UK Informative Inventory Report (1990 to 2013)

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Executive Summary

This is the 10th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) Programme. The report is compiled to accompany the UK's 2015 data submission under the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and contains detailed information on annual emission estimates of air quality pollutants by source in the UK from 1990 onwards. Estimates are however, compiled for a large number of pollutants, many of which are not reported directly under CLRTAP. Whilst providing focus on those covered under CLRTAP this report also discusses emission estimates that have been compiled for these other pollutants.

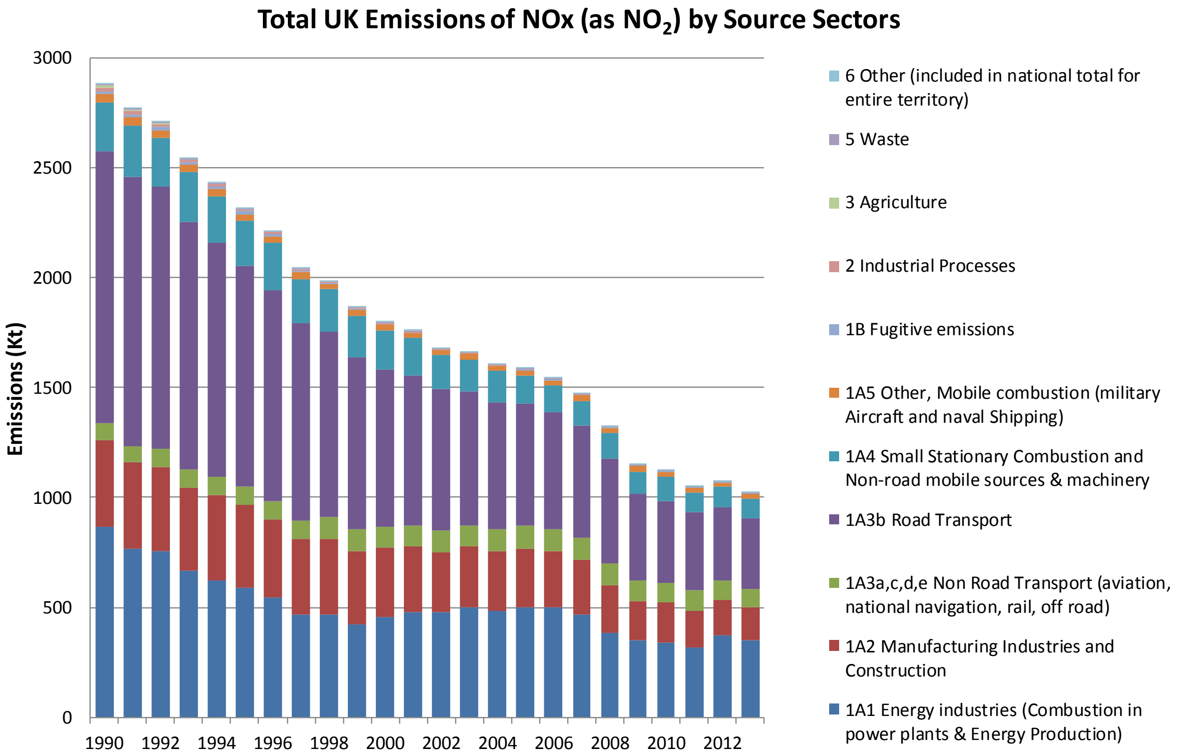
The UK submission to CLRTAP[1] comprises annual emission estimates presented in Nomenclature for Reporting (NFR) format, for:

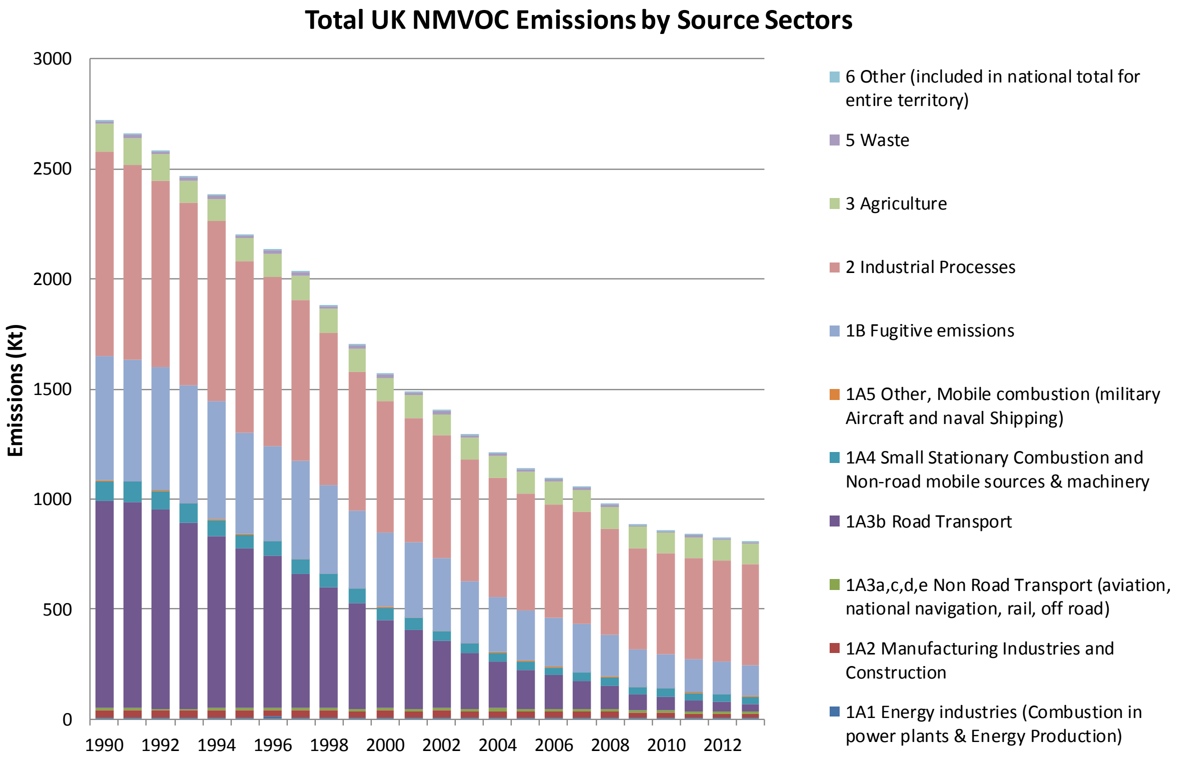
- Nitrogen oxides (NO_x as NO_2), carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_x as SO_2), non-methane volatile organic compounds (NMVOCs), particulate matter (PM) and heavy metals (1990 to 2013); and
- Persistent organic pollutants (1990 to 2013).

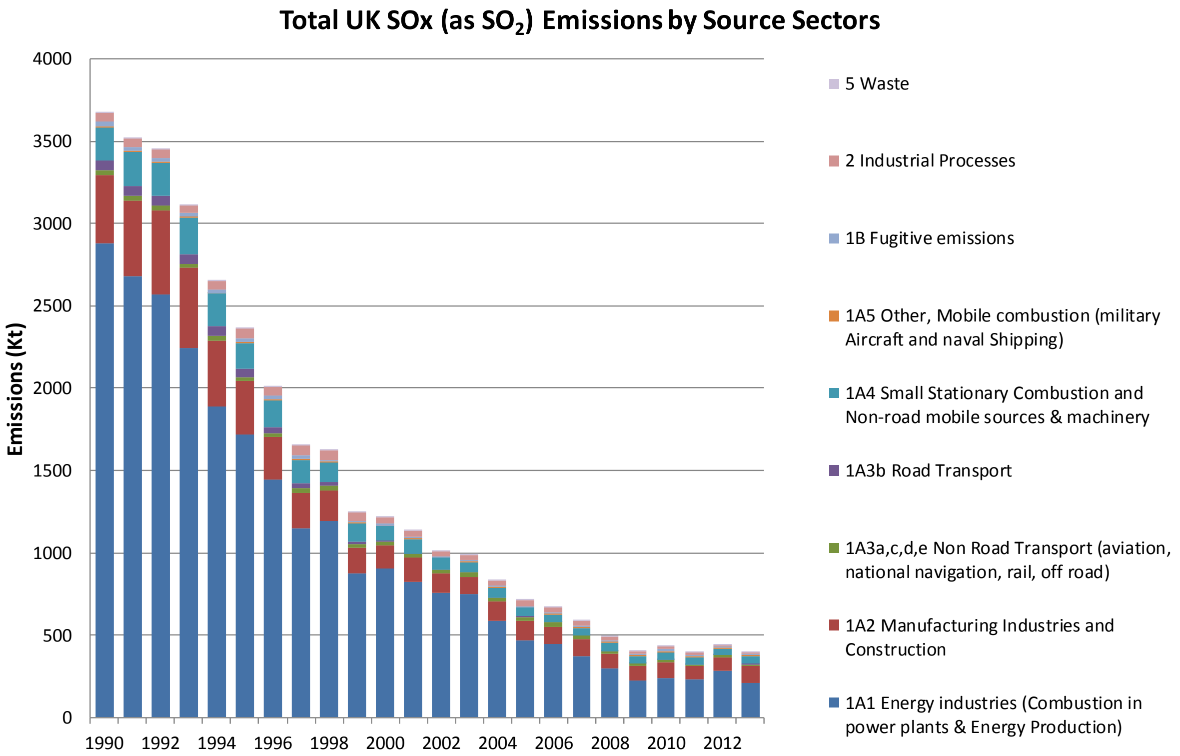
Selected pollutants under the CLRTAP are also covered under EU Directive 2001/81/EC on National Emissions Ceilings (NECD) which sets upper limits for each Member State for the total emissions in 2010. Under the NECD the UK submits the emissions for the previous five years and 2010 projections for nitrogen oxides (NO_x as NO_2), sulphur dioxide (SO_x as SO_2), non-methane volatile organic compounds (NMVOC) and ammonia (NH_3). In this, the 2015 report, emissions for 2010 are based on actual emissions rather than projections. An overview of emissions from 1990-2013 by source sectors for each of these pollutants is provided in Figure ES.0-1.

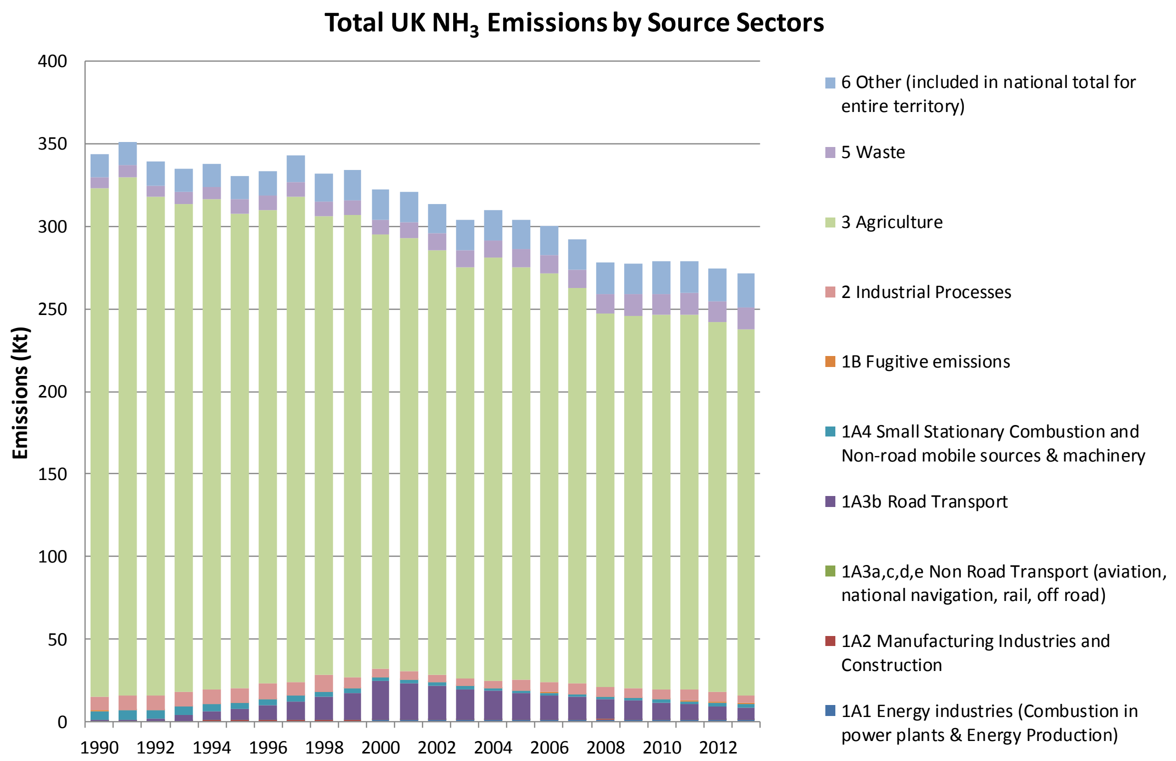
[1] See http://www.ceip.at/reporting-instructions/reporting-programme/ for reporting requirements set up by TFEIP/UNECE Guidelines for estimating and reporting emissions data under LRTAP.

Figure ES.0-1 Total UK Emissions by Source Sectors of Oxides of Nitrogen (NO_x as NO_2), Non-Methane Volatile Organic Compounds (NMVOCs), Sulphur Dioxide (SO_x as SO_2) and Ammonia (NH_3), 1990-2013.






Total UK SOx (as SO2) Emissions by Source Sectors
Emissions (kt)
4000
3500
3000
2500
2000
1500
1000
500
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
5 Waste
2 Industrial Processes
1B Fugitive emissions
1A5 Other, Mobile combustion (military Aircraft and naval Shipping)
1A4 Small Stationary Combustion and Non-road mobile sources & machinery
1A3b Road Transport
1A3a,c,d,e Non Road Transport (aviation, national navigation, rail, off road)
1A2 Manufacturing Industries and Construction
1A1 Energy industries (Combustion in power plants & Energy Production)


Total UK NH3 Emissions by Source Sectors
Emissions (kt)
400
350
300
250
200
150
100
50
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
6 Other (included in national total for entire territory)
5 Waste
3 Agriculture
2 Industrial Processes
1B Fugitive emissions
1A4 Small Stationary Combustion and Non-road mobile sources & machinery
1A3b Road Transport
1A3a,c,d,e Non Road Transport (aviation, national navigation, rail, off road)
1A2 Manufacturing Industries and Construction
1A1 Energy industries (Combustion in power plants & Energy Production)

Total percentage reductions in emissions of these pollutants from 1990-2013 are summarised in Table ES.0-1.

Table ES.0-1 Air Quality Pollutant Emission Reductions between 1990 and 2013

Pollutant	% Change from 1990 to 2013
NO_x (as NO_2)	-65%
SO_x (as SO_2)	-89%
NH_3	-21%
NMVOC	-70%
CO	-78%
PM_{10}	-55%
$PM_{2.5}$	-56%

The emissions inventory makes estimates of all known emissions to air, at the highest level of disaggregation possible. Estimated emissions are allocated to the corresponding NFR codes. However, in accordance with international guidelines[2] 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 is a primary emissions inventory (as per international guidelines). Consequently, re-suspension of e.g. particulate material is 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).
- Greenhouse gas (GHG) emissions associated with short-term changes to the carbon cycle are not included within national inventory totals; whilst this is not of particular concern here, the principle is extended to other pollutants.

National totals reported for the UK in the CLRTAP and the United Nations Framework Convention on Climate Change (UNFCCC) submissions differ, as the sources included in the national totals differ under the CLRTAP[3] and the UNFCCC reporting guidelines. The historic 2013 data submitted under the National Emissions Ceilings Directive (NECD) in December 2014 are provisional data only, however these data have not changed since the submission and so the CLRTAP and NECD totals 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 2013;
3. Explain the methodologies for key pollutants and key sectors used to compile the inventories, including a brief summary of the projections methodology;
4. Provide other supporting information pertinent to the CLRTAP data submission.

Information contained in this report is derived from the overall 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 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 CLRTAP submission. The latest emission factors used

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

to compile emissions estimates and the estimates themselves will be made available at http://naei.defra.gov.uk/data_warehouse.php in summer 2015. The complete 2015 UK CLRTAP submission templates are available from the European Environment Information and Observation Network (EIONET) under http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envvnsalq/index_html.

Any revisions to inventory compilation methodologies for key pollutants and key sectors between the 2014 and 2015 CLRTAP submissions are discussed in Chapter 2 whilst the changes in emission estimates due to revisions in source data or estimation methodology are summarised for each sector in respective NFR 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 (1980 to 2012) have been addressed in the 2013 inventory.

Planned improvements for future national inventory compilation cycles are discussed in section 8.9.

In addition, Table ES.0-2 compares overall emission estimates for each pollutant between 2014 and 2015 (current) submissions, summarising any differences in 2012 emissions between the two submissions that are associated with methodological improvements or source data revisions.

One major improvement for the 2015 submission was the inclusion of estimates for PM from livestock housing and arable farming, based on a Tier 2 methodology given in the 2013 EMEP/EEA Emission Inventory Guidebook. Other changes to the inventory are mostly related to revisions to UK national energy statistics and operator reported emissions.

Table ES.0-2 UK Inventory Recalculations, Comparing the 2014 and 2015 CLRTAP Submissions

Pollutant	2014 Submission	2015 Submission		Unit	% change	Comment/Explanation (changes between the 2014 and 2015 CLRTAP Submissions)
	2012	2012	2013		(% change for 2012 values)	
NO_x as NO_2	1,062	1,073	1,020	kt	1%	No significant revisions
CO	1,978	1,942	1,971	kt	-2%	The estimates of overall UK emissions have not changed significantly.
NMVOC	831.9	823.6	803.0	kt	-1%	There has been little change in the estimates for overall emissions of NMVOC.
SO_x as SO_2	426.8	439.7	393.2	kt	3%	The estimates of overall UK emissions have not changed significantly.
NH_3	277.3	274.9	271.3	kt	-1%	In the 2015 Submission there were no significant revisions to the NH_3 inventory.
TSP	202.7	258.7	258.4	kt	28%	Increase in emissions due to upward revisions in PM emissions from agriculture (using emission factors from the EMEP/EEA Emission Inventory Guidebook), and to a lesser degree, addition of emissions from charcoal manufacture.
PM_{10}	112.8	125.5	123.5	kt	11%	Increase in emissions due to upward revisions in PM emissions from agriculture (using emission factors from the EMEP/EEA Emission Inventory Guidebook), and to a lesser degree, addition of emissions from charcoal manufacture.
$PM_{2.5}$	77.19	80.89	80.34	kt	5%	Increase in emissions due to upward revisions in PM emissions from agriculture (using emission factors from the EMEP/EEA Emission Inventory Guidebook), and to a lesser degree, addition of emissions from charcoal manufacture.
BC	Not reported	18.46	16.87	kt		
Pb	61.48	60.68	62.72	tonnes	-1%	Revisions to emissions reported for non-ferrous metal processes
Cd	2.09	2.04	2.17	tonnes	-2%	Revisions to emissions reported for non-ferrous metal processes
Hg	5.78	5.70	6.12	tonnes	-1%	Revisions to UK energy statistics and correction to assumption for level of control of crematoria emissions.
As	16.81	16.76	17.97	tonnes	0%	No significant change

Pollutant	2014 Submission	2015 Submission		Unit	% change	Comment/Explanation (changes between the 2014 and 2015 CLRTAP Submissions)
Cr	28.44	28.55	30.05	tonnes	0%	No significant change
Cu	56.92	56.70	56.60	tonnes	0%	No significant change
Ni	84.49	83.79	128.9	tonnes	-1%	No significant change
Se	33.81	32.65	27.52	tonnes	-3%	Revised estimates for electric arc furnaces
Zn	377.3	377.4	406.6	tonnes	0%	No significant change
PCB	726.9	725.9	705.5	kg	0%	No significant change
PCDD/ PCDF (dioxins/ furans)	212.4	203.6	221.1	grams TEQ	-4%	Changes to factors from the power stations database are due to a combination of factors: a) revisions to default Emissions factors ; b) revisions to point source data in the DAs Pollution Inventories (PI/SPRI/NIPI); c) revisions to DUKES data for coal and gas use at power stations
benzo(a)pyrene	3.51	3.73	4.02	tonnes	6%	Change driven by revisions to FAO Stat charcoal statistics in the domestic combustion sector and changes to the allocation of petroleum coke in DUKES
benzo(b) fluoranthene	3.31	3.57	4.02	tonnes	8%	Change driven by revisions to FAO Stat charcoal statistics in the domestic combustion sector and changes to the allocation of petroleum coke in DUKES
benzo(k) fluoranthene	1.47	1.55	1.69	tonnes	6%	Change driven by revisions to FAO Stat charcoal statistics in the domestic combustion sector and changes to the allocation of petroleum coke in DUKES
Indeno (1,2,3-cd) pyrene	1.21	1.22	1.14	tonnes	1%	No significant change
HCB	25.08	23.43	23.21	kg	-7%	Reduction in emissions due to revision to DUKES for MSW burned in Power Station - the most significant emission source for HCB.

(I) Contacts and Acknowledgements

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Some NH_3 emission estimates and NH_3 mapping information are provided by the Centre for Ecology and Hydrology (CEH) Edinburgh (Contract CPEG 1).

NH_3 emissions from agriculture are provided for Defra under contract SCF0102 by a consortium led by Rothamsted Research in Okehampton, Devon.

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

(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 NO_2
- SO_x emissions are quoted in terms of SO_x as 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
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
EfW	Energy from Waste
EIONET	European Environment Information and Observation Network
EMEP/CORINAIR	After1999 called EMEP/EEA
EMEP/EEA	European Monitoring and Evaluation Program Emission Inventory Guidebook
EPR	Environmental Permitting Regulations
EPRTR	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
IEF	Implied Emission Factor
IPPC	Integrated Pollution Prevention and Control
ISR	Inventory of Statutory Releases (DoENI)
ISSB	Iron and Steel Statistics Bureau
kt	Kilo tonne
ktC	Kilo tonne of Carbon
ktC-e	Kilo tonne 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
NFR	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
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 Regulation
OT	Overseas Territories
PAHs	Polycyclic Aromatic Hydrocarbons
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 DECC)
RTFO	Renewable Transport Fuels Obligation
RVP	Reid Vapour Pressure
SCCP	Short Chain Chlorinated Paraffins
SEPA	Scottish Environmental Protection Agency
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 DECC)
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
WML	Waste Management Licensing
WID	Waste Incineration Directive

Abbreviations for Chemical Compounds

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
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	
- Benzo[k]fluoranthene	
- Indeno (1,2,3-cd)pyrene	I[123-cd]P
Polychlorinated dibenzo-p-dioxins/ Polychlorinated dibenzofurans	PCDD/PCDF
Polychlorinated Biphenyls	PCB
Lindane (gamma-HCH)	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

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Tables

1. Introduction

This chapter provides an overview of the activities that are undertaken as part of the UK emissions inventory programme. Different aspects of the annual inventory cycle are included in the following sections:

- 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 gives an overview of data flows and the annual inventory cycle.
- Section 1.4 provides a summary of compilation methods and the input data that is used in the inventory.
- 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.
- Section 1.6 summarises the QA/QC system that is operated throughout the inventory cycle, and in particular includes a description of the roles and responsibilities within the inventory team.
- Section 1.7 briefly summarises the results from the uncertainty analysis that is conducted on a wide range of the pollutants in the inventory programme.
- Section 1.8 provides a very brief 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 is reported on a voluntary basis as of this year.

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 has always taken 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 1.2.2 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 account for 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. 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 priority list of improvement actions. 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	✓	1970-2013	NAQS, AC, IGHG, O, E
Sulphur Dioxide	✓	1970-2013	NAQS, AC, IGHG
Carbon Monoxide	✓	1970-2013	NAQS, O
Non-Methane Volatile Organic Compounds *	✓	1970-2013	NAQS, O, IGHG
Black Smoke		1970-2013	NAQS
Black Carbon	✓	1990-2013	-
Particulates < 10 μm	✓	1970-2013	NAQS
Particulates < 2.5 μm	✓	1970-2013	NAQS
Particulates < 1 μm		1970-2013	-
Particulates < 0.1 μm		1970-2013	-
Total Suspended Particulates	✓	1970-2013	-
Ammonia	✓	1980-2013	AC, E
Hydrogen Chloride		1970-2013	AC
Hydrogen Fluoride		1970-2013	AC
Lead	✓	1970-2013	NAQS, TP
Cadmium	✓	1970-2013	TP
Mercury **	✓	1970-2013	TP
Copper	✓	1970-2013	TP
Zinc	✓	1970-2013	TP
Nickel **	✓	1970-2013	TP
Chromium **	✓	1970-2013	TP
Arsenic	✓	1970-2013	TP
Selenium	✓	1970-2013	TP
Vanadium		1970-2013	TP
Beryllium		2000-2013	TP
Manganese		2000-2013	TP
Tin		2000-2013	TP
Polycyclic Aromatic Hydrocarbons *	✓	1990-2013	TP
PCDDs and PCDFs	✓	1990-2013	TP
Polychlorinated Biphenyls *	✓	1990-2013	TP
Lindane (gamma-HCH)	✓ (until 2014)[3]	1990-2013	TP
Pentachlorophenol		1990-2013	TP
Hexachlorobenzene	✓	1990-2013	TP
Short-chain chlorinated paraffins		1990-2013	TP
Polychlorinated Naphthalene		NE	TP
Polybrominated diphenyl ethers		SE	TP
Sodium		1990-2013	BC
Potassium		1990-2013	BC
Calcium		1990-2013	BC
Magnesium		1990-2013	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] Reported as total HCH

* 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 National Emission Ceilings Directive (Directive 2001/81/EC, NECD) sets limits for each Member State for the total emissions of NOx, SOx, NMVOC and NH_3 in 2010 and subsequent years. 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 and emissions projections for 2010 for these pollutants.

The UK met all of its NECD targets for 2010 and all subsequent years to date.

The NECD submission uses the latest CLRTAP reporting templates (as requested by the European Environment Agency), and there are therefore strong parallels between the datasets under these two international commitments.

In December 2013, the European Commission published a proposal to revise the NECD. The proposed Directive would set emission reduction ceilings for 2020 and 2030 for the four pollutants currently regulated and would extend the Directive to set ceilings for $PM_{2.5}$ from 2020 and methane from 2030. The proposed Directive must be agreed by the Council of Ministers and the European Parliament before it can enter into force.

CLRTAP
There are several protocols within the CLRTAP that 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 the Persistent Organic Pollutants Protocol. The 2015 UK inventory reported to the NECD and Gothenburg Protocol have been compiled in line with the revised Gothenburg Protocol Guidance[4].

Under the NECD the UK submits the provisional emissions for the pollutants for the previous five years and under the CLRTAP, the final emissions of pollutants covering 1990 to the most recent reported year.

The pollutants required for reporting under the CLRTAP are listed in Table 1-2 below.

[4] 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

Group	Pollutant	Required reporting years	Reported years in 2015 UK submission
Main Pollutants	Nitrogen Oxides	1990 – reporting year minus 2	1990-2013
	Sulphur Dioxide		
	Carbon Monoxide		
	Non-Methane Volatile Organic Compounds		
	Ammonia		
Particulate Matter	Particulates < 10 μm	2000 – reporting year minus 2	1990-2013
	Particulates < 2.5 μm		
	Total Suspended Particulates		
	Black Carbon (voluntary)		
Priority Heavy Metals	Lead	1990 – reporting years minus 2	1990-2013
	Cadmium		
	Mercury		
Other Heavy Metals	Copper	1990 – reporting year minus 2	1990-2013
	Zinc		
	Nickel		
	Chromium		
	Arsenic		
	Selenium		
Persistent Organic Pollutants	Benzo[a]pyrene	1990 – reporting year minus 2	1990-2013
	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	1990-2013

Four-yearly reporting requirement
Every four years, starting in 2015, EU Member States have to report projected emissions for the years 2020, 2025 and 2030 and, where available, also for 2040 and 2050.

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

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.

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

Group	Pollutant	Required reporting years starting in 2017	Reported years in 2015 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,	2000 (optional) 2005, 2010, 2015	Not required

Group	Pollutant	Required reporting years starting in 2017	Reported years in 2015 UK submission
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,	2000 (optional) 2005, 2010, 2015	Not required
Projected emissions	SO_x as SO_2, NO_x as NO_2, NH_3, NMVOC, $PM_{2.5}$, BC (voluntary)	2020, 2025, 2030, 2040 and 2050	2020, 2025, 2030
Quantitative information on parameters underlying emission projections		reported for the projection target year (2020) and the historic year chosen as the starting year for the projections (2000)	2000, 2020, 2030

Table 1-4 and Table 1-5 provides a summary of the emission targets set under the original NECD and revised Gothenburg Protocol. The UK met all of its NECD targets for 2010, and all subsequent years and 2020 Gothenburg Protocol Target based on the current 2013 inventory.

Table 1-4 Comparison of UK 2013 national emissions with 2010 NECD emission ceilings for UK

Pollutant	NH_3	NO_x as NO_2	SO_x as SO_2	NMVOC
UK NECD 2010 Ceiling, ktonnes	297	1167	585	1200
UK 2013 National Total, ktonnes	271	1020	393	803
Percentage of NECD 2010 ceiling, %	91%	87%	67%	67%

Table 1-5 Comparison of UK 2013 national emissions with 2020 Gothenburg emission targets

Pollutant	NH_3	NO_x as NO_2	SO_x as SO_2	NMVOC	$PM_{2.5}$
2005 National Total, ktonnes	304	1586	710	1136	95
Emission reduction commitment	8%	55%	59%	32%	30%
2020 target, ktonnes[a]	280	714	291	773	67
2013 National Total, ktonnes	271	1020	393	803	80
Progress to date towards 2020 reductions	136%	65%	76%	92%	52%
Emission reduction required from 2013, ktonnes	0	306	102	30	14

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

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 Energy and Climate Change (DECC). 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 1-6, although there are also differences in the geographical coverage (see Section 1.1.4).

Table 1-6 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 known emissions to air at as high a level of disaggregation as is possible. However, by following international guidelines[5] on emissions reporting, there are a number of known sources which are deliberately not included in the inventory:

- 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).
- 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) and Crown Dependencies (CDs) are excluded.

Under the UNFCCC[6], 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.

1.2 Institutional Arrangements for Inventory Preparation

All UK emission inventories are compiled and maintained by the National Atmospheric Emissions Inventory (NAEI) team, led by Ricardo-AEA (the Inventory Agency). The NAEI is maintained under contract to the Air Quality Evidence Team, Atmosphere and Industrial Emissions, of the Department for Environment, Food and Rural Affairs (Defra) and the Science & Innovation Division at the Department of Energy and Climate Change (DECC). The NAEI work programme is also supported through research funding from the Scottish Government, Welsh Government and Northern Ireland Department of Environment. Emissions of NH_3 and GHGs from agriculture are compiled by Rothamsted Research, under a separate contract to Defra, which are then provided to the NAEI team who are responsible for compiling the complete inventory.

1.2.1 Defra

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

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

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

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-AEA

As the UK's inventory agency, the NAEI team, led by Ricardo-AEA, 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 DECC 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 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-AEA is the lead contractor in the consortium responsible for compiling and maintaining the NAEI. As the lead contractor, Ricardo-AEA 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.
- Emissions of NH_3 from non-agricultural sources are prepared by the UK Centre for Ecology and Hydrology (CEH), under subcontract to Ricardo-AEA.
- Aether, under subcontract to Ricardo-AEA, provides the Secretariat and Chair of the Task Force for Emission Inventories and Projections (TFEIP) activities. They also support Ricardo –AEA in the compilation of rail emission estimates and the inventories for the Overseas Territories and Crown Dependencies as well as providing expert advice on projections and QA/QC.
- AMEC FW, under subcontract to Ricardo-AEA, provide expert advice on projections.

Roles within the programme are illustrated in Figure 1.1 below.

Key Data Providers are also included on this figure, and include:

- Other government departments, such as the DECC and Department for Transport (DfT);
- 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), the Centre for Ecology and Hydrology (CEH), Rothamsted Research;
- Private companies such as Tata Steel; and
- Business organisations such as UK Petroleum Industry Association (UKPIA), the Mineral Products Association (MPA) and Oil & Gas UK.

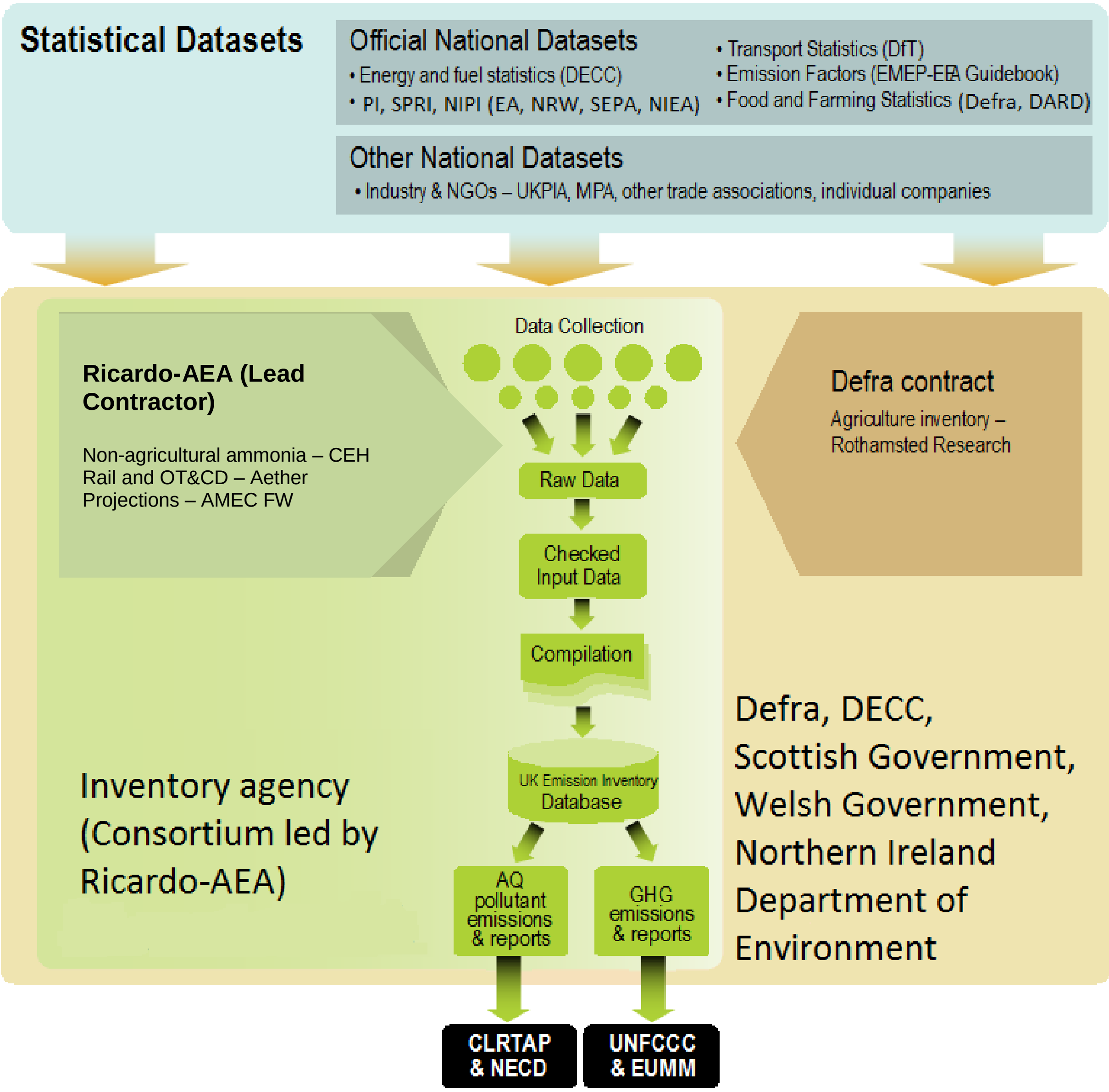


Figure 1-1 An Overview of the Roles within the Inventory Programme

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. A new, more up to date and user friendly interface was launched in January 2013.

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. These maps give 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 updated 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 methods 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:

https://www.gov.uk/government/policies/protecting-and-enhancing-our-urban-and-natural-environment-to-improve-public-health-and-wellbeing/supporting-pages/international-european-and-national-standards-for-air-quality
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-AEA 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 Process

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.

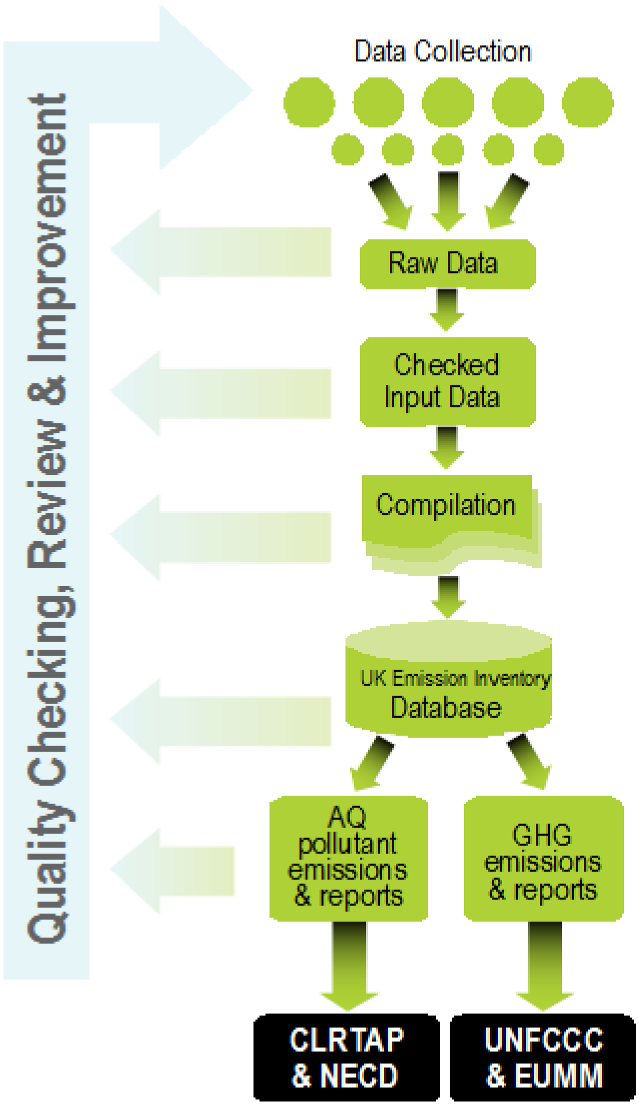


Figure 1-2 Overview of the Inventory Preparation Process

1.3.2 The Annual Cycle of Inventory Compilation

The NAEI is compiled annually, and over many years the activities outlined above in Figure 1.2 have been developed into an annual cycle. Each year the latest set of 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.

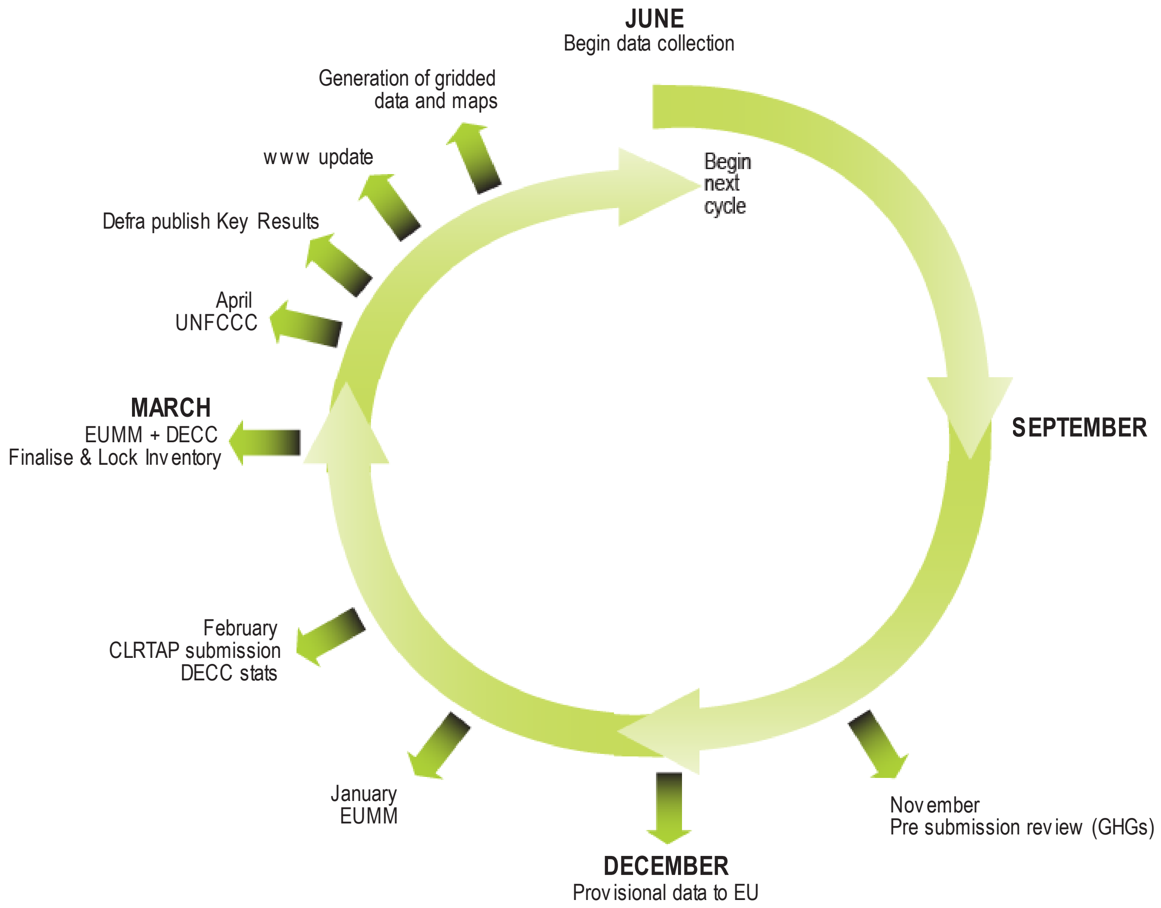


Figure 1-3 The Annual Inventory Cycle in the UK

1.3.3 Data Flows and Infrastructure of Compilation

The compilation of the UK inventory requires a systematic approach to the collation of quite disparate 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.

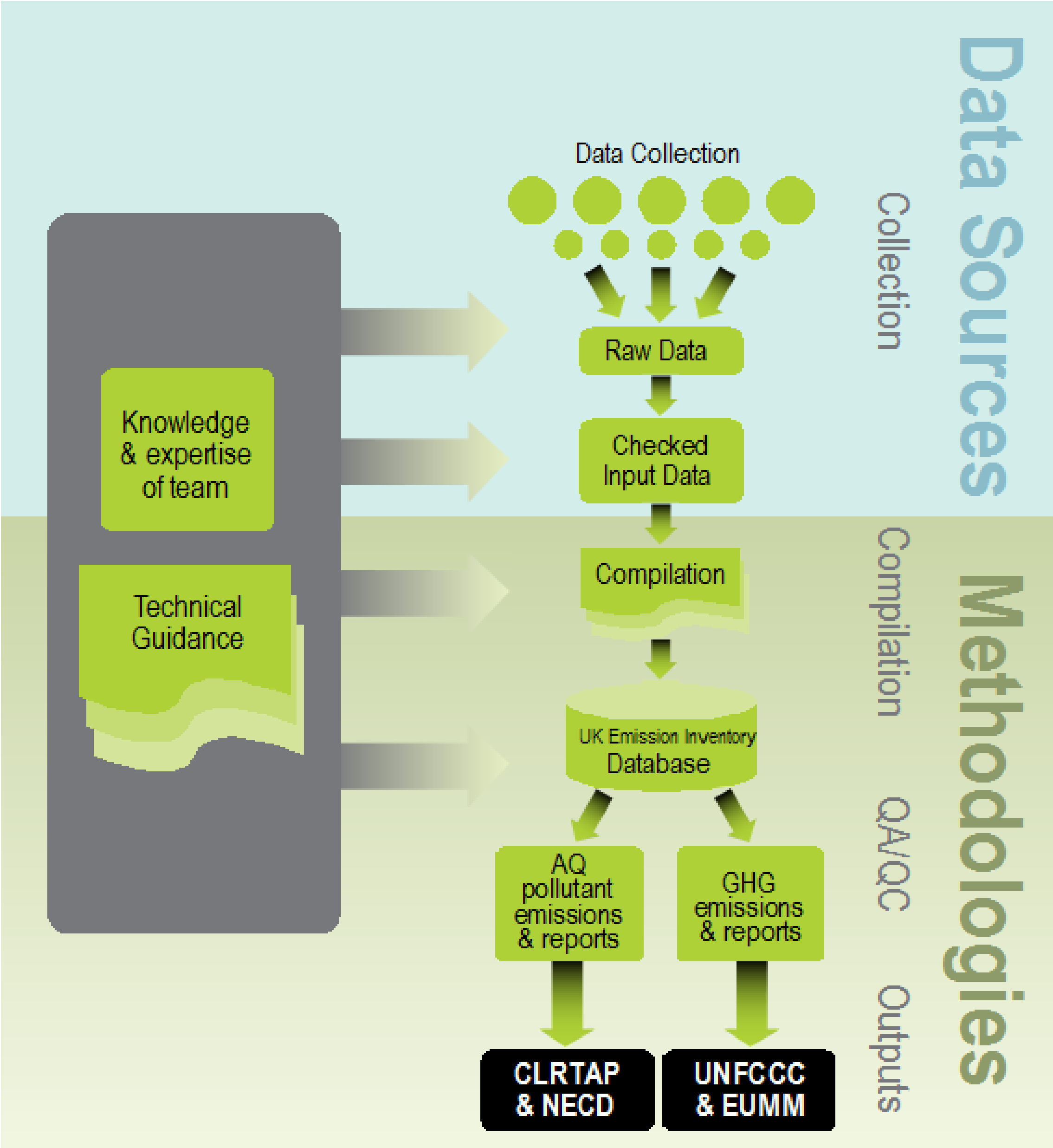


Figure 1-4 Summary of UK Inventory data flows

The compilation method can be summarised as follows:

1. **Data Collection**- source data are requested, collected and logged, from a wide variety of data providers.
2. **Raw Data Processing**- the received data are checked, and formatted for use.
3. **Spreadsheet Compilation-** formatted input data are added to bespoke spreadsheets to generate all required emission factors and activity data in the required format.
4. **Database Population-** emission factors and activity data are uploaded from the spreadsheets to the central emissions inventory database.
5. **Reporting Emissions Datasets-** data are extracted from the database and formatted to generate a variety of datasets used for national or international reporting requirements.

Each of these stages is explained in more detail in the following sections.

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.

The five-stage summary of the inventory cycle provides a simplistic overview. In practice there are considerably more tasks and the cycle is more complex. For example, some other tasks within the programme would be associated with:

- Quality assurance and quality control tasks and systems which operate throughout the entire inventory programme;
- Management of the work programme, overseeing stakeholder engagement and inventory delivery as well as organising staff;
- Other Government support activities, which are conducted by the team.

The QA/QC programme that operates throughout the inventory programme is explained in Section 1.6. This incorporates staff management and responsibilities.

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, phone, and across the internet. 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 data requests and data provision is a Contacts Database, which holds contact details of all data providers, and references to the data that has been provided by them 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.

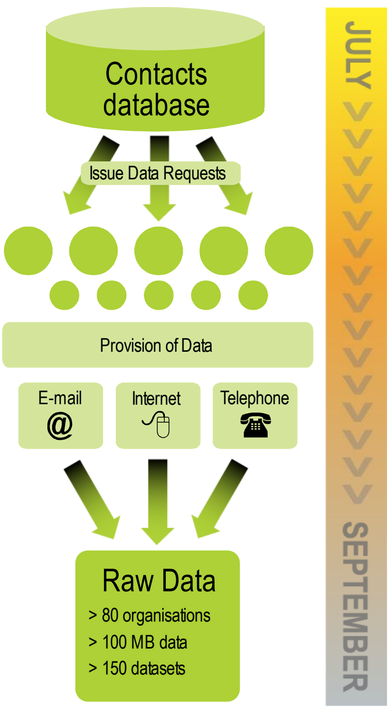


Figure 1-5 Data collection for core inventory compilation

There is a wide variety of organisations that provide data to the emissions inventory team. Whilst many of the providers are in the Government sector, there is also a lot of data sourced from private companies (who do not have any obligation to provide the data). It is therefore essential to build a strong working relationship with these data providers.

1.3.4.2 Key Data Providers

A number of the most important data providers have been defined as Key Data Providers. Whilst there are legal measures[7] 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 major 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, allowing for all required QA/QC procedures;
- Assessment of their data acquisition, processing & reporting systems, taking regard for QA/QC requirements;
- 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, Ricardo-AEA and their peers / members to help to disseminate information.

National Energy Statistics and Energy Balance of the Inventory
DECC provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the DECC 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/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes

The DECC 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, DECC 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. DECC also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. DECC 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.

At a detailed sector level, the activity data used in the UK inventory may not exactly match the fuel consumption figures given in DUKES and other national statistics. This occurs for one of three reasons:

1) Data in DUKES and other national statistics are not always available to the level of detail required in the inventory.
2) Data in DUKES and other national statistics are subject to varying levels of uncertainty, and in some cases better data are available from other sources.
3) DUKES and other national statistics do not include any data for a given source.

Deviation from the detailed data given 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

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

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. This is further compounded by the fact that the inventory needs to distinguish between gas oil burnt in mobile machinery and gas oil burnt in stationary combustion plant. Fuel suppliers and importers would not necessarily know whether a customer was using gas oil in mobile or stationary equipment.

Due to these issues, the inventory makes estimates of gas oil consumption for many sectors by 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. rail operating companies, power station operators). DUKES data are not used directly; however, estimates of consumption of this fuel by other sectors are then adjusted in the inventory in order to maintain consistency with the total gas oil consumption given in DUKES.

Other fuels with significant deviations from the detailed data given in DUKES include fuel oil, aviation turbine fuel, petroleum coke, other petroleum gases (OPG) and coal. Generally a similar approach is used to ensure that overall consumption of each fuel is consistent with the figures given in DUKES. However, for petroleum coke the deviations are sufficiently great that consistency cannot be maintained and in the case of OPG the UK inventory contains additional sources not included in DUKES so it is not appropriate to ensure consistency.

The data collection system used by DECC to collect and calculate sector-specific estimates for use of petroleum-based fuels has been changed. Since January 2005 a new electronic system of reporting has been introduced. This development has led to more consistent returns from petroleum industries, reducing misallocations and transcription errors that may have occurred under the previous paper-based system. Improvements are evident in DUKES from 2006 onwards.

Energy consumption data and process-related activity data are available for installations that are covered by the EU Emissions Trading System (EU ETS) and some of these data are used in an aggregated form in the UK inventory. As described previously, consistency with total UK fuel consumption data given in DUKES is maintained wherever possible.

Information on industrial processes is 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 NAEI wherever possible, either as emissions data, or surrogate data for particular source sectors. The information held in the PI is also extensively used in the generation of the NAEI maps, as the locations of individual point sources are known. The NAEI, 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, and may be found on the Environment Agency website:
http://www.environment-agency.gov.uk/business/topics/pollution/32254.aspx

The Scottish Environment Protection Agency – SPRI Inventory
The Scottish Environment Protection Agency (SEPA) compiles an emissions inventory for emissions reporting under the Integrated Pollution Prevention and Control (IPPC) Directive and the European Pollutant Emission Register (EPER and now EPRTR). The reporting of emissions is required for all activities listed in Annex I of the IPPC Directive. 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 EPER and this point source data, although not as 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

Other Key Data Providers
Rothamsted Research compiles, on behalf of Defra, the inventory for agricultural NH_3 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 (as well as providing information for mapping NH_3 emissions).

Aether contributes to the compilation of the inventory for the Devolved Administrations, and compiles the Overseas Territory and Crown Dependency inventories and the rail emissions estimates.

Defra also funds research to provide emissions 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.

The UK emission inventories are compiled according to international Good Practice Guidance (EMEP-EEA and IPCC). 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. 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 DECC. Information on improvements and recalculations can be found throughout this report, in Chapter 3-9 which describe the methods used in the different source sectors.

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.

For the majority of the data, no processing is required before the data are used in the compilation spreadsheets (Stage 3 below). However, for some datasets, work needs to be conducted on the received data before it is possible to use in Stage 3.

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

All data are transferred into the central database originates from a series of pre-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 emissions database. The spreadsheets also record the source of any originating data and the assumptions and calculations done to that data to create the data necessary for the emissions database. There are thorough checks on the compilation spreadsheets- as detailed in Section 1.6.

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 master 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 the 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 datasets

There are numerous queries in the database to allow the data to be output in a variety of different formats. A front end has been specifically designed to allow data handling to be conducted more efficiently.

For the CLRTAP submission, data for the relevant pollutants and years are extracted from the database in NFR format. This large data block is pasted into a spreadsheet. The NFR templates are then populated automatically by referring to the appropriate line in the large data block. A number of manual amendments are then required before the data are thoroughly checked and submitted.

1.4 Methods and Data Sources

Overview information on primary data providers and methodologies has been included in the above sections. Table 1-7 gives an indication of where UK specific data are used in the emissions inventory, and where methodologies that are more generic are used (where UK specific information is not available).

Table 1-7 UK Emissions Inventory Compilation Methodologies by NFR

NFR Category	Activity	EFs	Comment
1A1a Public Electricity & Heat Production	UK statistics (DUKES)	Operator reporting under IPPC/EPR	
1A1b Petroleum refining	UK statistics (DUKES)	Operator reporting under IPPC/EPR	
1A1c Manufacture of Solid Fuels etc.	UK statistics (DUKES)	Operator reporting under IPPC/EPR and EEMS	
1A2a Iron & Steel	UK statistics (DUKES)	Majority of EFs reported form Corus/Tata	
1A2b Non-ferrous Metals	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
1A2c Chemicals	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
1A2d Pulp, Paper & Print	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
1A2e Food Processing, Beverages & Tobacco	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
1A2f Non-metallic minerals	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
1A2g Other	UK statistics (DUKES)	UK factors & Operator reporting under IPPC/EPR	
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	

NFR Category	Activity	EFs	Comment
1A3e Pipeline compressors	IE	IE	Reported under 1A1c
1A4a Commercial / Institutional	UK statistics (DUKES)	UK factors	
1A4b i Residential	UK statistics (DUKES)	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)	-	-	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)	Operator reporting under IPPC/EPR, literature sources	
1B1c Other	-	-	Reported under 1B1b
1B2Oil & natural gas	UK statistics & Industry	Operator reporting under IPPC/EPR and via EEMS, data from UKPIA, data from UK gas network operators and from DECC	
2 A Mineral Products	Industry & Estimated	Industry & Operator reporting under IPPC/EPR	
2 B Chemical Industry	Industry & Estimated	Operator reporting under IPPC/EPR	
2 C Metal Production	UK statistics & Industry	Industry & Operator reporting under IPPC/EPR	
2 D Solvents	Industry	UK factors, Industry & Estimated	
2 G Other product use	Na	NA	
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 IPPC/EPR & UK factors	
5D Waste-Water Handling	UK statistics	UK factors	
5E Other Waste	Estimated	UK factors	
6A Other	Estimated	UK factors	
Memo Items			
1A3aii(ii) Civil Aviation (Domestic, Cruise)	UK statistics (CAA)	Literature sources	
1A3ai(ii) International Aviation (Cruise)	UK statistics (CAA)	Literature sources	

NFR Category	Activity	EFs	Comment
1A3di(i) International maritime Navigation	UK statistics and sector research (Entec, 2010)	Literature sources	
6B Other (Memo)	UK statistics	UK factors	
11 Other (Memo)	Estimated	UK factors	

The terms used here provide a simple overview to give an indication of where detailed or UK specific information has been used in the emissions inventory. The following definitions have been used in the table:

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).
- **Industry**: Process operators or trade associations have provided activity data directly.
- **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 has been 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.

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

1.5 Key Source Analysis

Table 1-8 provides an overview of the most important sources for selected pollutants reported under the CLRTAP in the 2015 inventory submission. The sources that add up to at least 80% of the national total in 2013 are defined as being a key source for each pollutant as per reporting guidance[8].

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 27% of the emissions from cattle. NMVOC sources are dominated by the use of domestic solvents including fungicides. 24% of CO emissions arise from passenger cars in the road transport sector, which has been a dominant source throughout the time series. However the share of emissions from this sector increased between 1990 and 2013 due to the decrease of emissions in other sectors such as combustion of coal in the household sector.

For PM_{10}, $PM_{2.5}$ and B[a]P emissions, the dominant source remains the combustion of fuel in the residential sector (1A4bi), although the percentage contribution of that source to overall emissions has

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

decreased significantly since 1990. Sinter production in the iron and steel production sector is the highest source for Pb and Cd emissions in 2013. There are only two key source categories for HCBs, which are from the use of pesticides in the agriculture sector and public electricity and heat production. The major sources for PCDD/PCDFs are combustion of fuel in the residential sector (1A4bi) and iron and steel production.

Table 1-8 Key NFR Sources of Air Quality Pollutants in the UK in 2013 (that together contribute at least 80% to the pollutant emission totals)

Component	Key categories (Sorted from high to low from left to right)																			Total (%)
SO_x (as SO_2)	1A1a 40.00%	1A2gviii 18.30%	1A4bi 11.30%	1A1b 10.90%																81
NO_x (as NO_2)	1A1a 26.60%	1A3bi 15.70%	1A3biii 9.50%	1A3bii 6.40%	1A1c 5.30%	1A2gviii 5.00%	1A4bi 3.90%	1A3c 3.50%	1A3dii 3.40%	1A2gvii 3.30%										83
NH_3	3Da2a 20.10%	3B1a 15.10%	3Da1 12.70%	3B1b 12.00%	3Da3 9.20%	6A 7.50%	3B3 4.90%													82
NMVOC	2D3a 18.00%	2D3d 12.90%	2H2 11.20%	2D3i 6.50%	3B1b 5.80%	1B2c 4.20%	1B2ai 3.90%	1B2b 3.80%	3B1a 3.70%	1A4bi 3.00%	1B2av 2.80%	1B2aiv 2.60%	2D3e 2.50%							81
CO	1A3bi 23.70%	1A4bi 15.30%	1A2gviii 10.60%	1A2a 10.40%	1A2gvii 9.60%	2C1 5.00%	1A1a 4.00%	1A4bii 3.60%												82
TSP	3B4gii 18.60%	3B4gi 11.40%	1A4bi 10.50%	3B4giii 5.50%	2A5a 4.30%	1A3bvi 4.10%	3B3 3.80%	1A3bvii 3.60%	1A1a 3.30%	1A4ci 3.00%	3B1a 2.60%	3B4giv 2.50%	1A2gviii 2.10%	2C1 2.10%	3B1b 1.80%	2D3d 1.80%				81
PM_{10}	1A4bi 17.50%	1A3bvi 7.20%	3B4gii 5.80%	1A1a 5.60%	1A4ci 4.90%	2A5a 4.60%	1A3bvii 3.80%	3Dc 3.70%	3B4gi 3.60%	1A2gviii 3.50%	2C1 3.40%	2D3d 3.20%	1A3bi 3.10%	1A2gvii 2.40%	1A3bii 2.20%	6A 1.80%	3B4giii 1.70%	1A3dii 1.60%	5C2 1.50%	81
$PM_{2.5}$	1A4bi 25.37%	1A4ci 7.37%	1A3bvi 6.15%	1A2gviii 5.27%	1A1a 5.11%	1A3bi 4.52%	2C1 3.71%	1A2gvii 3.45%	1A3bvii 3.18%	1A3bii 3.14%	6A 2.52%	1A3dii 2.33%	2D3d 2.19%	5C2 2.18%	1A4cii 1.86%	1A3biii 1.63%	1A3c 1.44%			81
Pb	2C1 44.40%	1A2gviii 15.30%	1A4bi 7.60%	1A1a 5.80%	2C7c 5.70%	1B1b 3.60%														82
Hg	1A1a 25.70%	1A2gviii 14.00%	2C1 11.60%	5C1bv 9.00%	2B10a 6.60%	5A 5.80%	1A2f 4.10%	2C7c 4.00%												81
Cd	2C1 36.00%	1A2gviii 11.10%	1A4bi 10.20%	1A3bi 9.00%	1A1a 6.10%	2C7c 4.00%	1A3biii 3.50%	1A3bii 2.00%												82
PCDD and PCDF	1A4bi 21.20%	2C1 17.20%	6A 11.90%	5C2 11.70%	1A2gviii 9.80%	1A4ci 8.30%														80
PAH	1A4bi 72.60%	6A 6.20%	1B1b 3.20%																	82
HCB	1A1a 50.60%	3Df 47.60%																		98

1.6 Quality Assurance and Quality Control, Verification Methods

This section presents the QA/QC system for the UK NAEI, including verification and treatment of confidentiality issues. QA/QC activities ensure that the inventory is as error free as possible (QC) reviewed by independent experts (QA) and where possible compared with independent datasets (Verification). The current 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 IPCC Good Practice Guidance). Ricardo-AEA (the inventory Agency) is also fully accredited to BS EN ISO 9001:2008 (see Box 1 below). This accreditation provides additional institutional standards that the inventory agency has to apply to all projects and ensures that the wider company conforms to good practice in project management and quality assurance.

Box 1: BS EN ISO 9001:2008 Accreditation:
In addition to the UK's own AQPI specific QA/QC system, through Ricardo-AEA, 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 and the Ricardo-AEA internal QA auditors. The NAEI has been audited favourably by Lloyds on three 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-AEA is currently accredited to BS EN ISO 9001:2008. Lloyds Register Quality Assurance carried out a three yearly recertification audit of Ricardo-AEA in September and October 2011. Ricardo-AEA successfully passed the recertification, with no major non compliances, and a new certificate was issued. Ricardo-AEA is currently certificated both for the Quality Assurance ISO 9001:2008, including TiCKIT, and Environmental Management System ISO 14001 standard.

The main requirements of Tier 1 are:

- There is an Inventory Agency (consortium managed by Ricardo-AEA)
- 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 current systems used by the inventory agency in preparing the UK emissions inventory comply with the Tier 1 requirements.

Source specific (tier 2) QA/QC details, typically applied to the most important "key categories" and/or where complex estimation methods (tier 2-3) have been used, are presented in the relevant sections of this IIR Chapters 1 to 7.

1.6.1 Overview of the QA/QC system

Whilst the organisations that provide data to the NAEI have their own QA/QC systems, the inventory agency is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, the inventory agency works with organisations supplying data to the National Atmospheric Emissions Inventory (NAEI) to request they demonstrate and document their own levels of QA/QC. Where possible data providers are also encouraged to introduce QA/QC procedures that comply with either IPCC Good Practice Guidance or the UK's National Statistics standards.

An overview of the UK's NAEI QA/QC system are illustrated in Figure 1-6 to Figure 1-8 below. The QA/QC activities encompass the planning of the inventory compilation (gathering and prioritisation of feedback for improvements), the logging of any data received for use in the inventory, documentation of methods and assumptions applied, final internal checks comparing new and previous estimates as well as peer and official review of the final estimates each year.

The QA/QC system includes three core components:

1. A QA/QC Plan, a set of working instructions embedded into each of the activities within the inventory programme, which 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 also assigns roles, responsibilities and a timeline for completion of QA/QC activities. There is also a set of manuals, which defines timetables, procedures for updating the database, document control, checking procedures and procedures for updating the methodology manual.

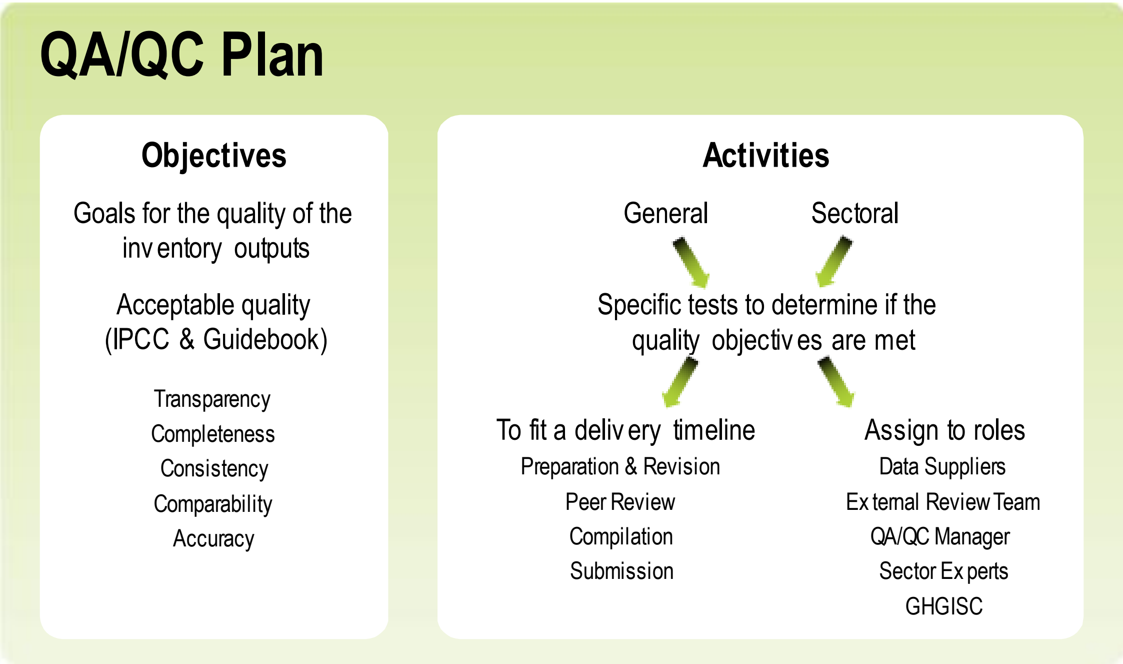


Figure 1-6 QA/QC Plan

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. A number of systems and tools for QA/QC implementation are described in the sections that follow

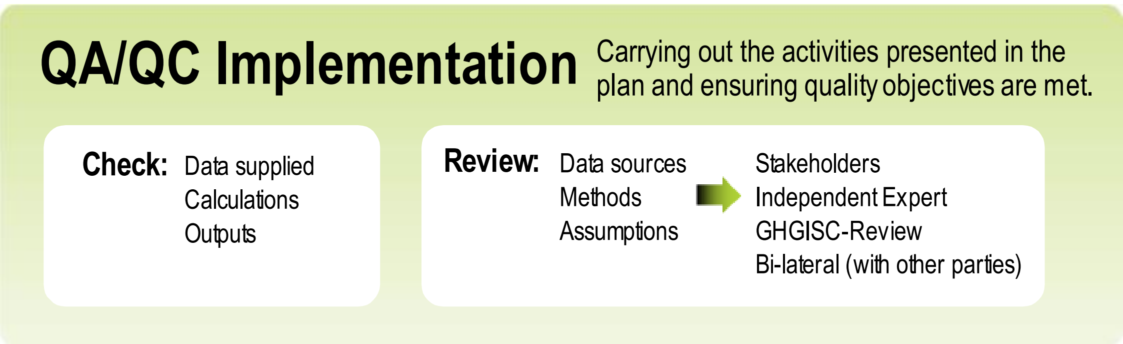


Figure 1-7 QA/QC Implementation

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; and b) transparent documentation of all QA/QC implementation including records of activities undertaken, findings/issue logs, recommendations and any necessary actions taken or planned.

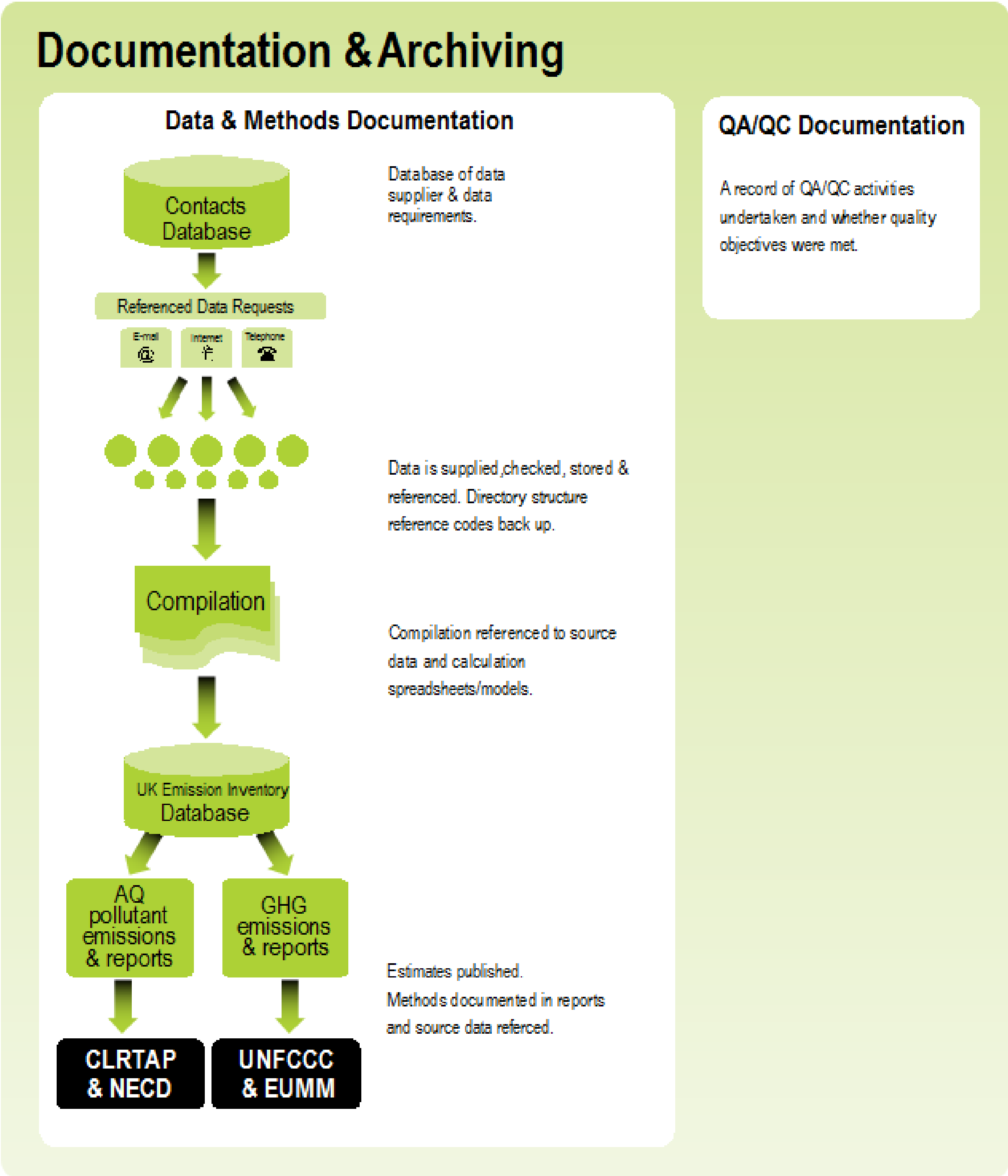


Figure 1-8 Documentation and Archiving

1.6.2 Quality Objectives

Quality objectives are set to ensure that the estimates in the NAEI are of an acceptable quality. The quality objectives relate to achieving Transparency, Completeness, Consistency, Comparability and Accuracy (TCCCA):

- **T**ransparent 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).
  - The documentation of QA/QC activities and their implementation using internal checklists and summarised in relevant public material (e.g. IIR).
- **C**omplete: includes 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 and, gases and scenarios.
- **C**onsistent: 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.
- **C**omparable: with other reported emission/removal estimates through use of the latest reporting templates and nomenclature consistent with reporting requirements. Using the correct NFR category level and consistent units for expressing mass of emissions/removals by gas.
- **A**ccurate: ensuring the most accurate methods are used in the application of methods, minimising the uncertainty in assumptions and in use of data sources for the estimates and inclusion of national assumptions.

As 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 (biggest contributors and/or most uncertain). The highest level of resources is usually focused on these key categories for improvement, estimation and QA/QC activities.

1.6.3 Staff Roles and Responsibilities

To allow an effective QA/QC system to be put in place and operated, staff roles must be clearly defined. Figure 1-9 gives an illustration of the way in which the UK emissions inventory team is organised. This well-defined structure is designed to use the specific strengths and expertise of the individual members in the team, and ensures that responsibilities are transparent.

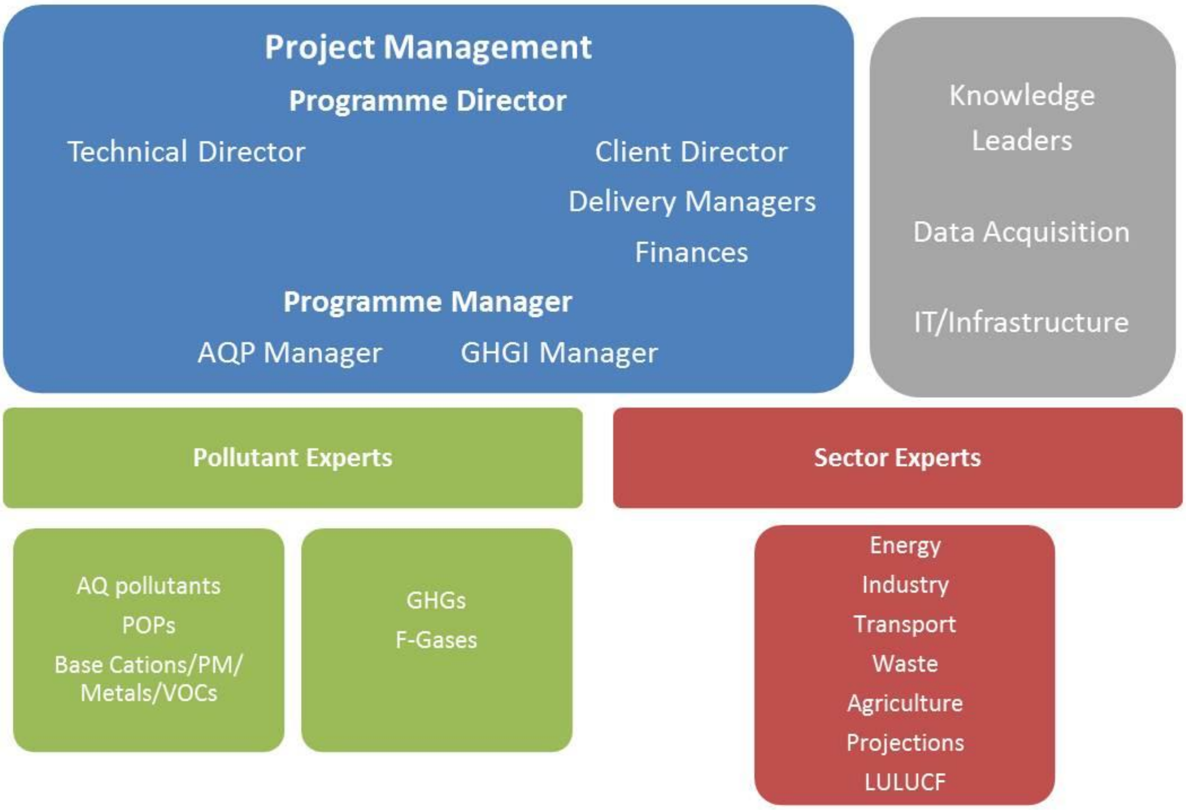


Figure 1-9 Inventory Team Organisation and Responsibilities

1.6.4 Implementation of the QA/QC Plan

The QA/QC plan defines the planned QA/QC arrangements necessary to maintain the NAEI quality objectives for:

1. Calculation of air pollutant estimates and reporting to UNECE (including emissions from all sources and pollutants).
2. Calculation of greenhouse gas estimates and reporting to UNFCCC and the European Union Monitoring Mechanism (EUMM) (including emissions and removals from all sources and gases).
3. Calculation of estimates and reporting to UK National Statistics.
4. Maintain consistency between Air Quality Pollutant and GHG inventories: This is very important to enable consistent data reporting across different pollutants for each source-activity, and facilitate consistent policy analysis for changing activity or abatement impacts on GHG and air pollutant emissions. Having one database for activity data and emission estimates ensures consistency. The two inventories are based on selections from this core database of the appropriate datasets.

1.6.4.1 QA/QC and Auditing Activities

Figure 1-10 gives an overview of the data flows and 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.

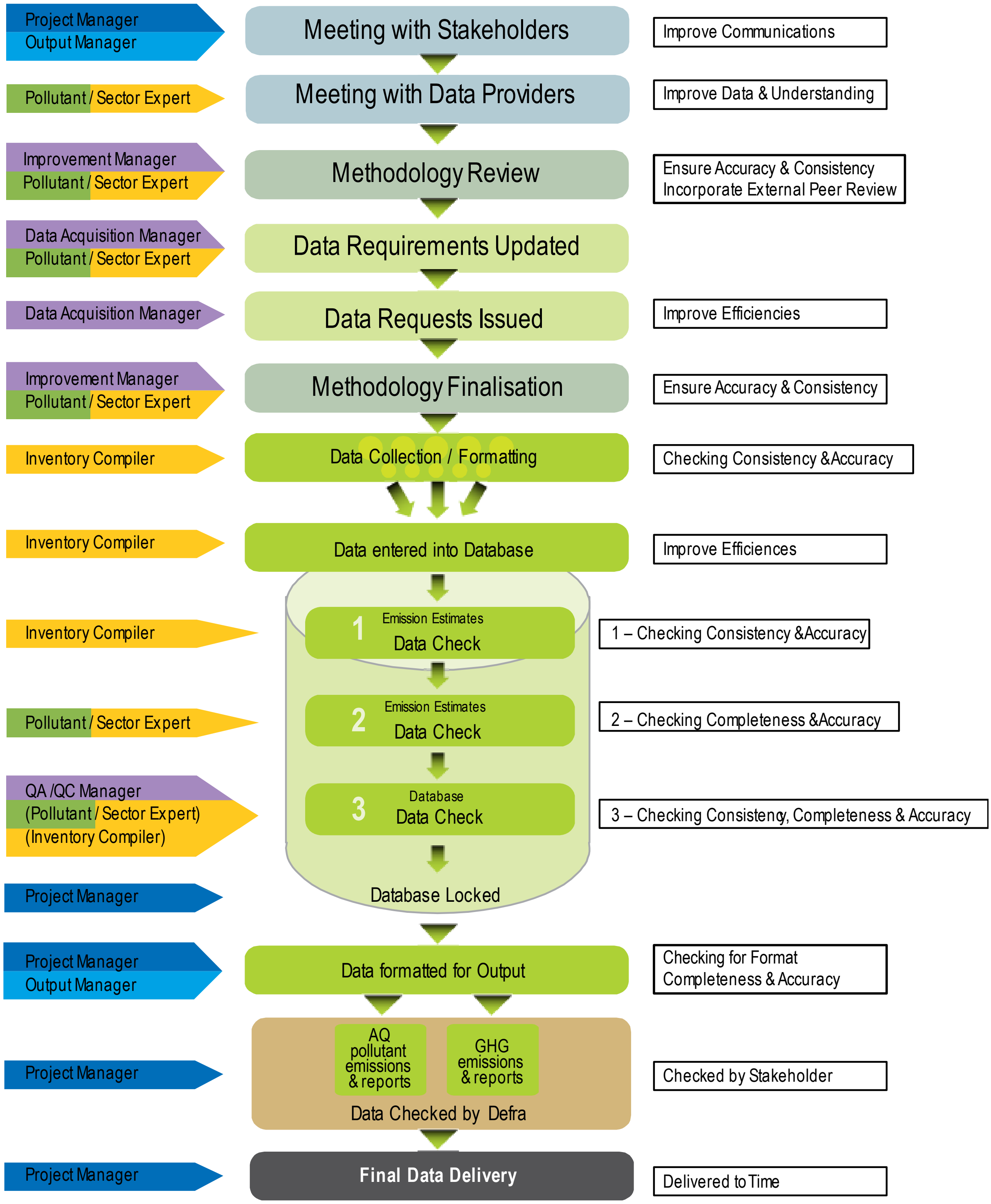


Figure 1-10 Data Flows and QA/QC

<u>Stages 1 and 2: Input Data Quality</u>

Whilst it is possible to maintain high standards of QA/QC on the processing and within systems managed directly by the inventory agency, the quality of the input data supplied can be variable. Meeting with data suppliers and the creation of data reporting templates and Data Supply Agreements for key data providers allows improved understanding of the data, and improved quality control. Quality audits are also regularly carried out to understand the QA/QC procedures data providers themselves utilise and the extent to which this complies with similar inventory procedures. Figure 1-11 illustrates how quality control is extended where possible from inventory agency activities to include the input data suppliers. The figure also indicates the auditing of the inventory agency, processes and data.

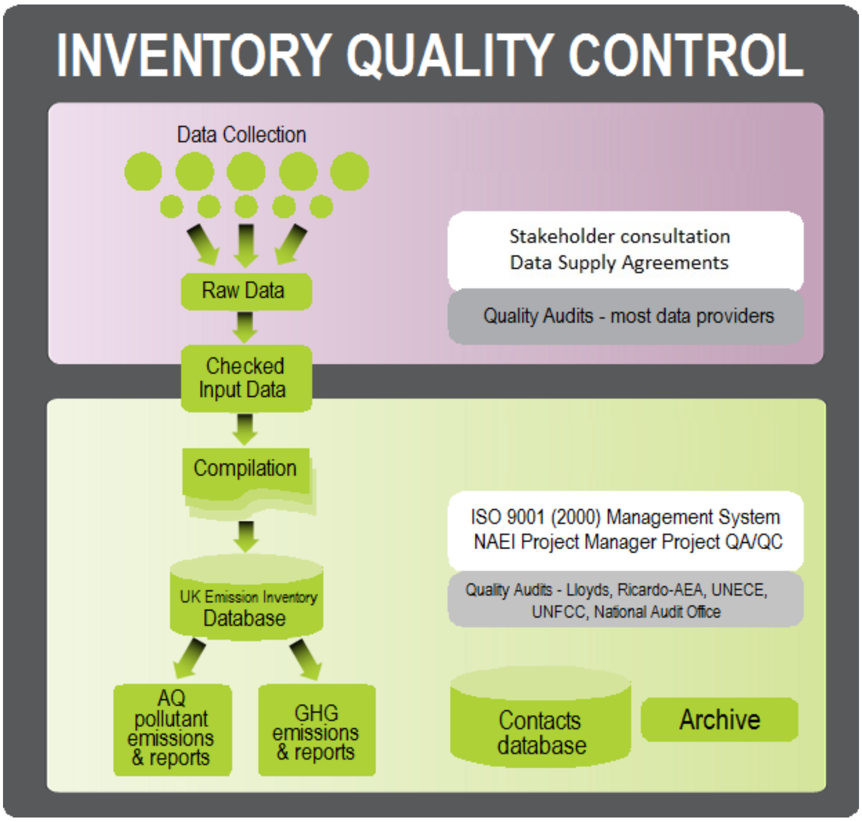


Figure 1-11 Auditing of the Inventory Agency, Processes and Data

<u>Stage 3: Spreadsheet Compilation</u>
There are a large number of QA/QC procedures which accompany this compilation stage. Each spreadsheet used for calculating estimates incorporates:

- a QC sheet which includes key information including the unique identifiers and the spreadsheet version and Spreadsheet Reference Number;
- Spreadsheet Name;
- NAEI year;
- Status;
- Completion Date;
- Author;
- Approved by;
- Approval date;
- Description of contents, scope categories included, Activities, Pollutants, Years;
- a list of the data sources and reference materials;
- a colour-coding scheme for easy reference to data, calculations, checking cells; inter-dependencies: whether (and how) this spreadsheet interacts with other spreadsheets and
- results of QA/QC checks.

Although these spreadsheets vary considerably in their level of complexity there is a standardised procedure for completing the calculations:

1. The sheet is completed by the assigned compiler, and signed off as “final”.
2. The sheet is then checked by a second member of the team (there is defined guidance on the checks, which include methodology checks, logic checks, and inclusion of cross-checks and correct formatting). Any issues arising are addressed. The sheet is then assigned as “checked”.

3. There is then a second check by a senior inventory expert, typically a Knowledge Leader or Project Manager (with similar checks).

The sheet is then identified as being ready for uploading into the database.

A “status” spreadsheet links to all of the individual compilation spreadsheets and shows the progress, not only of the spreadsheet compilation, but also of which data has been uploaded to the database.

Stage 4: Database Population

The central database is able to automatically upload data from the spreadsheets. However, as part of this upload there are a number of checks performed to ensure the data are complete, finalised and imported correctly. Once the system has checked that the individual calculation spreadsheets are finalised and up-to-date, the database then automatically uploads all output data from the spreadsheet into the compilation database. These systems ensure that the data, which is loaded from the spreadsheets into the database, is complete, and has been checked to standards as specified in the programme. There are then additional checks on the data in the database. Once all of these checks have been cleared, the database is then “locked” and no further changes are possible without permissions from the project manager.

Stage 5: Reporting Emissions Datasets

Data extracted from the database typically requires formatting for formal submissions. In the case of the CLRTAP and UNFCCC/EUMM submission, a degree of automation has been incorporated into populating the required templates to minimise transcription errors. However, additional manual data entry and cross-checks are necessary and used to ensure that all data is correctly exported into the reporting templates. This ensures that the national totals agree with previously established data, and that the memo items are correctly reported.

1.6.4.2 Timeline

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 AQPI and GHGI reporting commitments.

1.6.4.3 Quality Control and Documentation

The NAEI Quality Control (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle. Figure 1-12 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 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 SNAP, NFR 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.

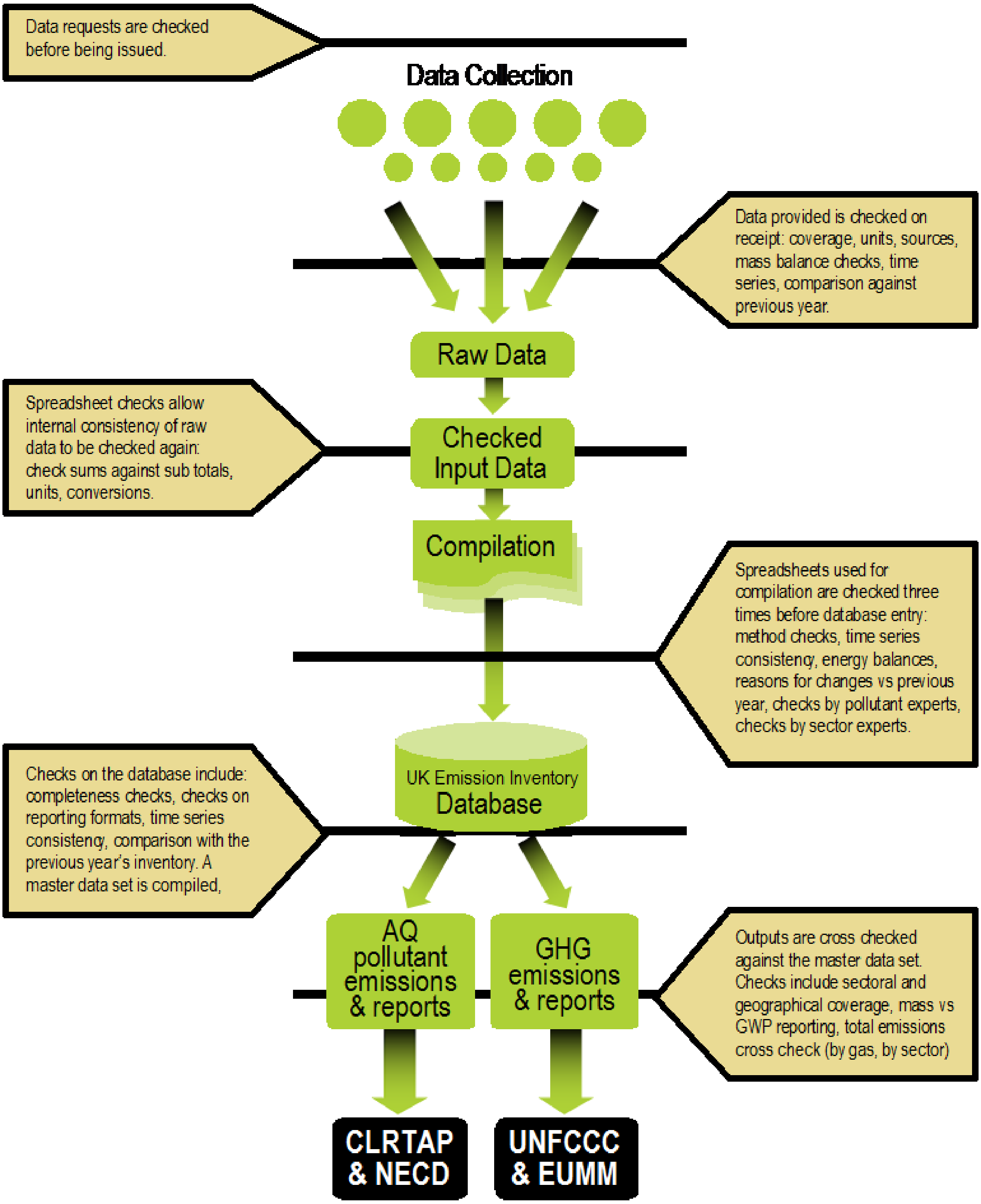


Figure 1-12 Summary of the system of data checks used within the UK inventory

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

1. **A database of contacts (the "contacts database")** 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/removals with unique references that are used to tag datasets through the inventory compilation process. The contacts database also tracks all products supplied 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 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 has not been properly checked. 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***[9] 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 from DECC;
   d. Other activity data checks (e.g. production and consumption with official national statistics).

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

e. Implied Emission Factor checks (assessing trends in IEF and comparison with previous submissions).
f. A consistency check between NFR output and IPCC CRF formatted output.

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, 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 hard disks 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.

1.6.5 Quality Assurance and Verification

Quality Assurance and verification activities take a more independent view on the choice of inputs to and assumptions used in the inventory estimation. 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

There is a team of experts who sit outside of the core inventory team (which include Ricardo-AEA and other emissions inventory knowledge leaders as well as experts from the modelling and research communities who use inventory data). These experts are available to the project for the purposes of Peer Review and Validation. These persons are drawn on as required, but in addition many of them 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, in particular the air pollutants contained in the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland and those covered by the EU

Directives on Ambient Air Quality. Specifically AQEG gives advice on levels, sources and characteristics of air pollutants in the UK. It does not advise on health impacts or air quality standards.

1.6.5.2 Bilateral reviews

The UK also has a programme of bilateral and external peer reviews which is managed as part of the improvement programme. Bilateral reviews are initiated with other countries as a means to learn from good practice on 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 1-9).

Table 1-9 Summary of Peer and Bilateral Review Activities

Review type	Date	Sector or source	Reviewer/ Participants	Summary
Peer review	2002	Fuel Combustion (1A)	T Simmons	This review provided recommendations, which have now been implemented, including: an improved method for estimating emissions from domestic and international civil aviation and a review of the proportion of recycled lubricants burnt.
Peer review	2005	Adipic acid production (2B3)	Defra, AEA, plant operators, the Met Office	The review included: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions clarified the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.
Bilateral	July 2008	Agriculture (4)	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. The focus was primarily on GHG emissions, but the activities were also relevant for AQ emission estimates. Specific activities undertaken included sharing good practice between the UK and France and the development of ideas for efficient future technical collaboration.
Peer review	2012	All, except sector 5	EC Technical Expert Review Team	The UK made 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 overestimate. The review also presented another 20 recommendations for the UK to consider.
Bilateral	May 2014	Energy, Industrial processes, Waste	German inventory team	UK took part in a bilateral review with the inventory agency from Germany. Scope was broad but focussed on high-emitting priority sectors for both countries across Energy, Industrial Processes and Waste.

1.6.5.3 Annual user feedback

Ricardo-AEA also includes specific improvement feedback from the wider user community including users of data for air pollution modelling and Local Authority review and assessment work.

1.6.5.4 Stakeholder Consultation with Key Data Providers

The inventory agency 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:

Department of Energy and Climate Change

- The inventory agency held a meeting with the DECC energy statistics team that produces the Digest of UK Energy Statistics to discuss what changes (to both activity and methodology) were expected in the 2014 publication of the statistics, and to clarify some outstanding queries. Some of the most significant changes were related consultations with the inventory agency on investigations made in the previous year, including to iron & steel and non-energy use (NEU) of fuels.
- Following the meeting mentioned above, follow up meetings with the DUKES team were held to understand the change in methodology to NEU of fuels, in particular refinery feedstock, and how those changes in DUKES methodology could be replicated for the entire time-series (in DUKES the time series was only revised back to 2008).
- As in previous years, data discrepancies between DUKES and EU ETS for the refinery sector were noted and resolved through consultation with the DECC DUKES team, EU ETS regulators and checked against data provided by the refinery sector trade association, UKPIA.
- Consultation with the DECC Offshore Inspectorate to discuss access to EU ETS data, information on the data quality checking and operator reporting system (e.g. EEMS reporting guidance), and to explore any options to access information regarding oil and gas blowouts.

Department for Transport

- The inventory agency had a meeting with the Department for Transport (DfT) Traffic Statistics team to review and update the use of DfT transport activity data within the inventory methodology.

Department for Environment, Food and Rural Affairs

Regular consultation with Defra is undertaken on data gathering and provision for estimates in the waste, water, agriculture and LULUCF sectors as well as for gathering data on specific environmental events and land cover.

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 Environmental 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 been contacting Environmental Regulators to clarify discrepancies between the Pollution Inventory (PI) and EU ETS, and other data sources.
- Because of the increasing responsibilities of NRW, which is taking over the roles of the EA in Wales, the inventory agency has had a number of consultations with NRW regarding the support required from them.

Other data providers

- The inventory agency has had discussions with a wide range of industry contacts, primarily in industries related to the use of solvents, chemicals and pharmaceuticals, seeking data (mainly) on emissions of VOCs, nitrous oxide and F-gases including: ABPI, BASA, ECSA, FESEPA and VBRA.
- Consultation with the Food and Drink Federation to seek available production data across a range of sector products, and to explore access to data regarding waste management and waste water treatment.
- Consultation with gas network providers to request additional information on the UK gas distribution and transmission system (in particular pipeline lengths). Several data revisions have

been implemented by the inventory agency as a result of clarifications of data previously reported by the gas network operators, leading to more accurate UK estimates for gas leakage as well as gas compositional data.

- Consultation with UKPIA regarding carbon emission factor data for petroleum fuels in response to review questions. This led to a number of further meetings including with the EA PI team, the International Institute of Applied Systems Analysis (IIASA) team in Austria and JRC.

1.6.5.5 Verification

Defra has an ongoing air pollution mapping and dispersion modelling programme which makes extensive use of emissions inventory data for comparison 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 includes 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. An example of this is the report by Carslaw et al (2011). Better agreement has been found in the trends for NMVOC emissions from traffic.

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.

1.6.5.6 Inventory Improvement Programme (UK and Devolved Administrations)

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 DECC for the GHGI. Improvements on activity data that improve both AQ and GHG emissions are jointly owned but will be 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.

- On-going 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 review.
- Inconsistencies identified in verification work.

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:

- **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** for UK and DA inventories to separate emissions of traded and non-traded emissions;
- **Iron and Steel sector estimates**. Consultation with DECC 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.
- **PM_{10} emissions from small regulated industrial processes**: Improvement of the methodology for PM_{10} emissions from processes regulated under Local Authority Pollution Prevention and Control (LAPPC), which were previously very uncertain estimates based on use of emission factors developed in the mid-1990s and expressed in terms of emission per process.
- **Periodic 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:** 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):** The inventory agency consulted with the DECC 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 DECC 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:** Additional consultation with the DECC 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:** Consultation with the DECC 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. Access to the detailed EU ETS dataset for offshore oil and gas installations has enabled the inventory agency to improve the accuracy of source allocation of emissions for the sector;

- **Road traffic data:** 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**: Consultation with the Department for Transport has secured improved data from their new Rail Emissions Model for updating the rail emissions inventory.
- **Waste water treatment and sewage sludge treatment and disposal:** 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 met 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. New information and reports obtained from Defra and the Environment Agency have enabled new estimates of emissions from industrial waste water treatment to be compiled across the time series;
- **Incineration and Landfill:** Research with the EA and Defra has progressed our understanding of the data availability for landfill methane flaring and use in gas engines. More research is needed to develop these new data and determine whether any revisions to UK assumptions / factors on methane utilisation should be considered in future inventory estimates. Currently the dataset is too limited to be regarded as representative of UK landfill activity.
- **Natural gas distribution:** Consultation with natural gas distribution network operating companies 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 to address a step-change in the previous inventory time series to improve the accuracy and consistency of the inventory time series, and (iii) to obtain new 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:** 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):** 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:** 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 has enabled a more complete, representative UK dataset to be used in the inventory;
- **Devolved Administration solid and liquid fuels:** 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 included consultation and review of reports published by Her Majesty's Revenue and Customs, oil brokers, local councils, the Climate Change Agreements (a national policy reporting mechanism operated by DECC), the National Housing Model, Welsh Government research into gas network expansion and fuel poverty;
- **Shale Gas:** The inventory agency conducted a review of available literature to support any future requirements in the UK to develop emission estimates from new AQ and GHG emission sources that may arise through future development of unconventional (shale) gas resources in the UK. This review encompassed an assessment of new emission sources associated with shale gas exploration and production, the appropriate data reporting requirements in the UK inventory, including: source allocations, activity data needs, available emission factor data and associated uncertainties, anticipated responsibilities and reporting expectations of different UK organisations.

- **Off-road machinery activities:** 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.
- **Shipping and inland waterway activities:** Discussions with the DUKES petroleum statistics team and UKPIA combined with research by Entec led to a review in the procedures for allocating marine fuel consumption between domestic and international shipping. Further research was done by the inventory agency to gain insight into the population and activities of inland waterway vessels so that a bottom-up method could be used to estimate emissions from these sources.

1.6.5.7 Capacity Building and Knowledge Sharing

The UK actively participates in capacity building and knowledge sharing activities with other countries. These initiatives are usually led by the National Inventory Steering Committee (NISC) but also include international projects that members of the inventory team have participated in. The list below highlights some recent examples of these activities.

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 emissions trading and energy and emissions statistics. This included a UK Inventory expert taking a seminar on this topic, involving approximately 30 Chinese statisticians.
3. Knowledge sharing with the Russian statistical agency that compiles the inventory for Russia.
4. Capacity building activities in South Africa in the agricultural sector.
5. Capacity building activities in Saudi Arabia – assistance with the production of their second National Communication and suggestions for the improvements of their greenhouse gas inventory.
6. Work with the Malta Environmental Protection Agency to set up a National Inventory System to produce both greenhouse gas and air quality pollutant inventories.
7. Knowledge sharing with the Romanian inventory team during December 2011 to support the improvement of energy sector reporting.
8. 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 emissions, working from provincial and facility-level data.

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 NFR 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 templates or the IIR.

The UK Informative Inventory Reports from the 2008 IIR onwards[10], and estimates of emissions of air quality pollutants, are all publicly available on the web; see http://naei.defra.gov.uk/

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

1.6.7 Uncertainty Assessments

A Tier 2 uncertainty analysis for national estimates of NAEI pollutants is carried out using a Monte Carlo technique. As summarised in Figure 1-13 the uncertainty analysis identifies ranges of uncertainty for each source for both the emission factor and the activity statistic. Each uncertainty range will also be associated with a probability distribution.

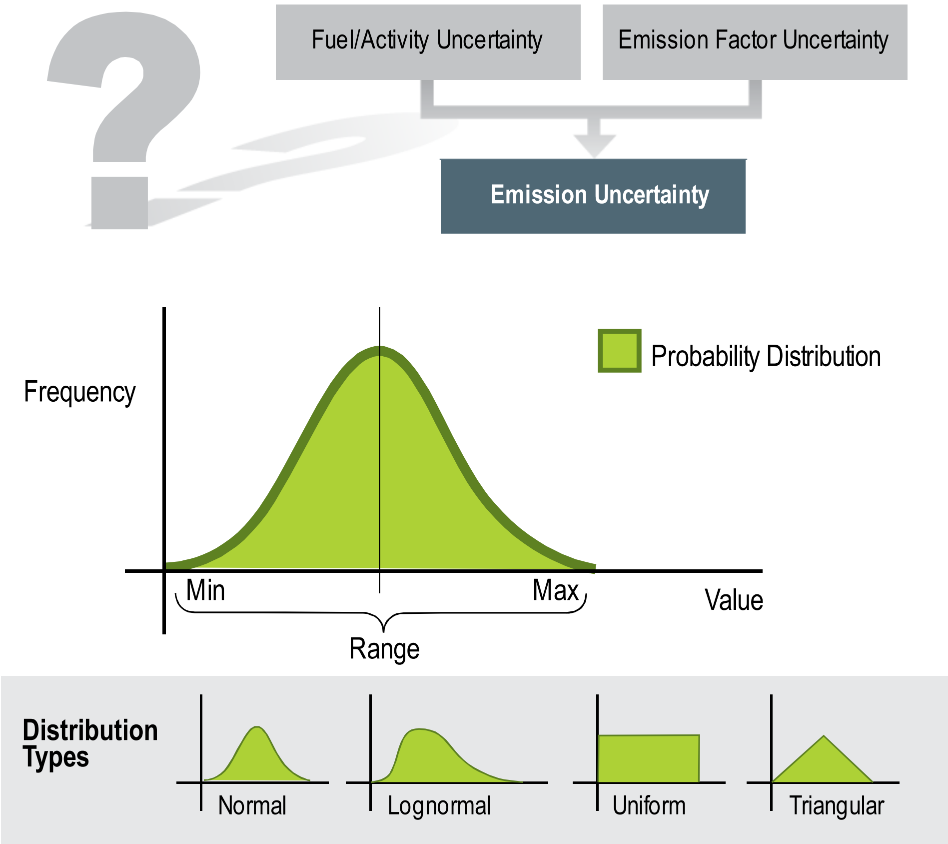


Figure 1-13 Illustration of Uncertainty Assessment Techniques

This determines the impact of uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. All analyses are consistent with the IPCC and EMEP/EEA good practice guidance. Uncertainties are assessed for each year's inventory by source sector and by pollutant. Results of the uncertainty analysis are also used to plan the programme of inventory improvement.

1.7 Uncertainty Evaluation

Uncertainty information is not intended to dispute the validity of the inventory estimates, but to help prioritise efforts to improve the accuracy of inventories in the future and guide decisions on methodological choice (IPCC Good Practice Guidance (2000)). The EMEP/EEA 2013 guidebook requires Member States to undertake an uncertainty assessment of the national totals of each pollutant reported under LRTAP.

Evaluation of uncertainty is carried out by a Monte-Carlo uncertainty assessment as indicated in Section 1.6.7.

Quantitative estimates of the uncertainties in emission inventories are based on calculations made using a direct simulation technique, which corresponds to the methodology proposed in the latest EMEP Guidebook (EMEP 2013b) produced by the UNECE Taskforce on Emission Inventories. This work is described in more detail by Passant (2002). Uncertainty estimates are shown in Table 1-10. These estimated uncertainties are one of the indicators used to guide the NAEI improvement programme and with the aim of reducing uncertainties in the NAEI.

Table 1-10 Uncertainty of the Emission Inventories for pollutants covered under the NAEI (excluding GHGs)

Pollutant	Estimated Uncertainty %
Carbon monoxide	-20 to +30
Benzene	-20 to +30
1,3-butadiene	-20 to +30
PM_{10}	-20 to +50
$PM_{2.5}$	-20 to +50
$PM_{1.0}$	-20 to +50
$PM_{0.1}$	-20 to +50
Black Carbon	-20 to +50
Black smoke	-30 to +50
Sulphur dioxide	+/- 4
Nitrogen oxides	+/- 10
Non-Methane Volatile Organic Compounds	+/- 10
Ammonia	+/- 20
Hydrogen chloride Hydrogen fluoride[a]	-30 to +>50 -30 to +>50
Arsenic	+/- >50
Cadmium	-30 to +>50
Chromium	-50 to +>50
Copper	+/- >50
Lead	-30 to +40
Mercury	-30 to +50
Nickel	-40 to + >50
Selenium	-30 to +40
Vanadium	-30 to +30
Zinc	-40 to + >50
Beryllium	+/- >50
Manganese	+/- >50
Benzo[a]pyrene	+/- >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 major agricultural sources. Emissions 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 wild animals are also highly uncertain. 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.

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

NO_x (as NO_2) emission estimates are less accurate than SO_x (as SO_2) because, although they are calculated using measured emission factors, these emission factors can vary much more with combustion conditions; emission factors given in the literature for combustion sources show large variations In the case of road transport (1A3b) emissions, while the inventory methodology takes into account variations in the amount of NO_x (as NO_2) emitted as a function of speed and vehicle type, significant variations in measured emission factors have been found between vehicles of the same type even when keeping these parameters constant.

From the above, one might expect the NO_x (as NO_2) inventory to be very uncertain, however the overall uncertainty is in fact lower than for any pollutant other than SO_x (as SO_2) for a number of reasons:

- While NO_x (as NO_2) emission factors are somewhat uncertain, activity data used in the NO_x (as NO_2) inventory is very much less uncertain. This contrasts with inventories for pollutants such as volatile organic compounds, PM_{10}, metals, and persistent organic pollutants, which contain a higher degree of uncertainty in source activity estimates.

- The NO_x (as NO_2) inventory is made up of a large number of independent emission sources with many of similar size and with none dominating. This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector. The other extreme is shown by the inventories for PCP, HCH and HCB where one or two sources dominate and the inventories are highly uncertain.

- Many of the larger point-source emission 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.

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 some sectors (e.g.

fugitive sources of NMVOC emissions from 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.

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, 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 CO_2, SO_x as SO_2, NO_x as NO_2 or NMVOC.

1.7.6 Sulphur Dioxide

Sulphur dioxide emissions can be estimated with the most confidence as they depend largely on 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.

1.7.7 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 and chemicals manufacture, compared with the contributions made by sources for which estimates are very uncertain, such as burning of impregnated wood

1.7.8 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.

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 1B1a (Fugitive emission from solid fuels: Coal mining and handling), 2A5a/b/c and 2D3c 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, we will continue to keep these sectors until review, in case suitable data should become available. SO_x as SO_2 from 1B1a and NH_3 from 5C1bv (Cremation) are also marked as not estimated, however, no emission factors are given for either in the 2013 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 2013 Guidebook that emission factors for these pollutants are not applicable.

1.8.2 Included Elsewhere

Emissions of sources that are unspecified within the NFR disaggregation for a specific sector are reported as IE. Table 1-11 lists all sources included in these categories.

Table 1-11 Explanation to the Notation key IE

NFR code	Substance(s)	Included in NFR code
1A3ei	NOx (as NO_2), SO_x (as SO_2) , NMVOC	1A1c
1A4aii	All	1A4ai
1A5a	All	1A5b
1A5b	NH_3	1A3eii
1B1c	All	1B1b
1B2aiv	SO_x (as SO_2)	1B2ai
1B2av	SO_x (as SO_2)	1B2ai
2B10b	NO_x (as NO_2), SO_x (as SO_2) , NH_3	2B10a
2C2	All	1A2a, 2C1 and 2A3
3B4d	NMVOC	3B2
3B4giii	NMVOC	3B4gii
5B2	All	6B (Memo Item)
5C1bi	All	5C1a

1.8.3 Other Notation Keys

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

2. Explanation of Key Trends

2.1 UK Emission Trends for key sources

This chapter discusses the latest estimates of the emissions of selected pollutants from large sources of pollutants in the NAEI, and discusses the trends in these emissions. 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 and a range of metals. Emissions of $PM_{2.5}$ are presented because emissions reduction commitments are included in the revised Gothenburg protocol. The sources considered are power generation, residential and commercial, industrial processes, transport, agriculture and finally, waste. The discussion of the magnitude and trends in emissions for each source concentrates on those pollutants where emissions are substantial from the source, or there have been large changes 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 discussion of the trends in emissions of NECD pollutants, and then moves on to discuss the latest source specific emissions and the trends in those emissions.

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 LRTAP covers the United Kingdom and Gibraltar.

2.1.1 Trends in the NECD set of Pollutants

Figure 2-1 shows the time series of UK emissions of SO_x as SO_2, NO_x as NO_2, NMVOC, and NH_3 from 1990 to 2013. The emissions of NH_3 are much smaller than those of SO_x as SO_2, NO_x as NO_2 and NMVOC and so they are presented on a separate axis. Emissions of SO_x as SO_2 have declined substantially since 1990 and reached their lowest point in 2011; however, emissions have risen in 2012 due to increased consumption of coal at the expense of natural gas as a fuel in power stations. Emissions of NMVOCs are now at their lowest since 1990. Emissions of NH_3 have declined steadily since the mid-1990s, reaching a minimum in 2013.

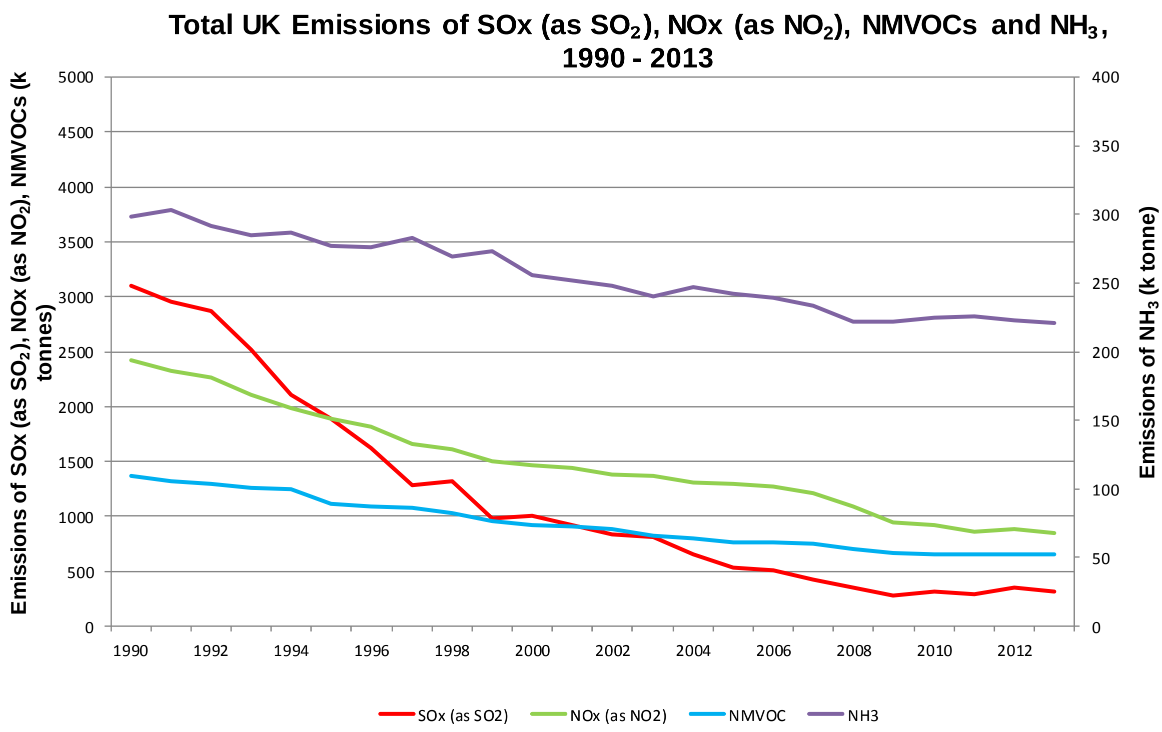


Figure 2-1 Total UK emissions of SO_x (as SO_2), NO_x (as NO_2), NMVOC, and NH_3, 1990 - 2013

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	% change from 1990 to 2013	Key factors and legislation driving the decline in emissions
SO_x (as SO_2)	-89%	• 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
NO_x (as NO_2)	-65%	• 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)

Pollutant	% change from 1990 to 2013	Key factors and legislation driving the decline in emissions
		• Implementation of the large combustion plant directive (LCPD, 2001/80/EC) • Series of Euro standards to limit vehicle tailpipe emissions, e.g. Euro 5 and Euro 6 Regulation (EC) No 715/2007 • LRTAP convention which includes measures to combat the effects of NOx 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-NOx 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 NOx formation.
NMVOC	-70%	• 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 and evaporative emissions, e.g. Euro 5 and Euro 6 Regulation (EC) No 715/2007 • UK National Air Quality Strategy • **LRTAP convention which includes measures to combat the effects of NMVOCs**
NH_3	-21%	• 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 (NFR 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 2013. However, there has been a substantial reduction in the magnitude of all these emissions from this source between 1990 and 2013 apart for HCB (see Table 2-2). Emissions of HCB have increased significantly between 1990 and 2013 due to the sharp increase in total municipal solid waste (MSW) used to generate electricity.

Table 2-2 Power Stations: Sector share of UK emissions total in 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
SO_x as SO_2	1A1a	40%	-94%
NO_x as NO_2	1A1a	27%	-65%
CO	1A1a	4%	-30%
TSP	1A1a	3%	-91%

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
PM_{10}	1A1a	6%	-90%
$PM_{2.5}$	1A1a	5%	-87%
Pb	1A1a	6%	-98%
Hg	1A1a	26%	-83%
Cd	1A1a	6%	-97%
HCB	1A1a	51%	733%

Figure 2-2 and Figure 2-3 show the emissions of a range of pollutants emitted from power stations between 1990 and 2013. The emissions for all the pollutants show substantial declines across the time series apart from HCB, due the increase in municipal solid waste (MSW) burned at power stations in 2013 compared to 1990. 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 2-2 are presented in k tonnes and those in Figure 2-3 are presented in tonnes.

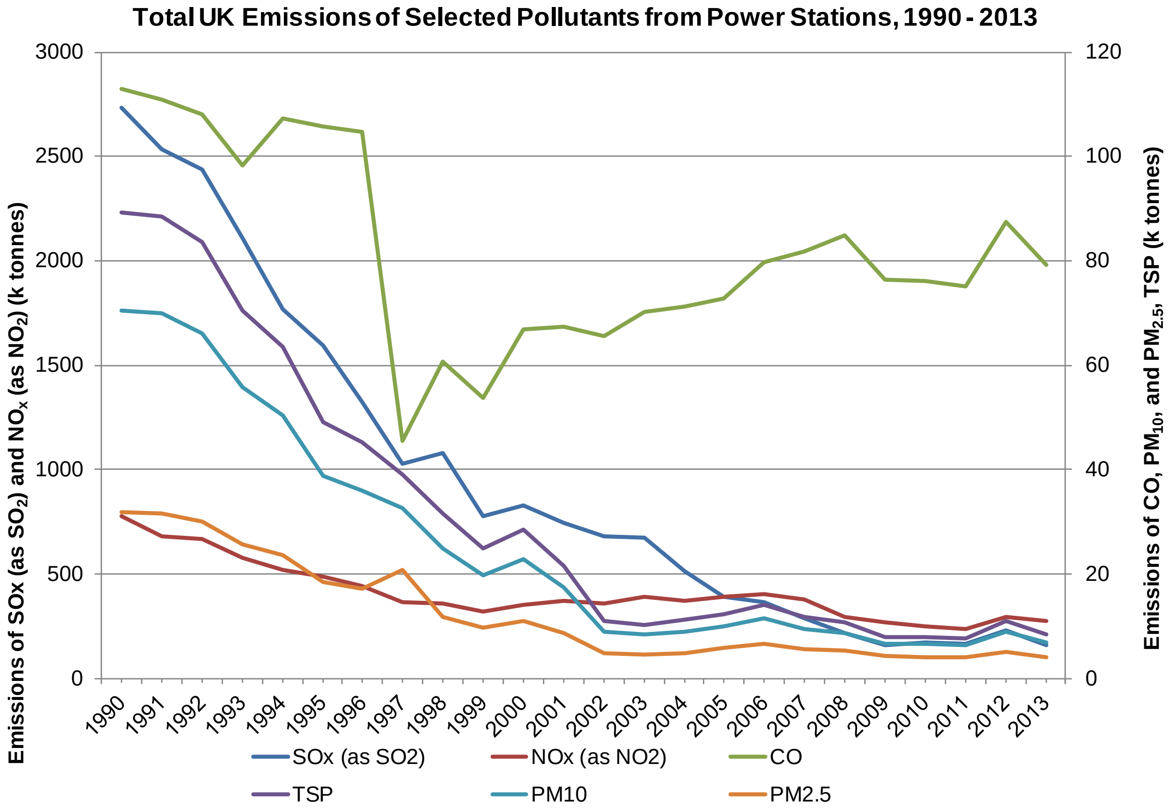


Figure 2-2 Total UK Emissions of SO_x (as SO_2), NO_x (as NO_2), CO, PM_{10}, $PM_{2.5}$ and TSP from Power Stations

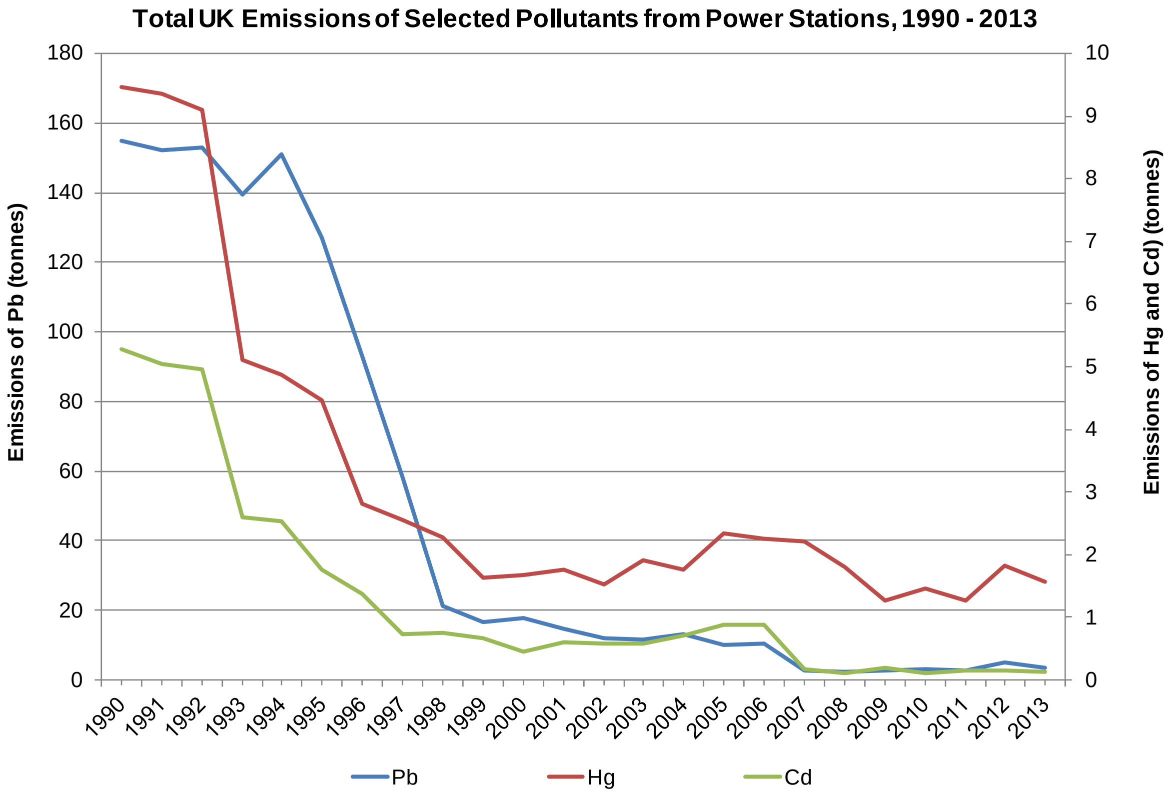


Figure 2-3 **Total UK Emissions of Pb, Cd and Hg from power stations**

Prior to 1989, the decline in emissions of SO_x as SO_2, NO_x as NO_2, CO, PM_{10} and $PM_{2.5}$ was mainly due to the increased use of nuclear plant to supply electricity, and improvements in the efficiency of fossil powered plant. Since 1988 the 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 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 SO_x as SO_2, NO_x as NO_2, CO, PM_{10}, $PM_{2.5}$, Pb, Cd and Hg showed a slight increase in 2012. This is due to the rise in the consumption of coal by the electricity supply sector. Despite this recent increase, power station emissions are expected to fall further, primarily as a result of a continuing reduction in electricity generation using coal, with gas-fired stations, nuclear plant, and renewable fuels being used instead.

2.1.3 Residential and Commercial Sectors

Residential combustion was a key source for emissions of SO_x (as SO_2), NO_x (as NO_2), NMVOC, CO, TSP, PM_{10}, $PM_{2.5}$, and Cd, Pb and POPs (PCDD/PCDFs and PAH) emissions during 2012. However there has been a substantial reduction in the magnitude of all these emissions from this source between 1990 and 2013 (see Table 2-3).

Table 2-3 Residential: Sector share of UK emissions total in 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
SO_x (as SO_2)	1A4bi	11%	-60%
NO_x (as NO_2)	1A4bi	4%	-61%
NMVOC	1A4bi	3%	-61%
CO	1A4bi	15%	-68%
TSP	1A4bi	11%	-48%
PM_{10}	1A4bi	18%	-48%
$PM_{2.5}$	1A4bi	25%	-49%
Pb	1A4bi	8%	-73%
Cd	1A4bi	10%	-21%
PCDD/Fs	1A4bi	73%	-37%
PAH[11]	1A4bi	11%	-60%

Figure 2-4 and Figure 2-5 show the emissions of a range of pollutants emitted from the residential and commercial sectors between 1990 and 2013. 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 2-4 are presented in k tonnes and those in Figure 2-5 are presented in tonnes.

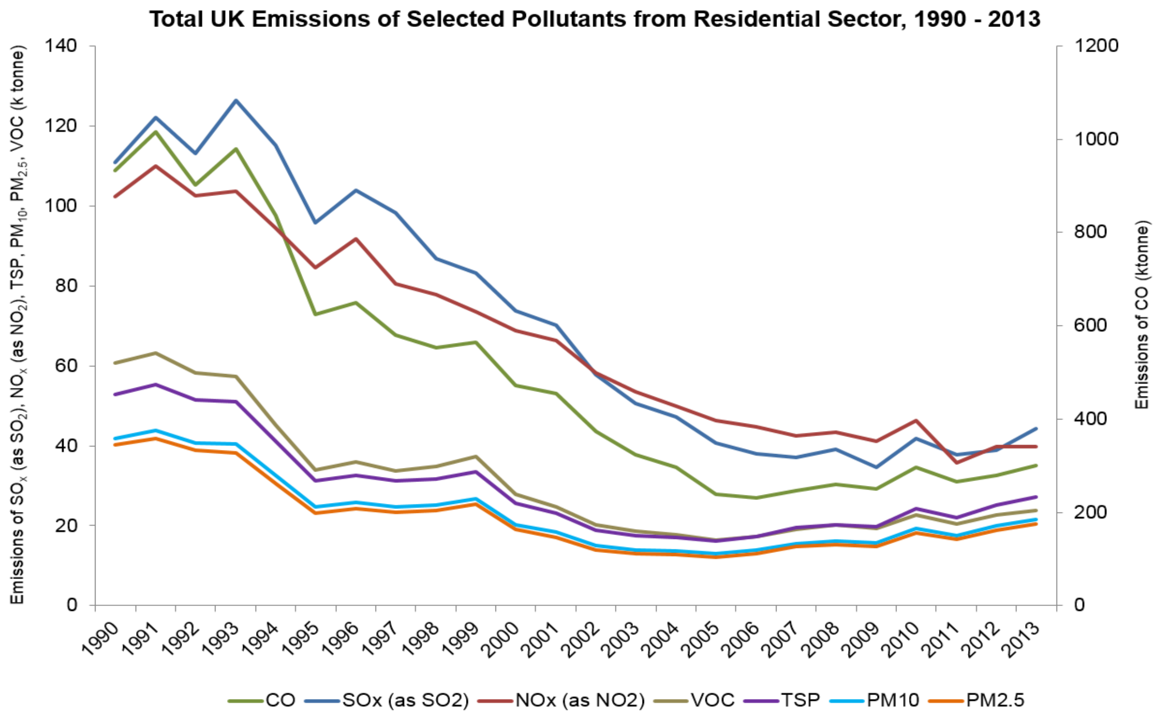


Figure 2-4 Total UK Emissions of CO, SO_x as SO_2, NO_x (as NO_2), NMVOC, PM_{10} and $PM_{2.5}$ from the Residential and Commercial Sectors

11 PAH under LRTAP include benzo(a)pyrene, benzo(b)fluoranthene , benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene only

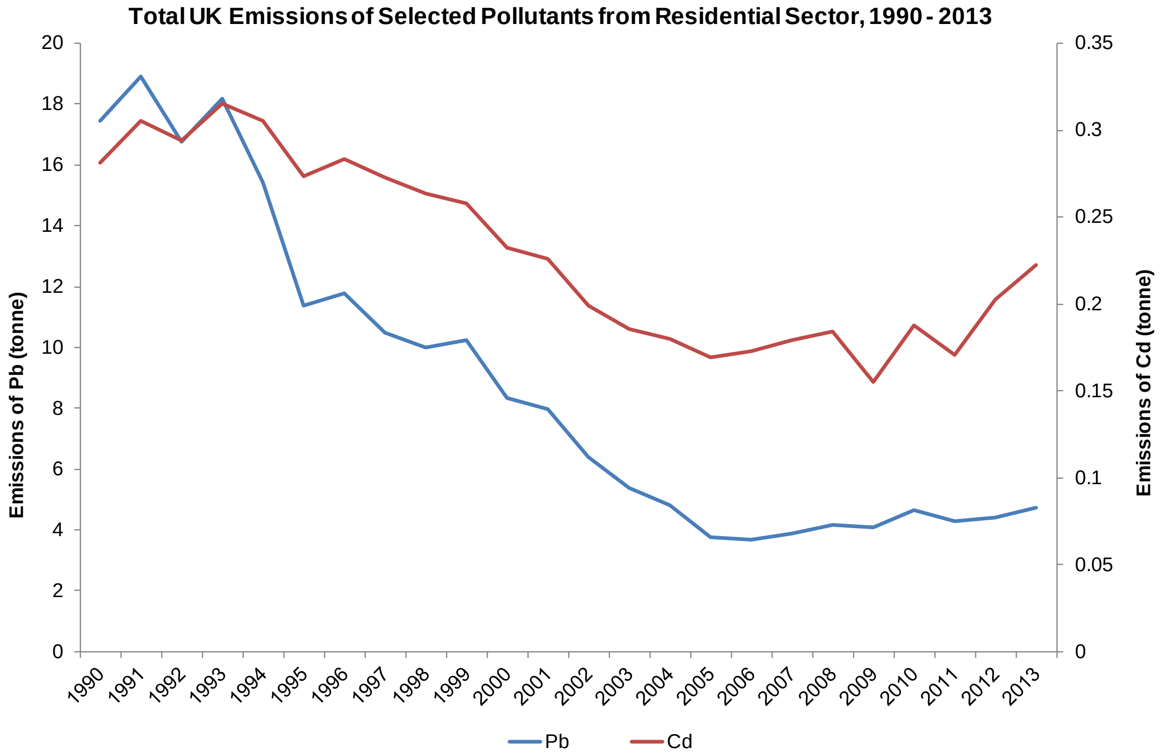


Figure 2-5 Total UK Emissions of Pb and Cd from the Residential and Commercial Sectors

There have been reductions in emissions of pollutants from this sector, mainly because of a decline in the use of solid fuels in favour of gas and electricity. Residential coal combustion has been the major source of particulate emissions in the UK. However, the use of coal for domestic combustion has been restricted in the UK by the Clean Air Act and this has helped substantially reduce emissions of PM_{10}. Between 1990 and 2013, PM_{10} emissions from domestic and commercial and institutional combustion (1A4ai and 1A4bi) have fallen by 74% and 48%, respectively. Fuel switching from coal to gas and electricity has also occurred in the commercial sector. This trend in the NO_x (as NO_2) emissions reflects this increased use of gas, and the decline in emissions of NO_x (as NO_2) over time is not as pronounced as the declines in the emissions of other pollutants.

2.1.4 Industrial Processes

The food and drink industry (2H2) is a key source category for NMVOC emissions; comprising 11% of the total NMVOC emission in 2013 (see Table 2-4). 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. The chemical industry (2B10a) is a key source category for mercury. Mercury emissions are predominantly from manufacture of chlorine using mercury cell technology. The production is decreasing over time, and emissions have fallen as well. Reductions will also have been due to increasing emission controls, but because only overall emissions data for these processes are available, it is not possible to determine the separate impacts of changes in production and reductions in emission rates.

Iron and steel production (2C1) and foundries (2C7c) are important sources of cadmium, mercury and lead. Emissions have mostly declined over time, 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. Abatement of emissions from electric arc and oxygen steel production has become more effective over the period covered by the inventory and so there is typically a decrease in emissions of metals from these processes between 1990 and 2013. In the case of mercury, however, the reported emissions suggest that emission rates have increased over time, possibly because the mercury content of scrap metal melted in electric arc furnaces may have increased over time.

Table 2-4 Industrial Processes: Sector share of UK emissions total in 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
TSP	2A5a Quarrying and mining of minerals other than coal	4%	-50%
PM_{10}	2A5a Quarrying and mining of minerals other than coal	5%	-50%
Hg	2B10a Chemical industry	7%	-95%
CO	2C1 Iron and steel production	5%	-22%
TSP	2C1 Iron and steel production	2%	-40%
PM_{10}	2C1 Iron and steel production	3%	-40%
$PM_{2.5}$	2C1 Iron and steel production	4%	-40%
Pb	2C1 Iron and steel production	44%	-54%
Hg	2C1 Iron and steel production	12%	32%
Cd	2C1 Iron and steel production	36%	-45%
PCDD/Fs	2C1 Iron and steel production	17%	-42%
Pb	2C7c Other metal production (foundries)	6%	-95%
Hg	2C7c Other metal production (foundries)	4%	-95%
Cd	2C7c Other metal production (foundries)	4%	-93%
NMVOC	2D3a Domestic solvent use including fungicides	18%	10%
NMVOC	2D3d Coating applications	13%	-66%
TSP	2D3d Coating applications	2%	-49%
PM_{10}	2D3d Coating applications	3%	-49%
$PM_{2.5}$	2D3d Coating applications	2%	-43%
NMVOC	2D3e Degreasing	3%	-73%
NMVOC	2D3i Other solvent use	6%	-30%
NMVOC	2H2 Food and beverages industry	11%	23%

Figure 2-6 and Figure 2-7 show the emissions of a range of pollutants emitted from the iron and steel industry between 1990 and 2013. 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.

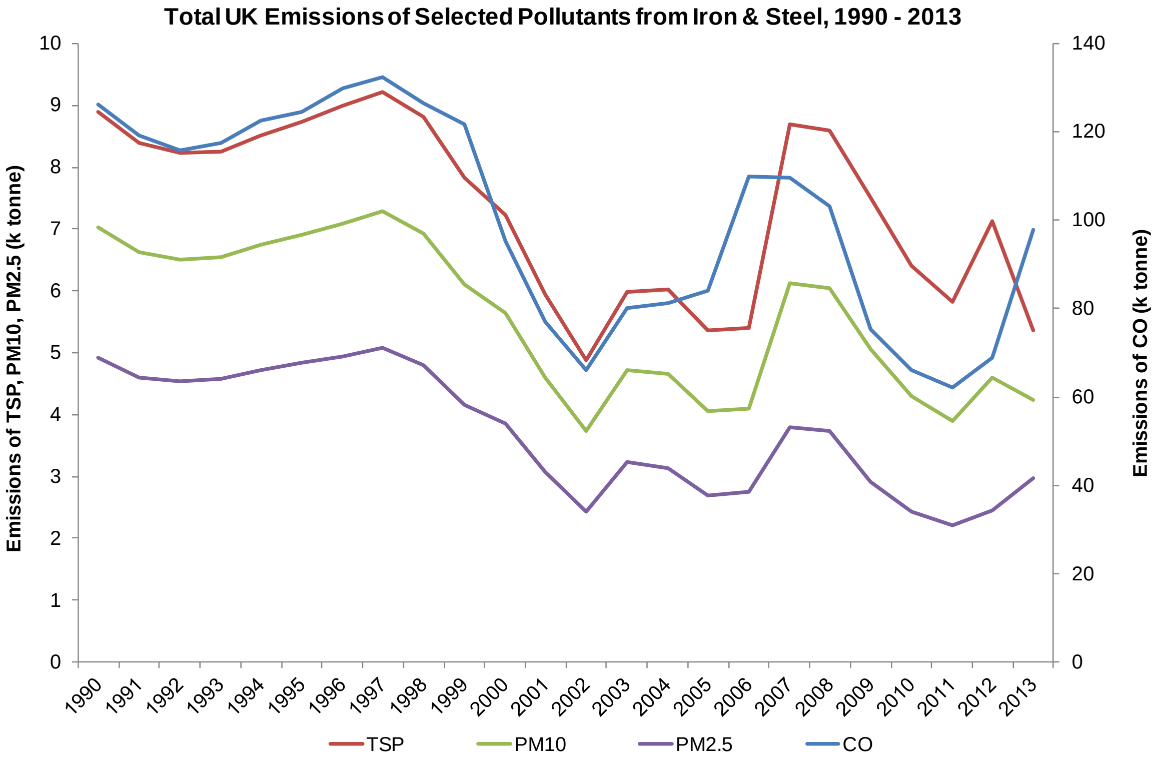


Figure 2-6 Total UK Emissions of CO, TSP, PM_{10} and $PM_{2.5}$ from Iron and Steel

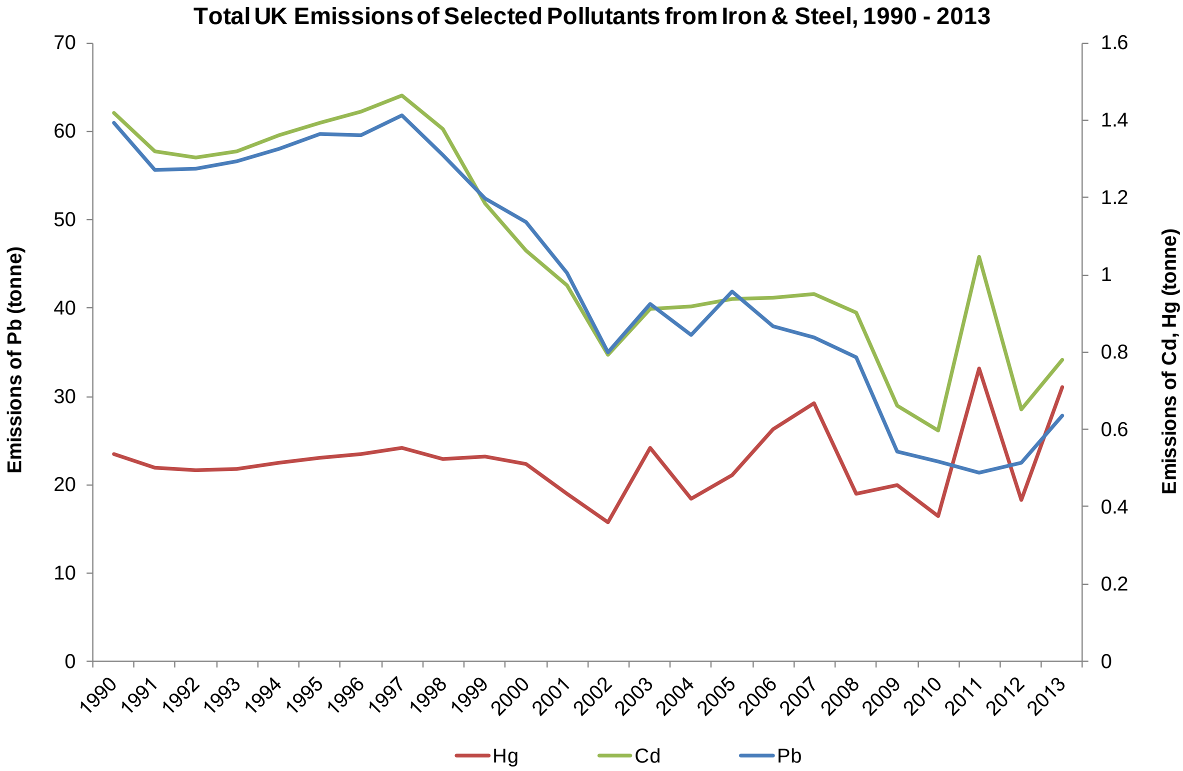


Figure 2-7 Total UK Emissions of Pb, Cd and Hg from Iron and Steel

Iron and steel production (2C1) is a key category for CO, TSP, PM_{10}, $PM_{2.5}$, Pb, Hg, Cd and PCDD/PCDFs. Trends in emissions from these sources are summarised in Table 2-4. Metal production emissions have typically declined since 1990 in line with declining production, although emissions of heavy metals from this category can be variable from year to year, and estimates are based on operator reporting to the pollution inventory.

2.1.5 Transport

The transport sector is composed of a number of categories, each of which has an NFR code and name (Table 2-5). This look up table can be used for the NFR codes in Table 2-6.

Table 2-5 NFR codes and NFR names used in the transport sector

NFR Code	NFR Name
1A3ai(i)	International aviation LTO (civil)
1A3aii(i)	Domestic aviation LTO (civil)
1A3bi	Road transport: Passenger cars
1A3bii	Road transport: Light duty vehicles
1A3biii	Road transport: Heavy duty vehicles and buses
1A3biv	Road transport: Mopeds & motorcycles
1A3bv	Road transport: Gasoline evaporation
1A3bvi	Road transport: Automobile tyre and brake wear
1A3bvii	Road transport: Automobile road abrasion
1A3c	Railways
1A3dii	National navigation (shipping)

Transport 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 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
NO_x (as NO_2)	1A3bi	16%	-81%
CO	1A3bi	24%	-91%
PM_{10}	1A3bi	3%	-33%
$PM_{2.5}$	1A3bi	5%	-33%
Cd	1A3bi	9%	-19%
NO_x (as NO_2)	1A3bii	6%	-39%
PM_{10}	1A3bii	2%	-55%
$PM_{2.5}$	1A3bii	3%	-55%
Cd	1A3bii	2%	45%
NO_x (as NO_2)	1A3biii	9%	-65%
$PM_{2.5}$	1A3biii	2%	-88%
Cd	1A3biii	4%	4%

Pollutant	**NFR Code**	**% of total emissions in 2013**	**% change from 1990 to 2013**
TSP	1A3bvi	4%	15%
PM_{10}	1A3bvi	7%	15%
$PM_{2.5}$	1A3bvi	6%	16%
TSP	1A3bvii	4%	16%
PM_{10}	1A3bvii	4%	16%
$PM_{2.5}$	1A3bvii	3%	16%
NO_x (as NO_2)	1A3c	4%	62%
NO_x (as NO_2)	1A3dii	3%	-20%
PM_{10}	1A3dii	2%	-46%
$PM_{2.5}$	1A3dii	2%	-46%

Figure 2-8 shows the emissions of a range of pollutants emitted from the road transport sector (1A3b) between 1990 and 2013. Note that this chart uses two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions.

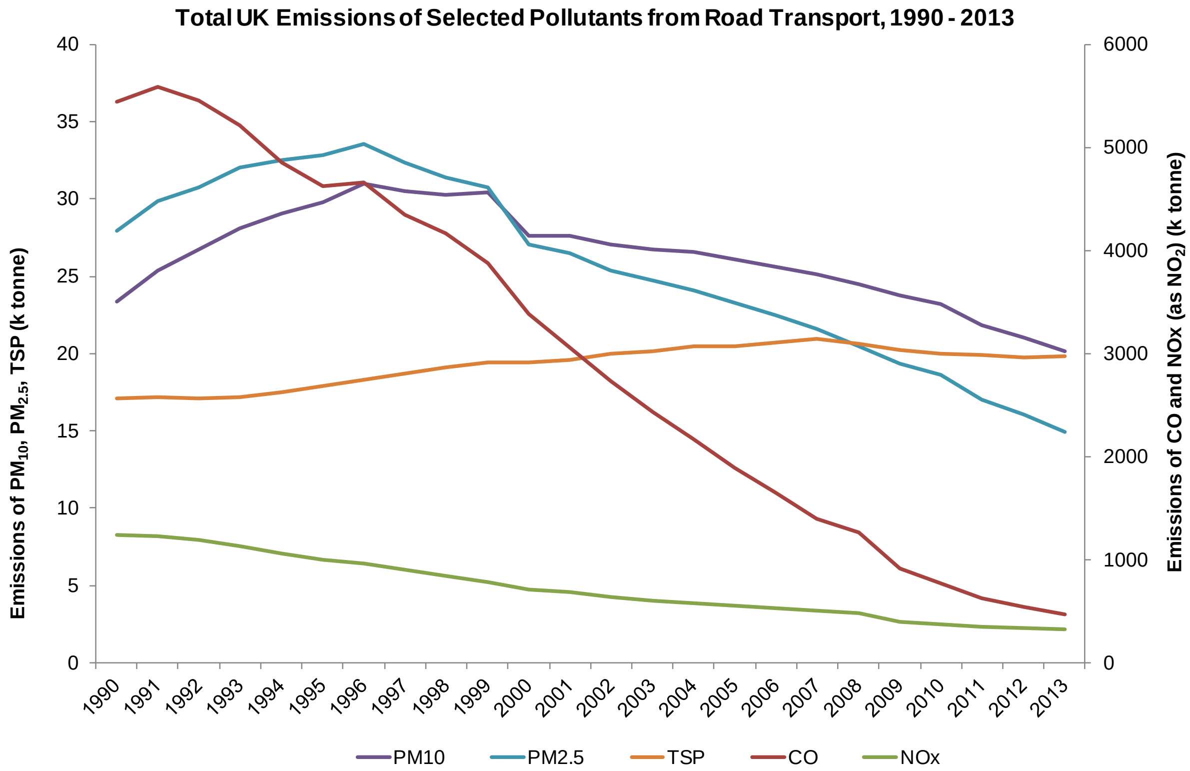


Figure 2-8 Total UK Emissions of CO, NO_x (as NO_2), PM_{10} and $PM_{2.5}$ Road Transport

Road traffic has grown over the time-series but there has been a decline in emissions for a number of reasons. Since 1989, 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; however, recent evidence has shown that diesel Euro 5 cars exceed their type approval limit for NO_x (as NO_2) in real-world operation by significant amounts and this has been reflected in the emissions factors provided in the 2013 EMEP/EEA Emission Inventory Guidebook (which has been incorporated into the UK 2013 inventory). 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. 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) and 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.

Further detailed information on Transport is covered in Chapter 3.3.

2.1.6 Agriculture

The agriculture sector is composed of a number of categories, each of which has an NFR code and name; see Table 2-7. This look up table can be used for the NFR codes in Table 2-8.

Table 2-7 NFR codes and NFR names used in the agriculture sector

NFR Code	NFR Name
3B1a	Manure management - Dairy cattle
3B1b	Manure management - Non-dairy cattle
3B2	Manure management - Sheep
3B3	Manure management - Swine
3B4a	Manure management - Buffalo
3B4d	Manure management - Goats
3B4e	Manure management - Horses
3B4f	Manure management - Mules and asses
3B4gi	Manure management - Laying hens
3B4gii	Manure management - Broilers
3B4giii	Manure management - Turkeys
3B4giv	Manure management - Other poultry
3B4h	Manure management - Other animals (please specify in IIR)
3Da1	Inorganic N-fertilizers (includes also urea application)
3Da2a	Animal manure applied to soils
3Da2b	Sewage sludge applied to soils
3Da2c	"Other organic fertilisers applied to soils (including compost)"
3Da3	Urine and dung deposited by grazing animals
3Da4	Crop residues applied to soils
3Db	Indirect emissions from managed soils
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products

NFR Code	NFR Name
3Dd	Off-farm storage, handling and transport of bulk agricultural products
3De	Cultivated crops
3Df	Use of pesticides
3F	Field burning of agricultural residues

Table 2-8 Agriculture: Sector share of UK emissions total in 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
NH_3	3B1a	15%	-21%
VOC	3B1a	4%	-12%
TSP	3B1a	3%	-27%
NH_3	3B1b	12%	-11%
NMVOC	3B1b	6%	-8%
TSP	3B1b	2%	-12%
NH_3	3B3	5%	-56%
TSP	3B3	4%	-40%
TSP	3B4gi	11%	-7%
PM_{10}	3B4gi	4%	-7%
TSP	3B4gii	19%	41%
PM_{10}	3B4gii	6%	41%
TSP	3B4giii	6%	100%[a]
PM_{10}	3B4giii	2%	100%[a]
TSP	3B4giv	3%	183%
NH_3	3Da1	13%	-46%
NH_3	3Da2a	20%	-26%
NH_3	3Da3	9%	-14%
PM_{10}	3Dc	4%	-14%
HCB	3Df	48%	-92%

[a] pre-2001 emissions from Turkeys were reported together with poultry (3B4giv) emissions.

Figure 2-9 shows the emissions of NH_3 emitted from the key source categories in the agriculture sector between 1990 and 2013.

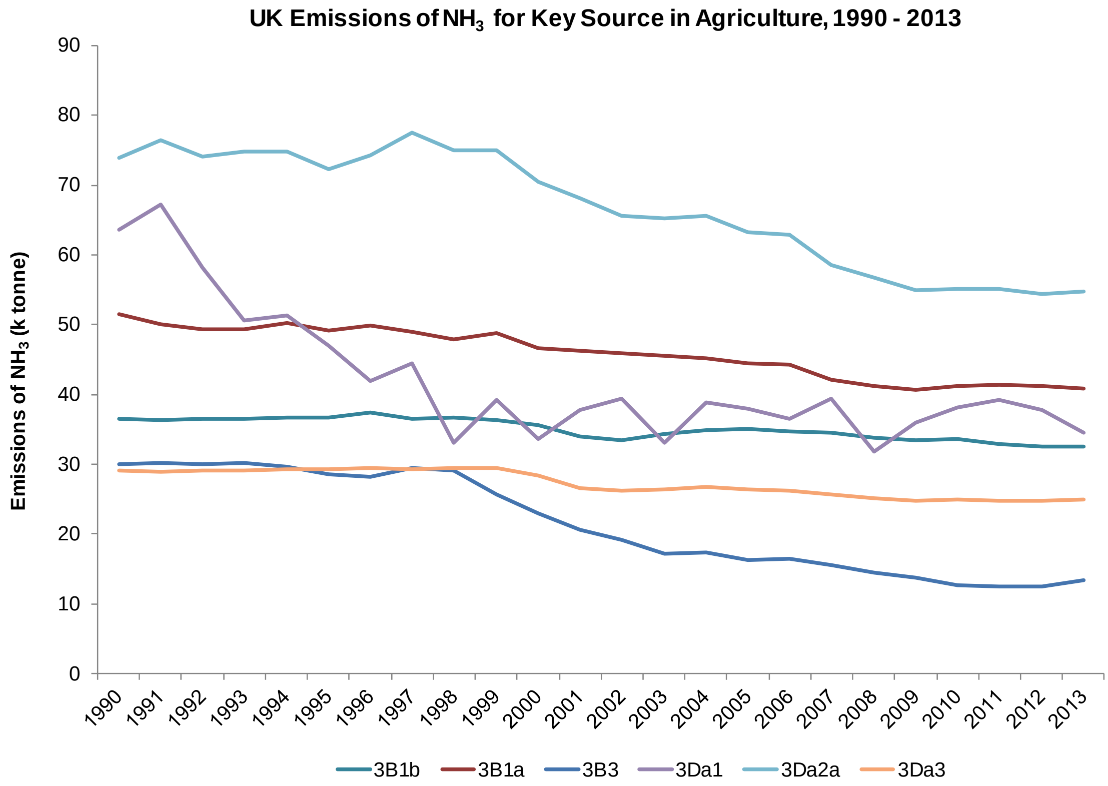


Figure 2-9 UK Emissions of NH_3 from Key Sources in Agriculture

Agricultural sources with emissions from livestock and their wastes (NFR 3B) are the major source of NH_3 emissions, contributing 40% of total emissions in 2013. 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. This has been driven by decreasing animal numbers. In addition, there has been a decline in fertiliser use (NFR 3Da1), which also caused a decrease in emissions (although the decline in emissions has levelled out to some extent in recent years due to increased usage of urea-based fertilisers which are associated with much higher ammonia emission factors). Total NH_3 emissions from agriculture in 2013 represent a decrease of 28% on the 1990 emissions.

Emissions from dairy (3B1a) and non-dairy cattle (3B1b) are key sources for NMVOC and TSP. Estimates of PM_{10}, $PM_{2.5}$ and TSP emissions from agricultural livestock have been calculated for the first time in the current inventory using default emission factors, published in the 2013 update of the EMEP/EEA Emission Inventory Guidebook. PM and TSP emissions from Boilers (3B4gii) have increased in line with an increase in livestock numbers between 1990 and 2013 (Misselbrook et al., 2014).

2.1.7 Waste

Emissions from the waste sector have a negligible effect on overall UK emissions. Emissions of $PM_{2.5}$ and PM_{10} from open burning of waste (5C2) contribute approximately 2% of total emissions, see Table 2-9.

Table 2-9 Waste: Sector share of UK emissions total in 2013 and Trends from 1990 to 2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
Hg	5A Biological treatment of waste - Solid waste disposal on land	6%	-42%

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
Hg	5C1bv Cremation	9%	9%
PM_{10}	5C2 Open burning of waste	2%	10%
$PM_{2.5}$	5C2 Open burning of waste	2%	10%
PCDD/Fs	5C2 Open burning of waste	12%	-49%

2.2 Summary of Trends

A summary table of all the key sources and their contributions to overall pollutant emissions is provided in Table 2-10 below.

Table 2-10 Key Sources: 2013 Significance and Trends, 1990-2013

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
Cd	1A3bii	2%	45%
	1A3biii	4%	4%
	2C7c	4%	-93%
	1A1a	6%	-97%
	1A3bi	9%	-19%
	1A4bi	10%	-21%
	1A2gviii	11%	-62%
	2C1	36%	-45%
CO	1A4bii	4%	-3%
	1A1a	4%	-30%
	2C1	5%	-22%
	1A2gvii	10%	-6%
	1A2a	10%	-46%
	1A2gviii	11%	198%
	1A4bi	15%	-68%
	1A3bi	24%	-91%
PCDD/PCDFs	1A4ci	8%	182%
	1A2gviii	10%	15%
	5C2	12%	-49%
	6A	12%	-61%
	2C1	17%	-42%
	1A4bi	21%	-68%
HCB	3Df	48%	-92%

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
	1A1a	51%	733%
Hg	2C7c	4%	-95%
	1A2f	4%	6%
	5A	6%	-42%
	2B10a	7%	-95%
	5C1bv	9%	9%
	2C1	12%	32%
	1A2gviii	14%	7%
	1A1a	26%	-83%
NH_3	3B3	5%	-56%
	6A[a]	8%	47%
	3Da3	9%	-14%
	3B1b	12%	-11%
	3Da1	13%	-46%
	3B1a	15%	-21%
	3Da2a	20%	-26%
NO_x (as NO_2)	1A2gvii	3%	-71%
	1A3dii	3%	-20%
	1A3c	4%	62%
	1A4bi	4%	-61%
	1A2gviii	5%	-32%
	1A1c	5%	18%
	1A3bii	6%	-39%
	1A3biii	9%	-65%
	1A3bi	16%	-81%
	1A1a	27%	-65%
PAH	1B1b	3%	-22%
	6A	6%	-46%
	1A4bi	73%	-37%
Pb	1B1b	4%	-52%
	2C7c	6%	-95%
	1A1a	6%	-98%
	1A4bi	8%	-73%
	1A2gviii	15%	-38%
	2C1	44%	-54%

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
PM_{10}	5C2	2%	10%
	1A3dii	2%	-46%
	3B4giii	2%	100%
	6A	2%	-38%
	1A3bii	2%	-55%
	1A2gvii	2%	-74%
	1A3bi	3%	-33%
	2D3d	3%	-49%
	2C1	3%	-40%
	1A2gviii	4%	3%
	3B4gi	4%	-7%
	3Dc	4%	-14%
	1A3bvii	4%	16%
	2A5a	5%	-50%
	1A4ci	5%	168%
	1A1a	6%	-90%
	3B4gii	6%	41%
	1A3bvi	7%	15%
	1A4bi	18%	-48%
$PM_{2.5}$	1A3biii	2%	-88%
	1A4cii	2%	-82%
	5C2	2%	10%
	2D3d	2%	-43%
	1A3dii	2%	-46%
	6A	3%	-39%
	1A3bii	3%	-55%
	1A3bvii	3%	16%
	1A2gvii	3%	-74%
	2C1	4%	-40%
	1A3bi	5%	-33%
	1A1a	5%	-87%
	1A2gviii	5%	2%
	1A3bvi	6%	16%
	1A4ci	7%	168%
	1A4bi	25%	-49%

Pollutant	NFR Code	% of total emissions in 2013	% change from 1990 to 2013
SO_x (as SO_2)	1A1b	11%	-69%
	1A4bi	11%	-60%
	1A2gviii	18%	-42%
	1A1a	40%	-94%
TSP	2D3d	2%	-49%
	3B1b	2%	-12%
	2C1	2%	-40%
	1A2gviii	2%	2%
	3B4giv	3%	183%
	3B1a	3%	-27%
	1A4ci	3%	168%
	1A1a	3%	-91%
	1A3bvii	4%	16%
	3B3	4%	-40%
	1A3bvi	4%	15%
	2A5a	4%	-50%
	3B4giii	6%	100%
	1A4bi	11%	-48%
	3B4gi	11%	-7%
	3B4gii	19%	41%
NMVOC	2D3e	3%	-73%
	1B2aiv	3%	-79%
	1B2av	3%	-81%
	1A4bi	3%	-61%
	3B1a	4%	-12%
	1B2b	4%	-31%
	1B2ai	4%	-88%
	1B2c	4%	-23%
	3B1b	6%	-8%
	2D3i	6%	-30%
	2H2	11%	23%
	2D3d	13%	-66%
	2D3a	18%	10%

[a] NH_3 emission under NFR 6A include emission from horses not used in the agriculture sector (profession horses and horse kept as pets).

3. NFR 1A: Energy (NFR 1)

3.1 NFR 1A1: Combustion in the Energy Industries

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

NFR 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)[12]
1 A 1 b Petroleum refining	All CLRTAP pollutants *(except NH_3, HCB and PCBs)*	Refineries
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)[13]
		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 NFR Category 1A1

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

[12] 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.
[13] 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 NFR category, rather than any emissions allocated to 1A3e Pipeline Compressors.

NAEI Source Category	Method	Activity Data	Emission Factors
			Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research, UKPIA)
Coke production	UK model	DECC energy statistics, EU ETS, ISSB	Major fuels: Operator-reported emissions data under IPPC/EPR, Tata Steel, SSI Steel Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research)
Collieries – fuel combustion	AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, UK-specific research)
Gas production (downstream gas)	AD x EF	DECC energy statistics, EU ETS	Default factors (USEPA, EMEP-EEA, UK-specific research)
Gas separation plant	AD x EF	DECC energy statistics, EEMS, EU ETS	EEMS and IPPC/EPR annual reporting by operators, UKOOA research, USEPA factors for PM_{10}
Upstream gas production	AD x EF	DECC energy statistics, EEMS, EU ETS	EEMS and IPPC/EPR annual reporting by operators, UKOOA / other UK-specific research, USEPA PM_{10} factor
Nuclear fuel production	AD x EF	DECC energy statistics	Default factors (USEPA, UK-specific research)
Upstream oil production	AD x EF	DECC energy statistics, EEMS, EU ETS	EEMS and IPPC/EPR annual reporting by operators, UKOOA / other UK-specific research, USEPA PM_{10} factor
Solid smokeless fuel production	AD x EF	DECC energy statistics, EU ETS	Default factors (USEPA, UK-specific research e.g. HMIP)
Town gas manufacture	AD x EF	DECC 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 (DECC, 2014), 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 NFR source categories. In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR source category; however there are some instances where the scope of NAEI and NFR 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 NFR 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	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
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 NFR 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 NFR sector.

3.1.2 General approach for 1A1

The methodology for NFR 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 and Wales, the Scottish Pollutant Release Inventory (SPRI), Northern Ireland's Pollution Inventory (NIPI), and the Environmental Emissions Monitoring System (EEMS)[14] for upstream oil and gas installations situated offshore.

The PI data are available from www.environment-agency.gov.uk,
SPRI data can be viewed at
http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx,
while 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

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

Department of Energy and Climate Change Offshore Inspectorate, which is the regulatory authority for upstream oil and gas installations.

The emissions reported in the PI, 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 (e.g. emissions data for an integrated steelworks would be given as a single figure, rather than separate data for coke ovens, sinter plant, boilers, furnaces etc., and would not separate out emissions from the various fuels used on site). 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 NFR 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-AEA 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. 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, the differences are assumed to be due to a sector mis-allocation in the energy balance. Hence where we deviate from the DUKES data for one sector, we make an equal and opposite amendment to the energy allocation of another source (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/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 PI/SPRI/NIPI/EEMS 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[15]. 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;

[15] 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.

- 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 as 'fuel oil', but 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 we make 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 and 2013 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 possible to reconcile the NAEI estimates of total UK demand for petroleum coke as a fuel, with the data given in DUKES, because the NAEI values for all sectors are based on more detailed data sources than DUKES.

- 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 DECC 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 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 in 2010-2013.

- 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 Other Petroleum Gas consumption 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 to 2013,

- In the latest UK energy commodity balance tables presented in DUKES 2014, the DECC energy statistics team has revised the energy / non-energy allocation for several petroleum-based fuels: propane, butane, naphtha, gas oil, petroleum coke. These revisions are based on re-analysis of the available data reported by fuel suppliers and HMRC, but the revisions to DUKES are 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-AEA 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. This has led to a number of revisions to emission estimates, including for the refinery sector.

3.1.4 Methodology for power stations (NFR 1A1a)

NFR 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 50 Mt of coal were burnt at 15 power stations during 2013, while approximately 5,900 Mtherms of natural gas were consumed at 42 large power stations and 11 small (<50MWth) regional stations (almost all gas plant are Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at two large facilities, and gas oil or burning oil was used by four large and nine small power stations; in most cases of gas 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, another site burns straw, another two burn wood, whilst 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 is also generated at 27 Energy from Waste (EfW) plants in the UK, with heat only being generated at another plant. Formerly referred to as municipal solid waste (MSW) incinerators, all such plant are now required to be fitted with boilers to raise power and heat, and their emissions are now reported under NFR source category 1A1. 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 NFR 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. In 2013, there were over 500 sites utilising landfill gas or sewage gas to generate electricity.

Nearly all UK power stations burning fossil fuels are required to report emissions in either the Pollution Inventory (PI), the Scottish Pollutant Release Inventory (SPRI), or 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 NOx as NO_2, reported emissions make up 96% of the total UK estimate, while the remaining 4% 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 PI, SPRI, and NIPI 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/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 PI, SPRI and NIPI. 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 and SPRI; 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 SOx 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 SOx as SO_2, factors for 1970-1987 are based on information provided by coal suppliers. The emission factors for NO_x (as NO_2) & SOx 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 SOx 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 NOx as NO_2 and SOx as SO_2 from landfill gas engines and NOx 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 PI, SPRI & NIPI 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 NOx 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 SOx 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)	1990-2013: O 1989: O/M 1970-1988: L
	SOx as SO_2	1990-2013: O 1988-1989: O/M 1970-1987: F
	HCl (coal only)	1993-2013: O 1992: O/M 1970-1991: E
	Pb	1997-2013: O 1990-1996: O/M 1970-1989: E
	CO, NMVOC, other metals, PM_{10}, HF	1997-2013: O 1993-1996: O/M 1970-1992: E
Sour gas	NO_x (as NO_2), SOx as SO_2	1992:2013: O 1970-1991: not occurring
	CO	1997:2013: O 1992-1996: L 1970-1991: not occurring
	VOC, PM10	1997:2013: O 1992-1996: O/M 1970-1991: not occurring
Coal slurry	NO_x (as NO_2), SOx as SO_2	1994:2013: O 1970-1993: not estimated separately, included with estimates for coal
	CO, NMVOC, HCl, metals, PM_{10}	1994:2013: O 1994-1996: O/M 1970-1993: not estimated separately, included with estimates for coal
Natural gas	NO_x (as NO_2)	1997-2013: O 1992-1996: O/M 1970-1991: E
	SOx as SO_2	1997-2013: O 1993-1996: O/M 1970-1992: not estimated
	CO	1997-2013: O 1993-1996: O/M

Fuels	Pollutant	Methodology
		1970-1992: E
	NMVOC, Hg, PM_{10}	1997-2013: O 1996: O/M 1970-1995: E
Gas oil	NO_x (as NO_2)	1997-2013: O 1994-1996: O/M 1970-1993: L
	SOx as SO_2	1997-2013: O 1994-1996: O/M 1970-1993: F
	CO	1997-2013: O 1996: O/M 1970-1995: L
	NMVOC, metals, PM_{10}	1997-2013: O 1970-1996: L
Poultry litter	All	1997-2013: O 1992-1996: O/M 1970-1991: not occurring
Straw	All	2000-2013: O 1970-1999: not occurring
Landfill/sewage gas	All	1970-2013: L

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

3.1.5 Methodology for refineries (NFR 1A1b)

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

The UK has 10 oil refineries, although three of these are small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 7 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 Pollution Inventory or the Scottish Pollutant Release Inventory. Additional data for CO, NO_x (as NO_2), SOx as SO_2, and PM_{10} are supplied annually by process operators via the United Kingdom Petroleum Industry Association (UKPIA, 2014). These data split the emissions[16] 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 VOCs 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 Pollution Inventory for the years 1998-2013. Data for Scotland's refineries are reported in the SPRI for the years 2002 and 2004-2013. Emissions data for NO_x (as NO_2) and SOx 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 SOx as SO_2, and back to 1998

[16] 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.

for other pollutants, while emission factors for earlier years are generated by extrapolation from 1990 data for NO_x (as NO_2) and SOx as SO_2, and 1998 data for other pollutants.

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, 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 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; therefore the source allocation of emissions is based on historic data and is somewhat more uncertain than for other refineries, but total emissions for Coryton in the UK inventory are aligned with Pollution Inventory 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 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), SOx 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 (DECC, 2014); 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 DECC data, with amendments to the DUKES statistics back to 2004 inclusive. (See also Section 3.1.3 above for further information.)

The DUKES/Ricardo-AEA revisions to assumed non-energy use of fuels affect the emission estimates for 1A1b. A small amount of naphtha is reported in DUKES allocated to energy by 'unclassified industry'; in the UK inventory estimates from this fuel use are reported in the refinery sector as there is no evidence of other sectors using naphtha as a fuel.

3.1.6 Methodology for other energy industries (NFR 1A1c)

NFR 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 one independent coke manufacturer also exists. At the end of 2013, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last ten years, due to closure of associated steelworks or closure of other coke consumers. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes regulated under IPPC/EPR 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, 1970-2013

Process type	Period	No of plant
Coke ovens	2004-2013	6
	2003	7
	1993-2002	9
	1991-1992	10
	1970-1990	No data
Solid smokeless fuel manufacture	2006-2013	2
	2000-2005	3
	1997-1999	4
	1996	5
	1991-1995	6
	1970-1990	No data

All of these sites are required to report emissions in the Pollution Inventory. 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 SOx 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 NFR 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, 2013) or earlier versions of the (EMEP-CORINAIR) guidebook, and several UK research reference sources from the early 1990s. These emissions are reported under NFR 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 (1A2f, 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 2013 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 NFR 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 DECC Offshore Inspectorate, whilst onshore facilities are regulated under IPPC/EPR by the Environment Agency 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 IPPC/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), SOx 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 IPPC/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} are derived using a default factor from USEPA AP-42.

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 2013 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 DECC 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, SEPA and NIEA) and reported via their respective inventories of pollutant releases (i.e. the PI, SPRI and NIPI) the data is subject to audit and review within established regulator QA systems. Within England & Wales, 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 by 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, SPRI & NIPI contain well in excess of 100,000 individual emissions datasets 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, 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 NFR 1A1

The most significant recalculations since the 2014 submission in NFR 1A1 are:

- Relatively small revisions to emission estimates for coal-fired power stations to take account of updated emissions data in the Pollution Inventory etc. Estimates of UK NO_x (as NO_2) emissions, for example, increase by 0.7% due to the changes in this sector.
- The addition of naphtha used for energy, reported in 1A1b, increases the estimate of UK NO_x (as NO_2) emissions in 2012 by 0.6%.

3.2 NFR 1A2: Manufacturing Industries and Construction

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

NFR 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)
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	Autogenerators
		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	Other industrial combustion

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

NAEI Source Category	Method	Activity Data	Emission Factors
Blast furnaces	UK model for integrated works	DECC energy statistics, EU ETS, ISSB	Operator-reported emissions data under IPPC/EPR, plant-specific data from Tata Steel. Default factors (EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Iron and steel - combustion plant	UK model for integrated works; AD x EF	DECC energy statistics, EU ETS, ISSB	Operator-reported emissions data under IPPC/EPR, plant-specific data from Tata Steel. Default factors (EMEP-EEA, USEPA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Non-ferrous metal (combustion)	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Ammonia production - combustion	AD x EF	DECC 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	DECC energy statistics, EU ETS	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx 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	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Food & drink, tobacco (combustion)	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Autogenerators	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Operator-reported emissions data under IPPC/EPR. Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Cement - non-decarbonising	AD x EF	Mineral Products Association clinker production data, EU ETS	IPPC/EPR 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	IPPC/EPR annual reporting by operators, default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Industrial engines	AD x EF	DECC energy statistics	Default factor for SO_2: Passant (2004)
Lime production - non decarbonising	AD x EF	EU ETS data, with extrapolation across time-series using IPPC/EPR emissions data and production estimates from British Geological Survey.	IPPC/EPR 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	DECC 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 SOx as SO_2.
Industrial off-road mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	Default factors (USEPA, UK-specific research)

3.2.1 Classification of activities and sources

As with NFR 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 3-2, whilst Table 4-1 relates the detailed NAEI source categories to the equivalent NFR 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 NFR 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 NFR source category. However, there are a few instances where the scope of NAEI and NFR 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 NFR 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.

Almost all of the NFR 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 NFR sector.

3.2.2 General approach for 1A2

NFR Sector 1A2a is a key source for CO,1A2f is a key source for Hg, 1A2gvii is a key source for NO_x (as NO_2), CO, $PM_{2.5}$ and PM_{10}, 1A2gviii is a key source for SO_x (as SO_x), NO_x (as NO_x),, CO, TSP, $PM_{2.5}$ and PM_{10}, Cd, Pb, Hg and PCDD/PCDFs.

Emissions are estimated separately for ammonia 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 based on reported data in the case of NO_x (as NO_2) but literature emission factors for other pollutants. Emissions of CO and NO_x (as NO_2) from OPG use in 1A2c, and emissions of most pollutants from coal-fired autogeneration in 1A2b are also 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, 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 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, 2014), 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. The fuels burnt at cement kilns include petroleum coke, which is not included in the energy consumption data in DUKES.
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 generate 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 2013), 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 elsewhere in industry. Therefore, we include our own estimates for petroleum coke use as fuel in NFR 1A2. In the case of petroleum coke, it is not possible to reconcile the NAEI estimates of total UK demand for petroleum coke as a fuel, with the data given in DUKES, because the NAEI values for all sectors are based on more detailed data sources than DUKES.
5) In the latest UK energy commodity balance tables presented in DUKES 2014, the DECC energy statistics team has revised the energy / non-energy allocation for several petroleum-based fuels: propane, butane, naphtha, gas oil, petroleum coke. These revisions are based on re-analysis of the available data reported by fuel suppliers and HMRC, but the revisions to DUKES are 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-AEA 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. This has led to a number of revisions to emission estimates, including for industrial combustion.
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 NFR sector 1A2f only covers the consumption in cement kilns and lime kilns, for which Ricardo-AEA make estimates based on data from the MPA and EUETS, 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 1990-2013, 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 NFR 1A1c for gas compressors is estimated based on data reported by operators under EU ETS. The data from EUETS 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 and the fuel consumption total 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 13 sites producing cement clinker during 2013. 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 15 UK sites during 2013. Two of these produce lime for use on-site in the Solvay process and four produce lime for use on-site in sugar manufacturing. Lime kilns are fired with natural gas, coke, anthracite or coal as the main fuel.

All cement and lime kilns are required to report emissions in the PI, 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 does 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. PM_{10} is also emitted from process sources as well as 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 2000-2013 are supplied by the process operators (Tata Steel, 2014; SSI, 2014). 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 NFR category 2C1.

For the period 1998-1999, emissions data are available from the Pollution Inventory (EA, 2014); 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 other industrial combustion of coal, coke and oil

Individual combustion plants range in scale from those scarcely larger than domestic central heating boilers, up to a relatively small number of 'large combustion plants' with thermal inputs exceeding 50 MW_{th}. Because of the large numbers of smaller plant that are not regulated under IPPC/EPR (and which do not therefore report emissions in the PI, SPRI or NIPI), it is not possible to derive bottom-up estimates. Emissions are therefore estimated using an appropriate literature-based emission factor applied to national fuel consumption statistics taken from DUKES:

$$E(p,s,f) = A(s,f) \times EF(p,s,f)$$

Where:

E (p,s,f)	=	Emission of pollutant *p* from source s from fuel *f* (kilotonne [kt])
A (s,f)	=	Consumption of fuel *f* by source *s* (Megatonne [Mt] or Megatherm [Mth])
EF (p,s,f)	=	Emission factor of pollutant *p* from source s from fuel *f* (kt/Mt or kt/Mth)

Emissions data are reported in the PI, SPRI, and NIPI for the 'large combustion plant' and the methodology allows for these reported data to be used in the case of NO_x (as NO_2) only. Data are also available for SO_2 but it is considered that the use of emission factors based on fuel composition data are more appropriate than use of plant-specific emissions data for SOx as SO_2. Reported data for other pollutants are much more limited and are not used directly in the inventory estimates. The limited nature of the reported data will be a reflection of the minimum reporting thresholds, which mean that most large combustion plant will not need to report emissions of, for example, metals or hydrogen chloride.

In most cases where literature emission factors are used, a single factor is applied for a given source category and pollutant. However, in the case of CO, NO_x (as NO_2) and PM_{10} emissions, a more detailed approach is taken in order to derive estimates that are more representative of the wide range of combustion appliances in existence (e.g. different designs, thermal capacities, varying levels of abatement). The more detailed approach breaks down the source/fuel combinations by a) thermal input of combustion devices; b) type of combustion process (e.g. boilers, furnaces, turbines etc.), and appliance-specific emission factors are then applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (US EPA, 2009), the EMEP/EEA Guidebook (EEA, 2013) and UK emission factor surveys (Walker et al, 1985). An updated edition of the EMEP/EEA Guidebook was issued in 2013, and all NAEI emission factors from the previous edition of the Guidebook have been replaced with factors taken from this latest edition. In many cases, the recommended factor has changed between the previous and current Guidebooks, and hence NAEI estimates have been revised. Guidebook factors are typically used only for minor sources (with UK-specific data more likely to be used for major sources), so the Guidebook changes do not impact significantly on UK emission totals.

Emissions data for NO_x (as NO_2) reported in the Pollution Inventory (EA, 2014) are also used in the generation of emission factors for larger combustion plants in the autogeneration, iron and steel combustion plant, and other industrial combustion source categories.

In the case of coal-fired autogeneration, one plant is responsible for practically all of the fuel used nationally, and so emissions from this sector 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 Methodology for industrial natural gas combustion

Emissions of NO_x (as NO_2) from industrial natural gas combustion are calculated using a somewhat different approach to that used for coal and oils. The main difference is that, rather than dividing fuel use into consumption by different technologies, it is split according to environmental regulation. For example, natural gas burnt by plant covered by the Large Combustion Plant Directive (LCPD) is separated from natural gas burnt by plant regulated under Local Air Pollution Control (LAPC) etc. Emissions are then estimated by reference to the emission standards that are imposed on those plants as a result of their regulation. The inventory method takes a conservative approach, by assuming that all plant achieve these standards but do not go beyond them, i.e. plants which have emission limit values achieve the maximum allowable concentration in stack gases rather than reducing this concentration below it. The method has been used to generate aggregate emission factors for 2010 to 2012, with the emission factor calculated for 2010 used for all earlier years in the NAEI, and the 2012 value applied to 2013 also.

Emissions of other pollutants are based on emission factors derived in the same way as for coal, coke and oil, and some revisions to factors have occurred due to the update of the EMEP/EEA Guidebook. As with solid and liquid fuels, these revisions tend to be limited to minor sources only.

3.2.8 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.

1A2
Allocations of fuel use are primarily derived from DECC 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 DECC (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.

3.2.9 Recalculations in NFR 1A2

The most significant recalculations since the 2014 submission in NFR 1A2 are:

- Revision of the quantity of petroleum coke used for non-energy, and therefore the quantity used for energy leads to increases in emissions from 1A2g. The most significant of these is SOx as SO_2, where the change leads to a 2.7% increase in UK emissions in 2012.

3.3 NFR 1A3: Transport

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

NFR 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 HCB and PCBs)*	Petrol cars with and without catalytic converter (cold start, urban, rural and motorway driving)	UK factors or factors from COPERT 4 v10 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 NH_3, PAHs, HCB and PCBs)*	Rail - coal	UK factors
		Railways - freight	
		Railways - intercity	
		Railways - regional	

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

Almost all of the NFR 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 NFR 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, whilst 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-AEA 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 BAA plc and representative of the fleets at those 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” (PSHD). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002. 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 APU emission indices and running times.

The UK method includes emission estimates for flights between the UK and overseas territories as part of the domestic aviation[17]. In addition, all flights originating from the overseas territories, irrespective of destination, are included in the inventory as have return flights from oil rigs.

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

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 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 LRTAP Convention. Note

[17] Gibraltar is the only Overseas territory covered under LRTAP. There are no Crown dependencies covered under LRTAP.

the reporting requirements to the LRTAP Convention 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 is 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 (DECC 2013). 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 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 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	786.7	360.9	1471.1	134.4

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. The emissions of CO_2, SOx as SO_2 and metals depend on the carbon, sulphur and metal contents of the aviation fuels (UKPIA, 2014). Emissions factors for CO_2, SOx as SO_2 and metals are derived from the contents of carbon, sulphur and metals in aviation fuels. 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 Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2013 (kg/t)

Fuel	CO_2 (kgC/t)	SOx as SO_2 (SO_2/t)
Aviation Turbine Fuel	859	1.18
Aviation Spirit	853	1.18

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).

Table 3-12 Average Non-CO_2 Emission Factors for Civil and Military Aviation in kt/Mt, 2013

	Fuel	CH_4	N_2O	NO_x (as NO_2)	CO	NMVOC
Civil aviation						
Domestic LTO	AS	0.82	0.10	4.22	82.16	6.70
Domestic Cruise	AS	-	0.10	1.61	1227	10.21
Domestic LTO	ATF	0.16	0.10	12.38	9.05	1.53
Domestic Cruise	ATF	-	0.10	15.11	6.03	0.66
International LTO	AS	1.11	0.10	3.60	307.7	9.04
International Cruise	AS	-	0.10	1.72	1221	10.17
International LTO	ATF	0.12	0.10	13.78	9.00	1.11
International Cruise	ATF	-	0.10	16.73	1.31	0.14
Military aviation						
Military aviation	AS	0.10	0.10	8.50	8.20	1.00
Military aviation	ATF	0.10	0.10	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 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

The EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 1996) 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 EMEP/CORINAIR Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data are assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al*. (2004).

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 SOx 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 NFR category 1A5 Other.

3.3.2.8 Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DECC 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)

3.3.3.1.1 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

There are a number of sources: COPERT 4, EMEP/EEA Emission Inventory Guidebook and UK specific emission factors as developed by Transport Research Laboratory (TRL) on behalf of the UK Department for Transport (DfT).

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 CLRTAP is currently based on fuel consumption derived from kilometres driven rather than fuel sales. The UK's interpretation of paragraph 26 of the revised Guidelines on Reporting (ECE/EB.AIR/125)[18] is that it does 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.

The UK does estimate fuel consumption estimated from kilometres driven and g/km factors and compares these each year with national fuel sales figures. This point is discussed in the road transport methodology section of this report. The agreement is good, to within $\pm$8% for both petrol and diesel consumption across the 1990-2013 time-series, but the agreement does fluctuate from year to year, probably reflecting uncertainty in the modelling approach and the gap in the link between fuel sales and consumption due to "fuel tourism" effects. In principle, the UK could develop a fuel sales-based inventory for air pollutants, but this would lead to erratic trends in emissions on a vehicle type basis from the adjustments necessary to align with fuel sales and this would be mis-interpreted by policy makers. 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 whereas for air pollutants the issue should be in relation to where the fuel is consumed.

Thus, 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 (SOx 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 DECC and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES (emissions

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

from the Crown Dependencies are calculated elsewhere). The figure on diesel consumption in DUKES was corrected for 2007 and it is 1.8% lower than the previous years' figures for 2007.

In 2013, 12.57 Mtonnes of petrol and 21.93 Mtonnes of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2012. It was estimated that of this, around 2.9% 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 12.15 Mtonnes of petrol consumed by road vehicles in the UK in 2013. Around 1.6% of road diesel is estimated to be 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 21.52 Mtonnes of diesel consumed by road vehicles in the UK in 2013.

According to figures in DUKES (DECC, 2014), 0.094 Mtonnes of LPG were used for transport in 2013, a small increase from 0.093 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 DECC refer only to mineral-based fuels (fossil fuels). According to statistics in DUKES and from HMRC (2014), 0.65 Mtonnes bioethanol and 0.68 Mtonnes biodiesel were consumed in the UK in 2013. On a volume basis, this represents about 4.6% of all petrol and 2.8% of all diesel sold in the UK, respectively. This is an increase in both bioethanol and biodiesel consumption compared with 2012. On an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.390 Mtonnes of mineral-based petrol (about 3.1% of total petrol that would have been consumed) and 0.592 Mtonnes of mineral-based diesel (about 2.7% 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
Equations relating fuel consumption to average speed are based on the relationships for detailed categories of vehicles compiled by TRL on behalf of DfT. The factors themselves are available at http://www.dft.gov.uk/publications/road-vehicle-emission-factors-2009/ together with appropriate documentation from TRL on how the emission factors were derived (see for example the report by Boulter et al. (2009) at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4249/report-3.pdf). The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, LGVs and motorcycles, the speed-related fuel consumption factors in g fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types as described below. The fleet-average fuel consumption factors calculated for these vehicle types grouped into their respective Euro emission standards are shown in Table 3-13 for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 3-13 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6
	Euro 4	50.8	47.2	53.4
	Euro 5	44.7	41.2	47.4
Diesel cars	Pre-Euro 1	60.3	55.0	61.2
	Euro 1	58.5	53.2	59.4
	Euro 2	54.9	49.6	55.8
	Euro 3	50.2	44.9	51.1
	Euro 4	47.7	42.4	48.7
	Euro 5	42.0	36.7	42.9

g fuel /km		Urban	Rural	Motorway
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8
	Euro 2	60.9	56.3	62.1
	Euro 3	57.1	52.5	58.3
	Euro 4	52.3	47.7	53.6
	Euro 5	46.9	42.2	48.2
Diesel LGV	Pre-Euro 1	61.9	68.4	91.9
	Euro 1	76.7	84.4	110.1
	Euro 2	71.5	77.5	106.0
	Euro 3	63.2	69.8	104.0
	Euro 4	63.2	69.8	104.0
	Euro 5	63.2	69.8	104.0
Mopeds, <50cc, 2st	Pre-Euro 1	25.5		
	Euro 1	15.3		
	Euro 2	12.3		
	Euro 3	10.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	27.5	30.2	
	Euro 1	25.3	27.8	
	Euro 2	25.3	27.8	
	Euro 3	25.3	27.8	
Motorcycles, >50cc, 4st	Pre-Euro 1	35.3	35.1	53.9
	Euro 1	33.5	33.2	46.9
	Euro 2	31.6	31.9	49.3
	Euro 3	31.6	31.9	49.3

For HGVs, the DfT provide statistics from a survey of haulage companies on the average miles per gallon (mpg) fuel efficiency of different sizes of vehicles within this class (DfT, 2011a). A time-series of mpg figures from 1989 to 2010 is provided by the Road Freight Statistics and these can be converted to g fuel per kilometre fuel consumption factors. The figures will reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorway roads. The shape of the DfT/TRL speed-related functions based on test cycle measurements of more limited samples of vehicles are then used to define the variation, relative to the averaged value, in fuel consumption factor with speed and hence road type. Figures for 2011-2013 from Road Freight Statistics were not available so overall HGV fuel efficiencies for 2010 were carried over to these years.

Table 3-14 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2013 calculated for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011) up to 2010.

Table 3-14 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

g fuel/km	Rigid HGVs			Artic HGVs		
	Urban	Rural	Motorway	Urban	Rural	Motorway
1990	272.4	217.7	231.5	438.8	337.1	343.6
1991	276.6	221.0	235.1	437.2	335.9	342.4
1992	277.0	221.4	235.4	433.9	333.3	339.8
1993	266.9	213.5	227.0	412.1	316.7	322.8
1994	259.0	207.8	221.1	405.1	311.6	317.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
1996	258.2	209.0	222.8	388.1	299.3	305.1
1997	256.3	208.4	222.3	387.2	299.2	304.9
1998	245.1	200.5	214.1	370.8	287.2	292.7
1999	249.8	205.4	219.6	370.3	287.3	292.8
2000	247.8	204.8	219.2	370.2	287.7	293.2
2001	259.8	214.2	228.8	375.5	292.0	297.6
2002	252.5	208.6	222.5	373.1	290.0	295.6
2003	262.6	216.2	230.1	378.3	293.7	299.4

g fuel/km	Rigid HGVs			Artic HGVs		
	Urban	Rural	Motorway	Urban	Rural	Motorway
2004	253.9	208.6	221.7	365.2	283.1	288.7
2005	250.9	205.0	217.3	361.2	279.7	285.2
2006	262.1	213.1	225.4	363.7	281.3	286.9
2007	270.4	218.5	230.5	366.3	283.1	288.6
2008	279.8	226.0	238.4	380.1	293.5	299.3
2009	281.9	228.0	240.7	381.4	294.3	300.1
2010	285.3	229.9	242.4	385.3	296.9	302.7
2011	284.7	229.2	241.6	384.4	296.0	301.8
2012	284.6	228.9	241.3	384.6	295.9	301.8
2013	285.8	229.6	242.0	385.8	296.7	302.5

For buses and coaches, the principal data source used was figures from DfT on the Bus Service Operators Grant system (BSOG). This is an audited subsidy, directly linked to the fuel consumed on local bus services. From BSOG financial figures, DfT were able to calculate the costs and hence quantity of fuel (in litres) used for local bus services going back to 1996 and using additional bus km data were able to derive implied fuel consumption factors for local service buses (DfT, 2013a). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. The BSOG data also take into account of fuel consumption on local bus services that were carried out on dead mileage, i.e. mileage to and from the start and end of a bus route. In terms of trend, the BSOG data imply a continual increase in the average fuel consumption factor for local buses from 1996 to 2009/10 (i.e. a reduction in fuel efficiency), but a slight improvement since then.

The BSOG data were used to define the fuel consumption factor for buses in the inventory over an urban cycle. However, the BSOG data do not cover rural bus services and coaches. For these, an approach similar to that used for HGVs was adopted by utilising the research-based, speed-related fuel consumption factors given by DfT/TRL in combination with the BSOG data. Using a combination of fleet composition data for different sizes of buses, the DfT/TRL functions were used to define how the fuel efficiency of the average bus and coach in the UK fleet varied with average speed and road type and year. The differences relative to the fuel efficiency factor for the average bus over an urban cycle were derived for the average bus on a rural cycle and the average coach on motorways. The relative differences were then applied to the BSOG-based urban bus factor to develop a series of internally consistent trends in bus and coach fuel consumption factor on urban, rural and motorway roads.

The BSOG data are provided on a financial year basis, the most recent being for 2012/13. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2012/13 figures were used for the 2012 calendar year. Data were not available for 2013/14 in time for the current inventory compilation and so the 2012/13 figures were also used for 2013 calendar year.

Table 3-15 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2013 for urban, rural and motorway conditions based on this method.

Table 3-15 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data.

g fuel/km	Urban	Rural	Motorway
1990	268.9	167.8	190.9
1991	268.9	167.8	190.9
1992	268.9	167.8	190.9
1993	268.2	167.5	190.5
1994	265.0	165.7	189.0
1995	260.8	163.3	187.0
1996	255.9	160.7	184.8
1997	255.3	160.9	185.8
1998	255.1	161.5	187.4

g fuel/km	Urban	Rural	Motorway
1999	264.5	168.2	195.9
2000	277.0	176.7	206.4
2001	278.3	177.9	208.4
2002	290.0	186.1	219.0
2003	303.9	195.0	229.8
2004	312.4	200.4	236.3
2005	322.7	207.1	244.3
2006	323.3	207.3	244.7
2007	328.9	210.6	248.7
2008	338.2	216.2	255.4
2009	340.8	217.5	257.2
2010	337.5	215.1	254.5
2011	336.8	214.4	253.8
2012	326.3	207.4	245.7
2013	327.1	207.6	246.1

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 DECC 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. The ratio fluctuates just above and below the 1 line, but the difference is never higher than 8%. In 2013, the bottom-up method underestimates petrol and diesel consumption by 6.9% and 2.6% respectively. This is considered well within the uncertainty of the factors used to derive the bottom-up estimates.

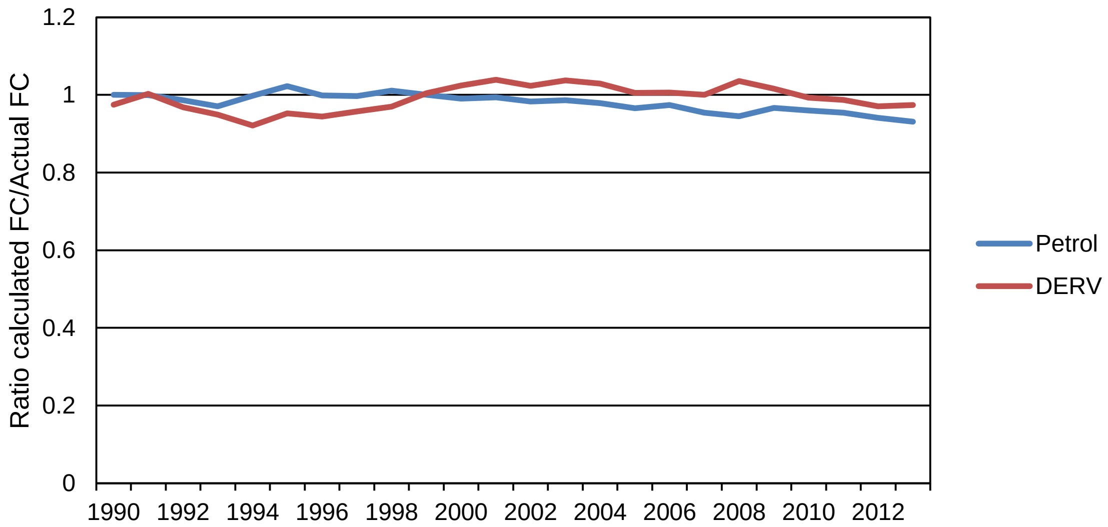


Figure 3-1 Ratio of calculated consumption of petrol and diesel fuel based on traffic movement and fuel consumption factors summed for different vehicle types to the DUKES figures for these fuels based on fuel sales in the UK.

The normalisation process introduces uncertainties into the fuel consumption estimates for individual vehicle classes even though the totals for road transport is known with high accuracy.

For petrol, the fuel consumption calculated for each vehicle type consuming petrol is scaled up or down by the same proportion to make the total petrol consumption align with DUKES. So for example, the fuel consumption estimated for petrol cars, LGVs and motorcycles are all increased by 6.9% to align with fuel sales in 2013. Cars consume the vast majority of this fuel, so the DUKES figures provide a relatively accurate description of the trends in fuel consumption by petrol cars. A small residual is consumed by petrol LGVs and motorcycles, so their estimates are susceptible to fairly high levels of uncertainty introduced by the normalisation process.

For diesel, a number of different vehicle classes (cars, LGVs, HGVs and buses) all consume similar amounts of fuel. Either the fuel consumption for all diesel vehicles can be scaled to align with DUKES, as carried out for petrol normalisation, or consumption for specific vehicle types can be adjusted to bring the total in line with DUKES. Because all vehicle types make a similar contribution to diesel consumption, adjusting the calculated figures for all vehicle types by scaling can lead to distorted trends in the figures for specific vehicle types over a time-series. After discussions with officials at DfT, it was decided to retain the consumption for cars, LGVs and buses at the values calculated by the bottom-up approach and use HGVs to “carry the burden” of bringing the total diesel consumption in line with DUKES (DfT, 2009a). There were two main reasons for this. First, because HGVs are the largest overall consumer of diesel, this approach of correcting for the difference between calculated diesel consumption and fuel sales figures from DUKES has a smaller effect on HGVs than other vehicle classes. A second reason is that a rationale can be given for HGVs leading to the overestimation of diesel consumption compared with sales since 1998 on the basis of “fuel tourism” effects. This is where vehicles consume fuel on UK roads that was purchased abroad. In this case, the fuel would not appear in the UK sales figures, but would be represented in consumption figures calculated from traffic movement data. Given the recent price differential between diesel sold in the UK and the rest of Europe and the amount of cross-border haulage operations, HGVs are believed to make a larger contribution to potential fuel tourism effects than any other class of vehicle. Furthermore, DfT were able to provide some data to back up this hypothesis. This included DfT estimates of the amount of fuel purchased abroad by UK vehicles and the kilometres travelled in the UK by foreign vehicles (DfT, 2009a). The 2009 figures suggested the total amount of fuel purchased abroad (and therefore not contributing to UK fuel sales in DUKES) by HGVs operating in the UK could be around 550 ktonnes compared with a gap of around 309 ktonnes in the estimate of total diesel consumption and the figures based on fuel sales in DUKES. This is at least consistent with a theory indicating HGV fuel tourism contributing to the gap and partial justification for adjusting the bottom-up estimated diesel consumption for HGVs to bring the total diesel consumption in line with DUKES. However, it is important to recognise that other factors including modelling uncertainty will also be playing a factor. Also, the increasing tendency to underestimate petrol and diesel consumption by the bottom-up method in the most recent years (Figure 3-1) may indicate increasing differences between real-world fuel efficiencies of modern vehicles compared with the factors used in the inventory.

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 is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest less than 0.4 of all light duty vehicles run on LPG in Table 3-13**.**.

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 DECC 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 3-16 for 2013 fuels based on data from UKPIA (2014).

Table 3-16 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	SO_2[a]
Petrol	0.009
Diesel	0.014

a 2013 emission factor calculated from UKPIA (2014) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2013

Metals

Emission factors for metals are based in 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 3-17.

Table 3-17: 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 the existing UK factors are retained and no changes in emissions occur.

In order to retain a consistent time-series in lead emissions from petrol consumption, UK-specific emission factors are continued to be used based on the lead content of leaded petrol (used up until 2000) and unleaded petrol. These figures are provided by the UK petroleum industry (UKPIA, 2014). The factor for unleaded petrol is 54 µg/kg fuel which is higher than the value of 33 µg/kg fuel given by 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 SOx 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 which 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 and 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 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4248/report-2.pdf). 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, 2014a). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2013 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 areused 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, 2013). These provided a consistent time-series of vehicle km data for all years up to 2012. Data for 2013 were not available in time for the current inventory compilation and thus they were extrapolated from 2012 vkm data for Northern Ireland based on the traffic growth rates between 2012 and 2013 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 the GB each year. The ratios were then applied to the motorcycle vehicle km activity data for the GB. 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, 2014).

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 2013. Table 3-18 shows the UK vehicle kilometres data from 1990 to 2010 (at five years interval) and for the most recent years (2012, 2013).

Table 3-18 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2005	2010	2012	2013
Petrol cars	urban	142.2	137.9	135.1	119.9	99.5	93.5	89.3
	rural	141.1	134.1	134.2	127.3	109.1	100.6	97.5
	m-way	49.2	48.4	53.0	48.8	41.7	37.8	35.9
Diesel cars	urban	5.8	17.2	26.1	40.8	54.1	60.6	63.1
	rural	6.1	18.0	28.3	47.6	65.8	72.9	76.5
	m-way	2.8	8.5	14.6	25.1	33.5	39.1	41.7
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.3	1.1	1.0
	rural	11.4	8.3	5.0	2.3	1.6	1.4	1.3
	m-way	3.9	3.2	2.0	0.9	0.6	0.6	0.6
Diesel LGVs	urban	5.7	10.2	15.5	21.2	22.6	22.9	23.2
	rural	6.1	11.5	18.8	26.0	29.5	28.9	30.2
	m-way	2.0	4.4	7.4	10.5	11.4	12.5	13.2
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	6.1
	m-way	3.7	3.7	4.2	4.2	4.1	3.5	3.4
Artic HGVs	urban	1.1	1.1	1.1	1.0	0.8	0.8	0.8
	rural	4.3	4.7	5.1	5.3	5.0	4.9	5.0
	m-way	4.7	6.0	7.4	7.9	7.5	7.6	7.8

Billion vkm		1990	1995	2000	2005	2010	2012	2013
Buses	urban	2.4	2.9	3.0	3.2	3.1	2.7	2.8
	rural	1.7	1.5	1.7	1.5	1.6	1.3	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	2.3	2.1
	rural	2.0	1.6	2.0	2.2	1.8	2.0	1.9
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Total		**423.4**	**443.9**	**483.0**	**513.0**	**507.9**	**506.9**	**508.7**

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, 2009b) 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 3-19 shows the speeds used in the inventory for light duty vehicles, HGVs and buses.

Table 3-19 Average Traffic Speeds in Great Britain

Road Type		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. Prior to the 2010 inventory, the petrol car/diesel car mix on different road types was defined by the DfT Vehicle Licensing Statistics and data on the relative mileage done by petrol and diesel cars (DfT, 2008b, pers comm). The latter information, as originated from the National Travel Survey (DfT, 2007b), indicated that diesel cars do on average 60% more annual mileage than petrol cars. It was assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, it was previously assumed that the petrol car/diesel car mix on urban roads was to be indicated by the population mix according to vehicle licensing data (i.e. that there is no preferential use of diesel or petrol cars on urban roads) and the mix on rural and motorways adjusted to give an overall mileage pattern over all roads in the UK that leads to an average 60% higher annual mileage by diesel cars compared with petrol cars.

Since then, the inventory has made use of the Automatic Number Plate Recognition (ANPR) data provided by DfT (2014b, pers comm) for defining 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 and 2013. 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.

Following a series of analysis and discussions with officials from DECC, Defra and DfT, it was concluded that the ANPR data should be best used to define the fleet composition on different road types for the whole of Great Britain (GB) while combining Devolved Administration-country specific vehicle licensing data (hereafter referred as DVLA data) to define regional variation (DfT, 2014b). The ANPR data is 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, 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 result was then further adjusted by the DVLA data to define the variation of the petrol/diesel mix by the Devolved Administration regions. 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 three years of ANPR data (2010, 2011 and 2013) 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, 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 3-18.

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

Table 3-20 shows the regulations that have come into force up to 2013 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 3-20 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
	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
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 new 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 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 factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with the GB average between 2007 and 2011 and 2013 and its impact on emissions. This factor is 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 or DA countries have no effect on emissions. This factor is then combined with a DA-specific "driver" derived from trends in licensing data to account for the relative differences in the fleet in each DA country compared with the GB average. An overall year-, vehicle-, road-, DA- and pollutant-specific factor is then applied to GB average emission factors calculated in the fleet model.

As no ANPR data were available for 2012, the trends observed between 2011 and 2013 marking the relative difference between the ANPR observations of vehicles on the road and the vehicle fleet according to registrations was applied to the registrations data for 2012. This ensured a smooth trend in the on-road fleet developed on a consistent basis across the time series.

It should be noted that the application of the ANPR and DVLA data is dependent on the vehicle, pollutant and region combination. For instance, when calculating fuel consumption, data on the average mpg fuel efficiency of different sizes of lorries from the Road Freight Statistics and the BSOG data for buses take precedence over the ANPR data, and they are continued to be used to define the fuel consumption for HGVs and buses respectively, without any adjustment to account for variations in the age of the HGV or bus fleets. For other pollutants where the mpg data from Road Freight Statistics are not used in the calculations of HGV emissions, the ANPR data are utilised. The ANPR or DVLA data have not been analysed or applied to the calculation of other pollutant emissions from buses/coaches, as there are likely to be variations in local bus fleets according to local authority measures to address air quality concerns that will not be reflected by licensing information alone, while coaches spend less time in the areas where they are registered. Similarly, neither the ANPR nor DVLA data have been analysed for motorcycles due to lack of data and their relative small contribution to the overall UK fleet.

The DfT/TRL 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, 2013c). In addition, the relative mileage done by different size of vehicles was factored into the ratios, this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2013b).

To utilise the DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover three different weight classes of LGVs, eight different size classes of rigid HGVs, five different weight classes of artic HGVs, five different weight classes of buses and coaches and seven 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, 2014), 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, 2011a) provided a time series of vehicle km (2000-2010) 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, while there has been an increase in traffic activity for rigid HGVs over 17 tonnes over the period 2000 to 2010.. Data for 2011 to 2013 were not available due to a delay in the publication of the Road Freight Statistics and so data for 2010 have been applied to these years. 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 assumption has 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 actually 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, 2013).

For motorcycle, 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 the only larger capacity motorcycles are used on motorways are the (>750cc, 4-stroke). 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 2009c). 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 takes account of the early introduction of certain emission standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro 3 emission standards for passenger cars (98/69/EC) came into effect from January 2001 (new registrations). However, some makes of cars sold in the UK already met the Euro 3 standards prior to this (DfT, 2001). Figures from the Society of Motor Manufacturers and Traders suggested that 3.7% of new cars sold in 1998 met Euro 3 standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro 3 standards in 1999 increasing to 10% and 100% in 2000 and 2001 respectively.

Euro 4 cars are assumed to be introduced from year 2006 onwards as set by the Directive. This is in light of the study by King’s College and Ricardo-AEA (Carslaw *et al.,* 2011) on the basis of ANPR data and manufacturers’ information.

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, and this would rise to 14,000 vehicles by the end of 2005 (DETR, 2000). This was accounted for in the inventory for its effects on PM, NO_x (as NO_2), CO and NMVOCs emissions using the effect these devices have on the baseline factors for relevant Euro standards of vehicles without traps as discussed later in this section (Table 3-21).

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) in London were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used and was updated in the 2012 inventory. Based on information from DfT, 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 (as NO_2) 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 were mostly taken from the database of vehicle emission factors released by DfT/TRL in 2009 (Boulter *et al.,* 2009) or from EMEP/EEA Emissions Inventory Guidebooks.

Regulated pollutants NO_x (as NO_2), CO, NMVOCs, $PM_{10}/_{2.5}$

For NO_x (as NO_2), emission factors for Euro 5 diesel cars were updated in the 2012 inventory by adopting the latest factors in COPERT 4 v10, published in November 2012. This replaced the NO_x emission factors from COPERT 4 v9 (published in October 2011) as used in the 2011 inventory. The development of the COPERT 4 model is coordinated by the European Environment Agency and is used widely by other Member States to calculate emissions from road transport. The latest version of the COPERT model is available for download from http://www.emisia.com/copert/. The new Euro 5 factors are higher than previously assumed reflecting the real-world performance of these vehicles, to levels 23% higher than factors for Euro 4 vehicles. Although not adopted for diesel LGVs in COPERT 4 v10, a conservative assumption was made that Euro 5 factors for these vehicles are also 23% higher than their Euro 4 equivalent factors. Emission factors for all other vehicle types were not changed in COPERT 4 v10. For NO_x (as NO_2), COPERT 4 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 expect that the UK situation will vary from this European average). The net result of adopting the COPERT 4 v10 factors is an increase in the estimates of diesel car and LGV NO_x (as NO_2) emissions in this year's inventory from 2010.

Emission factors for total hydrocarbons (THC) and PM have not been changed in the UK inventory as they remain unchanged in COPERT 4 v10. COPERT 4 emissions factors are used to compile THC and PM emissions in the inventory.

The COPERT NO_x, THC 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 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).

The TRL/DfT (Boulter et al., 2009) emission factors for CO continue to be used in the 2013 inventory, and are also represented as equations relating emission factor in g/km to average speed. The TRL/DfT emission factors are provided for an extensive range of vehicle types, sizes and Euro standards and are based on emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. 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 and THC emission factors.

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.

PM is also emitted from the re-suspension of deposited material on the road surface by the movement of vehicles. Inventory guidelines do not require an estimate for re-suspension of road dust PM, but a very approximate estimate is provided for air quality assessments. Emissions from this source are likely to be highly variable and will depend on local meteorological conditions (wind direction and speed, precipitation), the state of the road surface (paved, unpaved, dusty etc.), the height and proximity of buildings in the local area (street canyon or open) and the general traffic situation. More rigorous modelling of the contribution of road dust re-suspension to PM air quality requires more sophistication than a basic inventory approach can provide, taking into account the local conditions.
Table 3-29, Table 3-30, Table 3-31 and Table 3-32 summarise the baseline COPERT 4 NO_x and THC emission factors (before any degradation corrections to the petrol LDVs factors and normalised to current fuels), COPERT PM emission factors and the TRL/DfT's CO emission factors (normalised to 50,000 km accumulated mileage and current fuels) for all vehicle types under typical urban, rural and motorway road conditions in g/km. The factors have been averaged according to the proportion of different vehicle sizes in the UK fleet based on vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for CH_4 from the corresponding 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.

There is an important point to note from these tables of emission factors. The variation in emission factors with average speed differs with different vehicle types, Euro class and technology and the tables shown here are only meant as an illustration of how average emission factors vary across different road types with typical average speeds and Euro classes. Emission factors are especially sensitive to speed at the lower end of the urban speed range. Urban emission factors shown in these tables refer to the average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and some pollutants show a different trend across the Euro standards at these low speeds. This is especially true for NOx as NO_2 emission factors for diesel heavy duty vehicles where Euro V vehicles equipped with SCR can show higher factors for NOx as NO_2 than the same vehicle of a Euro IV class at particularly low speeds reflecting the poor performance of SCR systems under real-world urban cycles. The Euro V factors for NO_x shown in these tables for HGVs and buses are for a higher urban speed and are a weighted average of different factors for vehicles equipped with SCR and EGR technology. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors.

The inventory uses the TRL fuel scaling factors to take into account the prevailing fuel quality in different years. 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 (2014) 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 NOx as NO_2, CO and NMVOC emissions beyond that required by Directives. Emissions from buses 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. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in Table 3-21.

Table 3-21 Scale Factors for Emissions from a Euro II Bus Fitted with an Oxidation Catalyst or DPF

		NO_x	CO	NMVOCs	PM
Oxidation catalyst	Urban	0.97	0.20	0.39	0.35
	Rural	0.95	0.22	0.55	0.50
DPF	Urban	0.90	0.17	0.19	0.13
	Rural	0.88	0.19	0.27	0.18

These scale factors are based on data from LT Buses (1998).

Euro II HGVs equipped with DPFs have their emissions reduced by the amounts shown in Table 3-22.

Table 3-22 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

		NO_x	CO	NMVOCs	PM
DPF	Urban	0.81	0.10	0.12	0.15
	Rural	0.85	0.10	0.12	0.15

***Non-regulated pollutants: NH_3, PAHs,* PCDD/PCDFs**

Ammonia emissions from combustion sources are usually small, but significant levels can be emitted from road vehicles equipped with catalyst devices to control NOx as NO_2 emissions. Nitrous oxides (N_2O), and ammonia emissions are an unintended by-product of the NOx as NO_2 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) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*".

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 3-33 summarises the NH_3 emission factor for all vehicle types and road conditions in mg/km; the factors for petrol cars and LGVs are shown for zero accumulated mileage, but the inventory takes account of the increase in emissions with mileage.

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, 2009a); 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. An example of factors for benzo[a]pyrene is shown in Table 3-34.

Emission factors for PCDD/PCDFs were updated to be 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 (as NO_2), 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. Evidence has shown that diesel vehicles are particularly prone to high f-NO_2 values and especially those vehicles fitted with certain types of catalyst systems for controlling other pollutant emissions such as oxidation catalysts and diesel particulate filters for controlling CO, HC and PM. Thus, diesel vehicles meeting more recent Euro standards tend to have higher f-NO_2 values.

Values of f-NO_2 are given in the DfT/TRL emission factors review and the EMEP/EEA Emissions Inventory Guidebook (2007) 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 are given in Table 3-23. These should be used in conjunction with the NO_x (as NO_2) emissions calculated by the inventory to derive the corresponding emissions of NO_2.

Table 3-23 Fleet-average values of f-NO_2 for road vehicles representing the mass fraction of NO_x emitted as NO_2.

f-NO_2	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**
Petrol cars	0.040	0.040	0.040	0.035	0.032	0.031	0.031	0.031
Diesel cars	0.11	0.11	0.11	0.22	0.42	0.42	0.42	0.42
Petrol LGVs	0.040	0.040	0.040	0.037	0.034	0.034	0.033	0.033

f-NO_2	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**
Diesel LGVs	0.11	0.11	0.11	0.20	0.43	0.45	0.44	0.44
Rigid HGVs	0.11	0.11	0.11	0.13	0.13	0.13	0.12	0.12
Artic HGVs	0.11	0.11	0.11	0.13	0.13	0.12	0.11	0.11
Buses and coaches	0.11	0.11	0.11	0.12	0.13	0.13	0.12	0.12
Motorcycles	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040

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/EEA Emissions Inventory Guidebook (2007).

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:

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

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 Met Office data.

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

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

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 3-24. There are no cold start factors for HGVs and buses.

Table 3-24 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	4.4

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 (2014), 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/EEA, 2007).

An implied emission factor based on the population, composition of the fleet and trips made in 2013 is shown for petrol cars and motorcycles in Table 3-25. The units are in g per vehicle per day.

Table 3-25 Fleet-average emission factor for evaporative emissions of NMVOCs in 2013

g/vehicle.day	2013
Petrol cars	0.58
Motorcycles	1.56

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 3-26 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 NFR 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 3-27. 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 3-26 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 3-27 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 DfT/TRL emission factor review and EMEP/EEA Emissions Inventory Guidebook (EMEP/EEA, 2007), the fraction of PM_{10} emitted as $PM_{2.5}$ for tyre wear, brake wear and road abrasion is shown in Table 3-28.

Table 3-28 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.

PM is also emitted from the re-suspension of deposited material on the road surface by the movement of vehicles. Inventory guidelines do not require an estimate for re-suspension of road dust PM, but a very approximate estimate is provided for air quality assessments. Emissions from this source are likely to be highly variable and will depend on local meteorological conditions (wind direction and speed, precipitation), the state of the road surface (paved, unpaved, dusty etc.), the height and proximity of buildings in the local area (street canyon or open) and the general traffic situation. More rigorous modelling of the contribution of road dust re-suspension to PM air quality requires more sophistication than a basic inventory approach can provide, taking into account the local conditions.

Table 3-29 NO_x (as NO_2) Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs[19]

g NO_x (as NO_2 eq)/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2.11	2.66	3.58
	Euro 1	0.26	0.31	0.59
	Euro 2	0.14	0.16	0.19
	Euro 3	0.07	0.06	0.06
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Diesel cars	Pre-Euro 1	0.57	0.53	0.74
	Euro 1	0.57	0.58	0.74
	Euro 2	0.60	0.56	0.79
	Euro 3	0.69	0.67	0.86
	Euro 4	0.48	0.44	0.72
	Euro 5	0.59	0.54	0.89
Petrol LGVs	Pre-Euro 1	2.82	3.34	3.97
	Euro 1	0.41	0.42	0.61
	Euro 2	0.14	0.14	0.21
	Euro 3	0.09	0.09	0.13
	Euro 4	0.04	0.04	0.06
	Euro 5	0.03	0.03	0.04
Diesel LGV	Pre-Euro 1	1.29	0.81	2.08
	Euro 1	1.05	1.01	1.50
	Euro 2	1.05	1.01	1.50
	Euro 3	0.88	0.85	1.26
	Euro 4	0.71	0.68	1.02
	Euro 5	0.88	0.84	1.25
Rigid HGVs	Pre-Euro I	8.65	7.89	7.91
	Euro I	5.92	5.45	5.51
	Euro II	6.40	5.77	5.76
	Euro III	5.01	4.45	4.42
	Euro IV	3.47	3.19	2.86
	Euro V	2.77	1.34	0.81
	Euro VI	0.30	0.14	0.09
Artic HGVs	Pre-Euro I	13.95	11.17	10.07
	Euro I	9.79	7.87	7.13
	Euro II	10.42	8.36	7.59
	Euro III	8.35	6.72	6.14
	Euro IV	5.74	4.81	3.59
	Euro V	3.83	1.94	1.27

[19] The emission factors shown here are illustrative of magnitude and variability with vehicle and road type. The factors for urban roads refer to an average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and show a different trend across the Euro standards at these low speeds. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors. The Euro V factors for HDVs are a weighted average of factors vehicles equipped with SCR and EGR for NO_x control.

g NO_x (as NO_2 eq)/km	Standard	Urban	Rural	Motorway
	Euro VI	0.38	0.21	0.16
Buses & coaches	Pre-Euro I	10.84	9.31	8.64
	Euro I	7.26	6.00	6.42
	Euro II	7.85	6.47	7.00
	Euro III	6.14	4.66	5.33
	Euro IV	4.21	3.35	3.85
	Euro V	3.35	2.16	1.91
	Euro VI	0.33	0.18	0.17
Mopeds, <50cc, 2st	Pre-Euro 1	0.03		
	Euro 1	0.03		
	Euro 2	0.01		
	Euro 3	0.01		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.03	0.04	
	Euro 1	0.04	0.05	
	Euro 2	0.05	0.06	
	Euro 3	0.02	0.04	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.22	0.45	0.57
	Euro 1	0.23	0.44	0.57
	Euro 2	0.13	0.31	0.66
	Euro 3	0.07	0.16	0.34

Table 3-30 THC Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs. NMVOC emission factors are derived by subtracting methane factors from the THC factors.

g HC/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.30	0.82	0.71
	Euro 1	0.15	0.12	0.12
	Euro 2	0.06	0.05	0.04
	Euro 3	0.01	0.02	0.03
	Euro 4	0.01	0.01	0.02
	Euro 5	0.01	0.01	0.02
Diesel cars	Pre-Euro 1	0.12	0.08	0.06
	Euro 1	0.05	0.03	0.03
	Euro 2	0.05	0.03	0.02
	Euro 3	0.02	0.01	0.01
	Euro 4	0.01	0.01	0.01
	Euro 5	0.01	0.01	0.01
Petrol LGVs	Pre-Euro 1	1.40	0.48	0.88
	Euro 1	0.18	0.08	0.10
	Euro 2	0.04	0.02	0.02
	Euro 3	0.03	0.01	0.01
	Euro 4	0.01	0.01	0.01
	Euro 5	0.01	0.01	0.01
Diesel LGV	Pre-Euro 1	0.12	0.10	0.12
	Euro 1	0.12	0.10	0.12
	Euro 2	0.12	0.10	0.12
	Euro 3	0.07	0.06	0.07
	Euro 4	0.03	0.02	0.03
	Euro 5	0.03	0.02	0.03
Rigid HGVs	Pre-Euro I	0.83	0.54	0.37
	Euro I	0.42	0.29	0.22
	Euro II	0.28	0.19	0.14
	Euro III	0.26	0.18	0.13
	Euro IV	0.04	0.03	0.03
	Euro V	0.02	0.02	0.02
	Euro VI	0.02	0.01	0.01
Artic HGVs	Pre-Euro I	0.68	0.46	0.34
	Euro I	0.64	0.44	0.32
	Euro II	0.42	0.28	0.21

g HC/km	Standard	Urban	Rural	Motorway
	Euro III	0.39	0.26	0.19
	Euro IV	0.06	0.04	0.04
	Euro V	0.04	0.03	0.02
	Euro VI	0.03	0.02	0.02
Buses & coaches	Pre-Euro I	1.10	0.81	0.31
	Euro I	0.49	0.36	0.32
	Euro II	0.33	0.25	0.21
	Euro III	0.31	0.24	0.21
	Euro IV	0.05	0.04	0.03
	Euro V	0.03	0.02	0.02
	Euro VI	0.02	0.02	0.02
Mopeds, <50cc, 2st	Pre-Euro 1	13.91		
	Euro 1	2.73		
	Euro 2	1.56		
	Euro 3	1.20		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.52	7.44	
	Euro 1	2.36	2.86	
	Euro 2	1.25	1.52	
	Euro 3	0.78	0.95	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.60	1.30	1.73
	Euro 1	0.90	0.79	0.81
	Euro 2	0.39	0.43	0.58
	Euro 3	0.25	0.27	0.36

Table 3-31 PM_{10} Emission Factors for Road Transport (in g/km)

g PM/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	0.003	0.002	0.002
	Euro 1	0.003	0.002	0.002
	Euro 2	0.003	0.002	0.002
	Euro 3	0.001	0.001	0.001
	Euro 4	0.001	0.001	0.001
	Euro 5	0.001	0.001	0.001
Diesel cars	Pre-Euro 1	0.17	0.13	0.16
	Euro 1	0.05	0.07	0.10
	Euro 2	0.04	0.04	0.05
	Euro 3	0.03	0.03	0.04
	Euro 4	0.03	0.02	0.03
	Euro 5	0.001	0.001	0.001
Petrol LGVs	Pre-Euro 1	0.003	0.002	0.002
	Euro 1	0.003	0.002	0.002
	Euro 2	0.003	0.002	0.002
	Euro 3	0.001	0.001	0.001
	Euro 4	0.001	0.001	0.001
	Euro 5	0.001	0.001	0.001
Diesel LGV	Pre-Euro 1	0.29	0.32	0.35
	Euro 1	0.06	0.08	0.14
	Euro 2	0.06	0.08	0.14
	Euro 3	0.04	0.06	0.09
	Euro 4	0.02	0.03	0.05
	Euro 5	0.001	0.002	0.003
Rigid HGVs	Pre-Euro I	0.36	0.29	0.28
	Euro I	0.23	0.18	0.18
	Euro II	0.11	0.12	0.14
	Euro III	0.12	0.09	0.08
	Euro IV	0.03	0.02	0.02
	Euro V	0.03	0.02	0.02
	Euro VI	0.003	0.002	0.002
Artic HGVs	Pre-Euro I	0.48	0.42	0.27

g PM/km	Standard	Urban	Rural	Motorway
	Euro I	0.37	0.33	0.20
	Euro II	0.20	0.21	0.26
	Euro III	0.19	0.14	0.13
	Euro IV	0.04	0.03	0.03
	Euro V	0.04	0.03	0.03
	Euro VI	0.004	0.003	0.003
Buses & coaches	Pre-Euro I	0.45	0.34	0.27
	Euro I	0.27	0.21	0.20
	Euro II	0.14	0.13	0.12
	Euro III	0.14	0.11	0.11
	Euro IV	0.03	0.03	0.03
	Euro V	0.03	0.02	0.02
	Euro VI	0.003	0.003	0.003
Mopeds, <50cc, 2st	Pre-Euro 1	0.19		
	Euro 1	0.08		
	Euro 2	0.04		
	Euro 3	0.01		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.20	0.20	
	Euro 1	0.08	0.08	
	Euro 2	0.04	0.04	
	Euro 3	0.01	0.01	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.02	0.02	0.02
	Euro 1	0.02	0.02	0.02
	Euro 2	0.004	0.01	0.01
	Euro 3	0.004	0.01	0.01

Table 3-32 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13
	Euro 2	0.53	0.69	1.82
	Euro 3	0.23	0.62	1.58
	Euro 4	0.42	0.71	1.56
	Euro 5	0.34	0.58	1.29
Diesel cars	Pre-Euro 1	0.58	0.43	0.36
	Euro 1	0.32	0.22	0.18
	Euro 2	0.19	0.12	0.08
	Euro 3	0.06	0.04	0.02
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Petrol LGVs	Pre-Euro 1	11.69	8.17	6.69
	Euro 1	3.10	3.25	4.81
	Euro 2	0.10	1.15	3.12
	Euro 3	0.41	0.77	2.22
	Euro 4	0.41	0.77	2.22
	Euro 5	0.33	0.63	1.82
Diesel LGV	Pre-Euro 1	0.71	0.77	0.95
	Euro 1	0.55	0.46	0.43
	Euro 2	0.59	0.62	0.76
	Euro 3	0.17	0.13	0.12
	Euro 4	0.14	0.10	0.09
	Euro 5	0.11	0.08	0.08
Rigid HGVs	Pre-Euro I	2.14	1.96	2.06
	Euro I	1.38	1.30	1.37
	Euro II	1.17	1.12	1.18
	Euro III	1.04	0.96	0.98
	Euro IV	0.57	0.50	0.55
	Euro V	0.08	0.07	0.07

g CO/km	Standard	Urban	Rural	Motorway
	Euro VI	0.08	0.07	0.07
Artic HGVs	Pre-Euro I	2.49	2.26	2.39
	Euro I	2.17	1.98	2.10
	Euro II	1.80	1.69	1.83
	Euro III	1.91	1.74	1.86
	Euro IV	0.34	0.31	0.34
	Euro V	0.13	0.12	0.13
	Euro VI	0.13	0.12	0.13
Buses & coaches	Pre-Euro I	2.72	1.89	1.50
	Euro I	1.68	1.11	1.24
	Euro II	1.33	0.87	1.13
	Euro III	1.46	0.92	1.22
	Euro IV	0.13	0.08	0.09
	Euro V	0.13	0.09	0.09
	Euro VI	0.13	0.09	0.09
Mopeds, <50cc, 2st	Pre-Euro 1	13.80		
	Euro 1	5.60		
	Euro 2	1.30		
	Euro 3	1.30		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.08	23.67	
	Euro 1	10.61	15.62	
	Euro 2	8.39	12.35	
	Euro 3	4.63	6.82	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.59	22.01	25.84
	Euro 1	10.08	17.56	15.74
	Euro 2	5.27	8.98	9.51
	Euro 3	2.91	4.96	5.25

Table 3-33 NH_3 Emission Factors for Road Transport (in mg/km)

mg/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2	2	2
	Euro 1	70	131	73
	Euro 2	138	148	83
	Euro 3	2	29	65
	Euro 4	2	29	65
	Euro 5	2	29	65
Diesel cars	Pre-Euro 1	1	1	1
	Euro 1	1	1	1
	Euro 2	1	1	1
	Euro 3	1	1	1
	Euro 4	1	1	1
	Euro 5	1	1	1
Petrol LGVs	Pre-Euro 1	2	2	2
	Euro 1	70	131	73
	Euro 2	138	148	83
	Euro 3	2	29	65
	Euro 4	2	29	65
	Euro 5	2	29	65
Diesel LGV	Pre-Euro 1	1	1	1
	Euro 1	1	1	1
	Euro 2	1	1	1
	Euro 3	1	1	1
	Euro 4	1	1	1
	Euro 5	1	1	1
Rigid HGVs	Pre-1988	3	3	3
	88/77/EEC	3	3	3
	Euro I	3	3	3
	Euro II	3	3	3
	Euro III	3	3	3
	Euro IV	3	3	3

mg/km	Standard	Urban	Rural	Motorway
	Euro V	3	3	3
	Euro VI	3	3	3
Artic HGVs	Pre-1988	3	3	3
	88/77/EEC	3	3	3
	Euro I	3	3	3
	Euro II	3	3	3
	Euro III	3	3	3
	Euro IV	3	3	3
	Euro V	3	3	3
	Euro VI	3	3	3
Buses	Pre-1988	3	3	3
	88/77/EEC	3	3	3
	Euro I	3	3	3
	Euro II	3	3	3
	Euro III	3	3	3
	Euro IV	3	3	3
	Euro V	3	3	3
	Euro VI	3	3	3
Mopeds, <50cc, 2st	Pre-Euro 1	1		
	Euro 1	1		
	Euro 2	1		
	Euro 3	1		
Motorcycles, >50cc, 2st	Pre-Euro 1	2	2	
	Euro 1	2	2	
	Euro 2	2	2	
	Euro 3	2	2	
Motorcycles, >50cc, 4st	Pre-Euro 1	2	2	2
	Euro 1	2	2	2
	Euro 2	2	2	2
	Euro 3	2	2	2

Table 3-34 Benzo(a)pyrene Emission Factors for Road Transport (in g/km)

g B(a)P/km	Standard	All road types
Petrol cars	Pre-Euro 1	4.80E-07
	Euro 1	3.20E-07
	Euro 2	2.01E-07
	Euro 3	1.66E-07
	Euro 4	1.30E-07
	Euro 5	1.30E-07
Diesel cars	Pre - Euro 1	2.85E-06
	Euro 1	6.30E-07
	Euro 2	4.25E-07
	Euro 3	2.84E-07
	Euro 4	1.89E-07
	Euro 5	1.34E-07
Petrol LGVs	Pre-Euro 1	4.80E-07
	Euro 1	3.20E-07
	Euro 2	2.01E-07
	Euro 3	1.66E-07
	Euro 4	1.30E-07
	Euro 5	1.30E-07
Diesel LGVs	Pre-Euro 1	4.28E-06
	Euro 1	9.45E-07
	Euro 2	6.38E-07

g B(a)P/km	Standard	All road types
	Euro 3	4.25E-07
	Euro 4	2.84E-07
	Euro 5	2.01E-07
Rigid HGVs	Pre - Euro I	1.35E-06
	Euro I	6.75E-07
	Euro II	3.59E-07
	Euro III	3.31E-07
	Euro IV	1.53E-07
	Euro V	1.53E-07
	Euro VI	5.51E-08
Artic HGVs	Pre - Euro I	1.80E-06
	Euro I	9.00E-07
	Euro II	4.79E-07
	Euro III	4.41E-07
	Euro IV	2.04E-07
	Euro V	2.04E-07
	Euro VI	7.34E-08
Buses & coaches	Pre - Euro I	2.63E-06
	Euro I	1.31E-06
	Euro II	6.99E-07
	Euro III	6.44E-07
	Euro IV	2.97E-07
	Euro V	2.97E-07
	Euro VI	1.07E-07
Mopeds, <50cc, 2st	All	1.01E-06
Motorcycles, >50cc, 2st	All	1.01E-06
Motorcycles, >50cc, 4st	All	3.02E-06

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. Data from UKPIA on sulphur content of gas oil.

Gas oil consumption data from Office of Rail Regulation for passenger and freight trains for 2005-2013 combined with trends in train km 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.

Railways (stationary)
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 DECC (2014).

Railways (mobile)
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 the consumption of coal used to power steam trains and from gas oil.

Coal consumption data are obtained from DUKES. Estimates are made across the time-series from 1990-2013 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 NFR 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.

Vehicle kilometre data for intercity and regional trains are obtained from the UK's Department for Transport's Rail Emissions Model for 2009 to 2011 and then estimated for other years from train kilometre data from the Office of Rail Regulation's (ORRs) National Rail Trends Yearbook (NRTY) and data portal. Train kilometre data for freight trains are obtained for all years from the Office of Rail Regulation's (ORRs) National Rail Trends Yearbook (NRTY) and data portal.

Gas oil consumption by passenger and freight trains is obtained from the ORR's data portal for the years 2005 to 2013. No data was available for the years prior to 2009 and therefore fuel consumption for these years was estimated on the basis of the trend in train kilometres.

Fuel consumption by both passenger and freight rail is estimated to have increased year on year alongside increases in freight / train kilometres travelled up to and including 2012, but 2013 saw a decline in activity across both sources.

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 types. The fuel consumption is distributed according to:

- For passenger trains: Vehicle train kilometre and emission factor data taken from the Department for Transport's Rail Emissions Model and extrapolations for the years 2010 to 2013, assuming that the new trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations.

- For freight trains: Train kilometre data taken from the NRTY and extrapolations for the period 2010 to 2013 and the assumed mix of locomotives and fuel consumption factors for different types of locomotive. As with passenger trains, it has been assumed that the new freight trains introduced since 2012 are compliant with the European Non Road Mobile Machinery Stage IIIB regulations.

An improvement has been made to the benzene and 1,3-butadiene emission factors for the freight sector as these were thought to be too high; These are now consistent with the intercity emission factors.

The emission factor for SOx as SO_2 decreased from 0.76 kt/ Mt fuel in 2011 to 0.02 kt/ Mt fuel in 2012 in line with requirements introduced from the 1st January 2012 that limited the sulphur content of gasoil to 10ppm.

The emission factors shown in Table 3-35 are aggregate implied factors for trains running on gas oil in 2013, so that all factors are reported on the common basis of fuel consumption.

Table 3-35 Railway Emission Factors for 2013 (kt/Mt fuel)

	NO_x (as NO_2)	CO	NMVOC	SOx as SO_2	PM_{10}
Freight	108.4	14.8	6.1	0.02	1.5
Intercity	42.3	9.1	3.3	0.02	3.8
Regional	32.3	11.0	1.9	0.02	0.8

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 2013.

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 3-36.

Table 3-36 Sources of activity data and emission factors for navigation

		Source	NFR	Activity data			Emission factors
				Source	Base year	Time-series	
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 (2014)
		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 (2014)
		Fishing in non-UK sea territories	1A4ciii	MMO data on fish landings by sea territory from 1994-2013 and estimates of fish landed per trip			Entec (2010), EMEP/EEA Guidebook, UKPIA (2014)
		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	2000-2013	Trends for years before 2000 based on trends in fuel consumption derived by Entec for international shipping and trends in DfT data on number	Assumed same as international shipping vessels using fuel oil

		Source	NFR	Activity data			Emission factors
				Source	Base year	Time-series	
						of cruise passengers	
		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 (2014)
	Internatio nal (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 2013.

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, 2008c) 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 NFR 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 NFR 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 2013 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 1990-2013.
- 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 1990-2013
- 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, 2014).

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 2013.

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 3-37 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. 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 onwards at 1% and assumed to apply to all domestic vessels operating around the UK.

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 1990-2013 time-series. Information from UKPIA and DECC 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 1.4% sulphur in 2013. 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.

d) Summary of fuel consumption trends and implied emission factors

A summary of fuel consumption trends for coastal shipping and implied emission factors for 2013 are provided in Section 3.3.5.4.

3.3.5.2.2 Military shipping (1A5b)

Emissions from military shipping are reported separately under NFR code 1A5b. Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2014). 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 3.3.2.4.

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. In response to comments from reviewers during the In-Country review of the UK's Greenhouse Gas Inventory in 2012, emissions are estimated from 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)[20] produces a report annually on the UK fishing industry entitled "*UK Sea Fisheries Statistics*"[21]. This is classed as a National Statistics Publication. This report

[20] 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 DECC and the Department for Transport (DfT)

[21] https://www.gov.uk/government/collections/uk-sea-fisheries-annual-statistics

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[22] 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 fish landed in the UK from each of these areas from 1994-2013 (see for example, Table 3.8 in the 2013 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

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 (Webb et al, 2013).

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 2013 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)

In response to comments from expert reviewers during the In-Country review of the UK’s Greenhouse Gas Inventory in 2012, 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.

[22] ICES is the International Council for the Exploration of the Sea. See for example http://www.fao.org/docrep/009/a0210e/a0210e12.jpg

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 2013.

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/EEA Emissions Inventory Guidebook 2009[23].

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 to 2003[24]. 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.

Information held by the other OTs indicated that only Bermuda had any cruise ship sailings with the UK logged – one voyage in 2010[25]. 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 of 8 arrivals from Bermuda and 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 2013.

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.

[23] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009
[24] http://www.gibraltarport.com/cruise/schedules
[25] http://www.gov.bm/portal/server.pt/gateway/PTARGS_0_2_998_282_551_43/http;/ptpublisher.gov.bm;7087/publishedcontent/publish/ministry_of_tourism_and_transport/marine_and_ports/dept___marine_and_ports___shipping_news/2010_cruiseship_schedule_3.pdf

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 2013derived 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, 2009b). 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;
    - 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, 2009b) 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 – 2013:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on “Recreation and culture”[26]. 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)[27];

- Commercial passenger/tourist craft – Visit England, Visitor Attraction Trends in England 2013, Full Report (Page 13: "Total England Attractions")[28];

- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table PORT0104 - All UK port freight traffic, foreign, coastwise and one-port by direction[29]; 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)[30]

[26] http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html
[27] http://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE5
[28] http://www.visitengland.org/insight-statistics/major-tourism-surveys/attractions/Annual_Survey/
[29] https://www.gov.uk/government/statistical-data-sets/port01-uk-ports-and-traffic
[30] https://www.gov.uk/government/statistical-data-sets/dwf01-waterborne-transport

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 3-38 shows the trend in fuel consumption by inland waterways from 1990-2013 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.

Table 3-38 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	94.3	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	96.0	2.5	1.3	60.4	38.7	24.4
2003	96.4	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	2.0	91.3	55.9	36.9
2011	99.0	2.2	2.0	90.8	56.0	36.8
2012	96.5	2.3	2.0	94.1	57.5	38.1
2013	98.4	2.3	2.1	96.5	59.2	39.1

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 2013 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.

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 3.3.5.4 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 3-39 Total consumption of marine fuels (Mt fuel) for domestic and international shipping calculated by the Entec method compared 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, DECC 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 it was decided at a meeting with stakeholders (Defra, DECC, DfT and Entec) in July 2010 to adopt an approach for the inventory whereby the figures for domestic coastal shipping would be taken directly from the Entec study (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 Entec domestic shipping fuel consumption
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 3.3.5.4.

Table 3-40 Consumption of marine fuels by domestic and international shipping for 2007[a].

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.53	0.94
	International	1.04	0.63
	Total	1.57	1.57
	% domestic	34%	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) has 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 2013 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

3.3.5.4 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 3-41 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	0.025	0.09	1.60	0.35	0.008	1.12
1991	0.63	0.025	0.09	1.66	0.34	0.008	1.06
1992	0.59	0.025	0.09	1.68	0.34	0.008	1.09
1993	0.54	0.025	0.09	1.60	0.33	0.009	1.13
1994	0.52	0.025	0.10	1.53	0.35	0.009	0.94
1995	0.54	0.026	0.10	1.36	0.37	0.009	1.19
1996	0.54	0.034	0.10	1.57	0.37	0.009	1.25
1997	0.56	0.041	0.10	1.50	0.36	0.010	1.56
1998	0.45	0.038	0.10	1.79	0.37	0.011	1.41
1999	0.48	0.034	0.10	1.45	0.37	0.011	0.87
2000	0.46	0.032	0.10	1.46	0.35	0.012	0.62
2001	0.43	0.030	0.10	1.62	0.33	0.011	0.53
2002	0.41	0.029	0.10	1.21	0.35	0.008	0.45
2003	0.44	0.029	0.10	1.42	0.34	0.009	0.57
2004	0.47	0.028	0.10	1.32	0.34	0.010	0.93
2005	0.44	0.029	0.10	1.24	0.36	0.009	1.16
2006	0.43	0.038	0.10	1.65	0.34	0.013	1.47
2007	0.66	0.042	0.10	1.04	0.10	0.019	1.92
2008	0.65	0.074	0.10	1.03	0.10	0.011	2.45
2009	0.63	0.049	0.10	1.05	0.09	0.009	2.26
2010	0.62	0.064	0.10	0.96	0.09	0.011	1.85
2011	0.59	0.037	0.10	0.99	0.09	0.011	2.14
2012	0.55	0.040	0.10	1.12	0.08	0.009	1.54
2013	0.50	0.029	0.10	1.29	0.07	0.008	1.30

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 3-42 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2013. The units are in g/kg fuel and are implied by the figures in the Entec study and fuel sulphur content.

Table 3-42 2013 Inventory Implied Emission Factors for Shipping

Fuel	**Source**	**NO_x (as NO_2)**	**SOx as SO_2**	**NMVOC**	**PM_{10}**	**CO**
		g/kg	**g/kg**	**g/kg**	**g/kg**	**g/kg**
Gas Oil	Domestic (excl. fishing)	64.4	15.8	2.82	1.95	7.40
	Fishing	58.0	2.02	2.04	1.32	7.40
	International	69.3	17.7	2.74	1.85	7.40
Fuel Oil	Domestic	70.6	17.2	3.52	6.56	7.40
	International	77.7	27.6	2.92	6.75	7.40

Table 3-43 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2013.

Table 3-43 2013 Inventory Emission Factors for Inland Waterway Vessels

Fuel	NO_x (as NO_2)	SOx as SO_2	NMVOC	PM_{10}	CO
	g/kg	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.014	4.7	4.1	10.9
Gas Oil	42.5	0.020	4.7	4.1	10.9
Petrol	9	0.009	50	0.04	300

3.3.6 Other Sectors (1A4)

The mapping of NAEI categories to 1A4 Other Sectors is shown in Section 3.4. For most sources, the estimation procedure follows that of the base combustion module using DECC reported fuel use data and emission factors from Section 3.3. The NAEI category public service is mapped onto 1A4a Commercial and Institutional. This contains emissions from stationary combustion at military installations, which should be reported under 1A5a Stationary. Also included are stationary combustion emissions from the railway sector, including generating plant dedicated to railways. Also included in 1A4 are emissions from the 'miscellaneous' sector, which includes emissions from the commercial sector and some service industries.

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 below. Emissions from fishing vessels are included within the coastal shipping sector, due to the withdrawal of more detailed fuel use datasets that have historically been provided by DECC but are now determined to be of questionable accuracy.

3.3.7 Other

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.

Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data.

3.3.7.1 Estimation of Other Off-Road Sources (1Agvii, 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/EEA Guidebook (2009). Emission factors for more modern machinery based on engine or machinery-specific emission limits established in EU Non-Road Mobile Machinery Directive.

Activity data are derived from 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.

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 (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 *et al* (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 DECC on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. 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.

Further details of this review will be given in a separate report on the Improvement Programme currently under preparation. This will also include the findings from contacts with key industry groups using significant numbers of machinery that were not able to provide data for this inventory submission, but may be able to yield data in future.

The main changes made to activity data were:

- **Airport support equipment**: the review indicated that many of the smaller equipment had smaller engines than previously estimated, i.e. <56kW rated power which means they will not need to conform with Stage IV NRMM Directive regulations. Engine power was reduced to 40kW. To maintain the same overall fuel consumption rate for airport machinery, the activity rate for larger machinery (terminal tractors) was increased to compensate for the decrease in engine power for the small machinery.

- **Generator sets**: the hours of use for the large 100-1000kW generators was reduced from 844 hours/year to 500 hours/year. This followed discussions with organisations that use generators this size mainly as standby/emergency generators which are used less frequently than smaller generators. The new estimate comes from a study of the Swiss Federal office for the Environment.

- **Rollers, cranes and tracked bulldozers**: Lifetime reduced from 8.75 to 5 years (rollers), 11 to 6 years (cranes) and 15 to 10 years (bulldozers). Our study found that construction equipment is mostly hired rather than owned by the user so the population of used equipment is relatively young. The new shorter lifetimes were taken from Swiss Federal office for the Environment, except for bulldozers where a smaller reduction in lifetime was assumed compared with the Swiss study.

- **Dumpers**: Population increased from 850 to 8,500 units and engine power increased from 10 to 30kW. The increase in population was based on evidence from DfT licensing statistics.

These changes affected the estimated fuel consumption, but also the designated emission factor (where the engine size banding had changed) and the rate of turnover in the fleet.

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 2005-2013. 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 3-44.

For domestic house and garden machinery, historic and projected trends in number of households are used (CLG, 2011), for airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2013[31]), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2014) are used.

Table 3-44 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	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers

[31] http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&sglid=3&fld=2013Annual

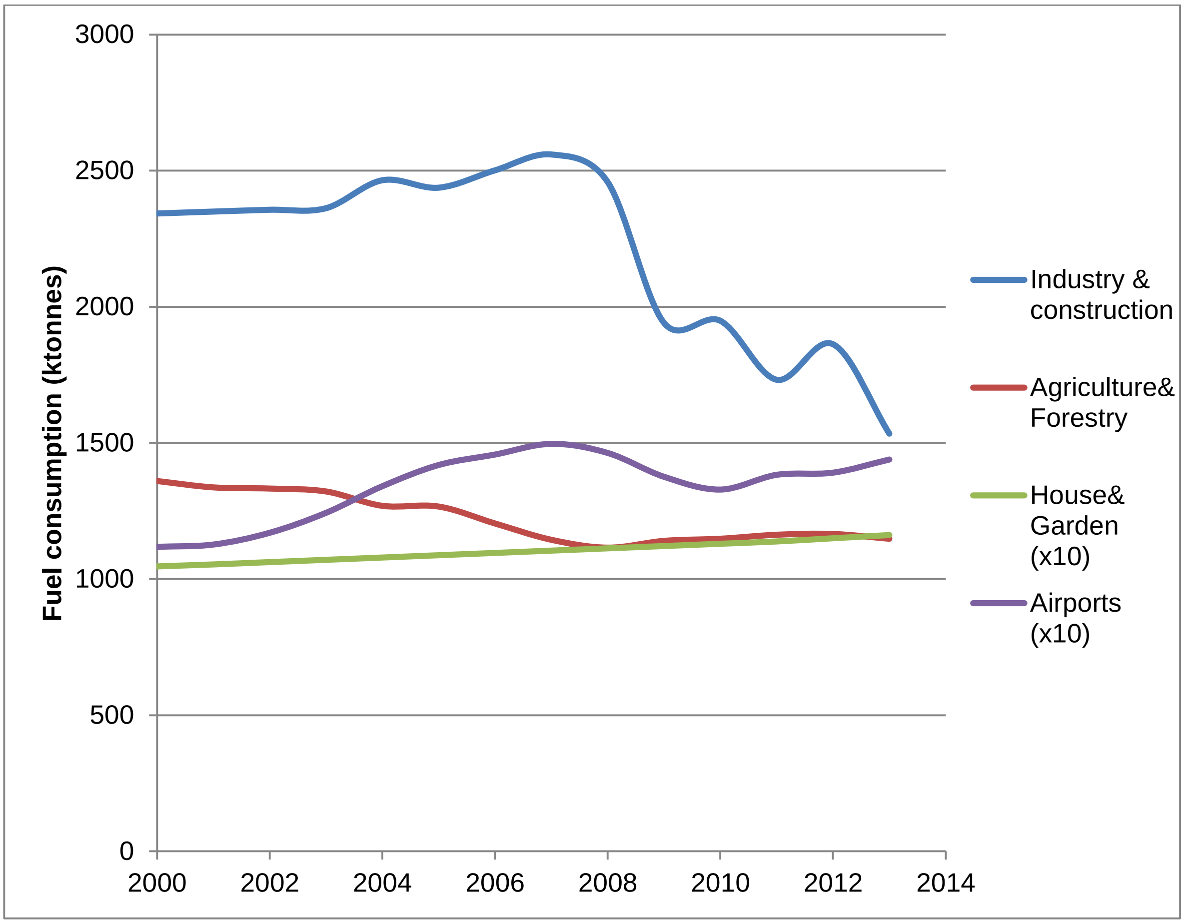
Category	Driver source	Machinery types
	Industry. Supplementary Tables July 2014", http://www.ons.gov.uk/ons/datasets-and-tables/index.html?pageSize=50&sortBy=none&sortDirection=none&newquery=output+in+the+construction+industry&content-type=Reference+table&content-type=Dataset Table 2b – Value of construction 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.	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 2014.	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 DECC 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

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.

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 Section 3.2.3.4. 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 3-2 shows 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 figures for airport machinery and house and garden machinery are multiplied by ten to put on the same scale as consumption by industry and construction machinery and agricultural machinery. The recent fall in consumption for the industry and construction machinery sector reflects the fuel reconciliation process used, but may also be explained by the recent economic downturn, particularly in the construction sector.



Note: Figures for house and garden and airport machinery are multiplied by 10 to put on the same scale as agriculture/forestry and industry and construction machinery.

Figure 3-2 Fuel consumption by off-road machinery in ktonnes fuel (2000-2013)

A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP/EEA (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 latest EMEP/EEA emission inventory guidebook (EMEP/EEA, 2009).

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 in 2013 are shown in Table 3-45 by fuel type.

The emission factors shown here for 2013 are generally the same as or lower than the factors for 2012. This is a consequence of the penetration of new machinery meeting the tighter emission regulations in the non-road mobile machinery fleet. Changes in some of the factors for industrial machinery and airport support equipment are also due to changes in activity parameters resulting from the improvement programme described above. The factors for SO_2 in 2013 reflect the sulphur content of fuels used, according to figures provided by UKPIA (2014).

Table 3-45 Aggregate Emission Factors for Off-Road Source Categories in 2013 (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	0.01	2.6
Domestic House&Garden	Petrol	668	3.2	0.03	0.01	23.2
Agricultural Power Units	Gas oil	16.7	17.5	1.4	0.02	3.3
Agricultural Power Units	Petrol	716	1.5	0.03	0.01	249
Industrial Off-road	DERV	14.9	23.7	2.2	0.01	5.1
Industrial Off-road	Gas oil	14.9	23.7	2.12	0.02	5.1
Industrial Off-road	Petrol	1034	6.2	0.03	0.01	39.3
Aircraft Support	Gas oil	12.6	21.3	1.6	0.02	3.7

[1] Based on sulphur content of fuels in 2013 from UKPIA (2014). 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 revisions to cruise data in the EMEP-EEA air pollutant emission inventory guidebook (EMEP, 2013). Small re-calculations occur for the following reasons:

- Corrections to climb thrust setting and engine bypass ratios for some aircraft engines
- Revisions to summary aircraft movement data on the CAA website
- Revisions to MOD fuel data

Road transport (1A3b)

Small re-calculations occur for the following reasons:

1) Revision to total diesel fuel sales in DUKES for 2007 (1.8% lower than the previous years' figures for 2007). This affects the estimates for fuel-based emissions such as SO_2;
2) 2012 emissions have been slightly revised due to an update to the petrol/diesel share for cars in Great Britain for 2012 and availability of ANPR data for 2013.

Rail (1A3c)
Fuel consumption data are now available from ORR for passenger and freight trains for 2011 and 2012 (the new data from ORR shows low fuel consumption than had been previously estimated using train km data). This affects the estimates for fuel-based emissions such as SO_2.

Navigation (1A3d)
Small re-calculations occur due to revisions in fuel consumption data:

- Gas oil consumption from domestic shipping has revised upward slightly for 2011, 2012 compared with last year's inventory due to a change in the activity drivers used for passenger vessels;
- Gas oil consumption from domestic fishing has revised upward slightly for 2009-2012 compared with last year's inventory due to a change in the fish landings data used as an activity driver.
- Revisions to some of the activity drivers used to estimate fuel consumption by inland waterway has led to a small change in emissions for 2010-2012; overall gas oil consumption in 2012 has revised upward slightly while petrol and diesel consumption in 2010-2012 have been revised downward slightly.

Off-road machinery (1A2gvii, 1A4bii, 1A4cii/iii, 1A3eii)
The inventory improvement programme led to changes in baseline activity data (population, engine size, hours of use, lifetime) and emission factors for certain construction machinery and airport support equipment.

Additional changes occurred due to revisions in activity drivers used to derive the time-series in fuel consumption:

- Changes in activity driver for industrial and quarrying machinery coupled with changes in gas oil used for other inventory sources leading to a change in overall fuel consumption for industrial off-road machinery in order to retain the gas oil fuel balance with DUKES
- Changes in number of households across the time-series from 2001 used to estimate fuel consumption by house and garden machinery
- Changes in gas oil consumption by agriculture in DUKES used as a driver for fuel consumption by agricultural machinery.

3.4 NFR 1A4: Combustion in the Residential / Commercial / Public Sectors

Table 3-46 Mapping of NFR Source Categories to NAEI Source Categories: Residential / Commercial / Public Sectors

NFR 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 3-47 Summary of Emission Estimation Methods for NAEI Source Categories in NFR 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	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Public sector combustion	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Railways - stationary combustion	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
Domestic combustion	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, IPCC, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SOx as SO_2.
House and garden machinery	AD x EF	DECC energy statistics	Default factors mainly from UK-specific research / analysis based on UK stock of combustion units, fuels and assumed

NAEI Source Category	Method	Activity Data	Emission Factors
			utilisation. Fuel analysis (UKPIA) for SOx as SO_2.
Agriculture - stationary combustion	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Default factors (USEPA, EMEP-EEA, IPCC, HMIP, UK-specific research). Fuel analysis (UKPIA) for SOx as SO_2.
Agricultural engines	AD x EF	Inventory agency estimate of fuel use by different mobile units	Default factors mainly from UK-specific research / analysis based on UK stock of combustion units, fuels and assumed utilisation. Fuel analysis (UKPIA) for SOx as SO_2.
Agriculture - mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	Default factors mainly from UK-specific research / analysis based on UK stock of combustion units, fuels and assumed utilisation. Fuel analysis (UKPIA) for SOx as SO_2.
Fishing vessels	AD x EF	Inventory agency estimate of fuel use across different shipping types, based on Entec 2010 study and DECC energy statistics	Default factors mainly from UK-specific research / analysis, including the Entec 2010 study on marine shipping. Fuel analysis (UKPIA) for SOx 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 (DECC, 2014). 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 3-46 relates the detailed NAEI source categories to the equivalent NFR source categories for stationary combustion. In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR (Nomenclature for Reporting) source category; however there are some instances where the scope of NAEI and NFR categories are 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 NFR system being used instead for submission under the CLRTAP.

Almost all of the NFR source categories listed in Table 3-46 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

3.4.2 General approach for 1A4

NFR Sector 1A4ai and 1A4b (i/ii) NO_x (as NO_2), PM_{10}, SOx as SO_2, NMVOC, CO, Pb, Cd, B[a]P and PCDD/PCDFs. Sector 1A4c (i/ii) is a key source only for PM_{10} and PCDD/PCDFs.

The NAEI 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, and an exclusively bottom-up approach utilizing reported emissions is not possible. Literature emission factors are therefore used extensively for 1A4.

3.4.3 Fuel consumption data

As stated previously, fuel consumption data are taken from DUKES. However, there are some areas of 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 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 is allocated to 'non-energy uses' in the commodity balance tables for petroleum products. Ricardo-AEA therefore include estimates of petroleum coke burnt by the domestic sector 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. Ricardo-AEA generate 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. 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, we continue to use the estimates of petroleum coke for the domestic sector as provided by industry;

- For 2009-2013, we use 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 'large combustion plant' 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 can best be estimated using an appropriate emission factor applied to national fuel consumption statistics taken from DUKES i.e. emissions are calculated according to the equation:

$$E(p,s,f) = A(s,f) \times e(p,s,f)$$

Where:

E(p,s,f)	=	Emission of pollutant *p* from source s from fuel *f* (Kilotonne [kt])
A(s,f)	=	Consumption of fuel *f* by source *s* (Megatonne [Mt] or Megatherm [Mth])
e(p,s,f)	=	Emission factor of pollutant *p* from source s from fuel *f* (kt/Mt or kt/Mth)

Emissions data are reported in the PI, SPRI, and NIPI for the 'large combustion plant' in the commercial and public sectors and the methodology allows for these reported data to be used in the case of NO_x (as NO_2) only. Data are also available for SOx as SO_2 but it is considered that the use of emission factors based on fuel composition data are more appropriate than use of plant-specific emissions data for SO_2. Reported data for other pollutants are extremely limited and are not used directly in the UK inventory for these sources.

For most pollutants, a single factor is applied for a given source category but, in the case of carbon monoxide, NO_x (as NO_2) and PM_{10} emissions for the commercial, agricultural and public sectors, a more detailed approach is taken. This is done in order to derive estimates that are more representative of the wide range of combustion appliances (e.g. different designs, thermal capacities) with different combustion performance, abatement and emission profiles that are evident within these source categories. The more detailed approach breaks down the source/fuel combinations by a) thermal input of combustion devices; b) type of combustion process (e.g. boilers, furnaces, turbines etc), and appliance-specific emission factors are then applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (US EPA, 2009), the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2013a) and UK emission factor surveys (Walker *et al*, 1985). An updated edition of the EMEP/EEA Guidebook was issued in 2013, and all NAEI emission factors from the previous edition of the Guidebook have been replaced with factors taken from this latest edition. In many cases, the recommended factor has changed between the previous and current Guidebooks, so the update has led to revisions to the NAEI as well. As a general rule, Guidebook factors tend to be used only for minor sources (with UK-specific data more likely to be used for major sources), so the Guidebook changes have not had much of an impact on UK emission totals.

Emissions data for NO_x (as NO_2) reported in the Pollution Inventory (EA, 2014) are also used in the generation of emission factors for larger combustion plants in the public and commercial sector source categories.

Emissions from domestic combustion are estimated using literature emission factors, generally a single factor across the entire time series. 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.

A constant emission factor is used across the time series for most domestic sector fuels, implying that combustion technology and, therefore, emission rates have not changed. This is an over-simplification since a range of developing technologies is available for all fuels, but it also reflects the absence of any data on the proportion of fuels consumed in different types of appliance.

In 2014 compilation work a the method for estimating Emission Factors for domestic solid fuel combustion was revised, so as to incorporate literature emission factors for specific technologies and appliances from the revised Guidebook. The proportions of each type of appliance using each fuel were based primarily on information from the 2007 report 'Preparatory Study for Eco-design Requirements of EuPs, Lot 15: Solid fuel small combustion installations'[32], with some more detailed splits utilising expert ellicitation. Since no other data has been sourced to indicate the change over time in the population of appliance types, the aggregate Emission Factors with respect to energy for each activity are non-time-dependant. However, it is intended that this will be reviewed and revised as new data becomes available to facilitate the calculation of time-dependant Emission Factors.

The NAEI does include a modelled approach to estimate changes in emission rates for domestic gas combustion. This method is necessarily still very simplistic, assuming 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
- 2005-2013 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 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.

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.

Some emission estimates for 1A4 rely partially upon emissions data reported in the PI, SPRI and NIPI. Section 3.1.7 discusses QA/QC issues regarding these data.

3.4.6 Recalculations in NFR Sector 1A4

Significant revisions to estimates for 2012 compared with the previous submission include:

- The changes in the way that DUKES records use of petroleum coke results in the re-allocation of some emissions from the NAEI source 'domestic combustion of petroleum coke' to the source 'domestic combustion of solid smokeless fuels'. For example, in the case of SOx as SO_2, the former decreases, reducing UK emissions in 2012 by 2.7%, but the latter increases by the same amount so there is no overall change in UK emissions.
- Revisions to emission factors for domestic solid fuel combustion for PM_{10}, CO and NO_x (as NO_2) result in revisions across the time series for these pollutants. The effect of these revisions for PM_{10} and NO_x (as NO_2) is to decrease the national total by 0.6% and 1.8% in 2013, and around 0.5-1.5% across the rest of the time series. The revision to CO emissions is negligible, increasing the national total by just 0.10% in 2013, and no more than 0.2% in any other historic inventory year.

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32 http://www.eceee.org/ecodesign/products/solid_fuel_small_combustion_installations/BIO_EuP_Lot%2015_Task3_Final.pdf

3.5 NFR 1B1 & 1B2: Fugitive Emissions from Fuels

Table 3-48 Mapping of NFR Source Categories to NAEI Source Categories: Fugitive Emissions from Fuels.

NFR Category	Pollutant coverage	Source
1 A 1 a Fugitive emission from solid fuels: Coal mining and handling	NA (not applicable)	
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_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
		Ship purging
1 B 2 b Natural gas (exploration, production, processing, transmission, storage, distribution and other)	NO_x (as NO_2) , NMVOC, 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_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 3-49 Summary of Emission Estimation Methods for NAEI Source Categories in NFR Category 1B

NAEI Source Category	Method	Activity Data	Emission Factors
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	DECC energy statistics, ISSB, EU ETS	Operator data reported under IPPC/EPR, Tata Steel, SSI, default factors (USEPA, EIPPCB)
Iron and steel flaring	UK I&S model, AD x EF	DECC energy statistics, EU ETS, Tata Steel	Operator data reported under IPPC/EPR; Default factors (EMEP-EEA 2013, IPCC 2006, Passant 2002)
Solid smokeless fuel production	UK model for SSF production, AD x EF	DECC energy statistics	Operator data reported under IPPC/EPR, default factors (EMEP-EEA 2013, EIPPCB)
Upstream Gas Production - Gas terminal storage	Operator data, time series assumptions	EEMS, Oil and Gas UK, DECC energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using DECC oil and gas production statistics.
Upstream Gas Production - process emissions	Operator data, time series assumptions	EEMS, Oil and Gas UK, DECC energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using DECC oil and gas production statistics.
Upstream Oil Production - process emissions	Operator data, time series assumptions	EEMS, Oil and Gas UK, DECC energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using DECC oil and gas production statistics.
Upstream Oil Production - Oil terminal storage	Operator data, time series assumptions	EEMS, Oil and Gas UK, DECC energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using DECC oil and gas production statistics.
Upstream Gas Production - Offshore Well Testing	AD x EF	EEMS, Oil and Gas UK, DECC 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 DECC oil and gas production statistics.
Upstream Oil Production - Offshore Well Testing	AD x EF	EEMS, Oil and Gas UK, DECC 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 DECC oil and gas production statistics.
Upstream Oil Production - Offshore Oil Loading	AD x EF	EEMS, Oil and Gas UK, DECC 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 DECC oil and gas production statistics.
Upstream Oil Production - Onshore Oil Loading	AD x EF	EEMS, Oil and Gas UK, DECC 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 DECC oil and gas production statistics.
Gasification processes	AD x EF	DECC energy statistics	Operator reported emissions under IPPC/EPR
Petroleum processes	Operator reported emissions	DECC energy statistics	Operator reported emissions under IPPC/EPR
Refineries – Drainage, General, Process, Tankage	Operator reported emissions	UKPIA, DECC energy statistics	Operator reported emissions under IPPC/EPR, UKPIA data for all refinery sources.
Petrol stations and terminals (all sources)	AD x EF	DECC 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	DECC 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	DECC energy statistics	UK periodic research (IoP) and annual data on fuel vapour pressures (UKPIA) and temperature data (Met Office).
Ship purging	UK research	n/a	Rudd & Mikkelsen, 1996
Gas transmission network leakage	UK gas leakage model	National Grid, Northern Gas Networks, Scotia Gas, Airtricity, Wales and West Utilities	Annual gas compositional analysis by the GB gas network operators.
Gas distribution network leakage	UK gas leakage model	National Grid, Northern Gas 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	DECC energy statistics. Leakage % of total by end	Annual gas compositional analysis by the GB gas network operators.

NAEI Source Category	Method	Activity Data	Emission Factors
		user sector based on assumptions on unit leakage, operational cycles of gas-fired heaters, boilers, cookers.	
Upstream gas production - gas flaring	AD x EF	EEMS, Oil and Gas UK, DECC 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 DECC 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, DECC energy statistics	Operator data reported under EEMS, with emissions reported since 1998. Earlier data based on estimates from UK Oil and Gas and using DECC oil and gas production statistics.
Upstream oil production - gas venting			
Refineries - flares	Trade association estimates	UKPIA, DECC energy statistics	Operator reported emissions under IPPC/EPR, UKPIA data for all refinery sources.

3.5.1 Classification of activities and sources

The following NFR source categories are key sources for major pollutants in 1990 and / or 2013:

- 1B1b: Pb (2013), PAH (2013)
- 1B2a(i): NMVOC (1990, 2013)
- 1B2a(iv): NMVOC (1990, 2013)
- 1B2a(v): NMVOC (1990, 2013)
- 1B2b: NMVOC (2013)
- 1B2c: NMVOC (2013)

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 gas flaring and venting volumes at UK oil and gas production sites (DECC, 2014);
- refinery activity and source emission estimates reported by refinery operators via the trade association (UKPIA, 2014);
- upstream oil & gas activity data from the EEMS reporting system managed by the DECC Offshore Inspectorate (DECC, 2014b); 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 2014).

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 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 NFR 1B1b: Solid fuel transformation

NFR Sector 1B1b is a key source category in the UK for Pb and PAH in the 2013 inventories. The main source of emissions of these pollutants is coke production, which alone is responsible for around 3% of total lead and total Benzo[a]pyrene emissions in 2013, .

Solid fuel transformations include the manufacture of coke, charcoal and other solid smokeless fuel (SSF); the sector also includes emissions from iron and steel flaring of coke oven gas from fuel transformation processes. Emissions 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 SSF manufacturing sites are reported annually to the IPPC/EPR 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 IPPC/EPR 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/EEA, 2013a), BREF notes, US EPA AP-42 and industry-specific studies.

Operator-reporting of annual emissions under IPPC/EPR is less comprehensive for smokeless solid fuel production, and therefore emissions in the UK inventory are estimated using literature factors and in some cases (e.g. SOx as SO_2) using a mass balance approach.

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. 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 IPPC/EPR permits. Emission estimates for the sector can be based on the emission data reported for individual sites:

UK Emission $= \Sigma$ 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 NFR 1B2: Fugitive emissions from oil & gas industries

The following are all key source categories for NMVOC (only) in 2013:

- 1B2c (4.2% 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 2013 are almost exactly a 50:50 split between flaring and venting sources; 1B2c emissions in 2013 from oil production far exceed that from gas production, by a factor of almost 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 2013, the oil loading / unloading emissions account for around 83% of this NFR sector total;

- 1B2b (3.8% 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 (95% of the NFR sector total in 2013) is the estimated fugitive losses from the downstream gas transmission and distribution networks;
- 1B2av (2.8% of the UK NMVOC inventory total). These emissions are from downstream oil distribution systems such as spillages storage and loading / unloading losses at petrol stations and intermediate oil storage terminals. The highest emitting sources are from petrol station vehicle refuelling activities and from loading/unloading of refined petroleum products into sea-going tankers for transfer or export; and
- 1B2aiv (2.6% of the UK NMVOC inventory total). These are fugitive releases at refineries from process sources, drainage and tankage.

There are no key source categories for any other pollutant in the 2013 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 some 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 NFR 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 DECC Offshore Inspectorate, which includes emission estimates of NMVOC, CO_2, CH_4, CO, NO_x (as NO_2), SO_2 and fluorinated gases reported by emission source and (where appropriate) fuel type. Under 1B2ai, emissions are reported from process emissions (such as acid gas treatment, degassing of associated oil), oil loading at offshore rigs (into ships) and at terminals (from ships to storage vessel), fugitive releases (including tank storage emissions), and emissions from well testing. All upstream oil & gas production sites operate under license to DECC, 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 DECC 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 upstream sites, there are some additional sites for petroleum and gas processing (e.g. gas compressor sites on the UK gas distribution network) that also report their emissions annually under IPPC/EPR to the Environment Agency, SEPA and NIEA. 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 NFR 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, 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, 2014), 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 9 UK refineries that are currently operating. 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.

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 distributed to approximately 60 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) Mains (National Grid, 2014);
- Losses from Low Pressure Distribution Network (National Grid, Scotia Gas, Northern Gas Networks, Wales & West, Airtricity; all 2014); and
- Other losses, from Above Ground Installations and other sources (National Grid, Scotia Gas, Northern Gas Networks, Wales & West; all 2014).

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 (DECC, 2014)
- Numbers of appliances in the UK in these sectors (Inventory agency estimate, 2014)
- 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, 2014, based on UK energy efficiency research for recent Government programmes)

The emissions of NMVOC from these sources are the calculated thus:

Emission (t) = UK mean NMVOC concentration in gas (t/kt) x total gas leakage (kt)

1B2c Oil and Natural Gas: Venting and Flaring

Emissions from gas flaring and venting at oil production sites, 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 DECC Offshore Inspectorate (DECC, 2014), whilst refinery flaring estimates are generated by operators and reported annually to the inventory agency via the refinery trade association (UKPIA, 2014). 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 (UK Oil and Gas: 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 DECC-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 perodic 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, DECC, 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 DECC and the UK environmental regulatory agencies, comparing and aligning data from DUKES, EEMS and EU ETS. In the latest inventory cycle, revisions to emission estimates from gas flaring for three installations (Clair platform, Hound Point terminal, Schiehallion platform) over 2011 and 2012 have led to small increases in NO_x (as NO_2), whilst a small gap in NMVOC emissions from one terminal (Barrow) in 2012 has also been corrected.

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.

3.5.5 Recalculations in NFR sectors 1B1 and 1B2

The most significant recalculations in NFR 1B1 and 1B2 since the previous submission are:

- Activity data for SSF manufacture presented in UK energy statistics (DECC, 2014) have been revised to include new allocations in recent years of petroleum coke to the SSF feedstock materials. In 2012 this has led to increases in estimated emissions of SO_x (as SO_2) by 0.135 kt SO_x (as SO_2) in NFR 1B1b.
- Revisions to gas flaring estimates for NO_x (as NO_2) in 2012 for two offshore installations (Clair, Schiehallion) have increased the UK estimates by 0.057 kt NO_x (as NO_2) in NFR 1B2c.
- Revisions to data on fugitive releases from the natural gas distribution and transmission system due to new data from operators for 2012 and a small revision to the compositional analysis for 2012 have led to overall changes in NMVOC emission estimates of -1.81 kt NMVOC from NFR 1B2b.
- New estimates of PM_{10} emissions from charcoal production in the UK have been added across the time series. In 2012 this led to an increase of 0.78 kt PM_{10} in NFR 1B1b.

4. NFR 2: Industrial Processes

Table 4-1 Mapping of NFR Source Categories to NAEI Source Categories: Industrial Processes (excluding solvent use).

NFR 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	Operator reporting under IPPC/EPR & 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	UK-specific factors
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 IPPC/EPR & UK-specific factors / research for PCDD/PCDFs (HMIP), PM_{10} from glass sector
		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	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Chemical industry – sodium pentachlorophenoxide	
		Chemical industry – trichloroethylene	
		Chemical industry – alkyl lead	Operator reporting under IPPC/EPR & 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 IPPC/EPR & 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 IPPC/EPR, 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 IPPC/EPR, plus additional operator reporting and literature sources for metal emissions
		Primary aluminium production - general	
		Primary aluminium production - pre-baked anode process	
		Primary aluminium production - vertical stud Soderberg process	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Secondary aluminium production	Operator reporting under IPPC/EPR, 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	
		Hot-dip galvanising	Literature factors (EIPPCB, EMEP/EEA, HMIP, UK industry research)
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 IPPC/EPR
		Tin production	Literature factors (HMIP, UK industry research)
2 D 1 Pulp and Paper	NH_3	Paper production	
2 D 3 a	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	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	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	
		Industrial coatings - vehicle refinishing	
		Industrial coatings - commercial vehicles	
		Industrial coatings - wood	
		Industrial coatings - marine	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		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	NMVOC	Leather degreasing	UK industry data and country-specific factors
		Surface cleaning - 111-trichloroethane	
		Surface cleaning - dichloromethane	
		Surface cleaning – tetrachloroethylene	
		Surface cleaning - hydrocarbons	
		Surface cleaning - oxygenated solvents	
2 D 3 f	NMVOC	Dry cleaning	UK industry data and country-specific factors
2 D 3 g	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	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	
		Printing - flexible packaging	Operator-reported data
		Printing - publication gravure	
2 D 3 i	NMVOC, PAHs	Seed oil extraction	Operator-reported data
		Other solvent use	UK industry data and country-specific factors (HMIP, Giddings et al)
2 H 2 Food and Drink	NMVOC and NH_3	Bread baking	Literature factors (HMIP, UK industry research)

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		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 IPPC/EPR
		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 and Particulate Matter	Wood products manufacture	Literature factors (USEPA AP-42)
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 NFR source categories.

The following NFR source categories are key sources for major pollutants: 2A5a (TSP, PM_{10}), 2B10a (Hg), 2C1 (CO, TSP, PM_{10}, $PM_{2.5}$, Pb, Hg, Cd, PCDD/ PCDFs), 2C7c (Hg, Pb, Cd), 2D3a (NMVOC), 2D3d (NMVOC, TSP, PM_{10}, $PM_{2.5}$), 2D3e (NMVOC), 2D3i (NMVOC) and 2H2 (NMVOC). Description of the inventory methodology will 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; many of the ONS activity data publications (such as PRODCOM) 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 hence are of limited usefulness for inventory estimation methods. Therefore the inventory agency uses the limited published data and 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 a few cases where emissions data are available directly for all sites in a sector (for example from the PI/SPRI/NIPI) and where activity data cannot easily be estimated, an arbitrary figure (usually 1) is used as the activity data in the inventory 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 remain constant in those years.

Emission estimates for NFR sector 2D3 are predominantly based on solvent consumption data supplied by industry or regulators; published sources of 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. Information direct from industrial contacts is therefore regarded as the best available.

4.3 Methodology for mining and quarrying (NFR 2A5a)

The UK has currently few 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 is now trivial in scale. 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 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 chemical processes (NFR 2B10a)

The UK has a large and varied chemical industry and process operators are required to report emissions in the PI, SPRI 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, 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 for which there is a high probability that emissions are process-related.

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 & NIPI are subject to the appropriate regulator's QA/QC procedures and are regarded to be good quality data for most pollutants. For NMVOC emissions data, however, the reported data are not all used directly, as further quality checks are conducted by the inventory agency to address known issues that affect data accuracy, completeness and time series consistency. Emissions of organic pollutants have, particularly during the early years of the regulators' inventories, been reported in such a way that double-counting of emissions is possible in some cases, while in other cases, inter-annual variations in reported emissions could indicate gaps in the emissions data. The NAEI estimates for NMVOC from chemical industry processes therefore rely upon a significant degree of interpretation of the PI/SPRI/NIPI data with some 'gaps' being filled (by using reported data for the same process in other years) 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 PI/SPRI/NIPI data.

Emission estimates for HCB from NFR 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 NFR 2B5a are assumed to be zero for 2009 onwards.

4.5 Methodology for iron & steel processes (NFR 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.

UK 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.

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. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. 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 cannot be collected and is lost and emissions from these gas losses are reported under NFR 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 NFR 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 2013 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 & SPRI for other electric arc steelworks and data covering 1998 to 1999 in the case of integrated steelworks. 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.

4.6 Methodology for aluminium processes (NFR 2C3)

The UK had one small primary aluminium producing site at the end of 2013, 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 largest secondary processes report emissions in the PI, SPRI, or NIPI and these data are used in the NAEI. It is possible that some small 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 or NIPI. There are no data available to the inventory agency to enable emissions to be estimated from any such sites, but their omission does 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 operating sites have closed emissions are zero or their contribution to the total PAHs emission is negligible.

4.7 Methodology for zinc processes (NFR 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 only since no significant processes operate in Scotland or Northern Ireland.

4.8 Methodology for copper processes (NFR 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 or Northern Ireland.

4.9 Methodology for other non-ferrous processes (NFR 2C7c)

The UK has a large number of mainly small foundries, which are regulated by local authorities. Unlike the non-ferrous metal processes covered by 2C5, 2C6, 2C7a, and 2C7b, these processes do not report emissions in the PI, so there is no data on which to base a bottom-up emission estimate. Emissions are instead generated using UK foundry activity data and UK-specific emission factors.

4.10 Methodology for solvent use (NFR 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 carried out 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. Processes such as publication gravure printing, seed oil extraction, and dry cleaning include recovery and re-use of solvent, although new solvent must be introduced to balance any fugitive losses. Emission estimates for these sectors can be made using solvent consumption data (i.e. assuming that purchases of new solvent is equal to emissions of solvent) or by using solvent mass balance data at a site by site level.

Manufacturers of paints, inks and other coatings also wish to minimise losses of solvent but in these cases, the solvent is not recovered and re-used, but is instead contained in products which are then used elsewhere. Emission estimates for these sectors can be made using emission factors (i.e. assuming some percentage loss of solvent).

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.

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	Solvent consumption data for the sector, assumption that little or no solvent is recovered or destroyed.

NAEI Source Category	General method
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	
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.
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.

4.11 Methodology for food and drink processes (NFR 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. Emission factors for other significant sources are taken from the EMEP/EEA Guidebook (EMEP/EEA, 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), because of the 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.

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.

4.12 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 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 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.

4.13 Recalculations in NFR 2

The most significant recalculations in NFR 2 since the previous submission are:

- Estimates of PCDD/PCDFs emissions in 2012 from electric arc furnaces and secondary aluminium production have been reduced by 6 g-ITEQ and 26 g-ITEQ as a result of corrections.

5. NFR 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 NFR 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 NFR Source Categories to NAEI Source Categories: Agriculture

NFR 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	
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 - Swine	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/wastes	
3B4e	Manure management - Horses	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – horses/wastes	UK Factors
3B4gi	Manure mangement - Laying hens	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - laying hens/wastes	
3B4gii	Manure mangement - Broilers	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – broilers/wastes	
3B4giii	Manure mangement - Turkeys	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – turkeys/wastes	
3B4giv	Manure management - Other poultry	NH_3, NMVOC, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock - other poultry/wastes	
3B4h	Manure management - Other animals (please specify in IIR)	NH_3, $PM_{2.5}$, PM_{10}, TSP	Agriculture livestock – deer/wastes	
3Da1	Inorganic N-fertilizers (includes also urea application)	NH_3	Agricultural soils	Literature sources
3Da2a	Animal manure applied to soils	NH_3	Agriculture livestock - Animal manure applied to soils	Literature sources
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	Literature sources
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	
			Agricultural pesticide use - chlorthal-dimethyl use	
			Agricultural pesticide use - quintozine	UK Factors
3F	Field burning of agricultural residues	NOx (as NO_2), NMVOC, Particulate Matter, PCDD/ PCDFs, PAHs, PCBs for 1990-1992 only	Field burning	

The following NFR source categories are key sources for major pollutants: 3B1a (NH_3, NMVOC, TSP), 3B1b (NH_3, NMVOC, TSP), 3B3 (NH_3, TSP), 3B4gi (PM_{10}, TSP), 3B4gii (PM_{10}, TSP), 3B4giii (PM_{10}, TSP), 3B4giv (TSP), 3Da1 (NH_3), 3Da2a (NH_3), 3Da3 (NH_3), 3Dc (PM_{10}), 3Df (HCB). Description of the inventory methodology will focus on these categories.

5.2 Activity statistics

National statistics on livestock numbers are obtained from June Agricultural Survey statistics provided by each Devolved Administration (England, Scotland, Wales and Northern Ireland). The UK inventory approach uses a number of subcategories of each major livestock category, as detailed in Table 5-2. The UK total emissions 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.* (2014), together with derivation of activity data and emission factors.

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

A review of livestock housing and manure management practices conducted by Ken Smith (ADAS) as part of Defra project AC0114 was used as the basis of developing the time series 1990 to 2014 of livestock housing and manure management practices for each country (England, Wales, Scotland and Northern Ireland). Uptake of mitigation methods was included in the review (Misselbrook *et al.* (2014)).

The proportion of sheep in uplands was provided by ADAS (personal communication Diane Spence) (Misselbrook *et al.* (2014)).

Manure output values per animal are from Smith and Frost (2000) and Smith *et al.,* (2000). Nitrogen excretion values are derived from Cottrill and Smith (2007). Manure Total Ammoniacal Nitrogen contents data are from expert opinion. The proportion of waste produced as slurry or farm yard manure (FYM) was derived from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith *et al.*, 2000c, 2001a, 2001b), (Misselbrook *et al.* (2014)).

Account is taken of time spent indoors and litter/bedding is included for FYM outputs. For milking dairy cattle, time indoors is increased to account for time in summer spent in buildings or yards for milking operation (equivalent to 3h per day throughout the grazing period). N excretion values are derived from Cottrill, B.R. and Smith,K.A. (2007) 'Nitrogen output of livestock excreta', Final report, Defra Project WT0715NVZ, (Misselbrook *et al.* (2014)).

Manure volume output data were derived by K Smith (ADAS) using data from Smith et al. (2000c, 2001a, 2001b) with interpretation for animal place and annual outputs. Nitrogen excretion data were derived from project WT0715NVZ with interpretation by B Cotteril and K Smith (ADAS) (Misselbrook *et al.* (2014)).

Tonnages of poultry litter incinerated in each year were obtained directly from EPRL and Fibropower websites (K Smith, ADAS) (Misselbrook *et al.* (2014)).

Fertiliser usage in England, Wales and Scotland were derived from the British Survey of Fertiliser Practice 2008 (http://www.defra.gov.uk/environ/pollute/bsfp/index.htm) and for Northern Ireland from DARDNI stats (http://www.dardni.gov.uk/econs/.htm) (Misselbrook *et al.* (2014)).

Statistics relating to the sale and use of pesticides within the UK are published by FERA (Food and Environmental Research Agency):
http://www.fera.defra.gov.uk/scienceResearch/science/lus/pesticideUsage.cfm

There has been a general decline in numbers of cattle, pigs and sheep since the mid-1990s, and a more recent decline in poultry numbers following increases between 1990 and 2000. Specifically between 2012 and 2013, there was a 0.6% decline in total cattle numbers (1.6% decline for dairy cows), a 8.9% increase in pig numbers, a 2% increase in sheep numbers and a 1.7% decrease in poultry numbers (with a 0.1% decrease in the laying hen flock and a 2.0% increase in broiler numbers).

Total fertiliser N use has also declined since 1990, although the decline has levelled out to some extent in recent years. Use of urea-based fertilisers which are associated with much higher ammonia emission factors has increased as a proportion of total fertiliser N use. However between 2012 and 2013, total fertiliser N use decreased by 0.6% and there was also a small decrease in the proportion applied as urea-based fertiliser from 24% to 19% of total fertiliser N applied.

5.3 Methods for estimating emissions

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 animal housing, manure storage, manure spreading and grazing animals. 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 is described in more detail in Misselbrook *et al.* (2014).

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).

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 2013 EMEP/EEA Emission Inventory Guidebook. A Tier 2 methodology has been used, full details of the algorithms used being given in EMEP/EEA (2013), 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} emissions from livestock housing and manure management were calculated for the first time in the latest inventory. $PM_{2.5}$ 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 2013 EMEP/EEA Emission Inventory Guidebook. A Tier 2 methodology has been used, full details of the algorithms used are given in EMEP/EEA (2013). 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.

5.4 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-AEA 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-AEA (the central inventory agency) and Defra for further checking prior to inclusion in the UK NAEI.

5.5 Recalculations in NFR3

Emissions from goats and deers are now reported separately for the 2013 NAEI; previously they were included together with sheep waste.

6. NFR 5: Waste

Table 6-1 Mapping of NFR Source Categories to NAEI Source Categories: Waste

NFR Category (5)	Pollutant coverage	NAEI Source Category	Source of EFs
5 A Biological treatment of waste - Solid waste disposal on land	NMVOC, NH_3, Hg, PCDD/ PCDFs and PCBs	Landfill	UK model and assumptions (NMVOC), UK industry research (NH_3, PCBs, PCDD/PCDFs)
		Application to land (PCB)	UK literature sources (Dyke, Wenborn)
		Waste disposal - batteries	
		Waste disposal - electrical equipment	
		Waste disposal - lighting fluorescent tubes	
		Waste disposal - measurement and control equipment	
5 B 1 Biological treatment of waste - Composting	NH_3	Composting (NH_3)	Literature factors (Wichmann, CEH, Dyke et al)
5 B 2 Biological treatment of waste – Anaerobic digestion at biogas facilities	NH_3	Anaerobic Digestion (NH_3)[1]	Literature factors (Wichmann, CEH, Dyke et al)
5 C 1 a Municipal waste incineration (d)	All CLRTAP pollutants *(except Se, Indeno (1,2,3-cd) pyrene)*	Incineration	Operator reporting under IPPC/EPR and literature factors (EMEP/EEA, HMIP, USEPA) Operator reporting under IPPC/EPR 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	
5 C 1 biii Clinical waste incineration (d)		Incineration - clinical waste	
5 C 1 biv Sewage sludge incineration (d)		Incineration - sewage sludge	
5 C 1 bv Cremation	NO_x (as NO_2), NMVOC, SOx 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	Accidental fires – vehicles (PDCC/Fs) Regeneration of activated carbon	Literature factors (Wichmann, CEH, Dyke et al)
		RDF manufacture (PCB)	

[1]Note: NH_3 emissions from anaerobic digestion are described in this chapter, but are reported as a Memo Item in the inventory.

6.1 Classification of activities and sources

Table 6-1 relates the detailed NAEI source categories for waste used in the inventory to the equivalent NFR source categories. NFR 5 source categories are key sources for one or more pollutants in the UK inventory in 2013 (except 5C1a, as there has been no significant MSW incineration without heat or electricity production in the UK since 1996 apart from a waste incinerator on the Scilly Isles, see Section 3.1.4):

- 5A is a key source for Hg
- 5C1bv is a key source for Hg
- 5C2 is a key source for d PCDD/ PCDFs, PM_{10}, and $PM_{2.5}$

6.2 Activity statistics

Waste-derived fuels used for electricity and heat generation are reported in DUKES (DECC, 2014) and these data are used to derive emission inventory estimates for municipal waste incinerators prior to 1997. Other national statistics on waste sector activities are limited in coverage and detail across the time series. Waste data reporting for later years are more comprehensive and the inventory agency obtains annual statistics on waste incineration facilities, landfill waste aggregated activity data and waste water treatment volumes and organic load from municipal and trade waste water. Data on aggregated waste landfilled extends back to 1945.

These annual datasets are supplemented by periodic studies, such as waste compositional surveys, which are used within the UK landfill waste decay model, MELMod.

Activity statistics for earlier years are derived either from periodic studies or surveys, or through extrapolation of data using proxy information or based on reported emissions data, where available, from regulatory agencies.

6.3 Methods for estimating emissions

NFR 5A: Biological treatment of waste - Solid waste disposal on land

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. Further calculations are then carried out to estimate:

- the quantity of methane captured and combusted in landfill gas engines;
- the quantity of methane captured and flared;
- the proportion of remaining methane oxidised in the surface layers of the landfill.

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, PCBs and PCDD/PCDFs are calculated by assuming a fixed ratio of the other released substances to methane in landfill gas emissions. The factors used in this calculation were taken from published data relevant to the UK.[33,34]

Emissions of PCDD/PCDFs are based on the activity estimates derived within the MELMod landfill model for methane emitted to the atmosphere and methane flared at landfills, applying emission factors derived from research by the regulatory authority (HMIP) in 1995. PCB emissions to atmosphere are estimated using emissions factors from UK research (Dyke et al, 1997), whilst ammonia emissions are estimated using emission factors provided by the Centre of Ecology and Hydrology (CEH, 2013).

Emissions of mercury from waste disposal of batteries, electrical equipment, fluorescent lighting tubes and monitoring and control equipment are based on factors derived from UK research (Wenborn et al, 1998).

NFR 5B: Biological treatment of waste – Composting and Anaerobic digestion at biogas facilities
Emissions of ammonia from composting and anaerobic digestion[35] are based on national statistics for these activities and research conducted by the Centre of Ecology and Hydrology (CEH, 2013). Emissions of PCBs from RDF manufacture are estimated by the inventory agency based on UK research (Dyke et al, 1997).

NFR 5C: Waste Incineration
In the UK all facilities that incinerate municipal solid waste (MSW), chemical waste, clinical waste, and sewage sludge are regulated under IPPC/EPR 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, 2014), supplemented using literature-based emission factors, largely taken from the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2013a). The quantity of waste burnt annually is estimated for the early part of the time-series, these estimates being based on active UK sites and assumed capacity, and based on actual tonnages incinerated for the period 2006-2013, these data being collected by the Environment Agency and published on their website (at http://www.environment-agency.gov.uk/research/library/data/34169.aspx).

33 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.
34 Parker T, Hillier J, Kelly S, and O’Leary S (2005). “*Quantification of trace components in landfill gas,*” Environment Agency, Bristol.
35 Ammonia emission estimates from anaerobic digestion are reported as a memo item in the 2013 NAEI as currently there is no methodology in the EMEP/EEA Emission Inventory Guidebook to estimate emissions for this source.

Emissions from **chemical waste incinerators** are estimated based on analysis of data reported to the Pollution Inventory (EA, 2014) 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 (1995) atmospheric guidelines for POPs published by External Affairs Canada (for PAHs).

Emissions from **sewage sludge incinerators** are estimated from a combination of data reported to the Pollution Inventory (EA, 2014) and Scottish Pollutant Release Inventory (SEPA, 2014), supplemented with the use of literature-based emission factors where the IPPC/EPR-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/EEA, 2013b). The quantity of waste burnt annually is estimated based on annual activity data from environmental regulators (EA, 2014 and SEPA, 2014) or plant capacity information where annual activity data are not available.

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, 2014) 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 (2013). Mercury emission estimates are based on calculations using UK population (ONS, 2013) 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. New plants operated using incineration with energy recovery, ie generating heat or power, the emissions from which are reported within NFR 1A1a. Estimates of emissions from MSW incineration up to 1996 are reported under NFR 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.

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, 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 2013 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 2013 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).

NFR 5D: Waste-water handling

The emission estimates for ammonia from sewage treatment & disposal and sewage work are based on research by the Centre of Ecology and Hydrology (CEH, 2013). 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.

NFR 5E: Other Waste

Emissions of PCDD/PCDFs from accidental vehicle fires are based on activity data from UK fire service reporting, together with literature emission factors (Wichmann et al, 1995).

6.4 Source specific QA/QC and verification

Many of the emission estimates reported in NFR 5 are based on facility-specific emissions reported to the PI, SPRI and NIPI, under IPPC/EPR regulation. Section 3.1.7 discusses QA/QC issues regarding these data.

The emission estimates for NFR 6A (landfill waste) are not directly verified, but the model 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.

6.5 Recalculations in NFR5

The most significant recalculations since the 2014 submission in NFR 5 are:

- The model used to calculate methane formation in landfill sites has been updated with new information on commercial waste receipts, waste composition and waste degradation rates.
- The calculation of the quantity of methane combusted in engines for the production of electricity has been updated
- The calculation of the quantity of methane combusted in flares is now based only on site-specific data provided by the regulatory authorities supplemented by the findings of new research

7. Other

Table 7-1 Mapping of NFR Source Categories to NAEI Source Categories: Other Sources

NFR 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
	PAHs, PCDD/PCDFs, NH_3	Cigarette smoking	Stockholm Convention Toolkit for PCDD/PCDFs and literature factors for PAHs and NH_3
	CO, Cu and Particulate Matter	Fireworks	Emission Agency estimates based on industry
	NH_3	Heather burning	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

NFR source category 6A is a key source for NH_3, PM_{10}, $PM_{2.5}$, PCDD/PCDFs and PAHs.

7.2 Activity Statistics

NFR 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. Prodcom data and statistics from the Statistics monthly digest are used to provide data on the quantity of fireworks and cigarettes sold in the UK respectively.

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 (5^{th} November) is treated as a separate source from other domestic burning events due to the large scale organised nature of the event and potential air quality impact over a short period of time. Backyard burning of waste and other bonfires throughout the year are reported under NFR 6 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. Emission factors for domestic wood fires (in the case of PM_{10} and PAH) and disposal of wood waste through open burning (in the case of PCDD/PCDFs) are used to generate emission estimates.

Cigarettes

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 Stockholm Dioxins and Furans Toolkit (2004),for PAHs (Xinhui, 2005) and for NH_3 (Sutton, 2000).

Fireworks

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 10% of fireworks are supplied by the UK manufacturers. 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.

Infant Emissions from Nappies
The emission estimate for ammonia from infants' nappies is based on research by the Centre of Ecology and Hydrology (CEH, 2014). 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, 2014), based on the UK population estimates for cats and dogs and an emission estimate per animal.

7.4 Source specific QA/QC and verification

Many of the emission estimates reported in NFR 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 NFR 6

There were no significant recalculation to the sources under NFR 6 this year.

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 NFR source category 1A1, which dominates the inventory for many pollutants, these are dominated by: (i) revisions to UK energy statistics by DECC (i.e. changes to fuel allocations to sector activities within DUKES), and (ii) revisions to operator-reported emissions via the IPPC/EPR inventories (PI/SPRI/NIPI).

In recent years, the impact of EU ETS has also had an effect on the UK air quality pollutant inventories, as this new (since 2005 only) dataset on fuel use and fuel quality has led to a series of revisions to source-specific activity estimates.

8.1 NO_X (as NO_2)

There have been a significant 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 NOx (as NO_2), while revisions have occurred at the detailed level, the total UK emission estimates are hardly changed.
NO_x (as NO_2) emissions have been revised up by 11kt (1%) for the calendar year 2012 between the 2014 and 2015 UK inventory submission. This is made up of a number of small changes to emissions, to revise categories both up and down. The top contributors to this change are:

- Emissions from Power Stations burning coal has been revised downwards by 4ktonnes as a result of (i) revisions to UK energy statistics by DECC (i.e. changes to fuel allocations to sector activities within DUKES), and (ii) revisions to operator-reported emissions via the IPPC/EPR inventories (PI/SPRI/NIPI)
- Automatic Number Plate Recognition (ANPR) data were available for 2013 (the ANPR data are used to define the petrol/diesel mix of car and provide indication of the age mix of the fleet) and this enabled the fleet composition analysis to be updated, affecting emission estimates for 2012.

8.2 CO

CO emissions have been revised down by 36kt (2%) for the calendar year 2012 between the 2014 and 2015 UK inventory submission. The top contributor to changes to CO emissions are changes to the methodology used for domestic combustion of solid fuels which reduced emission by 14 ktonnes in 2012 in the current inventory compared to last year’s inventory.

8.3 NMVOC

There has been little change in the estimates for overall emissions of NMVOC, although changes at the sectoral level have been quite significant. Emissions of NMVOC have been revised down by 9kt (1%) for the calendar year 2012 between the 2014 and 2015 UK inventory submission. The most significant change was a revision to the emission estimates for non-dairy cattle provided by Rothamsted.

8.4 SO_X (as SO_2)

There have been changes to the detailed emission estimates; however, the estimates of overall UK emissions have not changed as significantly. Net increases in emissions in 2010-2012 are largely due to changes in assumptions about the level of consumption of petroleum coke as an industrial fuel. Emissions of SO_x (as SO_2) have been revised up by 13kt (3%) for the calendar year 2012 between the 2014 and 2015 UK inventory submission.

8.5 NH_3

In the 2015 Inventory submission, there were no significant revisions to the NH_3 inventory. There were small revisions to the activity data and emission factors to various sources within small stationary combustion and non-road mobile sources & machinery, the most notable being domestic wood and petcoke combustion. Emissions of NH_3 have been revised down by 2kt (1%) for the calendar year 2012 between the 2014 and 2015 UK inventory submission.

8.6 PM_{10} and $PM_{2.5}$

UK estimates for particulate matter have increased significantly compared with last year's inventory submission. This is largely due to upward revisions in PM emissions from agriculture (using emission factors from the EMEP/EEA Emission Inventory Guidebook), and to a lesser degree, addition of emissions from charcoal manufacture. Upward revisions to gas oil consumption figures in DUKES also make a minor contribution to the increase.

In summary, emissions of PM_{10} and $PM_{2.5}$ have been revised up by 13kt (11%) and 4 kt (5%) respectively for the calendar year 2012 between the 2014 and 2015 UK inventory submission.

8.7 Metals

Emission estimates for metals are broadly similar in both the 2014 and 2015 UK inventory submissions. The estimates for the calendar year 2012 are higher in the 2015 submission for chromium (0.1 tonne, 0.4%) and zinc (0.1 tonnes, 0.03%), and lower for cadmium (0.04 tonne, 2%), lead (0.8 tonne, 1%), mercury (0.08 tonne, 1%), arsenic (0.06 tonne, 0.3%),), copper (0.2 tonne, 0.4%), nickel (0.7 tonne, 1%) and selenium (1 tonne, 3%).

8.8 POPs

Emissions of PCDD/PCDFs have been revised down by 4% (-8.8 g TEQ) for the calendar year 2012 between the 2014 and 2015 emissions inventory. This result from the use of updated emission factors from the power stations database due to: revisions to default emissions factors, revisions to point source data in the DAs Pollution Inventories (PI/SPRI/NIPI), and revisions to DUKES data for coal and gas use at power stations.

Revisions to charcoal statistics in the domestic combustion sector and changes to the allocation of petroleum coke in DUKES are responsible for increases in 2012 emissions estimates for benzo[a]pyrene (6%), benzo[b]fluoranthene (8%), and benzo[k]fluoranthene (6%).

There have not been significant changes to emissions of PCBs and Indeno (1,2,3-cd) pyrene.

8.9 Planned improvements

The UK inventory has been developed and improved over many years and the methodologies used are well established and, as a general rule, cannot be improved upon without committing significant resources to the task. UK Government does fund research aimed at improving the inventory, and the text below gives a summary of current thinking on areas where improvements are most likely, or easiest to achieve. However, the UK inventory improvement plan is constantly under review, and so improvements could also occur in other areas if opportunities arise.

General

The inventory will be updated to take appropriate 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;

A programme of consultation with industrial trade associations, Government departments and Agencies, and other stakeholders is carried out each year as part of the inventory programme. This may lead to improvements to the inventory methodology, although it is not possible to predict any details.

Energy

For stationary sources, emission factors for NOx as NO_2, CO and particulate matter are generated using a complex model which aims to take account of the types of combustion devices in use. This model is only updated periodically, and is always a key area for improvement work. Review of the assumptions for gas-fired plant, and for large combustion plant are probably the priorities. The methodology used for domestic combustion of solid fuels has been revised for the 2015 submission, so that the NAEI estimates are now based on a more detailed set of assumptions on fuels burnt and appliance types in use. The assumptions used in this new method will need to be kept under review, and the potential for extending this detailed model to liquid fuels could also be evaluated.

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 and for example, we may anticipate introducing changes in NO_x emission factors for diesel vehicles according to the latest releases of the COPERT model and factors in the latest version of the EMEP/EEEA Emissions Inventory Guidebook. This will likely be discussed with stakeholders in the UK road transport emissions inventory during the next year

A watching brief is kept on developments in emission factors and activity data for all modes of transport.

Industrial processes

Most of the emission estimates for industrial processes are based on emissions data reported by process operators in the PI/SPRI/NIPI, and so the inventory can be updated each year with a further year's worth of data. In the case of NMVOC sources in NFR 2D3, however, this is not the case – 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 5 years, partly because other areas of the NAEI have been a higher priority, but also because efforts to collect new data from industry have, to a large extent, not been particularly fruitful. As a result, the quality of the NMVOC inventory has slowly decreased 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 progress is very dependent upon assistance from industry or other stakeholders.

Waste

- Identify a mechanism for an annual update to the data on landfill gas flaring volumes from sites other than those regulated by the Environment Agency/SEPA/NRW.

- Review the assumed quantity of waste to landfill.

9. Projections

Projected emissions for the four National Emission Ceiling Directive (NECD) pollutants are compiled by the inventory agency to enable comparisons with international commitments to be assessed. Emission projections are submitted under the revised Gothenburg Protocol every 4 years starting in 2015, with the latest revised dataset being provided in July 2015, which are based on the 2012 UK inventory. This set of projections is based on the updated energy and emission projections 2014 issued by DECC in September 2014[36]. A detailed description of the underlying 2012 UK Inventory can be found in the UK Informative Inventory Report (1980 to 2012)[37].

9.1 UK air quality emission commitments

The UK has made commitments under the National Emissions Ceilings Directive (NECD) to reduce emissions of NO_x (as NO_2), SO_x (as SO_2), NMVOCs and NH_3 by 2010. The revised Gothenburg Protocol now also sets emission reduction commitments for the same four pollutants and for $PM_{2.5}$ to be achieved in 2020 and beyond. The NECD target emissions are provided in Table 9-1 below together with the UK's actual emissions in 2010, 2012 and 2013.The data shows that the NH_3, SO_x (as SO_2), NO_x (as NO_2) and NMVOC 2010 ceilings have been met in 2010 and subsequent years.

Table 9-1 The UK's final 2010, 2012 and 2013 emissions and targets for 2010 NECD target that the UK is committed to.

Pollutant	Emissions (kt)				NECD	
	2005	2010	2012	2013	NECD Emissions ceiling target in 2010 (kt)	Percentage of NECD 2010 ceiling, %
NO_x (as NO_2)	1586	1123	1073	1020	1,167	87%
SO_x (as SO_2)	710	428	440	393	585	67%
NMVOCs	1136	855	824	803	1,200	67%
NH_3	304	279	275	271	297	91%
$PM_{2.5}$	95	85	81	80	N/A	NA

Table 9-2 shows how the latest emission totals compare with 2020 targets based on applying the 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 2013 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 NH_3 emissions has already been met and more than half of the required mass reduction has also been achieved for the other pollutants, NOx as NO_2, SOx as SO_2 and NMVOC. Secondly, the row '**Emission reduction required from 2013**' shows the amount of reduction required from current (i.e. 2013) emissions to reach the 2020 commitment.

[36] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/368021/Updated_energy_and_emissions_projections2014.pdf
[37] http://uk-air.defra.gov.uk/assets/documents/reports/cat19/1405130812_UK_IIR_2014_Final.pdf

Table 9-2 Comparison of UK 2013 national emissions and 2020 Gothenburg emission targets

Pollutant	**NH_3**	**NO_x**	**SO_2**	**NMVOC**	**$PM_{2.5}$**
2005 National Total, ktonnes	304	1586	710	1136	95
2013 National Total, ktonnes	271	1020	393	803	80
Emission reduction commitment	8%	55%	59%	32%	30%
2020 target, ktonnes[a]	**280**	**714**	**291**	**773**	**67**
Progress to date towards 2020 reductions	136%	65%	76%	92%	52%
Emission reduction required from 2013, ktonnes	0	306	102	30	14
Projected emissions for 2020 (based on the 2012 inventory)	**280**	**711**	**197**	**749**	**72**

[a] The 2020 emission targets have been calculated using the 2005 emissions of the current inventory submission as the base year.

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