 3 d Coating applications	NMVOC, Particulate Matter	Decorative paint - retail decorative	UK industry data
		Decorative paint - trade decorative	
		Industrial coatings - agricultural and construction	
		Industrial coatings - aircraft	
		Industrial coatings - high performance	

NFR14 Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Industrial coatings - vehicle refinishing	
		Industrial coatings - commercial vehicles	
		Industrial coatings - wood	
		Industrial coatings - marine	
		Industrial coatings - metal and plastic	
		Industrial coatings - automotive	Operator-reported data and UK literature factors from industry sources
		Industrial coatings - coil coating	
		Industrial coatings - drum	
		Industrial coatings - metal packaging	
		Industrial adhesives - other	UK industry data and country-specific factors
		Industrial adhesives - pressure sensitive tapes	Operator-reported data
		Paper coating	
		Textile coating	
		Leather coating	
		Film coating	
2 D 3 e Degreasing	NMVOC	Leather degreasing	UK industry data and country-specific factors
		Surface cleaning - 111-trichloroethane	UK industry data and emission factors based on EMEP/EEA Guidebook
		Surface cleaning - dichloromethane	
		Surface cleaning – tetrachloroethylene	
		Surface cleaning - hydrocarbons	
		Surface cleaning - oxygenated solvents	
2 D 3 f Dry cleaning	NMVOC	Dry cleaning	UK industry data and country-specific factors
2 D 3 g Chemical products	NMVOC and Particulate Matter	Coating manufacture - adhesives	UK industry data and country-specific factors
		Coating manufacture - printing inks	
		Coating manufacture – other coatings	
		Tyre manufacture	
		Other rubber products	
2 D 3 h Printing	NMVOC	Printing - heatset web offset	UK industry data and country-specific factors (BCF)
		Printing - metal decorating	
		Printing – newspapers	
		Printing - other flexography	
		Printing - other inks	
		Printing - other offset	
		Printing - overprint varnishes	
		Printing - print chemicals	
		Printing - screen printing	

NFR14 Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Printing - flexible packaging	Operator-reported data
		Printing - publication gravure	
2 D 3 i Other solvent use	NMVOC, PAHs	Seed oil extraction	Operator-reported data
		Other solvent use	UK industry data and country-specific factors (HMIP, Giddings et al)
2G Other product use	PAHs, PCDD/PCDFs, NH_3	Cigarette smoking	UNEP (2013) for PCDD/PCDFs and literature factors for PAHs and NH_3
	CO, Cu and Particulate Matter	Fireworks	Emission Agency estimates based on industry
2 H 2 Food and Drink	NMVOC and NH_3	Bread baking	Literature factors (HMIP, UK industry research)
		Brewing - fermentation	Literature factors, mainly from UK industry research, some EMEP/EEA factors for NMVOCs
		Brewing - wort boiling	
		Cider manufacture	
		Malting - brewers' malts	
		Malting - distillers' malts	
		Malting - exported malt	
		Other food - animal feed manufacture	
		Other food - cakes biscuits and cereals	
		Other food - coffee roasting	Literature factors, mainly from UK industry research, some EMEP/EEA factors for NMVOCs
		Other food - margarine and other solid fats	
		Other food - meat fish and poultry	
		Other food - sugar production	Operator reported data under IED/E-PRTR
		Spirit manufacture - casking	Literature factors, mainly from UK industry research, some EMEP/EEA factors for NMVOCs
		Spirit manufacture - distillation	
		Spirit manufacture - fermentation	
		Spirit manufacture - other maturation	
		Spirit manufacture - Scotch whisky maturation	
		Sugar beet processing	
		Spirit manufacture - spent grain drying	Literature factor (USEPA AP-42)
		Wine manufacture	Literature factor (UNECE VOC Task Force)
2 H 3 Other	Particulate Matter	Other industry - part B processes	Literature factor from UK research
2 I Wood processing	NMVOC, Pb, Hg, As, Cr, Cu, Ni, Particulate Matter and PAHs	Wood products manufacture	Literature factors (USEPA AP-42) Operator reported data under IPPC
2 K Consumption of POPs and heavy metals	PCDD/ PCDFs, PCBs	Capacitors	Literature factors (Dyke et al)
		Fragmentisers	
		Previously treated wood	
		Transformers	

4.1 Classification of activities and sources

Table 4-1 relates the detailed NAEI source categories to the equivalent NFR14 source categories.

The following NFR14 source categories are key sources for major pollutants in 2014: 2A5a & 2A5b (TSP, PM_{10}), 2B10a (Hg, Pb), 2C1 (CO, TSP, PM_{10}, $PM_{2.5}$, Pb, Hg, Cd, PCDD/ PCDFs), 2C7c (Hg, Pb), 2D3a (NMVOC), 2D3d (NMVOC, TSP, PM_{10}, $PM_{2.5}$), 2D3h (NMVOC), 2D3i (NMVOC), 2H2 (NMVOC), and 2I (Pb). The Description of the inventory methodology will therefore focus on these source categories.

4.2 Activity data

Activity data for some industrial sources is readily available from national statistics published by the Office of National Statistics (ONS). Other suppliers of data include the Iron & Steel Statistics Bureau (ISSB), the British Geological Survey (BGS), and trade associations such as the Mineral Products Association (MPA) and the Scotch Whisky Association (SWA).

Complete and transparent activity data are not available for all sources from UK industry, primarily due to the limited availability of production statistics for key commodities. There are no suitable UK Government statistics for many industrial sectors/products and even where there are publications covering industry sectors (such as the PRODuction COMmunautaire (PRODCOM) publications from ONS), these are incomplete due to the need to suppress data that are commercially sensitive. Furthermore, the ONS production data are typically available on the basis of sales value or the number of items produced, and often disaggregate production down into categories that don't fit well with inventory reporting structures. Hence, the ONS data are of limited usefulness for inventory estimation methods and therefore, the inventory agency uses limited published data and mostly consults with trade associations to generate activity estimates for many high-emitting industrial sectors such as:

- chemical manufacture;
- mineral industry processes;
- secondary non-ferrous metal processes;
- foundry production; and
- pulp and paper processes.

In many cases, emissions data are available directly for all sites in a sector (for example from the PI/SPRI/WEI/NIPI) and so activity data have no direct impact on the UK emission estimates. In cases where we have activity data, this can of course be used to generate an 'implied emission factor (IEF) which can be compared against, for example, default factors given in the EMEP/EEA Guidebook. This is done to check consistency and accuracy of data where possible. In cases where activity data cannot easily be estimated, an arbitrary figure (usually 1) may be used as the activity data in the inventory database and the emission factor is then equal to the reported emissions. In these cases, while the emission estimates will be robust, the activity data and emission factors held in the NAEI database will be essentially arbitrary and cannot be used to, for example, compare UK emission estimates with data for other countries or in guidance documents. A further limitation is that where the reported emissions data only cover some years (which is normally the case), emissions for other years cannot be estimated on the basis of trends in activity data. Instead, emissions are assumed to be the same in those years as in the other years for which we have data

Emission estimates for NFR14 sector 2D3 are predominantly based on solvent consumption data supplied by industry or regulators; national activity data are not used to any significant extent, as few data are available that can reliably be used for the purposes of estimating emissions from solvent use. For example, we are not aware of any Government statistics that provide suitable detail on the consumption of paints, inks, adhesives, or other coatings, cleaning solvents, aerosols, or other consumer products. Information direct from industrial contacts is therefore regarded as the best available. This information is rarely available on a routine basis and so the time-series of data that we use requires some assumptions or extrapolation to fill the many gaps in the information we have.

4.3 Methodology for mining and quarrying (NFR14 2A5a)

The UK has currently few active underground mines and most minerals in the UK are extracted from quarries. Production is dominated by aggregate minerals, clays and industrial minerals; the production of metalliferous ores has been trivial in scale for many years. Emissions are predominantly from extraction of the minerals and primary processing stages such as crushing. Emissions are generally fugitive in nature and difficult to quantify. Emission estimates for PM_{10} are based on the use of a series of literature-based emission factors combined with national activity data. Emission factors are taken from the US EPA Compilation of Emission Factors (AP-42, US EPA, 2012) and are available for different types of sources within the mining and quarrying industries including extraction of quarried materials, initial processing of minerals (e.g. crushing and grinding), wind erosion of dusty materials and re-suspension of dust by quarry vehicles. Emission factors for each emission source category are applied to the activity data for the appropriate extracted minerals (e.g. emissions from product drying are included for clay minerals, but not for aggregates). Overall emissions from all mineral types and source categories are calculated, and an overall implied emission factor calculated by dividing this emission by total UK production of all mined/quarried products. The uncertainty of the emission estimates is considered to be high, but alternative data have not been found. During 2013, the inventory agency consulted with UK mineral sector research experts to seek any new data on particulate emission factors, but none were available; the use of USEPA AP-42 factors remains the industry standard approach in the UK, although the USEPA factors are widely considered to generate conservative emission estimates by the industry.

4.4 Methodology for construction (NFR14 2A5b)

Emissions of particulate matter from construction are estimated using the default method given in the 2013 EMEP/EEA Guidebook. This consists of an emission factor requiring activity data in the form of the annual area of new construction. This activity data does not exist for the UK so has to be estimated from other statistics such as the number of houses built. Both the emission factor and the activity data are subject to very high uncertainty.

4.5 Methodology for chemical processes (NFR14 2B10a)

The UK has a large and varied chemical industry and process operators are required by regulators to report emissions in the PI, SPRI, WEI or NIPI. Emission estimates for NMVOC, CO & metals are based on a bottom-up use of these data. In the case of CO and metals in particular, there is potential for emissions reported for chemical manufacturing sites to arise from site boilers and other combustion processes co-located with the chemical manufacturing plant. This potential problem has been minimised as far as possible by review of all of the permitted chemical processes in order to identify the nature of the chemical processes carried out at each site, and to thereby determine what emissions are likely from the chemical manufacturing process, and whether combustion processes are also present. The inventory agency then only reports emissions within 2B10 for those sites where we believe that emissions are most likely process-related, rather than due to fuel combustion.

Emission estimates for chemical industry processes are based on reported emissions data, and therefore the quality of the national emission estimates depends upon the quality of the operator-reported data. The operator-reported emissions data from the PI, SPRI, WEI & NIPI are subject to the appropriate regulator's QA/QC procedures and are regarded to be good quality data for most pollutants..

Emission estimates for HCB from NFR14 2B5a have historically related to the manufacture of, carbon tetrachloride, sodium pentachlorophenoxide, tetrachloroethylene and trichloroethylene. Production of carbon tetrachloride and sodium pentachlorophenoxide in the UK terminated in 1993 and 1996, respectively. The UK's sole manufacturer of tetrachloroethylene and trichloroethylene ceased production in early 2009, and hence emissions of HCB from NFR14 2B5a are assumed to be zero for 2009 onwards. For NMVOC emissions data, however, the reported data are not all used directly, as further calculations and extrapolations are required by the inventory agency to address known issues that affect data accuracy, completeness and time series consistency. Particularly during the early years of the PI, emissions of organic compounds were reported in such a way that double-counting of emissions was possible in many cases, with emissions of ‘total’ VOC reported as well as individual VOC species. But the species reported often changed from year to year and the emissions reported for many sites also varied greatly from one year to the next. It is not certain whether these inter-annual variations are due to gaps in reporting or whether they reflect real changes in emissions. The NAEI estimates for NMVOC from chemical industry processes therefore rely upon a significant degree of interpretation of the regulators’ data with ‘gaps’ being filled (by using reported data for the same process in other years) when this seems appropriate, and other reported data being ignored to minimise the risk of double-counts. As a result, the national emission estimates for NMVOC from chemical processes are associated with higher uncertainty than most other national estimates based on regulators’ data.

4.6 Methodology for iron & steel processes (NFR14 2C1)

UK iron and steel production leads to emissions from integrated steelworks, electric arc steelworks, downstream processes such as continuous casting and rolling of steel, and iron & steel foundries.

Integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. These works also have coke ovens to produce the coke oven coke needed in the process, but emissions from this part of the works are reported elsewhere in the UK inventory.

Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter.

Blast furnaces are used to reduce the iron oxides in iron ore to iron. The furnaces are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke and coal. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron.

Gas leaving the top of the blast furnace has a high heat value because of the residual CO content, and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. Subsequent cooling of the slag with water can cause emissions of SO_2.

Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is not collected and is instead lost and emissions from these gas losses are reported under NFR14 category 2C1.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, not all gases are collected, and some gas may be flared and emissions are reported with blast furnace gas losses under NFR14 category 2C1.

Electric arc furnaces produce steel from ferrous scrap, using electricity to provide the high temperatures necessary to melt the scrap. Emissions of NO_x (as NO_2) occur due to oxidation of nitrogen in air at the high temperatures within the furnace. Emissions of NMVOC and CO occur due to the presence of organic contaminants in the scrap, which are evaporated and partially oxidised.

Emission estimates for all of these processes are generally based on a bottom-up approach using i) data covering the period 2000 to 2015 from the operators of all UK integrated works, one large electric arc steelworks and a further electric arc furnace steelworks that ceased production in 2005 and ii) emissions reported in the PI, WEI & SPRI (there are no sites in Northern Ireland) for other electric arc steelworks and data covering 1998 to 1999 in the case of integrated steelworks. In recent years, there have been significant gaps in the data provided by the operators and so, data in the PI & WEI have had to be used instead. While the PI & WEI (sites are located only in England and Wales) emissions data should be comparable, they are less detailed, consisting of just a site-total for each works, rather than the separate figures for sintering, blast furnaces, oxygen furnaces etc. that the operators have normally provided. In these cases, we have had to estimate how to split the reported emission into the various processes, based on the pattern of emissions in other years. Literature emission factors are used for some minor emission sources, while emissions for the earlier part of the time series for processes at integrated and electric arc steelworks are estimated by extrapolation back of emission factors from later years.

4.7 Methodology for aluminium processes (NFR14 2C3)

The UK had one small primary aluminium producing site at the end of 2015 following the closure of a large smelter in Wales and another in England in late 2009 and early 2012 respectively. The UK also has a number of secondary aluminium processes, including the recovery of aluminium from beverage cans, and the production of aluminium foil and alloys.

All of the primary aluminium sites operating in the UK in the recent past have used the pre-baked anode process, with anodes baked at the two sites which closed in 2009 and 2012. One small smelter employed the vertical stud soderberg process, but closed in 2000. All of the primary sites and the large secondary processes reported emissions in the PI, SPRI, WEI or NIPI and these data are used in the NAEI. It is possible that some small secondary aluminium processes may operate in the UK and be regulated by local authorities in England, Wales or Northern Ireland, and therefore do not report emissions in the PI, WEI or NIPI. There are no data available to the inventory agency to enable emissions to be estimated from any such sites, but their omission should not add significantly to the uncertainty in UK inventory estimates for the sector. Aluminium processes used to be a key source of PAHs but since the largest sites have now closed, emissions are zero or much lower than previously and therefore no longer a key source.

4.8 Methodology for zinc processes (NFR14 2C6)

UK production of many non-ferrous metals has been relatively small for many years and the only primary lead/zinc producer closed in 2003. Various smaller zinc processes remain in operation, manufacturing zinc oxide, or zinc alloys, but emissions from these processes are relatively trivial.

Emission estimates are based on a bottom-up approach using emissions reported in the PI & WEI only since no significant processes operate in Scotland or Northern Ireland.

4.9 Methodology for copper processes (NFR14 2C7a)

The UK has no primary copper production and the only secondary copper production process closed in 1999. Various small copper processes producing copper wire, alloys etc. are still in operation but emissions from these sites are relatively trivial.

Emission estimates are based on a bottom-up approach using emissions reported in the PI only since no significant processes operate in Scotland, Wales, or Northern Ireland.

4.10 Methodology for other non-ferrous processes (NFR14 2C7c)

The UK has a large number of mainly small foundries, most of which are regulated by local authorities. Therefore, unlike the non-ferrous metal processes covered by 2C5, 2C6, 2C7a, and 2C7b, most of these processes do not report emissions in the available regulator inventories, so there is very little data on which to base a bottom-up emission estimate. Emissions are instead generated using UK foundry activity data and UK-specific emission factors. A small number of other non-ferrous metal processes are regulated by national regulators (solder manufacturers and production of precious metals for example) and do report in the PI, and emissions from these sites are also included in the estimates for 2C7c.

4.11 Methodology for solvent use (NFR14 2D3)

Solvents are used by a wide range of industrial sectors as well as being used by the general public. Many applications for industrial solvent use require that the solvent is evaporated at some stage, for example solvent in the numerous types of paints, inks, adhesives and other industrial coatings must evaporate in order for the coating to cure. The solvent contained in many consumer products such as fragrances, polishes and aerosols is also expected to be released to atmosphere when the product is used.

Emissions of NMVOC from use of these solvents can be assumed to be equal to solvent consumed in these products, less any solvent that is recovered or destroyed. In the case of consumer products and smaller industrial processes, such as vehicle refinishing processes, the use of arrestment devices such as thermal oxidisers would be prohibitively expensive and abatement strategies therefore concentrate on minimising the solvent consumption. Solvent recovery and destruction can be ignored for these processes.

In comparison, larger industrial solvent users such as flexible packaging print works, car manufacturing plants and specialist coating processes such as the manufacture of hot stamping foils are generally use using thermal oxidisers or other devices to capture and destroy solvent emissions. In these cases, NMVOC emissions will still occur, partly due to incomplete destruction of solvent by the arrestment device, but also because some ‘fugitive’ emissions will avoid being captured and treated by that device. The level of fugitive emissions will vary from process to process, and will depend upon the extent to which the process is enclosed. For these sectors, it is still possible to estimate emissions based on solvent consumed, but allowance must be made for solvent destroyed or recovered. This can only be done accurately if the extent of abatement can be reliably estimated for each site. In most cases this means that detailed information at individual plant level must be gathered.

Other uses of solvents do not rely upon the solvent being evaporated at some stage and, in contrast, losses of solvent in this way are prevented as far as possible – for example in paint & ink manufacture, where solvents are used in the manufacture of saleable products. Emission estimates for these sectors can be made using emission factors (i.e. assuming some percentage loss of solvent). Further processes such as publication gravure printing, seed oil extraction, and dry cleaning include recovery and re-use of as much of the solvent as possible, although new solvent must be introduced to balance any fugitive losses. Emission estimates for these sectors can be made using solvent consumption data. Finally there are some applications where solvent is used in products but is not entirely released to atmosphere. Solvent used in wood treatments and certain grades of bitumen can be retained in treated timber and in road dressings respectively. In these cases, emission estimates are based on solvent consumption data but include an allowance for solvent not released. Table 4-2 shows how estimates have been derived for each NAEI source category.

Most industrial solvent-using processes in England, Wales & Northern Ireland are regulated by local authorities rather than by the national regulator, and so any emissions data for these processes is dispersed across hundreds of separate authorities. Such data cannot easily or cheaply be collected for use in the UK inventory and so this is not done, although some data were acquired in the 1990s and early 2000s. Data for a number of Scottish sites is available from SEPA but these processes are believed to contribute only a very small proportion of UK emissions.

Table 4-2 Methods for Estimating Emissions from Solvent and Other Product Use.

NAEI Source Category	General method
Aerosols (car care, cosmetics & toiletries, household products) Agrochemicals use Decorative paint - retail decorative Decorative paint - trade decorative Dry cleaning Industrial adhesives (general) Industrial coatings - agricultural and construction Industrial coatings - aircraft Industrial coatings - commercial vehicles Industrial coatings - high performance Industrial coatings – marine Industrial coatings - metal & plastic Industrial coatings - vehicle refinishing Industrial coatings – wood Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Other rubber products Other solvent use Printing – newspapers Printing - other flexography Printing - other inks Printing - other offset Printing - overprint varnishes Printing - print chemicals Printing - screen printing Surface cleaning - hydrocarbons Surface cleaning - oxygenated solvents Leather degreasing	Solvent consumption data for the sector, assumption that little or no solvent is recovered or destroyed.
Industrial coatings – automotive Printing - heatset web offset Printing - metal decorating Surface cleaning - 111-trichloroethane Surface cleaning – dichloromethane Surface cleaning - tetrachloroethylene Surface cleaning – trichloroethylene	Solvent consumption data for the sector, with adjustments to take account of likely abatement of solvent. In the case of surface cleaning, assumptions on abatement efficiency are taken from the EMEP/EEA Guidebook.
Industrial coatings - coil coating Industrial coatings – drum Industrial coatings - metal packaging Printing - flexible packaging Film coating Industrial adhesives (pressure sensitive tapes) Leather coating Paper coating Textile coating Tyre manufacture	Solvent consumption data at individual site level with adjustments to take account of abatement at each site.
Printing - publication gravure Seed oil extraction	Mass balance data at individual site level
Coating manufacture – adhesives Coating manufacture - inks Coating manufacture - other coatings Wood Impregnation, Creosote use	Emission factor (assumed percentage loss of solvent)

Some solvent using processes have the potential to emit dust, for example when coatings are applied by spraying. UK-specific emission factors for industrial coating processes have been developed based on a limited set of data for individual sites and these factors are used to calculate UK wide emissions.

The estimates for solvent use are heavily dependent upon data from trade associations, process operators and regulators. Government statistics are not available for most of the activities that result in emissions of solvent – there are no detailed Government data on consumption of paints, inks, adhesives, aerosols or other consumer products, for example. Without suitable activity data, the emission factors provided in the EMEP/EEA Guidebook can't generally be used, and so the UK inventory methods mostly rely upon estimates of solvent consumption and/or solvent emissions in each sector. That information has been provided by UK industry and regulators, but on an ad-hoc basis and there is relatively little information that is updated routinely.

Collecting such data is resource-intensive both for the inventory agency and for industry and regulators, and has been assigned a lower priority to address compared to other tasks within the inventory improvement programme in recent years. The current estimates are therefore based on information gathered over a long period and some of the estimates are wholly dependent on very old data. The estimates for the period 1990-2005 are typically based on more data than is the case for estimates for 2006 onwards, and it is likely that estimates are becoming marginally more uncertain each year because of the shortage of new data.

4.12 Methodology for Other product use (NFR14 2G)

Emissions from cigarettes smoking and fireworks were previously reported under NFR 6, however, in response to the recommendations made in the 2016 Stage 3 review, these categories are now reported under 2G.

National statistics from the monthly digest (detailed consumer price index reference tables published by the Office for National Statistics) are used to provide data on the quantity of both readymade cigarettes and loose tobacco. To convert all activity to the same units the inventory agency makes assumptions about the weight of a hand rolled cigarette to convert loose tobacco into numbers of complete items. Literature factors are then used to calculate emission estimates for combustion of cigarettes. Emission factors are taken from; for PCDD/PCDFs the UNEP (2013), for PAHs (Xinhui, 2005) and for NH_3 (Sutton, 2000).

UK national statistics from Prodcom are used to quantify the amount of fireworks imported and sold in the UK each year plus an assumption that an additional 5% of fireworks are supplied by the UK manufacturers. Latest Prodcom data is available up to year 2013 only; so for years 2014 and 2015, it is assumed to be the same as 2013. More recent data are available from HMRC, but are based on product value rather than quantity. Adapting the HMRC data to provide data from 2014 onwards would be a valuable inventory improvement. It is also assumed that the quantity sold is equal to the quantity detonated in the same year. Individual fireworks are made up of a number of components which can simplistically be divided into the detonating charge (gunpowder) and 'effects' for colour and sound, usually based on metals. The inventory agency has produced profiles for the contents and ratios of metals in fireworks for different colours and then ratios for quantities of different colours in products sold, with reds, golds and silvers more easy to manufacture than greens and blues dominating the quantities of each sold within the total quantity of fireworks on sale.

Estimates of emissions of PM_{10} from fireworks are based on the assumption that all solid products from the combustion of the propellant charges in fireworks are emitted as PM_{10} and that no emissions occur from any of the reactions occurring to the 'effects' used in fireworks. Since the effects make up approximately half of the explosive charge in a typical firework, it is possible that they actually contribute significantly to PM_{10} emissions.

Estimates of the emissions of metals (Cu, K, Mg, and Na) are based on the profiles for different colours used within fireworks and likely ratio of each colour to the total sale. As stated approximately 50% of the weight of the firework will be the effect and this is used to derive the activity to provide emission estimates.

4.13 Methodology for food and drink processes (NFR14 2H2)

Emissions occur from a variety of processes including bakeries, malting, animal feed manufacture and production of fats and oils, but the most significant emissions are those from manufacture of Scotch Whisky and other spirits. Emission factors for spirits manufacturing, brewing and bakeries are UK-specific and derived based on information supplied by industry. The NMVOC emitting processes on these sites are either mainly or entirely outside the scope of the IED, and there is little or no NMVOC emissions data for these sites, and the industry data are therefore considered more reliable. We have no industry data for sugar production but all of the UK plant recovering sugar from sugar beet report emissions in the PI, including very limited data for NMVOC emissions, and this is used as the basis of the UK inventory estimate. Emission factors for other significant sources are taken from the EMEP/EEA Guidebook (EMEP, 2013).

Emission factors for significant sources related to spirits manufacture are expected to be quite reliable, despite being generally based on industry approximations (e.g. the factors used for whisky casking, distillation, and maturation). This is due to close monitoring of production and losses that is carried out both because of the value of the product, and the need for Government to monitor production for the purposes of calculating duty to be paid.

Factors for other processes, particularly those related to food production rather than manufacture of alcoholic beverages, are much more uncertain and are regarded as among the most uncertain sources within the NMVOC inventory.

4.14 Methodology for wood processes (NFR14 2I)

The manufacture of fibreboard, chipboard and oriented strand board is a key category for lead emissions. There were seven known sites manufacturing such products in 2014, with an eighth having closed in 2012. Three of these sites are located in Scotland and one in Northern Ireland, and these 4 sites have reported emissions data for metals to their respective UK regulators, and some emissions data for the remaining 3 sites is present in the E-PRTR. These data indicate that the sites emit significant quantities of metals, particularly lead, and for the Scottish sites at least, this is known to be due to the burning of waste wood as fuel. Metal emission estimates for the sector have been derived from the emissions data reported by the four sites, with extrapolation to the remaining UK sites on the basis of production capacity at each site.

Possibly the emissions of metals should be reported in 1A2g, but for the current version of the inventory they were reported in 2I, alongside emissions of VOC and particulate matter from the wood product manufacturing processes.

4.15 Source specific QA/QC and verification

For most industrial process sources, the QA/QC procedure is covered under the general QA/QC of the NAEI in Section 1.6. Additional procedures are given below for the indicated categories.

Some emission estimates for 2A, 2B and 2C rely upon emissions data reported in the PI, SPRI, WEI, and NIPI. Section 3.1.7 discusses QA/QC issues regarding these data.

There are numerous instances where data from EU ETS process emission sources has been used as a QC to check other data, for example cement production data from the MPA, and lime production data from BGS. QC of activity data for specific industries is also carried out between trade association data and other reference sources, such as a comparison between data from Tata steel and the ISSB. Any discrepancies are investigated and resolved via stakeholder consultation.

4.16 Recalculations in Industrial processes (NFR14 2)

The most significant recalculations in NFR14 2 since the previous submission are:

- Some updated coating sales data and E-PRTR emissions data were incorporated for solvent use (2D) and led to both increases and decreases in NMVOC emission estimates, although the net change was a slight increase of 5 kilotonnes in 2014.
- Emission estimates for fireworks and cigarette smoking have been moved to 2G from 6A.
- The inclusion of new data for wood-product plant in England and Wales has had varying impacts on emission factors for metals from 2I. Factors for arsenic, cadmium, lead and nickel are all typically higher for all years, although the increase varies from metal to metal and from year to

year. Factors for mercury are sometimes slightly lower, sometimes slightly higher. Figures for 2014 relative to the previous inventory are +1% (Hg), +32% (Ni), +87% (Cd), and +140% (As & Pb).

- A correction to the calculation of emissions for coke ovens leading to an increase in emissions of most pollutants from the sector, by between 5% and 15% in 2010 and 2011. Emissions in other years are not affected by this correction.
- Revised estimate for zinc alloys production on the basis of new information on the closure of a key site in 2005, whereas previously we had believed this plant to still be in operation. Emissions from this sector were, and still are utterly trivial but the change in the assumption does lead to a significant change in the PM_{10} emission estimate for the 2C6 sector in percentage terms – down 90% in 2014.
- There is also a fairly large recalculation in percentage terms (-50% for 2011-2013) for the 2C7a sector but again trivial in absolute terms. Like the change for 2C6 this recalculation occurs due to changes in our knowledge of a single site, this time manufacturing copper alloys. Emissions of PM_{10} from this site are now known to be lower than previously thought.

4.17 Planned Improvements in Industrial Processes (NFR14 2)

Many of the emission estimates for industrial processes are based on emissions data reported by process operators in the PI/SPRI/WEI/NIPI, and so the inventory can be updated each year with a further years' worth of data, and the quality of emission estimates is generally high. The completeness of the reported data varies from sector to sector and from pollutant to pollutant. Some source categories, such as processes at integrated steelworks consist solely of large plant emitting substantial quantities of pollutants and so reporting of emissions to regulators is complete or near-complete. Other categories, such as some types of non-ferrous metal works, are typically made up of much smaller operations and reporting is much less complete. Reporting to the PI/SPRI/WEI/NIPI is only required in cases where emissions from a permitted process exceed a pollutant-specific threshold, and so many smaller processes simply report that their emissions do not exceed the threshold. A particular problem however, is those other processes for which the operators provide no information on emissions (i.e. no emission estimate or confirmation that emissions are below reporting thresholds) and little other industry data or government statistics is available. In many of these cases it is reasonable to assume that the process does have some emissions and so the emissions must be estimated. This is done by extrapolation using the data for sites that do report and this 'gap-filling' can constitute a significant proportion of the sectoral emissions in some cases. The current approach also tends to accentuate the inter-annual fluctuations in reported emissions, because the gap-filling each year relies just upon the reported data for that year. For example, if just one plant within a sector reported emissions each year, that data would be used each year to calculate emissions at the non-reporting sites. If that one site happened to provide a higher than normal emission in one year, then the extrapolated emissions for that year would also be higher than normal. This example is an extreme case, but does illustrate a weakness of the method used in the inventory. Fortunately, the sectors where gap-filling and extrapolation of data are most necessary are those that consist of small processes, and so the sector emissions are almost always trivial compared with UK emissions as a whole. So, while it would be desirable to improve the methods, it is not a priority.

One relatively recent problem concerns 2C1 and emissions from integrated steelworks. These steelworks have emissions that need to be reported in 1A2a, 1B1b, and 2C1 and in the past we have received very detailed emissions data each year from the operators. Data available now from PI/WEI for these sites are only gives a site total emission, so the emissions in each of 1A2a, 1B1b and 2C1 aren't given. The data direct from the operators can still give this breakdown. However, the availability of the detailed data has deteriorated in the last 5 years, at least in part because of the financial problems at all of the UK steelworks (one of which was mothballed for a period and finally closed). We still have site total emissions via the PI & WEI so the UK inventory totals still include all emissions at UK steelworks, but the reporting to 1A2a, 1B1b and 2C1 is far less accurate and based on extrapolation and assumptions.

In the case of NMVOC sources in NFR14 2D3, emission estimates are largely based on data gathered over many years on an ad-hoc basis from process operators, trade associations, and regulators. Very little information has been gathered in the last 10 years, partly because the collection of new data is resource-intensive and other areas of and improvements to the NAEI have been assigned higher priority. However, also because efforts to collect new data from industry have, to a large extent, not been particularly fruitful, with consultees being unable to provide any data. As a result, the quality of the NMVOC inventory has slowly deteriorated due to the need to extrapolate from increasingly old data. This part of the NAEI is now therefore a priority area for improvement, although options for making improvements are limited and usually resource-intensive, and progress is very dependent upon assistance from industry or other stakeholders.

Many of the emission estimates for particulate matter are highly uncertain for two reasons, the first being that the emissions in many cases are essentially fugitive in nature and hard to quantify. Secondly, many processes that emit dust are regulated by local authorities, and there is no central database of emissions data for these processes (so nothing comparable to the PI, WEI, SPRI or NIPI). Emissions therefore have to be estimated using top-down approaches such as use of literature emission factors. Since the sites are regulated, it is reasonable to assume that some strategies will be in place to minimise dust emissions but again, the lack of any centrally-held records, and the fact that these sites will be regulated by hundreds of different authorities make it difficult to be certain what level of control of emissions will be in place or even what technologies and processes occur at each site.

5 NFR14 3: Agriculture

5.1 Classification of activities and sources

Table 5-1 relates the detailed NAEI source categories for agriculture used in the inventory to the equivalent NFR14 source categories. A number of the NAEI source categories are only used to describe emissions of greenhouse gases and the methodologies used to produce estimates for these categories are therefore not covered in this report.

Table 5-1 Mapping of NFR14 Source Categories to NAEI Source Categories: Agriculture

NFR14 Category		Pollutant coverage	NAEI Source	Source of EFs
3B1a	Manure management - Dairy cattle	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - dairy cattle/waste	UK Factors
3B1b	Manure management - Non-dairy cattle	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - other cattle/waste	
3B2	Manure management - Sheep	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - sheep/waste	
3B3	Manure management - Pigs	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – pigs/waste	
3B4d	Manure management - Goats	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – goats/manures	
3B4e	Manure management - Horses	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – horses/manures	
3B4gi	Manure management - Laying hens	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - laying hens/manures	
3B4gii	Manure management - Broilers	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – broilers/manures	
3B4giii	Manure management - Turkeys	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – turkeys/manures	
3B4giv	Manure management - Other poultry	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - other poultry/manures	
3B4h	Manure management - Other animals (please specify in IIR)	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – deer/manures	
3Da1	Inorganic N-fertilizers (includes also urea application)	NH_3	Agricultural soils	UK factors (model)
3Da2a	Livestock manure applied to soils	NH_3	Agriculture livestock - Animal manure applied to soils	UK factors (model)
3Da2b	Sewage sludge applied to soils	PCBs	Application to land	
3Da3	Urine and dung deposited by grazing animals	NH_3	N-excretion on pasture range and paddock unspecified	UK factors
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	$PM_{2.5}$, PM_{10}, TSP	Agricultural soils	Literature sources
3Df	Use of pesticides	HCB	Agricultural pesticide use - chlorothalonil use	UK Factors
			Agricultural pesticide use - chlorthal-dimethyl use	
			Agricultural pesticide use - quintozine	
3F	Field burning of agricultural residues	NO_x (as NO_2), NMVOC, Particulate Matter, PCDD/ PCDFs, PAHs, PCBs for 1990-1992 only	Field burning	

The following NFR14 source categories are key sources for major pollutants: 3B1a (NH_3, NMVOC, TSP, PM_{10}), 3B1b (NH_3, NMVOC, TSP), 3B3 (NH_3), 3B4gi (TSP), 3B4gii (PM_{10}, TSP), 3Da1 (NH_3), 3Da2a (NH_3), 3Da3 (NH_3), 3Dc (PM_{10}, TSP), 3Df (HCB). Description of the inventory methodology will focus on these categories.

The UK has an important ruminant livestock sector, largely concentrated in the west of the country where soil and climatic conditions favour the production of grass over arable crops, which are predominantly grown in the east of the country. Dairy and beef cattle production are the most important sectors in terms of NH_3 emissions. Although there is a trend for increasing year-round housing systems for dairy cows, most dairy and beef cattle spend much of the year grazing at pasture, unlike many other NW European countries. As the NH_3 emission factor from grazing tends to be less than from housed animals and subsequent manure management because of rapid infiltration of urine into the soil, the implied emission factor for UK beef and dairy cattle may be lower than for other European countries where grazing is not practised. Cattle housing also differs from that in many other European countries in that slatted floor systems are uncommon in the UK and for beef cattle in particular, straw-bedded solid manure systems are typical. Sheep are an important livestock sector, but as they spend the majority of the year outdoors they are associated with low emissions. Numbers of cattle, sheep and pigs have declined significantly since 1990, partly through efficiency measures (i.e. greater production per animal) but also in response to economic drivers. Poultry numbers have increased, with the poultry sector now representing the next most important livestock sector in terms of NH_3 emissions after cattle.

Dominant crops grown are cereals (wheat, barley) and oilseed rape, representing approximately 90% of total crop area. Nitrogen fertiliser use has decreased significantly since 1990, mostly because of lower rates being applied to grassland, although there has been little overall trend in total fertiliser N use since 2006. The proportion of nitrogen fertiliser applied as urea (associated with a much larger NH_3 emission than other fertiliser types) fluctuates annually, based on market prices, but has shown an increasing trend since 2000, with 28% of total fertiliser N use being applied as urea or urea-ammonium-nitrate (UAN) in 2015.

Although improvements in production efficiency have resulted in lower emission intensities for a number of products, there has been slow uptake by the UK agriculture sector of mitigation measures specifically targeted at abating NH_3 emissions (e.g. low emission slurry spreading methods).

5.2 Activity statistics

5.2.1 Livestock Statistics

National Agricultural Survey
National statistics on livestock numbers are obtained from June Agricultural Survey statistics provided by each Devolved Administration (England, Scotland, Wales and Northern Ireland).

Livestock population data are reported annually as statistical outputs of the four Devolved Administrations (DA) of the UK (i.e. England, Wales, Scotland and Northern Ireland), based on the annual June Agricultural Survey for each country. These data are summed to provide UK population data for the livestock categories and subcategories as used in the inventory compilation. Calculating at the DA level allows for the representation of differences in management practices and/or environmental factors to be reflected in the emission estimates. These surveys are considered the most complete and robust data sources for UK livestock numbers, have been relatively consistent over a long time scale, are structured to be representative of the UK agricultural sectors and associated with low uncertainties (actual values depending on year and livestock category).

The UK inventory approach uses a number of subcategories of each major livestock category, as detailed in Table 5-2. The UK total emission is derived as the sum of the DA emission values.

The data sources and approaches used are described in more detail in Misselbrook *et al.* (2016), together with derivation of activity data and emission factors.

Livestock Categorisation

Emissions from profession horses and horses kept as pets are not reported under NFR14 3, instead reported under NFR14 6A.

The June survey data provide a number of sub-categories within the major livestock categories, which are used as the basis for subsequent emission calculations. For animals which are present for less than 1 year (e.g. broilers, finishing pigs, lambs) the survey data are assumed to represent the number of animal places and all subsequent calculations are performed on an animal place basis (e.g. N excretion calculations will account for the number of crop cycles within a year for broilers).

Table 5-2 Livestock categories and sub-categories included in the UK inventory

Livestock type	Subcategories
Cattle	
Dairy cattle	Dairy cows and heifers (after first calf)
	Dairy heifers in calf
	Dairy replacements > 1 year old
	Dairy calves < 1 year old
Beef cattle	Beef cows and heifers (after first calf)
	Beef heifers in calf
	Other beef cattle > 1 year old
	Beef calves < 1 year old
Pigs	Sows
	Gilts
	Boars
	Finishing pigs >110 kg
	Finishing pigs 80-110 kg
	Finishing pigs 50-80 kg
	Finishing pigs 20-50 kg
	Weaners <20 kg
Sheep	Adult sheep
	Lambs
Goats	Adult goats
	Kids
Deer	Deer
Poultry	Laying hens
	Table fowl (broilers)
	Pullets
	Breeding hens
	Turkeys
	Ducks and geese
	Other poultry
Horses	Professional horses
	Other horses

Table 5-3 Animal numbers over the 1990-2015 period ('000 places)

Livestock Category	1990	1995	2000	2005	2010	2014	2015
Total cattle	12,192	11,857	11,135	10,440	10,109	9,837	9,919
- dairy cows and heifers[1]	2,848	2,603	2,336	2,060	1,847	1,841	1,895
- dairy heifers in calf[1]	530	566	532	446	408	405	389
- dairy replacements[1]	516	579	536	433	501	530	536
- dairy calves[1]	684	625	561	494	519	518	533
- beef cows and heifers[2]	1,632	1,840	1,842	1,746	1,657	1,569	1,576
- beef heifers in calf[2]	232	209	186	204	378	377	350
- other beef cattle >1yr[2]	2,983	2,772	2,708	2,813	2,458	2,314	2,259
- beef calves[2]	2,767	2,663	2,434	2,242	2,342	2,283	2,379
Sheep	44,469	43,304	42,264	35,416	31,086	33,743	33,337
Goats	98	75	74	95	93	100	101
Horses	202	273	287	346	312	303	303
Pigs	7,548	7,627	6,482	4,862	4,468	4,815	4,739
Poultry (x1000)	128	142	170	174	164	170	168
- laying hens (x1000)	34	32	29	30	29	28	28
- broilers (x1000)	74	77	106	111	105	110	107

[1]These cattle subcategories are all classified as dairy cattle in the UK inventory and manure management emissions are reported under 3B1a; [2]these cattle subcategories are all classified as beef cattle in the UK inventory and manure management emissions are reported under 3B1b; this will be revised in future submissions of the UK inventory such that 3B1a includes only Dairy cows and 3B1b includes all other cattle

Headline changes between 2014 and 2015 were a 0.8% increase in total cattle numbers, with 3.0% increase for dairy cows, 1.6% decrease in pig numbers, 1.2% decrease in sheep numbers and a 1.2% decrease in total poultry numbers, comprising a 3.0% decrease in broiler numbers but 0.7% increase in laying hens.

5.2.2 Nitrogen Excretion

The UK model for NH_3 emissions from agriculture uses the N flow approach, accounting for all nitrogen losses (NH_3, N_2O, NO, N_2) and transformations (mineralisation/immobilisation) through the manure management system with emission factors expressed as a proportion of the ammoniacal N in the manure for the given emission source (Webb and Misselbrook, 2004).

Nitrogen excretion values specific to UK livestock and production practices (Table 5-4) are derived from a report by Cottrill and Smith (2007; Defra project report WT0715NVZ). Livestock management and commercial feeding practices were reviewed in consultation with leading livestock advisers and specialist consultants, and all available research and industry data pertaining to feed inputs and product outputs for UK livestock production systems were also reviewed. The approach used for estimating N excretion by farm livestock was to assume that the amount excreted in faeces and urine is the total consumed minus the N content of products (milk, meat, eggs, live weight gain etc.). The approach was applied at the level of the individual animal, with an adjustment made according to the length of the production cycle and for non-use of the stock accommodation, to provide an annual output factor per 'animal place'. The latter is necessary to allow for non-productive time needed for cleaning and re-stocking the housing. Nutrition specialists provided typical input and performance data on which to base the calculations and, where possible, industry data was also considered. A time series from 1990 was established using expert judgement (Cottrill and Smith, ADAS) based on the report. For dairy cows, an empirical relationship was established between N excretion and annual milk yield whereby:

$$N\ excretion = 39.174 + (0.0112 * annual\ milk\ yield)$$

For other cattle subcategories, there was little evidence of significant changes in rearing methods and feeding, so N excretion values are assumed to be constant across the time series. Similarly, for sheep, goats and horses, it has been assumed that there are no changes in N excretion over the time series. For pig and poultry, the increasing application of phase feeding, use of dietary synthetic amino acids and genetic improvements in feed efficiencies that have been adopted by the industry have been reflected as a trend for decreasing N excretion from 1990 to 2010 (with values constant since then).

The proportion of N in livestock excretion assumed to be as ammoniacal N (the 'pool' from which ammonia volatilisation is assumed to take place) was based on expert opinion and verified by comparing the modelled estimate of total N and ammoniacal N in manures at manure storage and spreading with empirical data from on-farm measurements in the Manure analysis database (MANDE) (Defra project NT2006). The ammoniacal N proportions assumed for livestock excreta are consistent with those assumed by other European countries (Reidy et al., 2008; Reidy et al., 2009).

Table 5-4 Nitrogen excretion values for livestock categories (kg N per animal place per year)

Livestock Category	1990	1995	2000	2005	2010	2015
Dairy cows & heifers	96.9	99.6	106.1	117.4	121.0	127.6
Dairy heifers in calf	67	67	67	67	67	67
Dairy replacements > 1 yr	56	56	56	56	56	56
Dairy calves (< 1 yr)	38	38	38	38	38	38
Beef cows & heifers	79	79	79	79	79	79
Beef heifers in calf	56	56	56	56	56	56
Beef > 1 yr	56	56	56	56	56	56
Beef calves (< 1 yr)	38	38	38	38	38	38
Sows	23.6	22.5	21.4	20.1	18.1	18.1
Gilts	15.5	15.5	15.5	15.5	15.5	15.5
Boars	28.8	27.4	26.1	24.5	21.8	21.8
Fatteners > 80 kg	20.2	19.3	18.4	17.2	15.4	15.4
Fatteners 50-80 kg	17.5	16.7	15.9	14.9	13.3	13.3
Fatteners 20-50 kg	11.7	11.2	10.6	10.0	8.9	8.9
Weaners (<20 kg)	4.6	4.4	4.2	3.9	3.4	3.4
Ewes	9	9	9	9	9	9
Lambs	1.62	1.62	1.62	1.62	1.62	1.62
Goats - adults	20.6	20.6	20.6	20.6	20.6	20.6
Goats - kids	1.62	1.62	1.62	1.6	1.62	1.62
Horses	50	50	50	50	50	50
Laying hens - cages	0.85	0.82	0.78	0.74	0.67	0.67
Laying hens - free-range	0.95	0.91	0.87	0.83	0.75	0.75
Broilers	0.64	0.59	0.55	0.49	0.40	0.40
Pullets	0.42	0.39	0.36	0.34	0.33	0.33
Breeding Hens	1.16	1.13	1.10	1.07	1.02	1.02
Turkeys	1.50	1.59	1.68	1.76	1.82	1.82
Other poultry	1.30	1.41	1.52	1.62	1.71	1.71

5.2.3 Livestock Management Practices

A review of livestock housing and manure management practices conducted by Ken Smith (ADAS) as part of Defra project AC0114, updated with 2015 survey data on manure spreading practices from the British Survey of Fertiliser Practice 2015 (https://www.gov.uk/government/statistics/british-survey-of-fertiliser-practice-2015) was used as the basis of developing the time series 1990 to 2015 of livestock housing and manure management practices for each country (England, Wales, Scotland and Northern Ireland) from which a weighted average was derived for the UK. Broad management categories (managed as slurry, Farm Yard Manure or outdoor excreta) are given in Table 5-5 for the major livestock categories. More detailed practice-specific data are applied at a country scale for each livestock category for the livestock housing, manure storage and manure application phases of the manure management continuum. Estimates for these activity data across the time series are derived from a number of routine and ad-hoc surveys including the Defra Farm Practices Surveys (https://www.gov.uk/government/collections/farm-practices-survey) and published manure management surveys (Smith et al., 2000, 2001a, 2001b). Tonnages of poultry litter incinerated in each year were obtained directly from EPRL and Fibropower websites (K Smith, ADAS) (Misselbrook *et al.,* 2016).

Table 5-5 Manure management systems for livestock categories 1990-2015

Livestock category	1990	1995	2000	2005	2010	2015
Dairy cows						
% slurry	71	73	75	77	79	80
% FYM	29	27	25	23	21	20
Beef cattle						
% slurry	36	37	38	39	39	39
% FYM	64	63	62	61	61	61
Farrowing sows						
% slurry	61	56	52	35	36	36
% FYM	19	18	17	36	21	21
% outdoors	20	26	32	29	43	43
Weaners						
% slurry	90	67	50	47	40	41
% FYM	10	33	45	38	39	38
% outdoors	0	1	5	15	21	21
Finishing pigs						
% slurry	54	45	39	45	39	40
% FYM	46	54	60	52	59	58
% outdoors	0	1	1	3	2	2
Laying hens						
% indoors	86	80	74	68	62	65
% outdoors	14	20	26	32	38	35
Broilers						
% indoors	100	100	99	96	93	93
% outdoors	0	0	1	4	7	7

Uptake of mitigation methods was included in the AC0114 review and detailed in Misselbrook *et al.*, (2016). Specific mitigation practices considered and their estimated uptake are shown in Table 5-6.

Table 5-6 Ammonia mitigation methods in UK agriculture

Mitigation	Emission source	% abatement	% implementation			
			1990	2000	2010	2015
Part-slatted floor with reduced pit area	Finishing pig housing	30	0	0	12	27
Litter drying	Broiler housing	30	0	0	26	59
Crust formation	Cattle slurry tanks/lagoons	50	80	80	80	80
Rigid (tent) cover	Pig slurry tanks	80	0	0	12	24
Floating cover	Pig slurry lagoons	60	0	0	12	24
Shallow injection	Cattle slurry	70	0	0	6	8
Shallow injection	Pig slurry	70	0	2	7	8
Trailing shoe	Cattle slurry	60	0	0	1	2
Trailing shoe	Pig slurry	60	0	0	1	2
Trailing hose	Cattle slurry	30	0	3	5	7
Trailing hose	Pig slurry	30	0	3	16	21
Rapid incorporation[1]	Cattle slurry	59	11	11	11	11
Rapid incorporation[1]	Pig slurry	67	13	13	13	13
Rapid incorporation[1]	Cattle FYM	71	3	3	8	8
Rapid incorporation[1]	Pig FYM	71	3	3	8	8
Rapid incorporation[1]	Poultry manure	82	8	8	14	14

[1]Incorporated by plough within 4h of applicaiton

5.2.4 Synthetic Fertiliser Usage

Fertiliser usage in England, Wales and Scotland are derived from the annual British Survey of Fertiliser Practice (https://www.gov.uk/government/collections/fertiliser-usage) and for Northern Ireland from DARDNI stats (https://www.daera-ni.gov.uk/articles/fertiliser-statistics) and these are used to derive total UK fertiliser N use for each year (Table 5-7). Estimates for total N use by fertiliser type are derived using the survey data for total fertiliser quantity used and expert opinion/industry data on the N content for each type.

Table 5-7. Total fertiliser N use ('000 tonnes) by land use and fertiliser type

	1990	1995	2000	2005	2010	2014	2015
Total fertiliser N use	1570	1502	1359	1194	1133	1151	1103
Total to tillage	721	661	674	651	661	693	678
Ammonium nitrate	466	427	430	416	405	409	362
Urea	114	79	60	88	122	141	173
UAN	0	0	0	60	75	92	107
AS + DAP	34	29	11	21	11	15	16
Other	107	126	174	67	48	36	20
Total to grassland	848	842	685	543	472	458	425
Ammonium nitrate	294	285	197	121	122	135	121
Urea	44	34	21	20	24	23	26
UAN	0	0	0	2	7	6	5
AS + DAP	23	21	17	11	3	2	2
Other	487	502	449	390	318	292	271

Total fertiliser N use has also declined since 1990, although the decline has levelled out to some extent since 2006. Use of urea-based fertilisers which are associated with much higher ammonia emission factors has increased as a proportion of total fertiliser N use. Total fertiliser N use decreased by 4.2% from 2014 to 2015. The proportion applied as urea-based fertiliser increased from 23% in 2014 to 28% in 2015.

5.2.5 Use of Pesticides

Statistics relating to the sale and use of pesticides within the UK are published by FERA (Food and Environmental Research Agency) for England, Wales and Scotland (https://secure.fera.defra.gov.uk/pusstats/myindex.cfm) and by Agri-Food and Biosciences Institute (AFBINI) for Northern Ireland (http://www.afbini.gov.uk/index/services/services-specialist-advice/pesticide-usage/pesticide-reports-table.htm). Hexachlorobenzene (HCB) occurs as an impurity or a by-product in the manufacture of several pesticides currently in use in the UK (chlorothalonil and chlorthal-dimethyl) or used in the past (quintozene). Following the application to agricultural land, pesticides would volatilise from deposits on plant or soil into the atmosphere.

Estimates for HCB assume that more than 70% of the new HCB is emitted into atmosphere. Over 95% of the HCB emission into atmosphere is through the use of chlorthalonil.

Table 5-8. Total agricultural pesticide use in the UK (t)

	1990	1995	2000	2005	2010	2014	2015
Chlorothalonil	545	839	467	1,583	1,671	1,628	1,628
Chlorthal-dimethyl	48	32	8.0	8.3	6.3	0	0
Quintozene	0.4	0.3	4.5	0	0	0	0

Quintozene was withdrawn from the UK market in 2002 and its use had to cease within 18 months.

The Bailey (2001) US EPA emission factor of 0.04 kg/t has been used for chlorthalonil between 1990-1998. Following a new monitoring and sampling in 2010, which gave a weighted average of 0.008 kg/t, emission factors were extrapolated for the period between 1999 and 2009. Benezon's (1999) emission factor based on a Canadian study has been used for quintozene has been scaled down across the time series from 1 kg/t to 0.5 kg/t (AEA Technology, 2009).

Table 5-9 Pesticides emission factors (kg/t)

	1990	1995	2000	2005	2010	2014	2015
Chlorothalonil	0.04	0.04	0.034	0.020	0.008	0.008	0.008
Chlorthal-dimethyl	3	3	3	3	3	3	3
Quintozene	1	0.84	0.69	0.53	0.5	0.5	0.5

Although the pesticide use dataset is updated annually for Great Britain and every two years for Northern Ireland, the redistribution of emissions among air, land and water after the application of the pesticides is associated to some uncertainty. Tier 3 EF, having confirmed the UK working concentrations of HCB from pesticides through the monitoring of in use pesticides in 2010, has improved the reliability of HCB emissions.

5.2.6 Field burning of agricultural residues

Burning of crop residues leads to the emission of a number of atmospheric pollutants including: NH_3, NO_x, NMVOCs, SO_2, CO and PM including black carbon. Burning these residues will also give rise to emissions of heavy metals and PCDD/PCDF. Public pressure stemming from concerns over the effects on health of these emissions together with the nuisance caused by smoke from stubble burning, e.g. reductions in visibility on main roads and motorways, sometimes leading to serious accidents, were among the reasons for the ban on crop residue burning in the UK. In addition, there had been considerable losses of hedges and trees and wildlife [http://hansard.millbanksystems.com/commons/1989/nov/30/straw-and-stubble-burning].

The practice of burning off old growth on a heather moor to encourage new growth for grazing (muirburn) means that heather, rough grass, bracken, gorse or vaccinium may be burned on some types of pasture. The burning season is from 1 October to 15 April for uplands, and from 1 November to 31 March for other land. But as these are living plants they do not come under the category of 'crop residues'.

Table 5-10. Sources of activity data used for field burning of agricultural residues

Activity data	Source
Land areas for each type of crop burned	England: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june Scotland: http://www.scotland.gov.uk/Publications/2012/09/1148/downloads Wales: http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en and John Bleasdale, Welsh Government Northern Ireland: https://www.daera-ni.gov.uk/news/final-results-june-agricultural-census-2016 and Paul Caskie, DARDNI
Average harvested yields of those crops	England: https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june Scotland: http://www.scotland.gov.uk/Publications/2012/09/1148/downloads Wales: http://wales.gov.uk/statistics-and-research/survey-agricultural-horticulture/?lang=en and John Bleasdale, Welsh Government Northern Ireland: https://www.daera-ni.gov.uk/news/final-results-june-agricultural-census-2016 and Paul Caskie, DARDNI
Ratio of crop residue to harvested crop	EMEP/EEA Guidebook chapter 3F Field burning of agricultural wastes
Fraction of the residue burned	These data are not reported in the UK.

5.3 Methods for estimating emissions from Livestock Housing and Manure Management

NH_3

Agricultural sources are the most significant emission sources in the UK ammonia inventory. The UK uses a Tier 3 methodology to estimate ammonia emissions from manure management, with calculations for animal subcategories (Table 5-2) using detailed information on farm management practices and country-specific emission factors for livestock housing, manure storage, manure spreading and grazing. The model used (the National Ammonia Reduction Strategy Evaluation System; NARSES, Webb and Misselbrook, 2004) calculates the flow of total nitrogen and total ammoniacal nitrogen through the livestock production and manure management system, using a mass-flow approach. Ammonia emission factors at each management stage are expressed as a percentage of the ammoniacal nitrogen present within that stage. A number of abatement practices are also incorporated in the methodology. The UK methodology and derivation of the country-specific emission factors is described in more detail in Misselbrook *et al.* (2016).

NMVOC

NMVOC emission estimates from manure management have been calculated using agricultural activity data provided by the NARSES model. The emission estimates are based on assumed proportions of emissions which occur in the livestock building in line with the 2016 EMEP/EEA Emission Inventory Guidebook. A Tier 2 methodology has been used, full details of the algorithms used are as given in EMEP (2016), with fraction silage feed and fraction silage store recommended factors used, being 0.5 and 0.25 respectively.

NMVOC emissions are calculated as the sum of six different sources;

- Silage stores
- Feeding surface (if silage used for feeding)
- Housing
- Outdoor manure management
- Manure application
- Grazing

Silage feeding is a large source for dairy cows so two different methodologies are used: for ‘dairy cows plus other cattle’ and ‘remaining animal categories’. The dairy cow and other cattle method is based on gross feed intake whilst ‘remaining animal categories’ is based on excreted volatile compounds (VOCs). Both estimated gross feed intake and excreted NMVOCs are taken from the GHG inventory for agriculture, and are provided by Rothamsted. Improvements are planned to be made in the gross feed intake values that are used, as these vary between cattle categories such as between dairy cows and calves.

$PM_{2.5}$ and PM_{10}

$PM_{2.5}$ and PM_{10} emission estimates have been calculated using agricultural activity data provided by the NARSES model. The emission estimates are based on assumed proportions of emissions which occur in the livestock building in line with the 2016 EMEP/EEA Emission Inventory Guidebook. A Tier 1 methodology has been used (as the Guidebook no longer supports a Tier 2 methodology), full details of the default factors used are given in EMEP (2016). We also estimate $PM_{2.5}$ and PM_{10} emissions from agriculture soil using the Guidebook Emission Factors; this covers the followings stages of crop production: soil cultivation, harvesting, cleaning and drying.

The main source of PM emission is from buildings housing livestock. These emissions originate mainly from feed, which accounts for 80 to 90 % of total PM emissions from the agriculture sector. Bedding materials such as straw or wood shavings can also give rise to airborne particulates. Poultry and pig farms are the main agricultural sources of PM.

The main sources of PM emissions from soil are soil cultivation and crop harvesting, which together account for > 80 % of total PM_{10} emissions from tillage land. These emissions originate at the sites where the tractors and other machinery operate and are thought to consist of a mixture of organic fragments from the crop and soil mineral and organic matter. Field operations may also lead to re-suspension of dust already settled (re-entrainment). Emissions of PM are dependent on climatic conditions, and in particular the moisture of the soil and crop surfaces.

Emissions are calculated by multiplying the cultivated area of each crop by an EF and by the number of times the emitting practice is carried out. It is important to note that the PM emissions calculated are the amounts found immediately adjacent to the field operations. A substantial proportion of this emission will normally be deposited within a short distance of the location at which it is generated.

At the recent Stage 3 review, the Expert Review Team recommends a further expansion of the emission inventory by including NO_x emissions from all agricultural sources and NMVOC emissions from 3D (Agriculture Soil) The calculation of these emissions will be considered in future improvement programme.

5.4 Methods for estimating emissions from Soils

For emissions from fertiliser applications to agricultural land, the UK follows a Tier 3 approach, using the simple process-based model of Misselbrook *et al*. (2004).

The model used is based on Misselbrook et al. (2004) but modified according to data from the Defra-funded NT26 project. Each fertiliser type is associated with an EF_{max} value, which is then modified according to soil, weather and management factors (Table A11). Soil placement of N fertiliser is categorised as an abatement measure.

Table 5-11 Emissions from different fertiliser types

Fertiliser type	EF_{max} (as % of N applied)	Modifiers†
Ammonium nitrate	1.8	None
Ammonium sulphate and diammonium phosphate	45	Soil pH
Urea	45	Application rate, rainfall, temperature
Urea ammonium nitrate	23	Application rate, rainfall, temperature

†Modifiers:
Soil pH – if calcareous soil, assume EF as for urea; if non-calcareous, assume EF as for ammonium nitrate
Application rate

- if <=30 kg N ha^{-1}, apply a modifier of 0.62 to EF_{max}
- if >=150 kg N ha^{-1}, apply a modifier of 1 to EF_{max}
- if between 30 and 150 kg N ha^{-1}, apply a modifier of ((0.0032 x rate)+0.5238)

Rainfall – a modifier is applied based on the probability of significant rainfall (>5mm within a 24h period) within 1, 2, 3, 4 or 5 days following application, with respective modifiers of 0.3, 0.5, 0.7, 0.8 and 0.9 applied to EF_{max}.
Temperature – apply a modifier, with the maximum value constrained to 1, of

$$RF_{temp} = e^{(0.1386 \times (T_{month} - T_{UKannual}))} / 2$$

where $T_{UKannual}$ is the mean annual air temperature for the UK

An uncertainty bound to the EF_{max} values of ±0.3 x EF_{max} is suggested based on the measurements reported under the NT26 project.

5.5 Methods for estimating emissions from Field Burning of Agricultural Residues

Emissions are influenced by factors that affect the combustion efficiency of the fire and also by the residue characteristics, including chemical composition and residue mass per unit area. The larger emissions tend to be produced at greater moisture contents (15 to 20 % wet basis).

The method follows that provided in the 2013 EEA/EMEP Guidebook. The Tier 1 approach for emissions from field burning of agricultural residues uses the general equation:

$$E_{pollutant} = AR_{residue\_burnt} \cdot EF_{pollutant}$$

$E_{pollutant}$ = emission (E) of pollutant (kg),
$AR_{residue\_burnt}$ = activity rate (AR), mass of residue burnt (kg dry matter),
$EF_{pollutant}$ = emission factor (EF) for pollutant (kg kg-1 dry matter).

This equation is applied using annual national total amount of residue burnt. The default Tier 1 EFs are given in Table 3-1 of Chapter 3F of the 2013 EMEP/EEA Guidebook.

Legislation within the EU has largely outlawed the practice of field burning agricultural wastes. In the UK it is illegal to burn cereal straw and stubble and the residues of oilseed rape, peas and beans in the field, unless:

- It is for education or research purposes
- It is in compliance with a notice served under the Plant Health (Great Britain) Order 1993 (e.g. to eliminate pests)
- It is to dispose of broken bales and the remains of straw stacks.

The burning of linseed residues is exempted from the ban. While Tier 2 EFs are available in chapter 3F of the 2013 EEA/EMEP Guidebook for wheat and barley residues (Tables 3-3 and 3-4) there is no EF for linseed and hence the Tier 1 EF would need to be used.

5.6 Source specific QA/QC and verification

The inventory spreadsheet model includes some internal nitrogen mass balance checks to capture calculation errors. Data are input by one member of Rothamsted staff and checked by a second member. Trends in emission per sub-category and activity data are plotted (from 1990 - present year) and the reasons for any large deviations are scrutinised.

NMVOC and $PM_{2.5}$ and PM_{10} data are input and compiled by one member of Ricardo Energy & Environment staff before being checked by another. Trends in sub-categories and overall emissions are plotted from 1990 to the present year and again any large deviations from trends are scrutinised.

Following compilation, the inventory spreadsheet and report are checked by the wider compilation team (Rothamsted, ADAS and CEH), then sent to Ricardo Energy & Environment (the central inventory agency) and Defra for further checking prior to inclusion in the UK NAEI.

A bilateral review of the Agriculture sector GHG and ammonia inventories was held at a workshop in Dublin in July 2014. This was a very useful exchange of information at which the UK proposed improvements to the GHG inventory were discussed. Useful lessons were learned from the Irish approach regarding the structuring of their beef sector and also regarding the level and documentation of evidence required to underpin country-specific approaches and parameters, particularly regarding expert elicitation.

The UK also participate in the EAGER network (European Agricultural Gaseous Emissions Research) which has a strong focus on comparing approaches and parameter values used in the national NH_3 emission inventories of the participating countries (predominantly NW European). Two comparison exercises were conducted to verify the models gave comparable estimates for slurry-based (Reidy et al., 2008) and solid manure based (Reidy et al., 2009) livestock production systems.

5.7 Recalculations in Agriculture (NFR14 3)

Emissions from agriculture are recalculated when new information on emissions or activity data is obtained that is known to be applicable to previous years.

Recalculations from the 1990-2014 to 1990-2015 inventory submissions included:

- Updated PM emission factors from the 2016 EMEP/EEA Emission Inventory Guidebook
- A minor correction to the sheep housing emission factor – the sheep housing EF is assumed to be the same as that for beef housing. The beef housing EF had been revised in a previous submission, but the sheep housing EF had not been changed. This has now been corrected.
- Minor revisions to the fertiliser N use data series for Northern Ireland.

The individual and combined impact of these recalculations was very small (Table 5-11)

Table 5-12. Emissions from different fertiliser types

Source (NFR code)	1990 (2016 submission)	1990 (2017 submission	2014 (2016 submission)	2014 (2017 submission)
3B – manure management	137.7	137.7	107.2	107.1
3Da1 – inorganic N fertilisers	50.0	50.1	41.8	41.8
3Da2a – manure applied to soils	76.6	76.7	60.1	60.1
3Da3 – grazing returns	29.1	29.2	25.2	25.2

5.8 Planned Improvements in Agriculture (NFR14 3)

The improvements related to the agriculture NH_3 inventory are covered by Rothamsted under their separate contract (SCF0102) with Defra.

The major improvement in agricultural improvement activity is to integrate the GHG inventory into the current NH_3 inventory mass-flow structure. The NH_3 inventory structure and parameter values will largely remain unchanged. The mass-flow method adopted to calculate emissions is subject to continuous improvement by means of reviews and updates concentrating on the input factors identified by Webb and Misselbrook (2004) as those to which inventory output is most sensitive. These are:

- Annual N excretion
- The length of the winter housing period of cattle
- The proportion of N excreted by cattle deposited on hard standings
- The proportion of cattle excreta handled as slurry
- The proportion of cattle FYM spread directly onto fields without storage
- The proportion of cattle slurry with > 8% dry matter
- The proportion of poultry manure incinerated for power generation
- The proportion of slurry stored in lagoons
- The proportion of poultry manure spread directly onto fields without storage
- The proportion of cattle slurry spread directly onto fields without storage

5.8.1 Nitrogen Excretion

N excretion values will be revised according to data arising from Defra project AC0114, based on review of livestock N balances including best available data on feed N intakes and production output for the different livestock categories.

5.8.2 Livestock housing

New data will be available from Defra-funded project AC0123 on emissions from modern poultry housing systems and year-round dairy housing. These will be used to revise the currently used EF as appropriate.

6 NFR14 5: Waste

6.1 Classification of activities and key sources

Table 6-1 relates the detailed NAEI source categories for waste used in the inventory to the equivalent NFR14 source categories. NFR14 5 source categories are key sources for one or more pollutants in the UK inventory in 2015:

- 5A is a key source for Hg
- 5C1bv is a key source for Hg
- 5C2 is a key source for PCDD/PCDF

Table 6-1 Mapping of NFR14 Source Categories to NAEI Source Categories: Waste

NFR14 Category (5)	Pollutant coverage	NAEI Source Category	Source of EFs
5 A Biological treatment of waste - Solid waste disposal on land	NMVOC, NH_3, Benzene, 1,3-butadiene TPM, PM_{10}, $PM_{2.5}$, Hg, PCDD/PCDFs and PCBs	Landfill	UK model and data from UK research (NMVOC, benzene, 1,3-butadiene), international research (NH_3) and IPCC Guidelines (TSP, PM_{10} and $PM_{2.5}$)
		Application to land (PCB)	Dyke, 1997
		Waste disposal - batteries	Wenborn, 1998
		Waste disposal - electrical equipment	Wenborn, 1998
		Waste disposal - lighting fluorescent tubes	Wenborn, 1998
		Waste disposal - measurement and control equipment	Wenborn, 1998
5 B 1 Biological treatment of waste - Composting	NH_3	Composting (NH_3)	Literature factors (CEH)
5 B 2 Biological treatment of waste – Anaerobic digestion at biogas facilities	NH_3	Process emissions from Anaerobic Digestion (NH_3)	Literature factors (Bell et al., 2016; Cuhls et al., 2010; Cumby et al., 2005 quoted by CEH)
5 C 1 a Municipal waste incineration (d)	All CLRTAP pollutants *(except Se, Indeno(1,2,3-cd)pyrene)*	Incineration	Operator reporting under IED/E-PRTR and literature factors (EMEP/EEA, HMIP, USEPA)
5 C 1 bi Industrial waste incineration (d)		Incineration - chemical waste Other industrial combustion Regeneration of activated carbon	
5 C 1 bii Hazardous waste incineration (d)		Incineration - hazardous waste	Operator reporting under IED/E-PRTR and literature factors (EMEP/EEA, HMIP, USEPA)
5 C 1 biii Clinical waste incineration (d)		Incineration - clinical waste	

NFR14 Category (5)	Pollutant coverage	NAEI Source Category	Source of EFs
5 C 1 biv Sewage sludge incineration (d)		Incineration - sewage sludge	
5 C 1 bv Cremation	NO_x (as NO_2), NMVOC, SO_x as SO_2, Particulate Matter, CO, Hg, PCDD/PCDFs and benzo[a]pyrene	Crematoria	UK research (CAMEO) and literature factors (EMEP/EEA, HMIP)
		Foot and mouth pyres	
		Incineration - animal carcases	
5 C 2 Open burning of waste	NO_x (as NO_2), NMVOC, Particulate Matter, CO, POPs (except HCB)	Other industrial combustion	UK research and literature sources (Stewart et al, Passant)
		Small-scale waste burning	
		Agricultural waste burning	
5 D 1 Domestic wastewater handling	NH_3	Sewage sludge decomposition	UK industry research
5 D 2 Industrial wastewater handling		Industrial wastewater treatment	
5 E Other waste	NH_3, PCDD/PCDFs and PCBs	Regeneration of activated carbon	Literature factors (Wichmann, CEH, Dyke et al)
		RDF manufacture (PCB)	
		Land spreading of non-manure digestate (NH_3)	Cumby et al., 2005; WRAP, 2016a (quoted by CEH)

6.2 Activity statistics

National statistics on waste sector activities are limited in coverage and detail across the time series.

However, over recent years, the completeness and accuracy has improved and the UK has much better quality data now than it did in the earlier parts of the time series. There are some datasets that are of much lower quality than others. For example, the number of accidental fires will always be uncertain.

6.3 Landfill

6.3.1 Waste to Landfill

Waste data reporting for later years are more comprehensive and the inventory agency obtains annual statistics on landfill waste. Annual data on waste landfilled extends back to 1945. Whilst earlier data is much less reliable, the nature of landfill processes means that the influence of these uncertainties on calculated emissions in 2015 is minimal.

The UK approach to calculating emissions from landfills uses a methodology based on national data for waste quantities, composition, properties and disposal practices over several decades. Annual updates to data on Local Authority Collected Waste (LACW) landfilled are compiled by the Devolved Administrations and the relevant regulatory authorities (Environment Agency; Scottish Environmental Protection Agency; Natural Resources Wales; Northern Ireland Environment Agency). Because landfill processes are now well-controlled, recent data on landfill receipts of Local Authority Controlled Waste are considered to be of high quality. Data on Commercial & Industrial (C&I) waste landfilled is obtained from data on landfill tax returns compiled by HMRC and (from 2015) Scottish Government. This information is considered to be of reasonable quality.

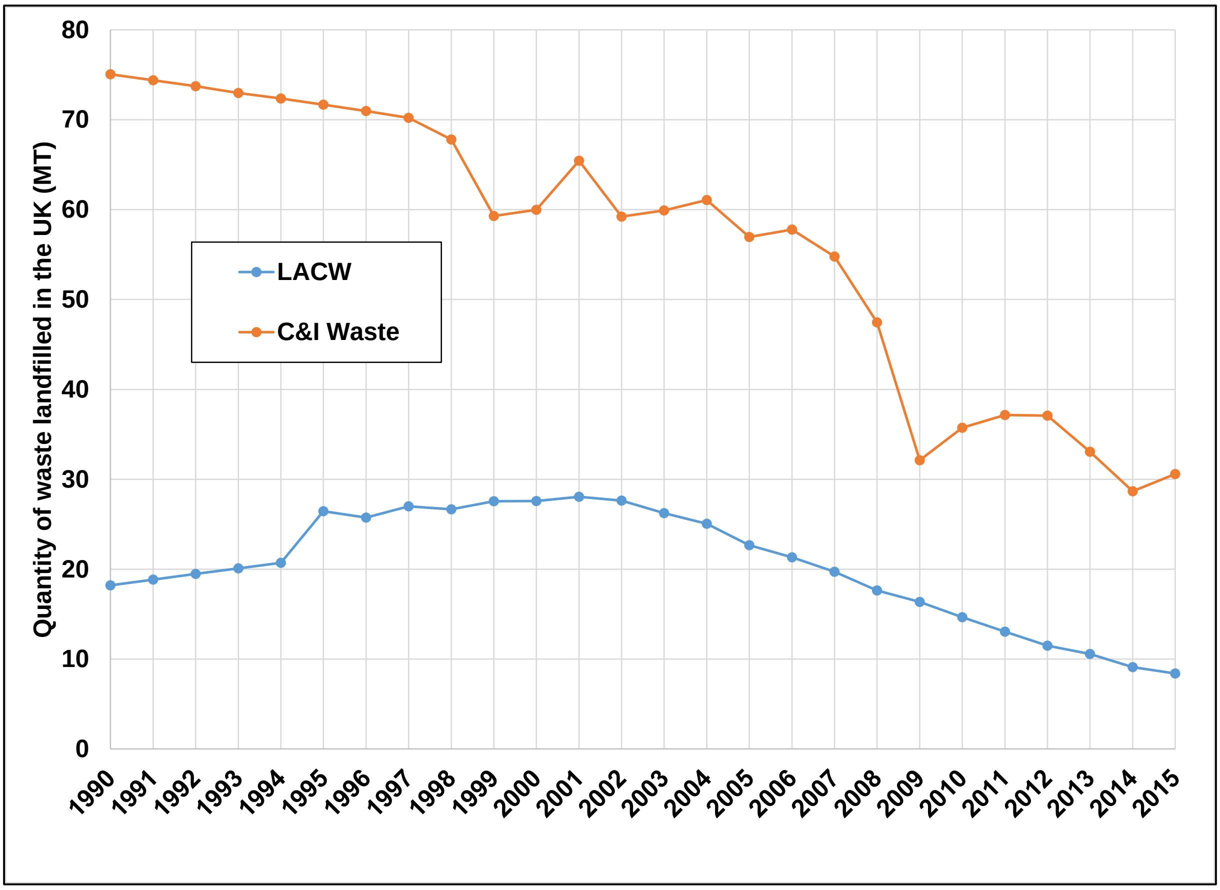
These datasets are supplemented by periodic studies, such as waste compositional surveys. Waste composition data is less robust than waste receipt data, as it relies on surveys of residual waste rather than annual data collection supported by regulation. Survey data are allocated to the categories currently used in the landfill gas model, as follows:

Table 6-2 Composition of residual waste landfilled in 2015

Material	LACW	Material	C&I waste
Paper	11%	Paper and Card	3.9%
Card	8%	Food and Abattoir	1.7%
Nappies	3%	Miscellaneous combustible	0.5%
Textiles and footwear	6%	Furniture	0.7%
Miscellaneous combustible	1%	Garden	0.6%
Wood	5%	Sewage sludge	0%
Food	21%	Textiles / Carpet and Underlay	1.9%
Garden	3%	Wood	2.0%
Soil and other organic	2%	Sanitary waste	0%
Furniture	5%	Other inert materials	88%
Mattresses	0%		
Non-inert Fines	2%		
Other inert materials	33%		
Total	100%	Total	100%

In recent years, improvements in waste management in the UK have resulted in a reduction in the quantity of waste landfilled, and changes to the composition of waste as the recovery of recyclable materials has improved. This has been driven by a combination of measures, including setting recycling targets for local authorities; investment in recycling infrastructure and services; and increasing the cost of landfill via the landfill tax. The quantities of waste landfilled in the UK between 1990 and 2015 are shown in Figure 6-1.

Figure 6-1 Quantities of waste landfilled in the UK, 1990 to 2015



The quantity of LACW landfilled in the UK peaked at 28.1 Mt in 2001, and has steadily reduced to about one third of this quantity by 2015. Over this period, the estimated proportion of card and textiles in LACW have reduced by about half, and the proportion of garden waste has reduced by over 80%. The estimated proportions of paper, nappies and food in LACW have remained more constant.

The quantities of C&I waste landfilled have decreased from the mid-1960s to 2010, peaking at 92.1 Mt in 1965. There was a modest increase from 32.1 Mt in 2009 to 37.2 Mt in 2011. The majority of C&I waste is inert materials, estimated to account for 88% of C&I waste in 2015.

6.3.2 Estimating Emissions from Landfill

Landfill emission estimates are based on a UK first-order decay model (MELMod) that has been developed by the inventory agency to estimate the methane emissions from UK landfills. The landfill model uses activity data including:

- Annual data on Local Authority controlled waste disposed to UK landfills;
- Periodic survey data on Commercial & Industrial waste disposed to UK landfills;
- An estimate of the annual disposal to different types of landfills, comprising old (now closed) landfills with no gas collection and control, and modern engineered landfills with gas management systems, and in some cases, gas flares and landfill gas engines;
- Waste composition data (from periodic surveys by regulators), to assess the quantities of different waste types disposed to UK landfills and enable separate factors to be applied to reflect the degradable organic content of the different waste streams.

The model generates estimates of the methane production from landfill waste. Landfill operators are required to assess and, where practicable, collect and burn landfill gas generated at operational and recently closed landfill sites. However, it is not practicable to do this at every landfill site, and landfill gas collection is never completely effective. Methane which is not collected in this way is assumed to be released via the landfill surface to the atmosphere. Some oxidation of methane takes place as the methane passes through the landfill surface layers. Further calculations are therefore carried out to estimate:

- the quantity of methane captured and combusted in landfill gas engines. This is based on national statistics for electricity generation from the combustion of landfill gas, combined with the assumed efficiency of landfill gas engines. The results of this calculation are considered to be of good quality;
- the quantity of methane captured and flared. This is based on individual site reports from operators. In circumstances where site-specific data are not available, no account is taken of landfill methane flaring. Hence, the calculation of methane flaring is conservative, in that the quantity of methane captured and flared is, if anything, underestimated. Consequently, this will tend to over-estimate the quantity of methane released to the atmosphere;
- the proportion of remaining methane oxidised in the surface layers of the landfill. It is assumed that 10% of the remaining methane is oxidised in the landfill surface, following the recommended approach for greenhouse gas inventories. Studies carried out at a small number of UK landfills are consistent with this figure. The results of this calculation are considered to be of reasonable quality.

Combining the total methane generation estimate with the methane captured and oxidised enables an estimate to be derived for the total quantity of methane emitted to atmosphere annually from UK landfills.

Using the model outputs, estimates of ammonia, NMVOC, benzene, 1,3-butadiene, TSP, PM_{10} and $PM_{2.5}$ are calculated by assuming a fixed ratio of the other released substances to methane in landfill gas emissions which is assumed to be constant across the time series for all substances. The factors used in this calculation were taken from published data relevant to the UK.[39,40] The factors used are as follows:

Table 6-3 Emission factors for landfill emissions

Substance	Value	Units	Reference
NMVOC	0.0036	t NMVOC / t CH_4	Based on Broomfield et al., (2010)
benzene	0.000053	t benzene / t CH_4	Based on Parker et al., (2005)
1,3-butadiene	0.000000058	t benzene / t CH_4	Based on Parker et al., (2005)
TSP	0.000463	kg/Mg waste landfilled	Inventory guidelines (EMEP, 2016) quoting AP-42 (US EPA, 2009)
PM_{10}	0.000219	kg/Mg waste landfilled	Inventory guidelines (EMEP, 2016) quoting AP-42 (US EPA, 2009)
$PM_{2.5}$	0.000033	kg/Mg waste landfilled	Inventory guidelines (EMEP, 2016) quoting AP-42 (US EPA, 2009)

Emission factors are available in the EMEP/EEA Guidebook for NMVOC. However, the Guidebook references the UK 2004 inventory as the data source. The emission factor for NMVOC in data in Table 6-3 are considered to represent an improvement on the EMEP/EEA Guidebook value for NMVOC.

Ammonia emissions are estimated using emission factors provided by the Centre of Ecology and Hydrology (CEH, 2016).

Emissions of mercury from waste disposal of batteries, electrical equipment, fluorescent lighting tubes and monitoring and control equipment are calculated based on factors derived from UK research (Wenborn et al, 1998).

[39] Broomfield M, Davies J, Furmston P, Levy L, Pollard SJT, Smith R (2010). "*Exposure Assessment of Landfill Sites Volume 1: Main report.*" Environment Agency, Bristol. Report: P1-396/R.
[40] Parker T, Hillier J, Kelly S, and O'Leary S (2005). "*Quantification of trace components in landfill gas,*" Environment Agency, Bristol.

6.4 Composting and Anaerobic Digestion

Emissions of ammonia from composting and anaerobic digestion are based on national statistics for these activities and research conducted by the Centre of Ecology and Hydrology (CEH, 2016).

The basic information and evolution in the inventoried period on the data of the composting activity is shown in Table 6-4. Activity data refer to net inflows to the composting process and are expressed in mega-grams (Mg). No changes have been made to previous activity data in the current edition of the inventory.

Table 6-4 Inputs in the composting process (Amounts in Mg)

Type of waste	1990	1995	2000	2005	2010	2011	2012	2013
Non-household	0	140,000	1,034,000	3,424,000	5,444,092	6,053,273	5,850,257	5,867,640
Household	54,816	54,816	54,816	91,733	171,175	176,783	182,392	188,000

Type of waste	2014	2015
Non-household	6,398,423	6,365,042
Household	208,661	219,043

NH_3 emissions associated with composting exhibit an upward trend throughout the inventory period, which has levelled off in recent years. The significant increase in NH_3 emission levels for this category 5.B.2 since 1997 is determined by the progressive increase in the amount of non-household composted waste.

The NH_3 emission factor used is generated by the Centre of Ecology and Hydrology (CEH). The emission factor for household composting is 0.452 kg NH_3-N /tonne dry matter. This emission factor is constant across the whole series. On the other hand, the emission factor for non-household composting is split into garden/green composting and kitchen/food composting. The EFs for the two streams are based on multiple factors such as N content, types of waste, type of composting facility, etc. so a flat rate emission factor is not used. This means the emission factor can change from year to year based on waste flows, amount of inputs, the compost facilities themselves. Table 6-5 lists the implied emission factors for recent years (note it is expressed as NH_3-N and not NH_3).

Table 6-5 NH_3 implied emission factors for non-household composting in recent years

Year	Value	Units	Value	Units
2015	0.813	NH_3-N per tonne freshweight	2.04	kg NH_3-N per tonne dry matter
2014	0.813	NH_3-N per tonne freshweight	2.04	kg NH_3-N per tonne dry matter
2013	0.813	NH_3-N per tonne freshweight	2.04	kg NH_3-N per tonne dry matter
2012	0.809	NH_3-N per tonne freshweight	2.03	kg NH_3-N per tonne dry matter
2011	0.751	NH_3-N per tonne freshweight	1.88	kg NH_3-N per tonne dry matter
2010	0.751	NH_3-N per tonne freshweight	1.88	kg NH_3-N per tonne dry matter
2009	0.751	NH_3-N per tonne freshweight	1.88	kg NH_3-N per tonne dry matter

NH_3 emissions associated with anaerobic digestion (AD) are reported in the following NFR categories:

- Process (fugitive and storage) emissions from AD are reported in '5B2 Biological treatment of waste - Anaerobic digestion at biogas facilities'
- Emissions from land spreading of non-manure digestate[41] are reported in '5E Other waste'

Emission factors calculated for fugitive and storage emissions at AD plants are based on a thorough review of relevant literature. The best estimate emission factor for fugitive and storage emissions at UK AD plants is 0.056 kg NH_3-N t^{-1} feedstocks (range 0.053 – 0.205 kg). This is based on a careful re-

[41] Manure sources are assumed to be mostly included in the agricultural inventory already in terms of landspreading emissions, and were omitted here, to avoid potential double-counting.

analysis of existing data from the UK and elsewhere to provide an emission factor for the three main stages of emissions at the site: pre-AD storage (0.004 kg NH_3-N t^{-1} feedstocks), process emissions (0.003 kg NH_3-N t^{-1} feedstocks) and post-AD storage (0.048 kg NH_3-N t-1 feedstocks) (Bell et al., 2016; Cuhls et al., 2010; Cumby et al., 2005). Post-AD storage incorporates an emissions reduction factor of 95% (Cumby et al., 2005) from sealed covers on digestate materials on site. The proportion of sites using the covering was estimated to increase from 0% in 2001 up to 100% from 2010 onwards, to account for legislation that requires all AD plants to cover input and output storage areas (WRAP/EA 2009).

The emission factor for landspreading digestates from non-manure materials are based on latest evidence of spreading emissions (Cumby et al., 2005; WRAP, 2016a) combined with analysis of inputs to all AD sites in the UK (Biogas, 2016; WRAP, 2014; WRAP, 2016b) to produce an average emission factor of 1.39 kg NH_3-N t^{-1} feedstocks (range 1.39 – 1.59 kg). This average emission factor has accounted for the high N content of food-based digestates.

The amounts of materials treated in UK AD plants are considerable, and this source has been growing rapidly. A total of 356 plants were found to be operated during 2015 (Biogas, 2016; WRAP, 2016b), a large increase from 265 plants in 2014 (and 149 plants in 2013). These plants were estimated to process 9,418 kt of materials (fresh weight) during 2015, an increase of approx. 37% on 2014. Prior to emission calculations, large volumes of materials were removed from the non-farm based input stream after it was established they did not enter the AD process (vegetable washings in particular). It should also be noted that distillery and brewery wastes were not included in the emissions estimates as they are likely to be processed in other ways. For estimating fugitive and storage emissions, all processed materials were included in the calculations, whereas for estimating landspreading emissions for digestate, farm-based products (i.e., mainly manure/slurry) were excluded, to avoid double-counting with the agricultural inventory. A reduction factor of 0.84 (WRAP, 2014) was also used to reflect the fact that the amount of digestate produced in comparison to the amount of inputs used at the site is usually lower (due to the recycling of digestate to catalyse the process in the digester etc.).

6.5 Incineration of Waste

The quantities of waste-derived fuels used for electricity and heat generation are reported in DUKES (BEIS, 2016) and these data are used to derive emission inventory estimates for municipal waste incinerators prior to 1997. Waste data reporting for later years are more comprehensive and the inventory agency obtains annual statistics on waste incineration facilities.

In the UK all facilities that incinerate municipal solid waste (MSW), chemical waste, clinical waste, and sewage sludge are regulated under IED/E-PRTR and all plant operators are required to report annual estimates of emissions to their respective Pollution Inventory (England and Wales, Scotland or Northern Ireland). Wherever possible, the operator-reported emissions are used directly in the national inventory, however the paucity of reported data for some pollutants makes this approach impossible, typically for the smaller incinerators burning clinical waste and sewage sludge. In these cases, literature emission factors are used. Even in cases where reported data are used, some incinerators are likely to report emissions to the PI/SPRI/NIPI as “Below Reporting Threshold”, and so the inventory agency generates estimates for the emissions at those sites based on previous plant performance, activity data for waste burned and/or emission factors. This gap-filling increases the uncertainty of the time-series of estimates, and the estimates for years prior to the PI (operator reporting to which began in 1998) are based on national waste activity statistics and emission factors.

Emissions from **clinical waste incinerators** are estimated from a combination of data reported to the Pollution Inventory (EA, 2016), supplemented using literature-based emission factors, largely taken from the EMEP/EEA Emission Inventory Guidebook (EMEP, 2016). The quantity of waste burnt annually is also estimated, these estimates being based on information given in the following sources in Table 6-6:

Table 6-6 Sources of waste burnt from clinical waste incinerators

Years	Source
1991	RCEP, 1993
1997	Wenborn *et* al, 1998
2002	Entec, 2003
2006-2015	Environment Agency, waste disposal data for individual sites in England and Wales

Years	Source
2004-2015	Scottish Environment Protection Agency, estimates of total clinical waste incinerated in Scotland

Interpolation between the various estimates is used to fill the gaps in the activity data time series.

Emissions from **chemical waste incinerators** are estimated based on analysis of data reported to the Pollution Inventory (EA, 2016) with the exception of benzene and polyaromatic hydrocarbons (PAHs), estimates for which are based on activity data for waste burnt at operational sites and literature emission factors from US EPA 42 profiles (for benzene) and Parma et al. (1995) atmospheric guidelines for POPs published by External Affairs Canada (for PAHs). Waste tonnages burnt at the largest individual chemical waste incinerators for the period 2006 – 2012 have been obtained from the Environment Agency, but the overall quantity of chemical waste burnt must then be estimated by the Inventory Agency, based on the capacity of the smaller plant. For the earlier part of the time series, we use the following estimates of waste burnt in Table 6-7:

Table 6-7 Sources and quantities of waste burnt from chemical waste incinerators

Years	Source
1993	290,000 tonnes (HMIP, 1995)
2002	284,000 tonnes (Entec, 2003)

The HMIP figure is assumed to also be applicable for 1990-1992, and we interpolate between the HMIP and Entec figures for the years 1994-2001. For the period 2003-2005, we interpolate between the Entec figure of 284,000 tonnes and our estimate for 2006 of 177,000 tonnes.

Emissions from **sewage sludge incinerators** are estimated from a combination of data reported to the Pollution Inventory (EA, 2016) and Scottish Pollutant Release Inventory (SEPA, 2016), supplemented with the use of literature-based emission factors where the IED/E-PRTR-reported data are incomplete. Emissions of NO_x (as NO_2) are estimated using PI and SPRI data while emissions of all other pollutants are estimated from literature-based emission factors, taken from the EMEP/EEA Emission Inventory Guidebook (EMEP 2013). The quantity of waste burnt annually is estimated based on annual activity data from environmental regulators (EA, 2016 and SEPA, 2016) or plant capacity information where annual activity data are not available. The quantity of waste burnt annually in previous years is estimated using data from various sources are shown in Table 6-8:

Table 6-8 Sources of sewage sludge burnt from clinical waste incinerators

Years	Source
1990	RCEP, 1993
1991-1998	Digest of Environmental Statistics (Defra, 2004)
2006-2012	Environment Agency, waste disposal data for individual sites in England
2013-2015	Scottish Environment Protection Agency, estimate of total sewage sludge incinerated in Scotland

Interpolation between the various estimates is used to fill the gaps in the activity data time series.

Emission estimates for **animal carcass incinerators** are taken directly from a Defra-funded study (AEA Technology, 2002) and are based on emissions monitoring carried out at a cross section of incineration plant. No activity data are available and so the emission estimates given in this report are assumed to apply for all years. The inventory agency has also reviewed data on the small proportion of animal carcass incinerators that are covered in the Pollution Inventory (EA, 2016) but there is insufficient new data to warrant a revision to the estimates from the 2002 report, without more detailed industry-focussed research and consultation.

Emissions from **crematoria** are predominantly based on literature-based emission factors, expressed as emissions per corpse (USEPA, 2009). Data on the annual number of cremations is available from The Cremation Society of Great Britain (2016). Mercury emission estimates are based on calculations using UK population (ONS, 2016) and dental record data (2009 Dental Health Survey) produced by the

UK National Health Service (NHS). The mercury estimation method was revised in 2011 through consultation with the Cremation Society of Great Britain to take account of the impact of the Crematoria Abatement of Mercury Emissions Organisation (CAMEO) scheme, through which a rolling programme of mercury emissions abatement at UK crematoria has been implemented to achieve industry-wide targets.

Emissions from **municipal waste incinerators** in the UK have been zero since 1997, as new regulations in 1996, such as the EU Landfill Directive, required that existing plants were closed down, if they did not meet new emission limits. Emissions from plants operated using incineration with energy recovery, i.e. generating heat or power, are reported within NFR14 1A1a. There were still emissions from Gibraltar until 2000 however. Estimates of emissions from MSW incineration up to 1996 are reported under NFR14 6C, and are generally based on Pollution Inventory data for the period 1993-1997 with use of literature factors for the period 1990-1992 to reflect the higher emissions likely from UK MSW incinerators in that period before plant shutdowns and upgrades occurred in the 1993-1995 period. The inventory uses the emissions data that the operators submit for inclusion in the PI (in England & Wales) and the Scottish Pollutant Release Inventory (for the one or two sites in Scotland). The data that these operators submit can be based on measurements, calculations etc. and it is assumed that the data available to the process operator on site-specific factors, such as abatement and quantities and types of waste burnt, are the best ones. In addition, they would need to monitor emissions of most pollutants on at least a periodic basis and some continuously, so they would also have site-specific data on emission rates, considered better than default emission factors. Table 6-9 shows the activities as inputs into the incineration waste process. The incineration of animal carcasses is input into the incineration waste process; however, the NAEI does not hold activity data for this activity. Instead, emissions are considered, by pollutant, from AEA Technology (2002).

Table 6-9 Inputs into waste incineration processes

Input	Units	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Clinical waste	Megatonnes	0.35	0.27	0.25	0.15	0.13	0.11	0.12	0.11	0.11	0.10
Chemical waste	Megatonnes	0.29	0.29	0.29	0.20	0.14	0.14	0.16	0.17	0.17	0.17
Sewage sludge	Megatonnes	0.08	0.08	0.19	0.22	0.23	0.21	0.20	0.19	0.18	0.18
Crematoria	Million cremations	0.44	0.45	0.44	0.42	0.41	0.43	0.44	0.43	0.46	0.46
Municipal waste	Megatonnes	2.2	1.2	0.02	0	0	0	0	0	0	0

6.5.1 Open Burning of Waste

Emission estimates in the UK inventory from small-scale waste burning comprise emissions from combustion of agricultural and domestic waste, and also from burning of treated wood (i.e. treated with fungicides and used in construction). For all sources, the activity data are not routinely collected as annual statistics across the time series, and the inventory agency generates time series estimates of activity based on available survey data and published statistics, together with proxy data to extrapolate across years where data are missing. The activity estimates were further refined in 2011 and 2012 in the light of a national waste burning habits survey of a thousand UK households completed on behalf of Defra in 2010 (Whiting et al 2011), and with improved representation of numbers of households and allotments across the time-series.

The emission factors for emissions of copper, chromium and arsenic from treated wood are taken from a UK study (Passant et al., 2004). Emissions of PCDD/PCDFs and PCBs from all the small-scale burning sources are based on composite factors derived from estimates of the individual waste types burnt and factors for specific waste types from UK research (Coleman et al, 2001 and Perry, 2002).

The PCDD/PCDF emission factors for small-scale waste burning used in the UK inventory have also been reviewed against the 2016 EMEP/EEA Emission Inventory Guidebook. The Guidebook refers users to the USEPA guidance for waste other than agriculture waste. The UK factors for domestic waste burning and bonfires were based on a UK study published in 2001 and are more recent than the USEPA AP42 guidance, thus they continued to be applied in the 2015 UK inventory. Emissions of NO_x (as NO_2), PM_{10} and NMVOCs from all the small-scale waste burning sources are based on composite factors derived from estimates of the individual waste types burnt and factors for specific waste types from UK and US research (USEPA, 2004 and Perry, 2002).

Table 6-10 Inputs in the open burning waste process (Amounts in kilotonnes)

Source	1990	1995	2000	2005	2010	2012	2013	2014	2015
Agriculture	97.8	97.8	97.8	97.8	2.93	2.93	2.93	2.93	2.93
Domestic waste (with treated wood)	188	148	131	107	108	107	107	106	107

6.6 Wastewater

The emission estimates for ammonia from sewage treatment & disposal and sewage work are based on research by the Centre of Ecology and Hydrology (CEH, 2016). The approach uses factors of kt NH_3-N per Mt sewage sludge and activity data estimates based on a time series of sewage sludge disposal data from the UK water companies.

The amount of sewage sludge applied to land was adjusted to match that used in the UK Greenhouse Gas Inventory, for emissions from spreading of sewage to agricultural land (Cardenas *et al*. 2016), of 1,430 total dry solids year^{-1}, more than the 1,332 kt estimated for 2014 (Cardenas *et al.* 2015).

As the N content of 3.6% has not been updated by Cardenas *et al*. (2016), the emission factor of 2.4 kg (range 0.9-4.5) NH_3-N t^{-1} (dry solids) is still considered the best estimate.

All of these aspects have given rise to an emission estimate of 3.4 kt NH_3-N yr^{-1} (range 1.3 – 6 kt) for 2015, compared with 3.2 kt NH_3-N yr^{-1} for 2014.

Table 6-11 Application of sewage sludge to land (t DM/yr)

1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
507,855	546,746	590,160	1,216,378	1,281,602	1,259,683	1,269,713	1,286,915	1,332,056	1,429,629

6.7 Source specific QA/QC and verification

Many of the emission estimates reported in NFR14 5 are based on facility-specific emissions reported to the PI, SPRI and NIPI, under IED/E-PRTR regulation. Section 3.1.7 discusses QA/QC issues regarding these data.

The emission estimates for NFR14 5A (landfill waste) are not directly verified, but the model (MELMod) upon which the air quality pollutant estimates are based is designed and used specifically to estimate methane emissions from landfills. This model and the associated calculations have been audited for the purposes of the UNFCCC inventory for 2013, resulting in improvements to the calculation of landfill methane collection and combustion. Additionally, MELMod was subject to a further peer review process in 2014 (Golder Associates, 2014). In the light of this peer review, changes were made to the assumed waste decay rates, and to the assumed efficiency of landfill gas engines.

The rest of source categories are covered by the general QA/QC, please refer to Section 1.6.

6.8 Recalculations in Waste (NFR5)

The most significant recalculations since the 2016 submission in NFR14 5 are related to landfills and inclusion of NH_3 emissions from anaerobic digestion across the time series. The latter is a growing source and it has added approximately <0.5 kilotonnes and 8 kilotonnes of NH_3 emissions to 2005 and 2014 NH_3 national totals respectively.

A number of changes have been made to the landfill model for reporting in the 2017 submission, as summarised below:

- Actual local authority collected waste data for 2014 was included (data not available at the time of compilation of 2014 inventory). Data on local authority collected waste for 2015 was also included where available

- A new source of data on the quantity of commercial and industrial waste landfilled using official statistics obtained from landfill tax records has been identified and used
- Assumptions regarding waste decomposition rates have been brought into line with IPCC defaults
- Data on methane collection and combustion in landfill gas engines and flares have been updated
- An improved source of data on the quantities of waste processed by anaerobic digestion has been identified and used. Ammonia emissions from anaerobic digestion have been included in the inventory for the first year, following the introduction of a methodology for calculating ammonia emissions from this source in the 2016 edition of the EMEP EEA Guidebook.

6.9 Planned Improvements in Waste (NFR14 5)

The UK inventory team operate a continuous improvement programme that spans all sources sectors of the inventory. Among the inventory improvements foreseen, consideration is given on the one hand to improvements influencing the whole system of the national inventory and, on the other hand, improvements aimed at specific activity sectors.

The planned improvements in this sector are:

- Ongoing improvements in sourcing better quality data on the quantity and composition of Commercial and Industrial waste.

7 NFR14 6: Other

Table 7-1 Mapping of NFR14 Source Categories to NAEI Source Categories: Other Sources

NFR14 Category (6)	Pollutant coverage	NAEI Source Category	Source of EFs
6 A Other (included in national total for entire territory)	NO_x (as NO_2), NMVOC, Particulate Matter, CO, and POPs (except HCB)	Accidental fires – dwellings	US EPA Factors alongside UK Factors supported by the UK Toxic Organic MicroPollutant (TOMPs) ambient monitoring data
		Accidental fires - other buildings	
		Accidental fires – vehicles	
	CO, Particulate Matter, PAHs, PCDD/PCDFs, PCBs	Bonfire night	UK Factors
	NH_3	Infant emissions from nappies	UK Factors
		Domestic pets	
		Non-agriculture livestock - horses wastes	
		Professional horse wastes	
		Park and garden fertiliser application	Literature sources

7.1 Classification of activities and sources

NFR14 source category 6A is a key source for NH_3, PM_{10}, $PM_{2.5}$ and PCDD/PCDFs.

7.2 Activity Statistics

NFR14 category 6 – 'Other' captures those sources not covered in other parts of the inventory. National fire statistics produced by the UK's Office of National Statistics (ONS) are used to provide data on the number and type of incident the UK fire and rescue services are required to attend to annually, disaggregated by buildings and vehicles.

Additional activity data and estimates for quantities of material burnt for bonfires and also for ammonia emissions linked to infants nappies, fertiliser applied to parks and gardens and golf courses are based on the UK Inventory agencies' estimates for the UK. These estimates carry a higher level of uncertainty due to the lack of viable UK statistical data.

7.3 Methods for Estimating Emissions

Accidental Fires

UK national statistics provide data on the number and type of fires which the UK fire and rescue services attend annually. This provides disaggregation to type of incident (dwelling, other building, and vehicle) and for some, but not all years, provides further detail on scale of the fire. The data do not specify the quantity of material destroyed. For dwellings and other buildings, the most detailed statistics are available for the period 1987-2007, and for the remaining years in the time series the inventory agency has constructed and makes use of a set of profiles to help predict the scale of the fire (contained to one room, whole room destroyed, whole building destroyed) based on the detailed statistics for 1987-2007. A similar combination of detailed statistics and extrapolation for the earliest and latest part of the time series is necessary for vehicle fires (detailed statistics broken down by vehicle type available for 1985-2008 only). The inventory approach is then to make assumptions based on the scale of the fire for how much material has been destroyed. For example, for fires described in the statistics as confined to a single item, the assumption is that 1 kg of materials is combusted. Applying this approach to the UK fire statistics allows the inventory agency to generate activity data in the form of material burnt, which will cover a range of material types (wood, plastic, textiles etc.). Literature emission factors for all pollutants under this source are then used to estimate emissions to air based on factors taken from the US EPA (2004) excluding polyaromatic hydrocarbons (PAHs), which make use of UK research by Coleman (2001) supported by UK ambient monitoring data.

Bonfire Night

The celebration of Bonfire night in the UK (5th November) is treated as a separate source from other domestic burning events due to the large scale organised nature of the event (predominately public firework displays) and potential air quality impact over a short period of time. Backyard burning of waste and other bonfires throughout the year are reported under NFR14 5 and detailed within the corresponding chapter in this report.

Emission estimates for Bonfire night are based on the inventory agency estimates of the quantity of material burnt in bonfires and firework displays. Emission factors for domestic wood fires (in the case of CO, PM_{10} and PAH) and disposal of wood waste through open burning (in the case of PCDD/PCDFs and PCBs) are used to generate emission estimates.

Infant Emissions from Nappies

The emission estimate for ammonia from infants' nappies is based on research by the Centre of Ecology and Hydrology (CEH, 2016). The approach uses population data for the under 4 years of age group and assumed generation rates for sewage which equates to kt of NH_3 per head of population.

Domestic Pets

Ammonia emission estimates for domestic pets are provided by the Centre of Ecology and Hydrology (CEH, 2016), based on the UK population estimates for cats and dogs and an emission estimate per animal.

Emission factors and activity data are available on the NAEI website: http://naei.defra.gov.uk/data/

7.4 Source specific QA/QC and verification

Many of the emission estimates reported in NFR14 6 come from sources with less well defined activity data and emission factors based on literature. Where possible national statistics have been used to help better define the sources with inbuilt QA/QC from the data utilised. Emission estimate methodologies have adopted innovative approaches to provide robust estimates. However the likely uncertainty in such estimates for bonfire night, accidental fires and fireworks is high.

7.5 Recalculations in "Other" (NFR14 6)

There were no significant recalculations to the sources under NFR14 6 this year. Emissions from cigarette smoking and use of fireworks are now reported under NFR 2G instead of NFR 6, in response to the 2016 Stage 3 review's recommendations.

7.6 Planned Improvements in "Other" (NFR14 6)

There are no planned improvements to the sources under NFR14 6.

8 Recalculations and Methodology Changes

Sector specific recalculations are described within each of the relevant chapters. These chapters should be referred to for details of recalculations and method changes. This chapter summarises the impact of these changes on the emissions totals, and highlights the largest changes for each pollutant.

Throughout the UK inventory, emission estimates are updated annually across the full time series in response to new research and revisions to data sources. In NFR14 source category 1A1 reviewing
In NFR14 source category 1A2 updates to emission estimates are caused mainly by: (i) revisions to UK energy statistics by BEIS (i.e. changes to fuel allocations to sector activities within DUKES), and (ii) revisions to emission factors for wood & biomass combustion. The main changes to 1A3b are caused by revisions to emission factors (NO_x (as NO_2) and changes to the degradation methodology (CO), and updates to 1A4 emission estimates are caused mainly by revisions to DUKES and changes to emission factors for stationary combustion processes and key assumptions, particularly regarding the calorific value of fuels. There have been no major revisions to 1A1.

8.1 NO_x (as NO_2)

There have been a number of revisions to emission estimates, either because of new data being available, or because of an improved understanding of emission sources leading to changes in assumptions used in emission calculations. In the case of NO_x (as NO_2), while revisions have occurred at the detailed level, the total UK emission estimates have not significantly altered.

NO_x (as NO_2) emissions have been revised up by 7 kilotonnes (1%) for the calendar year 2014 between the 2016 and 2017 UK inventory submission. This is made up of a number of changes to emissions, to revise categories both up and down. The top contributors to this change are:

- Revisions to DUKES figures for many fuels have had a notable impact on emissions in 1A2 for 2014 with emissions decreasing by 10 kilotonnes NO_x (as NO_2).
- NO_x emission factors for Euro 5 diesel LGVs have been revised upward based on COPERT 5, which led to an increase in 2014 emission estimates for 1A3b of 21 kilotonnes NO_x (as NO_2).
- Emission factors for stationary combustion processes have been reviewed and key assumptions revised, particularly regarding the calorific value of fuels. The factors have been harmonised with the 2016 EMEP/EEA Guidebook, in place of the 2013 edition used in the previous inventory. This results in a reduction in 2014 emission estimates for 1A4 of 3 kilotonnes NO_x (as NO_2).

8.2 CO

CO emissions have been revised down by 363 kilotonnes (18%) for the calendar year 2014 between the 2016 and 2017 UK inventory submission. The top contributors to this change are:

- Emission factors for wood & biomass combustion have been revised to use GB rather than IPCC default. This combined with DUKES revisions for a number of fuels, changes to drivers used to derive AD for off-road vehicles and minor revisions to CV assumptions results in a reduction in 2014 emission estimates for 1A2 of 238 kilotonnes CO.
- The COPERT 4 degradation methodology for road vehicle emissions has replaced the TRL method, which led to a reduction in 2014 emission estimates for 1A3b of 65 kilotonnes CO.
- Emission factors for agricultural straw combustion have been revised to use GB rather than IPCC default. This, combined with DUKES revisions for residential wood combustion and improvement to the modelling of technology change over time, results in a reduction in 2014 emission estimates for 1A4 of 58 kilotonnes CO.
- The use of a more realistic time series for waste burnt on domestic grates led to a reduction in 2014 emission estimates for 5C2 of 2 kilotonnes CO.

8.3 NMVOC

NMVOC emissions have been revised up by 22 kilotonnes (3%) for the calendar year 2014 between the 2016 and 2017 UK inventory submission. The main reason for the change is the addition of emissions from coal mining to the inventory, which has led to an increase in 2014 emission estimates for 1B of 12 kilotonnes NMVOC. There have also been a number of small revisions to the calculation of emissions from industrial processes, largely as a result of the incorporation of newly available data for the various categories of solvent use, and for the Scotch Whisky industry. These combine to yield an increase in 2014 emission estimates for NRF Code 2 of 8 kilotonnes NMVOC. In addition, updates to DUKES and a review of emission factors and key assumptions, particularly regarding the calorific value of fuels, has led to a decrease in 2014 emission estimates for 1A2 of 1 kilotonne NMVOC and an increase for 1A4 of 2 kilotonnes NMVOC.

8.4 SO_x (as SO_2)

There have been no major recalculations for the calendar year 2014 between the 2016 and 2017 UK inventory submission. Very small revisions to emissions from autogeneration and other industrial combustion have led to a decrease in 2014 emission estimates for 1A2 of less than 2 kilotonnes SO_x (as SO_2). Other revisions only have a slight impact on 2014 emission estimates (less than a 1 kilotonne change).

8.5 NH_3

NH_3 emissions have been revised up by 7 kilotonnes (2%) for the calendar year 2014 between the 2016 and 2017 UK inventory submission. The main reason for the change is the inclusion of NH_3 emissions from anaerobic digestion as part of the national total (rather than a memo item), which has led to an increase in 2014 emission estimates for NFR Code 5 of approximately 8 kilotonnes NH_3. In addition, the inclusion of an emerging source from other industrial biomass combustion led to a small increase in 2014 emission estimates for 1A2 of less than 1 kilotonne.

8.6 PM_{10} and $PM_{2.5}$

PM_{10} and $PM_{2.5}$ emissions have been revised down by 3 kilotonnes (2%) and 1 kilotonnes (1%), respectively, for the calendar year 2014 between the 2016 and 2017 UK inventory submission. Revisions to DUKES, along with a review of emission factors for stationary combustion processes and key assumptions, particularly regarding the calorific value of fuels, have led to an increase in 2014 emission estimates for 1A2 of 4 kilotonnes PM_{10} (4 kilotonnes $PM_{2.5}$) and a decrease in 2014 emission estimates for 1A4 of 6 kilotonnes PM_{10} (6 kilotonnes $PM_{2.5}$). PM_{10} emissions from the agriculture sector (NFR Code 3) for the calendar year 2014 have been revised down by 2 kilotonnes PM_{10} between the 2016 and 2017 UK inventory submission. This is due to the use of Tier 1 emission factors, as the 2016 Guidebook no longer supports the inclusion of Tier 2 EFs, which were used previously. The changes made to the PM_{10} factors have only a small impact on $PM_{2.5}$ emissions, as a coarser fraction is assumed for PM emissions from agriculture.

8.7 Metals

Emission estimates for metals are broadly similar in both the 2016 and 2017 UK inventory submissions. The estimates for the calendar year 2014 are higher in the 2017 submission for Cd (0.6 tonnes), Cr (0.9 tonnes), Ni (4 tonnes), Pb (3 tonne) and Zn (17 tonnes). The estimates for the calendar year 2014 are lower in the 2017 submission for As (0.5 tonne), Cu (1 tonne) and Se (0.2 tonnes).

8.8 POPs

Emissions of PCDD/PCDFs have been revised down by 4.4% (9.5g TEQ) for the calendar year 2014 between the 2016 and 2017 emissions inventory. The reduction is largely based on a revised methodology for using operator-reported data for waste burnt on domestic grates.

Emission estimates have also been revised for PAHs in 2014. These revisions are as follows; benzo[a]pyrene (-15%), benzo[b]fluoranthene (-14%), and benzo[k]fluoranthene (-14%) and Indeno(1,2,3-cd)pyrene (-20%). These changes are mainly due to an improved methodology for calculating domestic wood emission factors, taking into account differences in emission characteristics of installed appliances according to age.

PCB emissions have been revised down by 10% for the calendar year 2014. This is mainly due to revisions to the methodology for calculations of losses from transformer and capacitor, and the burning of vehicles, and the incorporation of a more realistic time series for waste burnt on domestic grates, based on numbers of households using solid fuels as a main fuel,

HCB emissions have been revised up by 7% for the calendar year 2014. New statistics published by FERA for Great Britain and by the Agri-Food and Biosciences Institute (AFBINI) for Northern Ireland have been used to revise activity data for HCB. Northern Ireland data is published every two years, while statistics for GB are made available every year only after the NAEI compilation. Following the withdrawal of chlorthal-dimethyl from the authorised active substance list in 2010 and the final ban in 2011 and the lack of new published data after 2013, the usage has been assumed zero and retrospectively updated for 2014. A DUKES revision to the municipal solid waste incineration has also led to an increase in emissions for 1A1a of 3 kg.

9 Projections

Projected emissions for the five pollutants covered by the revised NECD (2016/2284/EU) and the revised Gothenburg Protocol are compiled by the inventory agency to enable comparisons with international commitments to be assessed. Emission projections are submitted under the CLRTAP every 4 years starting from 2015 while reporting of projections is required every 2 years starting from 2017 under the revised NECD. The UK has reported an updated set of projected emissions with their 2017 NECD and CLRTAP submissions. The latest dataset being provided in March 2017 is based on the 2015 UK inventory. This set of projections is based on the updated 2016 Energy and Emissions projections first issued by BEIS in November 2015[42] and DfT 2015 traffic projections.

9.1 UK air quality emission commitments

The revised Gothenburg Protocol sets emission reduction commitments for NO_x (as NO_2), SO_x (as SO_2), NMVOCs, NH_3 and for $PM_{2.5}$ to be achieved in 2020 and beyond. The revised NECD sets emission reduction commitments for 2020 (in line with the Gothenburg Protocol ceilings) as well as 2030 for the same air pollutants. These are ambitious reduction commitments which aim to halve deaths from poor air quality by 2030. Under the revised NECD, the UK Government will set out by April 2019 the measures it intends to put in place to meet its 2020 and 2030 emission reduction commitments, in a National Air Pollution Control Programme.

Table 9-1 shows how the latest emission totals compare with 2020 targets based on applying the NECD and Gothenburg Emission Reduction Commitments to the current 2005 baseline. The progress made towards the 2020 targets has been shown in two ways. Firstly, the reduction achieved in emissions between the 2005 base year and 2015 has been shown as a percentage of the reduction required to meet the emission reduction commitment (see row '**Progress to date towards 2020 reductions**'). This shows that the target for SO_x (as SO_2) emissions has already been met and more than half of the required mass reduction has also been achieved for the other pollutants, NO_x (as NO_2), NH_3 and NMVOC. Secondly, the row '**Emission reduction required from 2015**' shows the amount of reduction required from current (i.e. 2015) emissions to reach the 2020 commitment. Similarly, Table 9-2 shows how the latest emission totals compare with 2030 targets based on applying the NECD Emission Reduction Commitments to the current 2005 baseline.

[42] https://www.gov.uk/government/collections/energy-and-emissions-projections

Table 9-1 Comparison of UK 2015 national emissions, projected emission estimates for year 2020 and 2020 NECD / Gothenburg emission targets. Please note that emission values have been rounded.

Pollutant	NH_3	NO_x (as NO_2)	SO_x (as SO_2)	NMVOC (include 3B)[b]	NMVOC (exclude 3B)	$PM_{2.5}$
2005 National Total, kilotonnes	307	1608	711	1174	1072	113
2015 National Total, kilotonnes	293	918	236	835	733	105
Emission reduction commitment	8%	55%	59%	NR[c]	32%	30%
2020 target, kilotonnes[a]	283	724	292	NR	729	79
Progress to date towards 2020 reductions	59%	78%	113%	NR	99%	26%
Emission reduction required from 2015, kilotonnes	10	195	0	NR	4	25
Projected 2020 National Total, kilotonnes	299	758	163	793	689	100
Exceedance of, or amount below, 2020 targets, kilotonnes	16	35	-128	NR	-41	20

[a] The 2020 emission targets have been calculated using the 2005 emissions of the current inventory submission as the base year.

[b] The UK inventory currently covers NMVOCs emissions from 3B Manure management; under the revised NECD, NMVOCs and NO_x emissions from 3B Manure management and 3D Agriculture Soil are not accounted for the purpose of complying the 2020 (or 2030) ceiling targets; however, the NMVOCs figures quoted in this column include emissions from 3B, which are the currently reported national total for NMVOCs consistent with the Defra national statistics (published in December 2016) and the recent NECD/CLRAP submissions in February 2017. This is to be in line with the reporting requirement for the 2010 ceiling target which is in place up to inventory year 2019.

[c] NR = not relevant

Table 9-2 Comparison of UK 2015 national emissions, projected emission estimates for year 2030 and 2030 NECD emission targets. Please note that emission values have been rounded.

Pollutant	NH_3	NO_x (as NO_2)	SO_x (as SO_2)	NMVOC (include 3B)	NMVOC (exclude 3B)	$PM_{2.5}$
2005 National Total, kilotonnes	307	1608	711	1174	1072	113
2015 National Total, kilotonnes	293	918	236	835	733	105
Emission reduction commitment	16%	73%	88%	NR	39%	46%
2030 target, kilotonnes[d]	258	434	85	NR	654	61
Progress to date towards 2030 reductions	30%	59%	76%	NR	81%	17%
Emission reduction required from 2015, kilotonnes	35	484	151	NR	79	43
Projected 2030 National Total, kilotonnes	300	531	122	792	689	97
Exceedance of, or amount below, 2030 targets, kilotonnes	41	97	37	NR	35	35

[d] The 2030 emission targets have been calculated using the 2005 emissions of the current inventory submission as the base year.

The United Kingdom will meet its SO_x (as SO_2) and NMVOC 2020 ceilings based on the 'with measure' projections. Based on these latest projections, the UK is predicted to exceed its 2020 ceilings for NO_x by 35 kt, NH_3 by 16 kt and $PM_{2.5}$ by 20 kt. The apparent difficulty for the UK to meet the emission ceilings results partly from growth in emissions from some key sources, including the use of biomass fuels by both the residential and non-residential sectors and various waste sectors sources such as composting and anaerobic digestion. These have a particular impact on the projections for $PM_{2.5}$ and NH_3. Estimates of future emissions from use of biomass fuels were influenced by a methodological change in how BEIS estimates the amount of domestic wood burning which resulted in an increase over the whole time period. The lack of any future reduction in emission estimates for agriculture has a major impact on the overall projections for NH_3 exceeding the ceiling. The projected exceedance in the emissions ceiling for NO_x is driven by the adoption of COPERT 5 emission factors for road transport which reflects higher real world NO_x emissions from Euro 6 diesel cars and LGVs than considered in previous versions of COPERT.

It should be noted that in order to address some of the uncertainties inherent in setting national emission reduction commitments, an inventory adjustment mechanism has been established under both the revised NECD and the revised Gothenburg Protocol. There are three extraordinary circumstances under which such an adjustment can be applied: in cases of there being significantly different emission factors or methodologies used for determining emissions from specific source categories between the time when emission reduction commitments were set and the year they are to be attained, and in cases of new emission source categories being identified that were not accounted for at the time when emission reduction commitments were set. A number of countries have previously applied and been granted an adjustment to their inventories for the purpose of comparing total national emissions with emission reduction commitments under the aforementioned circumstances[43]. One of the most common cases was due to increases in the available NO_x emission factors for the road transport sector in the inventory to reflect new evidence for higher real world NO_x emissions from new diesel vehicles than was previously considered, as a consequence of the Euro standards not delivering the originally predicted emissions reductions in the real world. Adjustments have also been granted for NH_3 and NMVOCs, including for new sources which were not accounted for at the time the emission reduction commitment was set[44].

[43] http://www.ceip.at/ms/ceip_home1/ceip_home/adjustments_gp/adj_country_data/

[44] https://www.unece.org/fileadmin/DAM/env/documents/2016/AIR/EMEP/ECE_EB.AIR_GE.1_2016_10_E.pdf

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