UK Informative Inventory Report (1980 to 2011)

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Executive Summary

This is the 8th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) Programme. The report is compiled to accompany the UK's 2013 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 1980 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 for other pollutants that have been compiled.

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

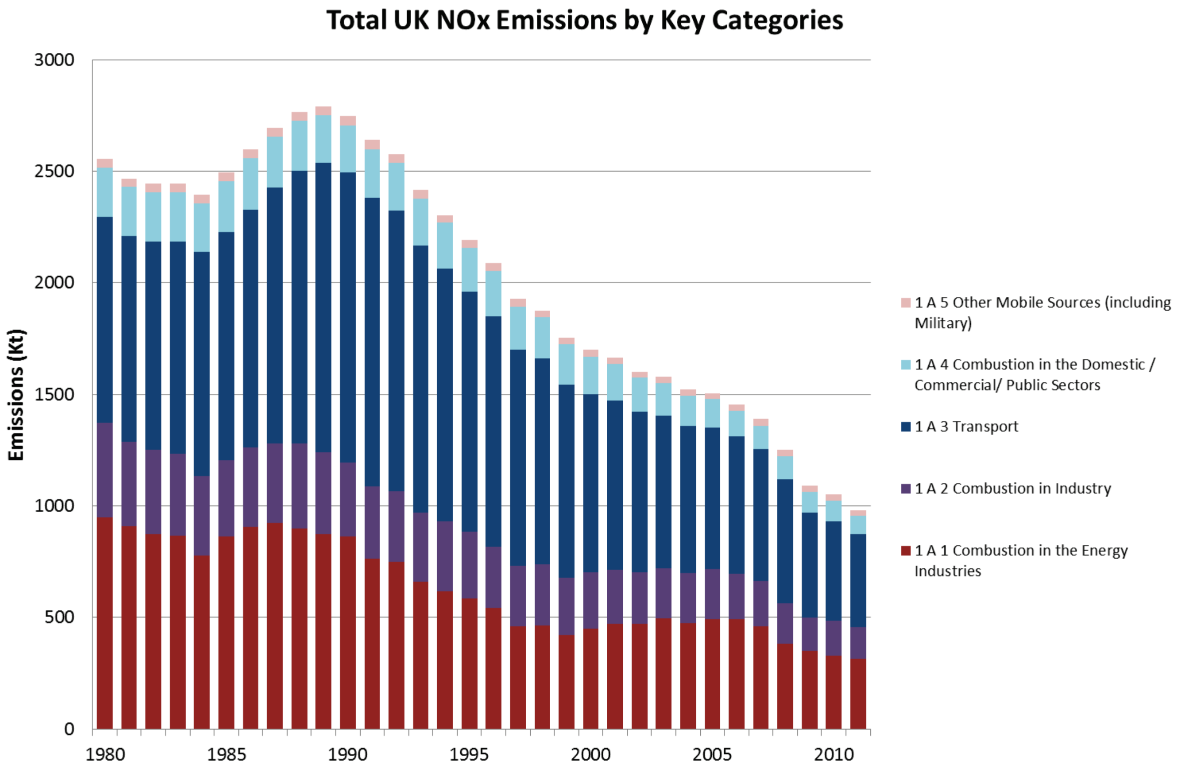
- Nitrogen oxides (NO_x), carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs), particulate matter (PM) and heavy metals (1980 to 2011); and
- Persistent organic pollutants (1990 to 2011).

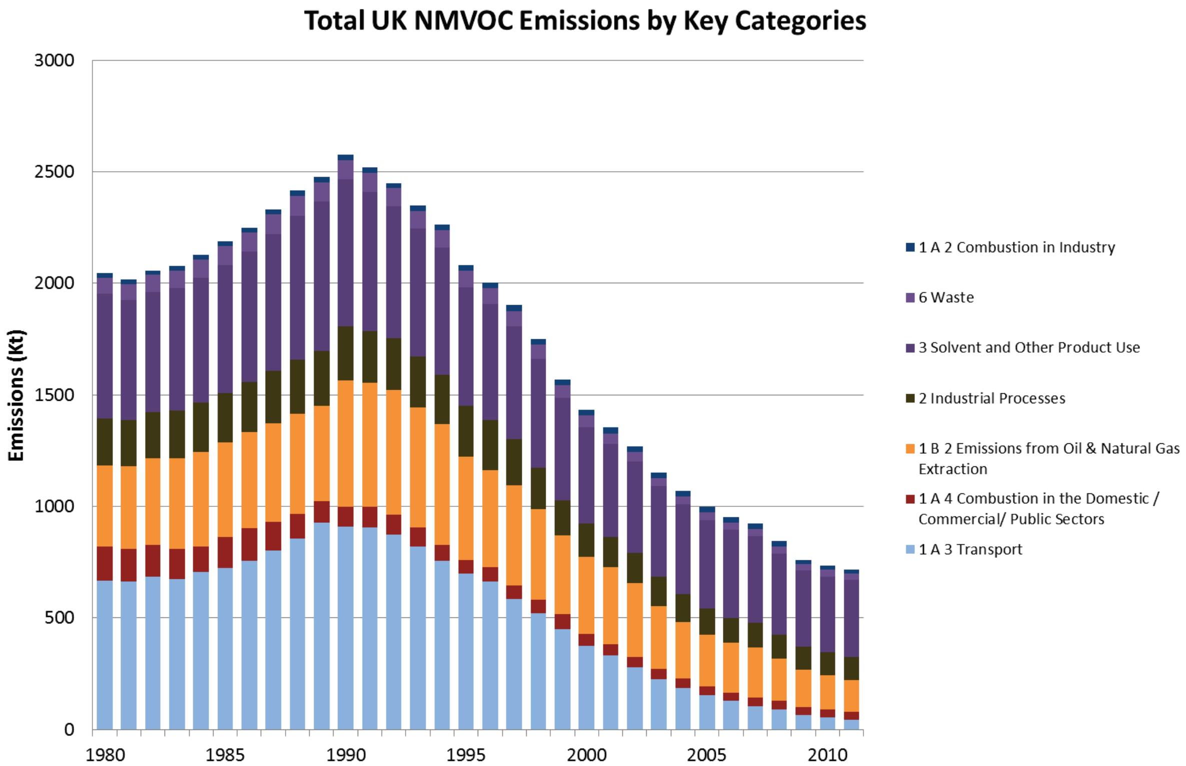
In 2012 Parties were required to report gridded data and Large Point Source (LPS) data for 2005 and 2010 under CLRTAP. The 2010 gridded and LPS data were not available at the time of the submission, and have therefore been included as part of this submission.

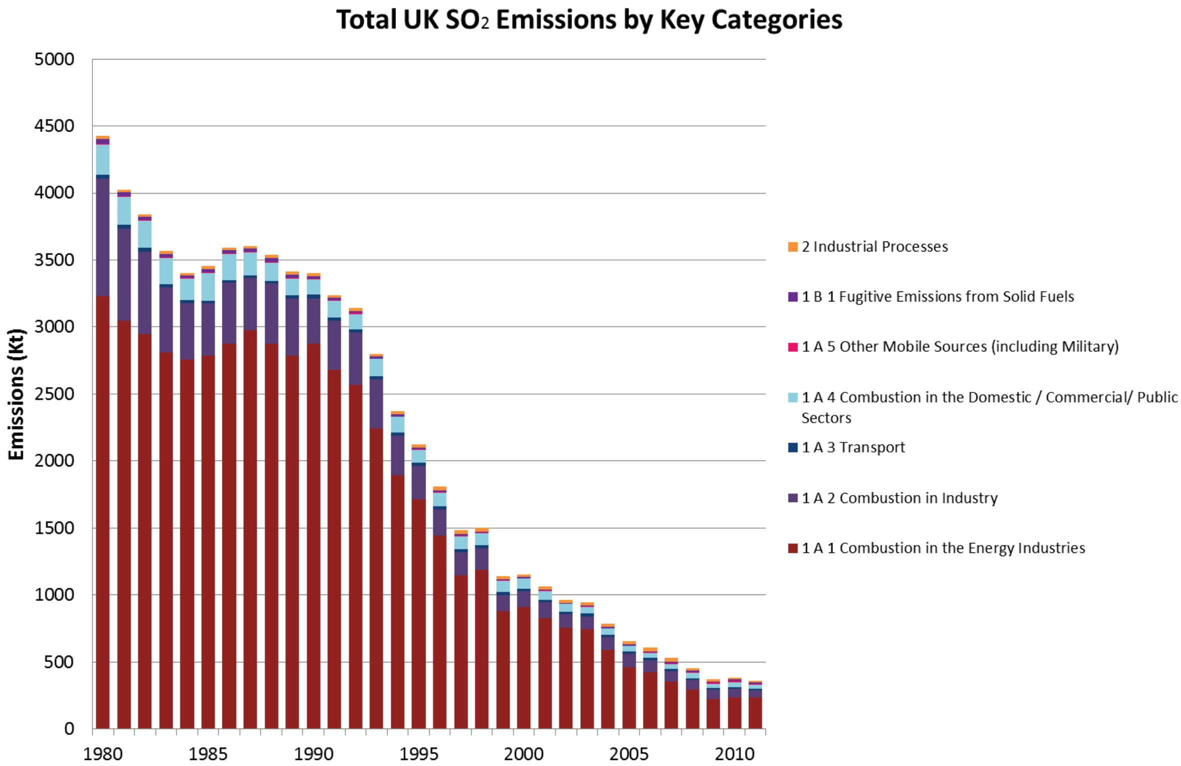
Selected pollutants under the CLRTAP are also covered under EU Directive 2001/81/EC on National Emissions Ceilings (NECD) which sets upper limits for each Member State for the total emissions in 2010. Under the NECD the UK submits the emissions for the previous five years and 2010 projections for nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and ammonia (NH_3). In this, the 2013 report, emissions for 2010 are based on actual emissions rather than projections. An overview of emissions from 1980-2011 from key categories for each of these pollutants is provided in Figure ES.1.

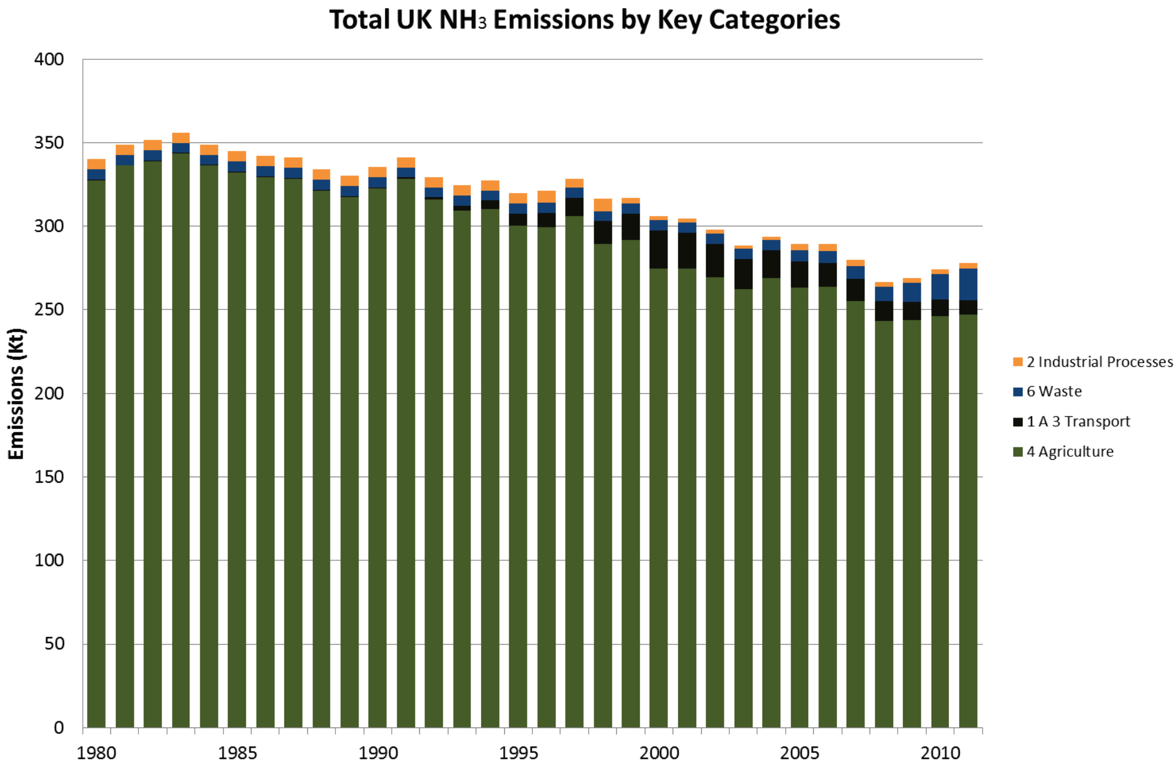
[1] See http://www.ceip.at/reporting-instructions/reporting-programme/ for reporting requirements set up by TFEIP/UNECE Guidelines for estimating and reporting emissions data under LRTAP.

Figure ES. 1 Total UK Emissions by Key Categories of Oxides of Nitrogen (NOx as NO_2), Non-Methane Volatile Organic Compounds (NMVOCs), Sulphur Dioxide (SO_2) and Ammonia (NH_3), 1980-2011.






Total UK SO2 Emissions by Key Categories
Emissions (Kt)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2 Industrial Processes
1 B 1 Fugitive Emissions from Solid Fuels
1 A 5 Other Mobile Sources (including Military)
1 A 4 Combustion in the Domestic / Commercial/ Public Sectors
1 A 3 Transport
1 A 2 Combustion in Industry
1 A 1 Combustion in the Energy Industries


Total UK NH3 Emissions by Key Categories
Emissions (Kt)
400
350
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2 Industrial Processes
6 Waste
1 A 3 Transport
4 Agriculture

Total percentage reductions in emissions of these pollutants from1980-2011 are summarised in the table ES.1.

Table ES.1 Air Quality Pollutant Emission Reductions between 1980 and 2011

Pollutant	% Change from 1980 to 2011
NO_x	-61%
SO_2	-92%
NH_3	-20%
NMVOC	-66%
CO	-74%
PM_{10}	-65%

The emissions inventory makes estimates of all known emissions to air, at the highest a level of disaggregation as is possible. 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 2011 data submitted under the NECD in December 2011 are provisional data only, however these data have not changed since the submission and so the CLRTAP and NECD totals are identical. Estimated emissions are allocated to the corresponding NFR codes.

The purpose of this report is to:

- *Present an overview of institutional arrangements and the emission inventory compilation process in the UK;*
- *Present the emission estimates for each pollutant up to 2011;*
- *Explain the methodologies for key pollutants and key sectors used to compile the inventories, including a brief summary of the projections methodology;*
- *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, quality checking 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 to compile emissions estimates and the estimates themselves are available from http://naei.defra.gov.uk/data_warehouse.php. The complete 2013 UK CLRTAP submission

[2] http://www.ceip.at/reporting-instructions/reporting-programme/#c11273
[3] Includes the United Kingdom (England, Scotland, Wales, Northern Ireland) and Gibraltar

templates are available from the European Environment Information and Observation Network (EIONET) under http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envtzp7xq/index_html.

Any revisions to inventory compilation methodologies for key pollutants and key sectors between the 2012 and 2013 CLRTAP submissions are discussed in Chapter 13, 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 and some of the planned improvements that were outlined within the previous Informative Inventory Report (1970 to 2010) have been addressed in the 2011 inventory.

Planned improvements for future national inventory compilation cycles are discussed in section 13.9.

In addition, Table ES.2 compares overall emission estimates for each pollutant between 2012 and 2013 (current) submissions, summarising any differences in 2010 emissions between the two submissions that are associated with methodological improvements or source data revisions. Most of the overall differences are small, with no pollutants being revised more than 10% in 2010.

One major improvement for the 2013 submission has been an upgrade to the model on which emissions from rail are calculated, using new research undertaken by the UK Department for Transport (DfT). This has affected assumptions on the breakdown of fuel use between freight, intercity and regional rail, and also the emission factors used. Other changes to the inventory are mostly related to revisions to UK national energy statistics and operator reported emissions. In addition, the UNFCCC review of the UK's GHG inventory identified some omissions. Where these relate to fuel consumption, the inclusion of new sources or changes in existing ones has impacted on emissions of air quality pollutants alongside that for GHGs.

Table ES.2 UK Inventory Recalculations, Comparing the 2011 and 2012 CLRTAP Submissions

Pollutant	2012 Submission	2013 Submission		Unit	% change	Comment/Explanation (changes between the 2012 and 2013 CLRTAP Submissions)
	2010	2010	2011		2010	
NO_x	1106	1107	1033	kt	0%	Small change to overall total. The main increases relate to rail improvements; inclusion of additional OPG in other industry to address a gap identified in the GHG inventory and inclusion of fishing outside of UK waters. These increases have been offset by decreases in estimates from off-road machinery and natural gas use for upstream oil production
CO	2125	2241	2145	kt	5%	This change is dominated by the inclusion of additional biomass for the other industry category to improve completeness. In addition, a new source has been added for charcoal use.
NMVOC	789	771	752	kt	-2%	Estimates for cold start emissions from cars and surface and dry cleaning have been improved.
SO_2	406	407	379	kt	0%	There have been no major recalculations to SO_2 emissions
NH_3	284	286	290	kt	0%	A new source for anaerobic digestion has included, but this has been largely offset by a decreased estimate for cattle
TSP	204	207	202	kt	1%	Changes for TSP broadly follow changes for PM_{10}
PM_{10}	114	116	113	kt	2%	The overall change is made up of a number of small changes, including the addition of biomass in the other industry category, rail improvements, and revised straw combustion estimates (from DUKES)
$PM_{2.5}$	67	70	67	kt	6%	$PM_{2.5}$ emissions have been affected by changes to PM_{10} emissions and revised size profiles for a number of sources in line with the EMEP/EEA Guidebook.
Pb	59	61	59	tonnes	3%	Emissions from foundries and clinical waste incineration have been revised up, based on new Prodcom data and revised PI data, respectively
Cd	2	2	3	tonnes	3%	Cadmium emission have been impacted by a DUKES revision to fuel oil use in other industry, and the addition of biomass to the same source
Hg	6	6	6	tonnes	1%	Impacted by revisions to emissions from foundries and the addition of biomass to other industry.
As	13	13	13	tonnes	2%	This changes is dominated by the addition of biomass use in the other industry category
Cr	26	27	26	tonnes	2%	Impacted by revisions to emissions from foundries and the addition of biomass to other industry.
Cu	51	51	55	tonnes	0%	No significant changes
Ni	79	83	73	tonnes	6%	This change is dominated by a revision to fuel oil use in the other industry category
Se	32	32	35	tonnes	0%	No significant changes

Pollutant	2012 Submission	2013 Submission		Unit	% change	Comment/Explanation (changes between the 2012 and 2013 CLRTAP Submissions)
Zn	355	359	346	tonnes	1%	Impacted by revisions to emissions from foundries and the addition of biomass to other industry.
HCH	7709	7709	6784	kg	0%	No significant changes
PCB	800	799	778	kg	0%	No significant changes
PCDD/PCDF	186	188	178	grams TEQ	1%	Change dominated by an increase in emissions from agricultural combustion of straw (DUKES revision), and clinical waste incineration (PI revisions)
Benzo[a]pyrene	3	3	3	tonnes	0%	No significant changes.
Benzo[b]fluoranthene	3	3	3	tonnes	7%	Revisions to road transport emissions have led to an increase in total emissions
Benzo[k]fluoranthene	1	1	1	tonnes	0%	No significant changes.
Indeno(1,2,3-cd)pyrene	1	1	1	tonnes	0%	No significant changes.
HCB	32	32	24	kg	0%	No significant changes.
PCP	NR	NR	NR	kg		Not reported.
SCCP	NR	NR	NR	kg		Not reported.

NR: Not Reported

(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 AC0112 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
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
DECC	Department of Energy & Climate Change
DEFRA	Department of Environment, Food and Rural Affairs
DfT	Department for Transport
DERV	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
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
EPRTR	European Pollutant Release and Transfer Register
EUETS	European Union Emissions Trading Scheme
FGD	Flue gas desulphurisation
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
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. most power station operators)
MSW	Municipal Solid Waste
Mt	Megatonne
Mtherms	Megatherms
NFR	Nomenclature for Reporting
NAEI	National Atmospheric Emissions Inventory
NECD	National Emission Ceiling Directive
NIEA	Northern Ireland Environment Agency
NMVOC	Non-Methane Volatile Organic Compounds
OCGT	Open Cycle Gas Turbine
ONS	Office for National Statistics
ORR	Office of Rail Regulation
OT	Overseas Territories
PAHs	Polycyclic Aromatic Hydrocarbons
PAMs	Policies and Measures
PI	Pollution Inventory (of the Environment Agency of England & Wales)
POC	Port of call
POPs	Persistent Organic Pollutants
ppm	Parts per million
PRODCOM	PRODuction COMmunautaire
PSDH	Project for the Sustainable Development of Heathrow
QA/QC	Quality assurance and quality control
RASCO	Regional Air Services Co-ordination
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
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
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
Sulphur Dioxide	SO_2
Carbon Monoxide	CO
Non-Methane Volatile Organic Compounds	NMVOC
Black Smoke	BS
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	
Polychlorinateddibenzo-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

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1. Introduction

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. The scope of pollutants and years for which they are compiled are reported in Table 1.5.

Inclusion of new pollutants in the inventory is usually as a result of legislation being introduced that sets limits on total emissions and/or requires quantitative information on this to be reported. However, the UK government has taken somewhat of a more pro-active approach leading to the inventory including emission estimates for pollutants which are not currently required by international or national reporting obligations, but which are of use to various areas of the scientific community. For instance reporting emissions of base cations enables more accurate modelled estimates for the impacts of acidic gases on human health and the environment. Those pollutants that are required to be reported to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) are highlighted in Table 1.2.

Improvements to methodologies are logged on a continuous basis, and are reviewed every six to twelve months.

Data sources used to calculate the emissions are discussed in section 1.4.

1.1.2 Reporting Requirements: NECD and CLRTAP

The UK emissions inventory, compiled on behalf of Defra, is responsible for reporting the pollutants covered under the EU National Emissions Ceilings Directive (NECD) and the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP).

NECD

Directive 2001/81/EC of the European Parliament and the Council on National Emissions Ceilings for NO_x, SO_2, NMVOC and NH_3 sets limits for each Member State for the total emissions in 2010. 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. Since 2012, emissions for 2010 are reported as actual emissions rather than projections.

The revision of the NECD is part of the implementation of the EU Clean Air For Europe (CAFÉ) Programme and associated Thematic Strategy on Air Pollution. The proposal to amend the NECD is still under preparation and should set emission ceilings to be reached by 2020 for the four already regulated substances and for the primary emissions of $PM_{2.5}$.

CLRTAP

Parallel to the development of the EU NECD, the EU Member States together with Central and Eastern European countries, the United States and Canada have negotiated the ‘multi-pollutant’ protocol under the Convention on Long-Range Transboundary Air Pollution (the so-called Gothenburg Protocol agreed in November 1999). The emission ceilings of this protocol are equal to or less ambitious than those in the NECD. The Gothenburg Protocol was revised in May 2012 and now sets emission reduction commitments (expressed as percentage reduction from 2005 levels) for the same four pollutants as the NECD, with the addition of $PM_{2.5,}$ to be achieved in 2020 and beyond.

Table 1.1 provides a summary of the emission targets set under the NECD and Gothenburg Protocol.

The pollutants required for reporting under the CLRTAP are listed in Table 1.2.

Table 1.1 Summary of the emission targets under NECD and Gothenburg Protocol

Pollutant	Gothenburg Protocol target in 2010 (kt)	NECD Emissions ceiling target in 2010 (kt)	Revised Gothenburg Protocol - Emission reduction commitments between 2005 and 2020	Emissions in 2005 (kt) reported in 2013	Gothenburg Protocol target in 2020 (kt)
NO_x	1,181	1,167	55%	1,570	707
SO_2	625	585	59%	700	287
NMVOCs	1,200	1,200	32%	1,049	714
NH_3	297	297	8%	304	279
$PM_{2.5}$	N/A	N/A	30%	84	59

Table 1.2 Summary of reporting requirements for estimating and reporting emissions under the CLRTAP[4]

Group	Pollutant	Required reporting years	Reported years in 2013 UK submission
Main Pollutants	Nitrogen Oxides	1980 – reporting year minus 2	1980-2011
	Sulphur Dioxide		
	Carbon Monoxide		
	Non-Methane Volatile Organic Compounds		
	Ammonia		
Particulate Matter	Particulates < 10 µm	2000 – reporting year minus 2	1980-2011
	Particulates < 2.5 µm		
	Total Suspended Particulates		
Priority Heavy Metals	Lead	1990 – reporting years minus 2	1980-2011
	Cadmium		
	Mercury		
Other Heavy Metals	Copper	1990 – reporting year minus 2	1980-2011
	Zinc		
	Nickel		
	Chromium		
	Arsenic		
	Selenium		
Persistent Organic Pollutants	Benzo[a]pyrene	1990 – reporting year minus 2	1990-2011
	Benzo[b]fluoranthene		
	Benzo[k]fluoranthene		
	Indeno (1,2,3-cd)pyrene		
	PCDD/PCDF		
	Polychlorinated Biphenyls		
	HCH		
	Hexachlorobenzene		

[4] http://www.ceip.at/reporting-instructions/reporting-programme/#c11273

Every five years, starting in 2007 (2005 emissions), EU Member States also have to report gridded emissions and emissions from large point sources under CLRTAP. 2012 is a five yearly reporting year and gridded data for 2005 and 2009 were submitted instead as 2010 data were not available at that time of the UK compilation cycle. 2010 gridded data in the EMEP 50 x 50 km^2 grid and emissions from large point sources have now been provided as part of the 2013 CLRTAP submission. In addition, the 2010 gridded data have also been provided in the new EMEP grid (0.1° × 0.1° long-lat) as recommended by the EMEP Steering Body. The required information is listed in Table 1.3.

Table 1.3 Summary of five yearly reporting requirements for estimating and reporting emissions under the CLRTAP[5]

Group	Pollutant	Required reporting years	Reported years in 2012 UK submission	Reported years in 2013 UK submission
Gridded data in the EMEP 50x50 km^2 grid	SO_2, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$ Pb, Cd, Hg and POPs	2005, 2010	2005, 2009	2010
Gridded data in the new EMEP grid (0.1° × 0.1° long-lat)	SO_2, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$, Pb, Cd, Hg and POPs	(currently on voluntary basis)	N/A	2010
Emissions from large-point sources (LPS)	SO_2, NO_x, NH_3, NMVOC, CO, PM_{10}, $PM_{2.5}$ Pb, Cd, Hg and POPs	2005, 2010	2005, 2009	2010
Historical activity data[6]		1990-2010	1990-2010	1990-2011
Projected activity data and projected emissions[7]	SO_2, NO_x, NH_3, NMVOC, PM	2010, 2015, 2020, 2025, 2030	2010, 2015, 2020, 2025, 2030	Not required

As requested by the Centre on Emission Inventories and Projections[8] the gridded emissions do not include emissions from large-point sources and are reported separately.

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 1980 to the most recent reported year (see Table 1.1).

In addition, the UK national Atmospheric Emissions Inventory team reports GHG emissions to the United Nations Framework Convention on Climate Change (UNFCCC) for compliance with the Kyoto Protocol 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 and the major ones are highlighted in **Table 1.4**.

[5] http://www.ceip.at/reporting-instructions/reporting-programme/#c11273
[6] Included in the UK LRTAP submission every year
[7] Included in the UK LRTAP submission every year
[8] http://www.ceip.at/ceip/

Table 1.4 Scope of UK Emissions Inventory Reporting under the CLRTAP, NECD and UNFCCC

Sector category	CLRTAP/NECD (included)	UNFCCC (included)
Domestic aviation (landing and take-off cycle (LTO)[9]	Yes	Yes
Domestic aviation (cruise)	No	Yes
International aviation (LTO)	Yes	No
International aviation (cruise)	No	No
National Navigation (Domestic Shipping)	Yes	Yes
International inland waterways	Yes	No

Table 1.5 Scope of UK Inventory Reporting: Pollutants by Type, Time series

Pollutant	Reported under CLRTAP	Inventory Timeseries[1]	Type of Pollutant[2]
Nitrogen Oxides	✓	1970-2011	NAQS, AC, IGHG, O, E
Sulphur Dioxide	✓	1970-2011	NAQS, AC, IGHG
Carbon Monoxide	✓	1970-2011	NAQS, O
Non-Methane Volatile Organic Compounds *	✓	1970-2011	NAQS, O, IGHG
Black Smoke		1970-2011	NAQS
Particulates < 10 μm	✓	1970-2011	NAQS
Particulates < 2.5 μm	✓	1970-2011	-
Particulates < 1 μm		1970-2011	-
Particulates < 0.1 μm		1970-2011	-
Total Suspended Particulates	✓	1970-2011	-
Ammonia	✓	1980-2011	AC, E
Hydrogen Chloride		1970-2011	AC
Hydrogen Fluoride		1970-2011	AC
Lead	✓	1970-2011	NAQS, TP
Cadmium	✓	1970-2011	TP
Mercury **	✓	1970-2011	TP
Copper	✓	1970-2011	TP
Zinc	✓	1970-2011	TP
Nickel **	✓	1970-2011	TP
Chromium **	✓	1970-2011	TP
Arsenic	✓	1970-2011	TP
Selenium	✓	1970-2011	TP
Vanadium		1970-2011	TP
Beryllium		2000-2011	TP
Manganese		2000-2011	TP
Tin		2000-2011	TP
Polycyclic Aromatic Hydrocarbons *	✓	1990-2011	TP
PCDD and PCDF	✓	1990-2011	TP
Polychlorinated Biphenyls *	✓	1990-2011	TP
Lindane (gamma-HCH)	✓[10]	1990-2011	TP
Pentachlorophenol		1990-2011	TP
Hexachlorobenzene	✓	1990-2011	TP
Short-chain chlorinated paraffins		1990-2011	TP
Polychlorinated Naphthalene		NE	TP
Polybrominated diphenyl ethers		SE	TP
Sodium		1990-2011	BC

[9] Emissions from the LTO cycle include emissions within a 1000 m ceiling of landing.
[10] Reported as total HCH

Pollutant	Reported under CLRTAP	Inventory Timeseries[1]	Type of Pollutant[2]
Potassium		1990-2011	BC
Calcium		1990-2011	BC
Magnesium		1990-2011	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

* A group of compounds, for which the inventory makes emission estimates of the individual compounds within the group
** A group of compounds, for which the inventory makes emission estimates of the chemical form of the emissions.

1.1.3 Sources

In principle, the emissions inventory makes estimates of all known emissions to air in as high a level of disaggregation as is possible. However, by following international guidelines 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).
- The inventory reports only primary emissions (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 are not included in the national totals.
- Estimates of "International" emissions such as shipping are made, and reported as memo items (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 emissions data in this report is the UK plus Gibraltar, excluding all other Overseas Territories (OTs) and Crown Dependencies (CDs).

Note that the NECD submission uses the CLRTAP reporting templates (as requested by the European Environment Agency).

Under the UNFCCC[11], GHG emissions from all CDs and OTs are included in the national totals. This leads to differences in emissions estimates between the NECD pollutants (NOx and NMVOCs) reported under the CLRTAP to when they are reported as e indirect GHG emissions for the UK under the UNFCCC.

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 Science and Evidence Team, Atmosphere and Local Environment Programme (ALE) of the Department for Environment, Food and Rural Affairs (Defra) and the Science & Innovation Division at DECC. Emissions of ammonia and greenhouse gases 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.

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

1.2.1 Defra ALE

The Science and Evidence Team, Atmosphere and Local Environment Programme (ALE) at 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:

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.

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 National Atmospheric Emissions Inventory team, led by Ricardo-AEA, is responsible for compiling the emission inventories, including the following roles and responsibilities:

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 & archiving;
- 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 rail emission estimates, inventories for the Overseas Territories and Crown Dependencies, expert advice on projections and QA/QC, and lead on the Task Force for Emission Inventories and Projections (TFEIP) activities.
- SKM Enviros, under subcontract to Ricardo-AEA, provide expert advice on Industrial processes and solvents.

- AMEC, under subcontract to Ricardo-AEA, provide expert advice on projections.

Information Dissemination
Data from the NAEI is 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 Administrations.

In addition there is a continuous drive to make information 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, and a new, more up to date and user friendly inventory has been 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, but also give general overview information on air pollutants and emissions inventories. Information resources available on the NAEI web pages include:

- **Data Warehouse: -** Emissions data is 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 is also currently being developed.

- **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:

http://www.defra.gov.uk/environment/quality/air/air-quality/
and http://www.defra.gov.uk/environment/climate/

Information Archiving and Electronic Back-ups
The UK emissions inventory team also have the responsibility for 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, and incremental tape backups are also performed. The data files (in particular the compilation data and central database) are backed up whenever the files are being changed.

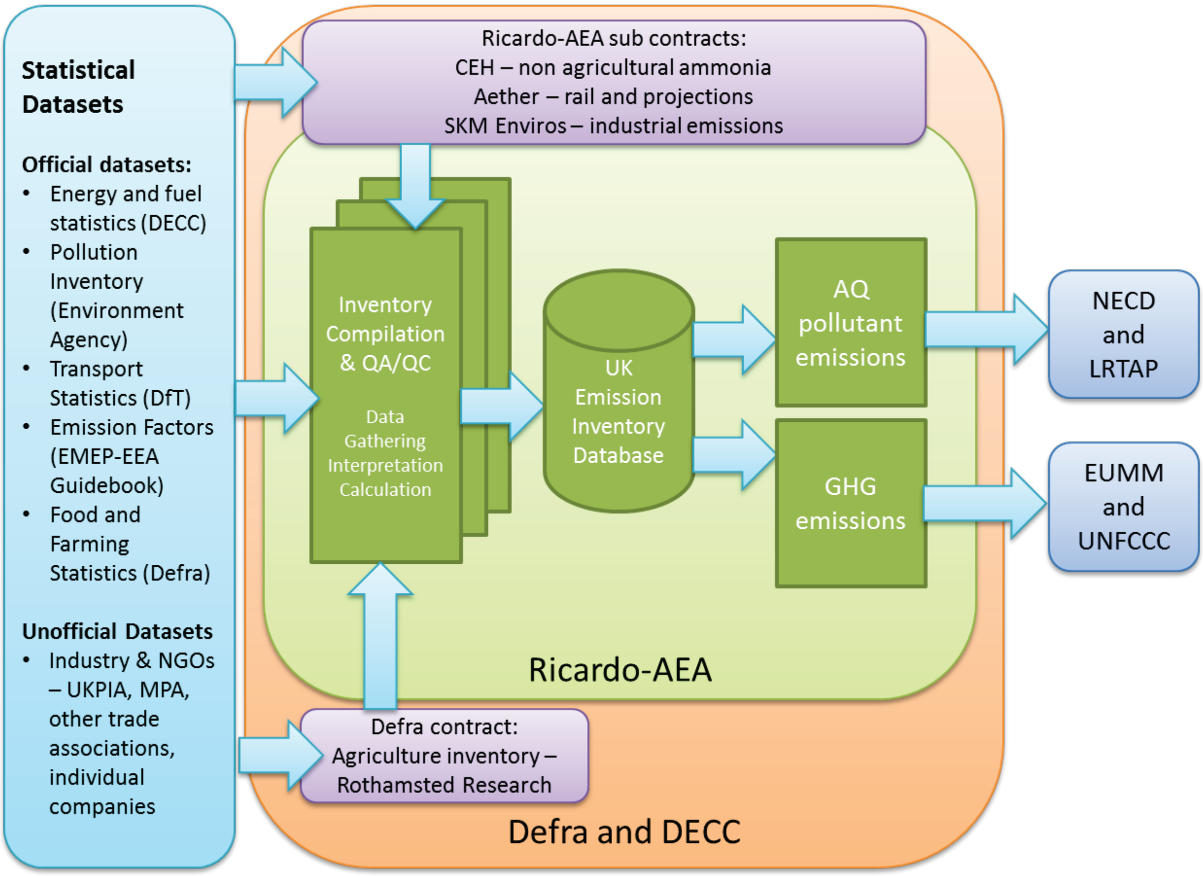
1.3 Inventory preparation process

1.3.1 Introduction

Figure 1.1 shows the main elements of the UK emissions inventory system, including provision of data to international organisations.

- Defra is the UK Government Department responsible for submitting the UK's emission inventories under the NEC Directive and the CLRTAP Convention.
- Ricardo-AEA, with support from partner organisations, compiles the emissions inventory on behalf of Defra.

Figure 1.1 Main elements for the preparation of the UK Emissions Inventory



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 for England and Wales (EA), 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.

1.3.2 The Annual Cycle of Inventory Compilation

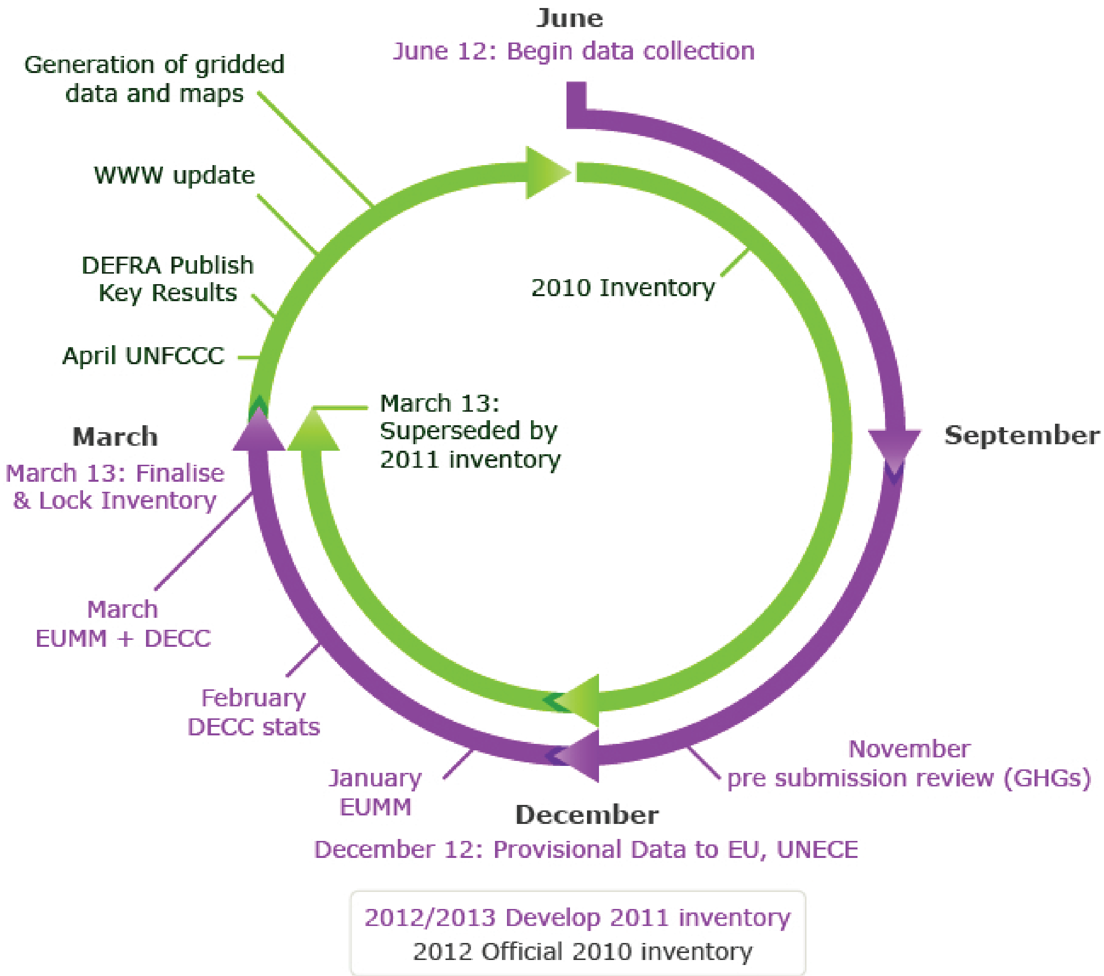
The NAEI is compiled on an annual cycle that encompasses: data collection, compilation, reporting, review and improvement. Each year the latest set of data are added to the inventory and the full time series is updated to take account of improved data and any advances in the methodology used to estimate the emissions. Updating the full time series, making re-calculations where necessary, is an important process as it ensures that:

- the full NAEI dataset is based on the latest available data, using the most recent research, 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 1.2, 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.

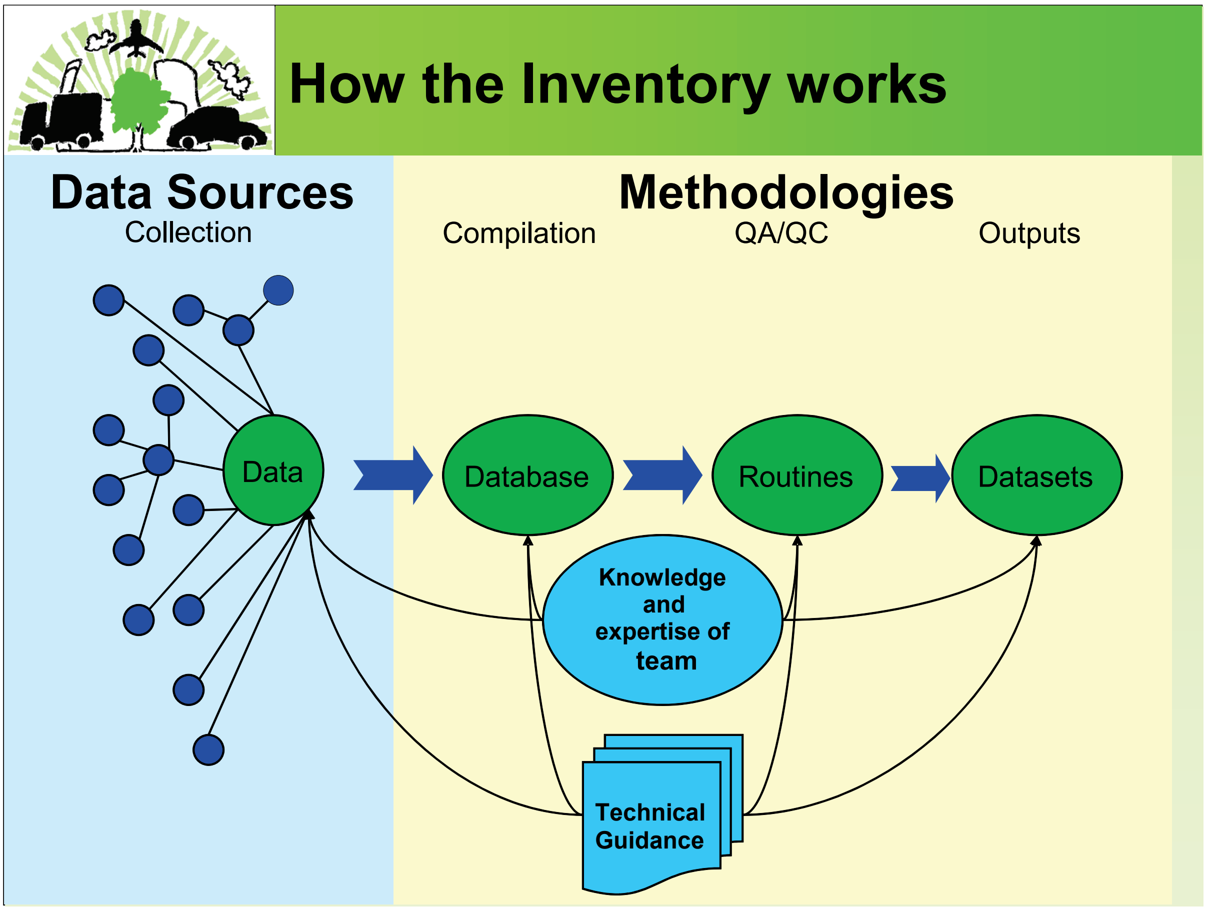
Figure 1.2 The Annual Inventory Cycle in the UK



1.3.3 Data Flows and Infrastructure Organisation

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 1.3.

Figure 1.3 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 is checked, and formatted for use.
3. **Spreadsheet Compilation-** formatted input data is added to 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 is 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.

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 (QA/QC) tasks and systems 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.

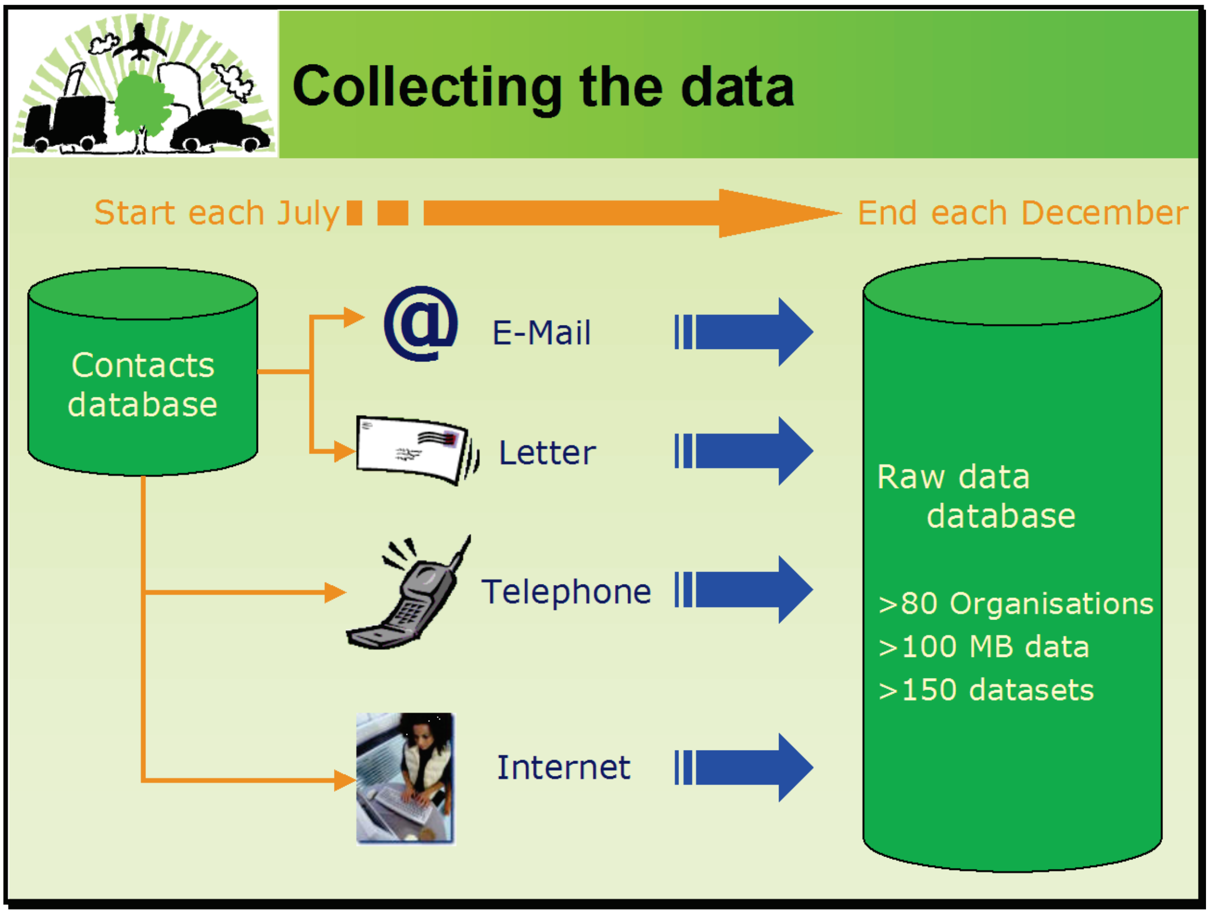
The QA/QC programme that operates throughout the inventory programme is explained in section 1.6. This incorporates staff management and responsibilities.

1.3.4 Stage 1: Data Collection

Data Management

Figure 1.4 describes the data collection process for core inventory compilation. Data requests are made by letter, e-mail, fax, 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 1.4 Data collection for core inventory compilation



There are 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 obligations to provide the data). It is therefore essential to build a strong working relationship with these data providers.

Key Data Providers

A number of the most important data providers have been assigned as Key Data Providers. Whilst there are legal measures[12] 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

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

pertinent specifically to the air quality pollutant inventories. However, the major data providers to the emissions inventory are encouraged to undertake the following responsibilities:

Data Quality, Format, Timeliness, 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.

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* – 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.

Energy balance of the inventory

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 plant such as furnaces. DUKES relies on data provided by fuel suppliers but data on industrial use of gas oil is very uncertain. The distribution chain for refinery products is complex, and the gas oil producers have very little knowledge of where their product is used once it leaves their refineries. 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 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, 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 (EUETS) 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 Ricardo-AEA by the individual plant operators or from:

The Environment Agency of England & Wales - Pollution Inventory
The Environment Agency of England & Wales compiles 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 and the Environment Agency 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 Environment Agency Pollution Inventory, the point source emissions data provided via the SPRI is 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 – ISR Inventory
The Northern Ireland Environment Agency compiles an 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

Rothamsted Research compiles, on behalf of Defra, the inventory for agricultural NH_3 emissions using agricultural statistics from Defra.

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 compiles the Devolved Administration, Overseas Territory and Crown Dependency inventories and the rail inventory.

Defra also funds research contracts to provide emissions estimates for certain sources. The results of all research programmes 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.

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 is 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 mater 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 is 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 is 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 1.6 gives an indication of where UK specific data is used in the emissions inventory, and where more generic methodologies are used (where UK specific information is not available).

Table 1.6 UK Emissions Inventory Compilation Methodologies by NFR

NFR Category	Activity	EFs	Comment
1A1a Public Electricity & Heat Production	UK statistics (DUKES)	Operator reporting under IPPC	
1A1b Petroleum refining	UK statistics (DUKES)	Operator reporting under IPPC	
1A1c Manufacture of Solid Fuels etc.	UK statistics (DUKES)	Operator reporting under IPPC 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	
1A2c Chemicals	UK statistics (DUKES)	UK factors & Operator reporting under IPPC	
1A2d Pulp, Paper & Print	UK statistics (DUKES)	UK factors & Operator reporting under IPPC	
1A2e Food Processing, Beverages & Tobacco	UK statistics (DUKES)	UK factors & Operator reporting under IPPC	
1A2f Other	UK statistics (DUKES)	UK factors & Operator reporting under IPPC	
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)	UK factors	
1A3c Railways	Estimated	UK factors	
1A3di (ii) International inland waterways	-	-	Not Occurring (NO)
1A3d ii National Navigation	UK statistics and sector research (Entec, 2010)	Literature sources	
1A3e Pipeline compressors	-	-	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 Off-road Vehicles & Other Machinery	Estimated	Literature sources	
1A5a Other, Stationary (including Military)	-	-	Reported under 1A4a
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, literature sources	
1B1c Other	-	-	Reported under 1B1b
1B2Oil & natural gas	UK statistics & Industry	Operator reporting under IPPC and via EEMS, data from UKPIA, data from UK	

NFR Category	Activity	EFs	Comment
		gas network operators and from DECC	
1 B 3 Other fugitive emissions from geothermal energy			Not Occurring (NO)
2 A Mineral Products	Industry & Estimated	Industry & Operator reporting under IPPC	
2 B Chemical Industry	Industry & Estimated	Operator reporting under IPPC	
2 C Metal Production	UK statistics & Industry	Industry & Operator reporting under IPPC	
2 D Other Production	UK statistics & Industry	UK factors	
2 E Production of POPs			Not Reported (NA)
2 F Consumption of POPs and heavy metals	Estimated	Literature	
2 G Other	Estimated	UK factors	
3A Paint Application	Industry	Industry & Estimated	
3B Degreasing & Dry Cleaning	Industry	UK factors	
3C Chemical Products, Manufacture & Processing	Industry	Industry & Estimated	
3D Other Inc. HMs & POPs Products	Industry	Industry & Estimated	
4B Manure Management	UK statistics	UK factors	
4D Agricultural Soils	Majority based on UK farm surveys and fertiliser sales data	Literature sources	
4F Field Burning Of Agricultural Wastes	Majority based on UK farm surveys and fertiliser sales data , Estimates used for foot and mouth pyres	Literature sources	
4G Other	UK Statistics & Estimated	UK factors	
6A Solid Waste Disposal On Land	UK waste arisings and disposal statistics	UK model and assumptions	
6B Waste-Water Handling	UK statistics	UK factors	
6C Waste Incineration	UK Statistics & Estimated	Operator reporting under IPPC & UK factors	
6D Other Waste	Estimated	UK factors	
7A Other	Estimated	UK factors	
1A3aii (ii) Civil Aviation (Domestic, Cruise)	UK statistics (CAA)	Literature sources	
1A3ai (ii) International Aviation (Cruise)	UK statistics (CAA)	Literature sources	
1A3di (i) International maritime Navigation	UK statistics and sector research (Entec, 2010)	Literature sources	
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 NAEI team (or other external organisations). This has been necessary in cases where UK statistics are not available or are

available only for a limited number of years. The estimates will usually be based on at least some published data 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**: UK-specific methodology based on use of emission factors.
- **Industry**: Process operators or trade associations have provided emissions data directly
- **Estimated**: Emissions have been estimated by the NAEI team for some sources of NMVOC, based on detailed information on solvent consumption at each plant and abatement systems in place.

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 1.7 provides an overview of the most important sources for selected pollutants reported under the CLRTAP in the 2011 inventory submission. The sources that add up to at least 95% of the national total in 2011 are defined as being a key source for each pollutant.

For SO_2 and NO_x the single dominant source is 1A1a Public Electricity and Heat Production. Nine of the 13 key sources for NH_3 are from the agriculture sector, with 39% of the emissions from cattle. NMVOC sources are dominated by the use of domestic solvents including fungicides. 29% 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 1970 and 2011 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 decreased significantly since 1970. Sinter production in the iron and steel production sector is the highest source for Pb and Cd emissions in 2011. 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/PCDF are small scale waste burning, other waste sources and iron and steel production.

Table 1.7 Key NFR Sources of Air Quality Pollutants in the UK in 2011 (that together contribute <95% to the pollutant emission totals)

Pollutant	Source category (*% of total emissions*)																	
SO_2	1A1a	1A1b	1A2fi	1A4bi	1A3dii	2C1	1B1b	2A7d	1A2c	1A5b	1A2a	1A1c						
	44.1%	*16.0%*	*11.9%*	*8.7%*	*2.4%*	*2.2%*	*2.0%*	*1.8%*	*1.7%*	*1.5%*	*1.4%*	*1.3%*						
NO_x	1A1a	1A3bi	1A3biii	1A2fi	1A3bii	1A2fii	1A1c	1A3c	1A3dii	1A4bi	1A4cii	1A5b	1A1b	1A4ai	1A2c			
	22.7%	*14.6%*	*12.3%*	*7.1%*	*5.8%*	*5.6%*	*5.5%*	*3.9%*	*3.8%*	*3.4%*	*2.6%*	*2.5%*	*2.2%*	*1.8%*	*1.4%*			
NH_3	4B1a	4B1b	4D1a	4D2c	4B9d	4B13	4B8	6D	1A3bi	4B9a	6B	4B6	2B5a					
	22.6%	*16.5%*	*13.8%*	*8.5%*	*7.6%*	*6.5%*	*5.7%*	*4.9%*	*3.0%*	*2.7%*	*1.7%*	*1.4%*	*1.1%*					
NMVOCs	3D2	3D3	2D2	3A2	1B2b	3A1	1B2ai	1B2c	6A	1B2av	1A3bi	1A4bi	1B2aiv	3B1	2B5a	1A2fii	3D1	3C, 1A3dii, 1A3bv, 1A4cii, 1A4ci, 1A3bii, 1A4bii
	17.9%	*12.4%*	*11.1%*	*4.8%*	*4.4%*	*4.4%*	*4.2%*	*4.0%*	*3.7%*	*3.7%*	*3.5%*	*2.8%*	*2.8%*	*2.7%*	*2.6%*	*2.4%*	*2.0%*	*5.8%*
CO	1A3bi	1A4bi	1A2fi	1A2fii	2C1	1A1a	1A4bii	1A3bii	1A3biv	1A4ci	1A3dii	2C3	1A3aii(i)	1A4cii	2B5a	1A3biii	1A1c	7A
	29.0%	*14.9%*	*11.9%*	*10.0%*	*8.5%*	*3.5%*	*3.3%*	*2.3%*	*2.2%*	*1.8%*	*1.6%*	*1.0%*	*1.0%*	*0.9%*	*0.9%*	*0.8%*	*0.8%*	*0.6%*
PM_{10}	1A4bi	1A3bvi	1A4ci	1A1a	4B9b	2A7a	1A2fii	1A3bvii	1A2fi	1A3bi	2C1	3A2	1A3bii	7A	2A7d	1A4cii	1A3dii	6Ce, 1A3biii, 1A1b, 1A3c, 2G, 4B8, 1B2c, 1A5b, 2D3, 1A4ai, 1A2c
	16.2%	*8.0%*	*6.9%*	*5.6%*	*5.3%*	*5.2%*	*4.3%*	*4.2%*	*4.1%*	*4.0%*	*3.4%*	*3.2%*	*3.2%*	*2.3%*	*2.3%*	*2.1%*	*1.9%*	*13.4%*
$PM_{2.5}$	1A4bi	1A3bvi	1A2fii	1A3bi	1A1a	1A3bii	1A2fi	1A4ci	1A3bvii	1A4cii	1A3dii	2A7d	2C1	6Ce	1A3biii	2A7a	7A	1A3c, 3A2, 4B9b, 1B2c, 1A5b, 2D3, 2G, 1A1b, 1A4ai, 1A2c, 1A1c
	15.8%	*7.4%*	*6.8%*	*6.3%*	*5.4%*	*5.0%*	*4.9%*	*4.9%*	*3.8%*	*3.4%*	*3.0%*	*3.0%*	*2.8%*	*2.8%*	*2.7%*	*2.5%*	*2.1%*	*13%*
Pb	2C1	1A2fi	1A4bi	2B5a	2C5e	1A1a	1B1b	2C5b	6Ca	2C3	1A4ai	1A3bi	1A1b	1A2fii	1A2c			
	36.5%	*18.4%*	*7.3%*	*6.5%*	*5.8%*	*4.6%*	*3.9%*	*2.5%*	*1.8%*	*1.7%*	*1.5%*	*1.5%*	*1.5%*	*0.8%*	*0.8%*			
Hg	1A1a	2C1	2B5a	1A2fi	6Cd	6A	2C5e	2C5b	1A4bi	1A2c	1A4ai	6Ca	1A2d					
	22.8%	*13.6%*	*12.0%*	*11.5%*	*11.3%*	*6.3%*	*4.1%*	*3.7%*	*3.4%*	*2.9%*	*1.4%*	*1.0%*	*1.0%*					
Cd	2C1	1A2fi	1A3bi	1A4bi	1A1a	1B1b	1A3biii	2C5e	2C3	1A4ai	1A3bii	1A2fii	1A3dii	2C5b	1A4cii	1A1b	1A3bvi	1A3c, 1A2c
	39.4%	*9.3%*	*7.6%*	*6.9%*	*5.9%*	*5.2%*	*3.2%*	*2.9%*	*2.5%*	*1.8%*	*1.8%*	*1.5%*	*1.4%*	*1.4%*	*1.2%*	*1.1%*	*1.0%*	*1.3%*
PCDD/ PCDF	7A	2C1	6Ce	1A2fi	1A4ci	6Cd	1A4bi	1A1b	2C3	6Cb	1A1a	6Ca	1A2fii	1A3bi	1A4cii	6D		
	22.8%	*17.8%*	*14.5%*	*9.7%*	*9.4%*	*5.9%*	*3.4%*	*2.4%*	*2.3%*	*1.5%*	*1.3%*	*1.0%*	*0.9%*	*0.9%*	*0.7%*	*0.6%*		
B[a]P	1A4bi	7A	1B1b	1A3bi	2C1	1A1b	2B5a	6Ce	1A2fi	1A2fii								

Pollutant	Source category (*% of total emissions*)									
	75.1%	*8.0%*	*3.2%*	*2.1%*	*2.1%*	*1.4%*	*1.0%*	*1.0%*	*1.0%*	*0.8%*
HCB	4G *55.9%*	1A1a *42.9%*								

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 Figure 1.5). This accreditation provides additional institutional standards which 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.

The main requirements of Tier 1 are:

- There is an Inventory Agency (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 Ricardo-AEA 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 3 to 12.

1.6.1 Description of the QA/QC system

Whilst the organisations that provide data to the NAEI have their own QA/QC systems, Ricardo-AEA is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, Ricardo-AEA is working continuously with organisations supplying data to the AQPI to encourage them to demonstrate their own levels of QA/QC 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 is illustrated in Figure 1.5 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.

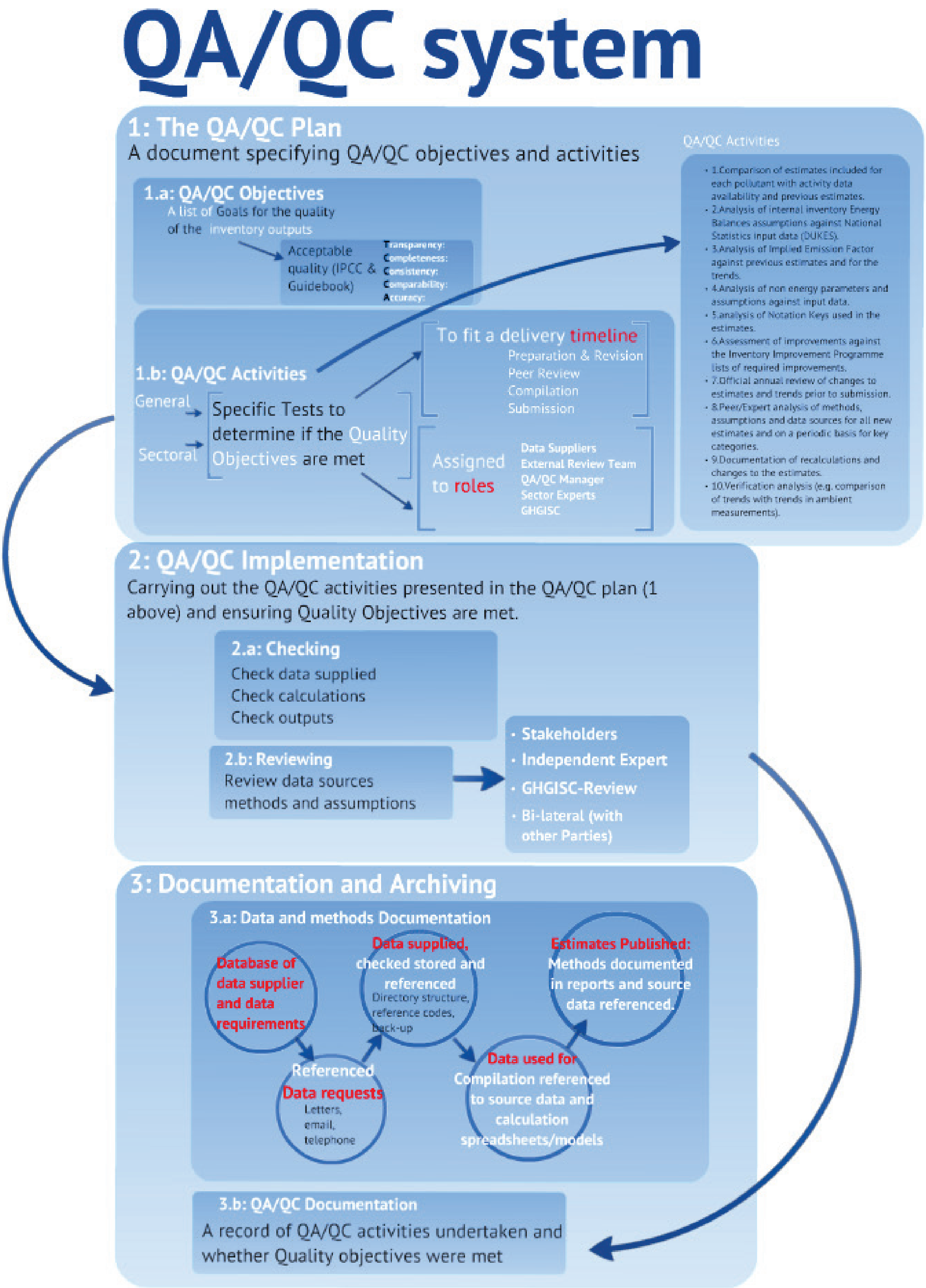
The QA/QC system includes three core components.

1. <u>The QA/QC Plan</u> which is maintained by the AQPI’s QA/QC manager (at Ricardo-AEA) 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 an online system of manuals, which defines timetables, procedures for updating the database, document control, checking procedures and procedures for updating the methodology manual.

2. <u>QA/QC implementation</u> 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

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 1.5 QA/QC system used within UK air quality pollutant and greenhouse gas inventory



> ***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.*

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):

- **Transparent in:**
  - The description of methods, assumptions, data sources used to compile estimates in internal (spreadsheets and other calculation tools) and published material (e.g. the IIR).
  - The documentation of QA/QC activities and their implementation using internal checklists and summarised in relevant public material (e.g. IIR).
- **Complete:** and include all relevant (anthropogenic) emission/removal activities, using representative data for the national territory for socio-economic assumptions and policies and measures for all required years, categories and, gases and scenarios.
- **Consistent:** across trends in emissions/removals for all years (especially where applicable between the historic and projected estimates) and that there is internal consistency in aggregation of emissions/removals.
- **Comparable:** 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.
- **Accurate**: 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.

QA/QC Roles and Responsibilities

Specific responsibilities have been assigned to the different QA (review) and QC (checking) activities and to different roles within the compilation and reporting process. A QA/QC manager co-ordinates all QA/QC activities and manages the contributions from data suppliers, sector experts and independent experts. The following responsibilities are outlined in the QA/QC plan:

- **QA/QC Manager**: maintains the QA/QC plan, sets quality objectives, co-ordinates QA/QC activities and undertakes cross cutting QA/QC activities.
- **Sectoral Experts**: Perform sector specific review and checking activities and report to the QA/QC Manager. Sector Experts also liaise with **Data suppliers** and other key stakeholders to review estimates and check supplied material.
- **Knowledge Leaders**: Manage periodic review and perform final checking activities on data and report submissions. Knowledge Leaders have been selected for this role due to their recognised technical experience and authority in the field of emissions inventories.

- **External Review experts:** Provide expert/peer review of estimates for specific sectors and report to the **QA/QC Manager.**

Co-ordinated by the QA/QC Manager, the inventory undergoes regular peer review by senior inventory personnel. A small team of experts are on hand to ensure that new or variant methodologies (changed because of availability of different datasets) are consistent with the guidelines for inventory reporting and under the UNFCCC and UNECE and are scientifically sound.

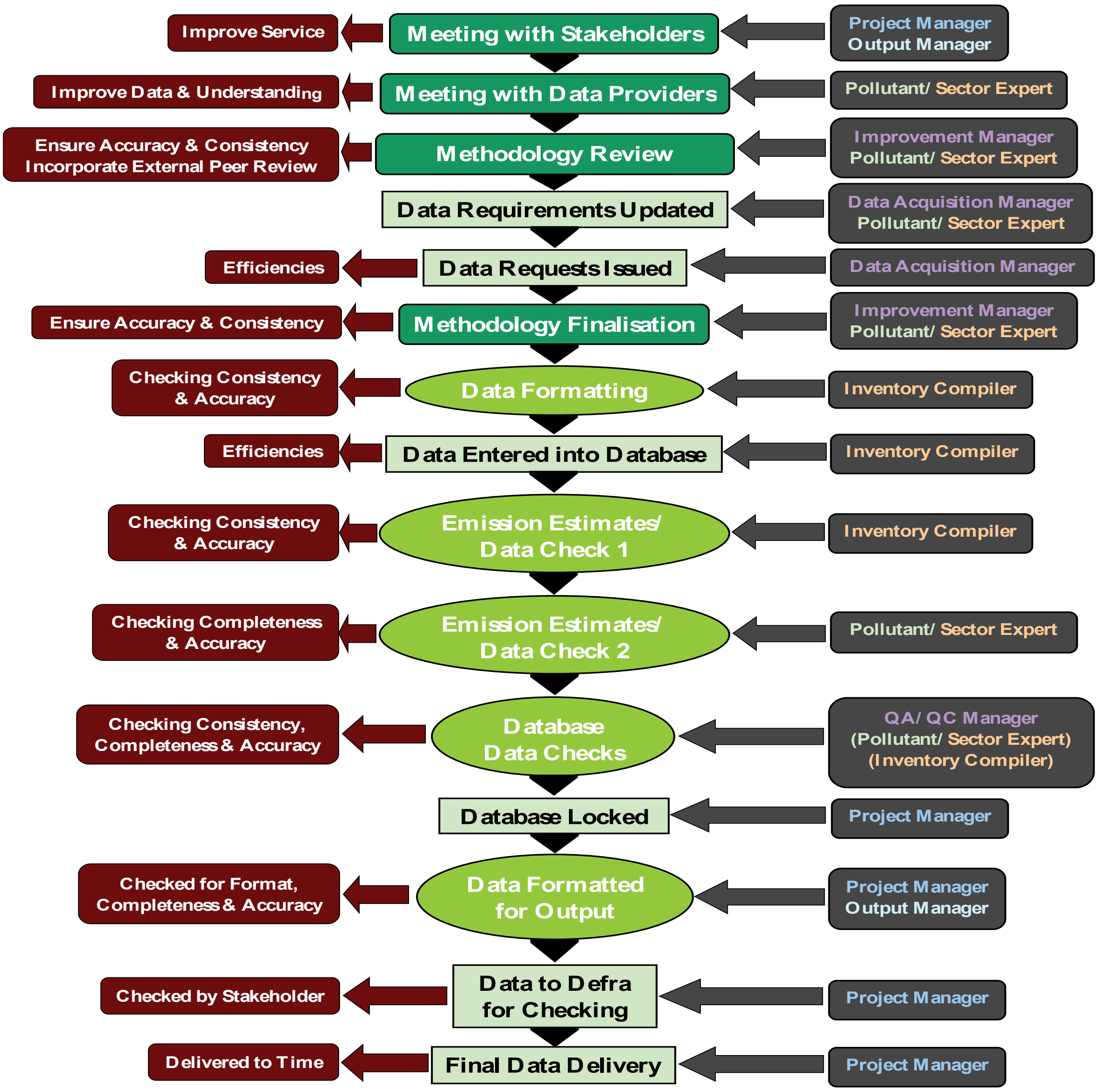
The QA/QC plan

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.

Figure 1.6 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 (in red on the left).

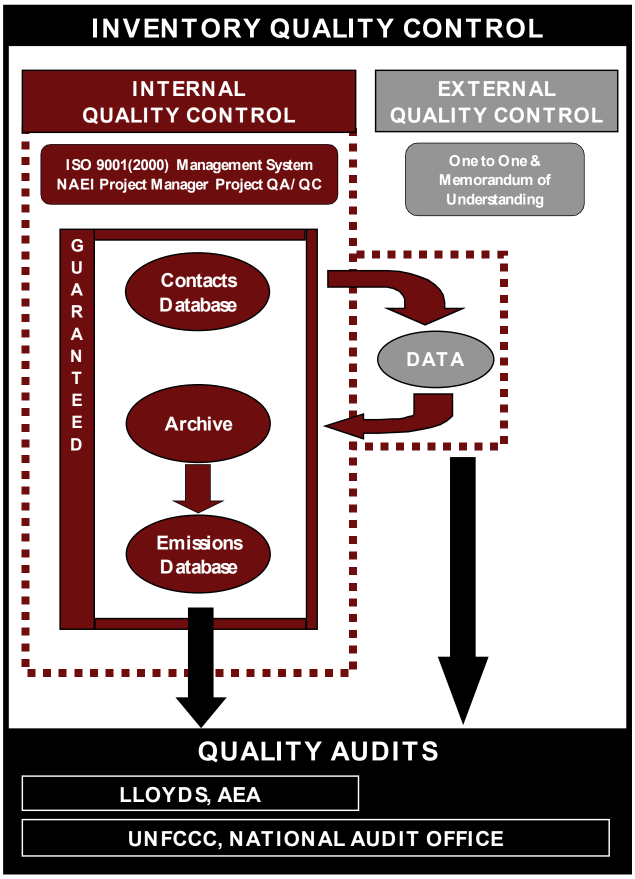
Figure 1.6 Data Flows and QA/QC



Stages 1 and 2: Input Data Quality

Whilst it is possible to maintain high standards of QA/QC on the processing and within systems managed directly by the inventory team, the quality of the input data supplied can be variable. Meeting with data suppliers (The 'One to One' Programme) and the creation of a Memorandum of Understanding for each of the data providers allows improved understanding of the data, and improved quality control. Figure 1.7 illustrates how quality control is extended where possible from inventory team activities to include the input data suppliers. The figure also indicates the auditing of the inventory team, processes and data.

Figure 1.7 Auditing of the inventory team, processes and data



Stage 3: Spreadsheet Compilation
There are a large number of QA/QC procedures which accompany this compilation stage. Each spreadsheet used for calculating estimates incorporates a QA sheet which includes key information including the unique identifiers and versioning 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, 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 the 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 sector 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 is 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.

Timeline

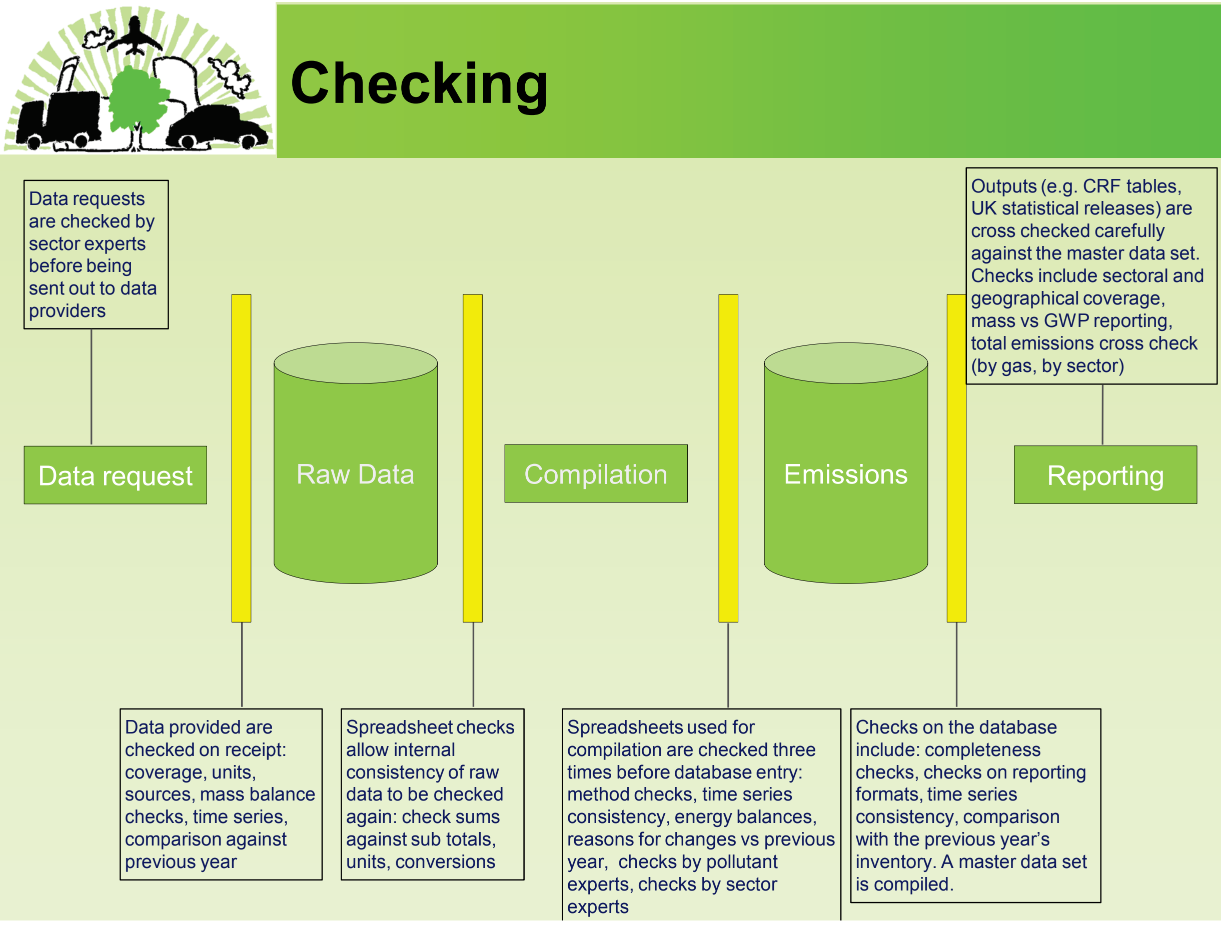
The QA/QC plan sets out a detailed timeline for QA/QC checks. The timeline is designed to fit in with compilation and reporting requirements for all UK AQPI and GHGI reporting commitments.

Quality Control and Documentation

The NAEI Quality Control (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle. Figure 1.8 illustrates the process of data checks used within the UK inventory compilation cycle. The yellow vertical 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 seem 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 back revision of data.
5. Time series Checks- 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. Analysis of Implied Emission Factor against previous estimates and for the trends.
7. Unit Checks- Units of each emission are taken from the data in the compilation spreadsheets, but these are also checked.

Figure 1.8 Summary of the system of data checks used within the UK inventory



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

1. **<u>A database of contacts (the "contacts database")</u>** Containing uniquely referenced data suppliers and data users, detailed data requirement specifications (including requirements for supplier QA/QC and uncertainty information) and data supplied to and delivered from the AQPI. This database tracks all data sources and suppliers used for the estimation of emissions/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. **<u>Individual data processing tools</u>** 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***[13] 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).
    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

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

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.

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.

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 community that use the inventory data). These experts are available to the project for 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 Air Quality Expert Group (AQEG) analyse and use the NAEI whilst assessing policy and science questions related to reducing problems associated with air pollution emissions and poor 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.

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 1.8).

Comparison with Other Inventories:
A recent study (May 2012)[14] provided a review of the UK CLRTAP emissions inventory in the context of the data that are also available from other national inventories including:

- An assessment of sources that might be omitted from the UK inventory;
- An assessment of sources that might be omitted from other national inventories;
- The variations across countries of the contribution that individual sources make to the corresponding national total;
- Comparison of PM fractionation;
- Direct comparison of emission factors;
- Comparison of implied emission factors.

[14] NAEI Validation by Comparison with Methods and Emission Factors from European Sources (May 2012) Aether

The GHGI and AQPI regularly feedback ideas for improvement identified through international review and comparison work.

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

Verification with ambient concentration data and modelling.
The annual use of mapped emissions for air pollutant dispersion models (for Defra's programme of air pollution mapping) provides valuable feedback and verification analysis on how well emissions are correlated to measured ambient concentration data. This provides insights into where emissions trends and concentration trends do or do not agree and where emissions may be under or over estimated.

Stakeholder Consultation with Key Data Providers
The AQPI team have an on-going programme of one-to-one meetings and engage in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data. The UK inventory team plan and participates in a series of one-to-one meetings and engagement activities each year. Regular and important stakeholder consultation includes:

Department of Energy and Climate Change

A series of meetings, emails and phone calls with the DECC energy statistics team that produces DUKES and the regulators of the EUETS data collection and reporting systems. These meetings focus on improving the consistency between the UK's energy statistics and other bottom up datasets that could improve the sector-specific and fuel-specific quality parameters for the UK. These include checking and resolve any outlier data or inconsistencies between EUETS data and other source data from regulators with sector- and fuel-specific activity data published in UK energy statistics. Specific recent analysis has looked at inconsistencies between UK Energy statistics (DUKES) and the EUETS for OPG use in the chemical / petrochemical / other industry sectors were identified.

Department for Transport

Consultation with the Department for Transport Traffic Statistics team to discuss provision of detailed regular transport statistics in formats consistent with NAEI reporting needs for air transport, road and rail.

Department for Environment, Food and Rural Affairs

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

Environmental Regulators

Regular consultation teleconferences and emails with sector experts and emission inventory analysts from the environmental regulatory agencies in the UK (EA, SEPA, NIEA on the emissions reporting from large industrial plant, on landfill and waste incineration data sources.

Other data providers

- Consultation with natural gas distribution network operating companies on gas leakage from the transmission system and gas demand;
- 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 and access sector-specific production statistics.
- 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.

- Consultation with colliery operators and UK Coal, combined with review of annual reports on coal mine methane use in the UK to support estimates of methane recovery and emissions in recent years.

Verification

Defra have an ongoing air pollution mapping and dispersion modelling programme which make extensive use of emissions inventory data as input or for comparison. These activities compare emissions with ambient concentrations and deposition estimates and provide some independent verification activities for air quality pollutants.

DECC has a research programme that derives independent emission estimates for the UK using in-situ high-precision high-frequency atmospheric observations of the Kyoto gases and a range of other trace gases at the Mace Head Atmospheric Research Station on the west coast of the Republic of Ireland. The UK Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) driven by 3D synoptic meteorology from the Unified Model to sort the observations made at Mace Head into those that represent northern hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Met Office inversion modelling system, InTEM (Inversion Technique for Emission Modelling), is then used to estimate the magnitude and spatial distribution of the UK and European emissions that best support the observations and provide a fully independent estimate of annual emission trends for the UK. The technique has been applied to 2 year rolling subsets of the data.

Integrated UK and Devolved Administration Inventory Improvement Programme

New information needs to be regularly assessed to ensure the inventory is accurate and up-to-date. The AQPI and GHGI estimates are updated annually and incorporate as many improvements to methods, data and assumptions as possible. These 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 EUETS data** for UK and DA inventories to separate emissions of traded and non-traded emissions;
- **PM10 emissions from small regulated industrial processes**: Improvement of the methodology for PM10 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 NOx, CO, PM10 & 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, EUETS 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 industrial use of OPG was estimated across the time series (reported under 1A2f). As in previous years, data discrepancies between DUKES and EUETS for the refinery sector were noted and resolved through consultation with the DECC DUKES team, EUETS 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 included discrepancies from the EUETS and EEMS emission reporting systems. In the 1990-2011 inventory reporting cycle, the inventory agency has been able to access full details of EUETS information for the offshore oil and gas installations for the first time, due to improvements in data management systems by the UK regulators (DECC). This has enabled the inventory agency to improve the accuracy of source allocation of emissions for the sector;
- **Oil and gas well blow-outs:** Linked to the item above, the inventory agency has also consulted with the DECC Offshore Inspectorate and the Health and Safety Executive to research available data on upstream oil and gas well blow-outs. This has led to the identification of some potentially useful annual estimates of such incidents on the UK Continental Shelf, although this has not proved sufficient to enable new emission estimates for these sources to be estimated. The inventory agency has also contacted IPCC chapter authors from Norway and Canada, as well as inventory agency counterparts in other countries, to seek any data or methodological advice on deriving estimates of methane emissions from oil and gas well blowouts. This is an area for further research in the UK inventory;
- **Road traffic data:** Specific consultation with the Department for Transport Traffic Statistics team has secured the provision of 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 for England and Wales and water and sewerage companies in the UK, to improve methane estimates from 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, although we still do not have 100% reporting from UK water companies for municipal waste water systems. 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:** Consultation with the Environment Agency of England and Wales (EA) and Defra has led to a revision of the time series of carbon content of MSW incinerated within energy from waste facilities in the UK, leading to a more representative UK carbon emission factor. Furthermore, 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.

Bilateral and peer review activities:

Table 1.8 Summary of Peer and Bilateral review activities

Review type	Date	Sector or source	Reviewer/ Participants	Summary
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	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.
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 over estimate. The review also presented another 20 recommendations for the UK to consider.

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 NISC but also include some projects lead by AEA and funded by the EU and EEA through the European Topic Centre on Air and Climate Mitigation. The list below highlights some recent examples of these activities.

1. Knowledge sharing with the Russian statistical agency who compile the inventory for Russia.
2. Capacity building activities in South Africa in the agricultural sector.
3. Knowledge sharing with the Sao Paulo inventory team.
4. 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.
5. Work with the Malta Environmental Protection Agency to set up a National Inventory System to produce both greenhouse gas and air quality pollutant inventories.
6. Knowledge sharing with the Romanian inventory team during December 2011 to support the improvement of energy sector reporting.

7. 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.

1.6.2 Treatment of Confidentiality

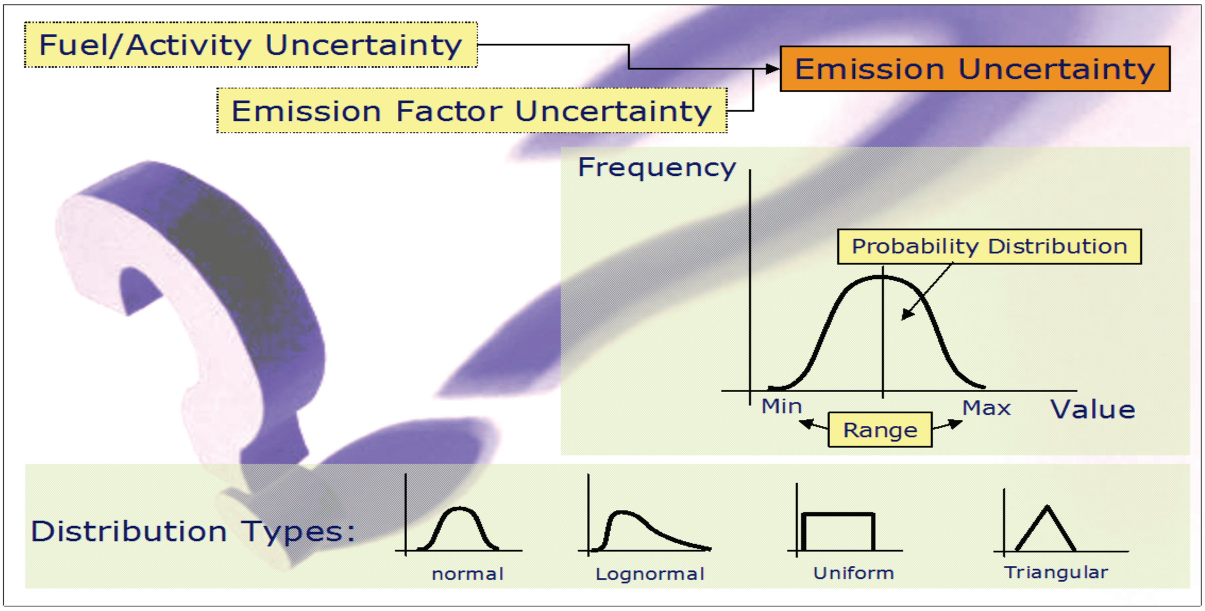
Much of the data necessary to compile the UK inventory are publicly available. However, some of the industrial production data are commercially sensitive, such as cement production and adipic acid production. For these sectors, whilst emissions data are reported openly, the activity data are not reported 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 2010 IIR onwards, and estimates of emissions of air quality pollutants, are all publicly available on the web; see http://naei.defra.gov.uk/

1.6.3 Uncertainty assessments

Uncertainty analysis for national estimates of NAEI pollutants are carried out using a Monte Carlo technique. As summarised in Figure 1.9 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 1.9 Illustration of uncertainty assessment techniques

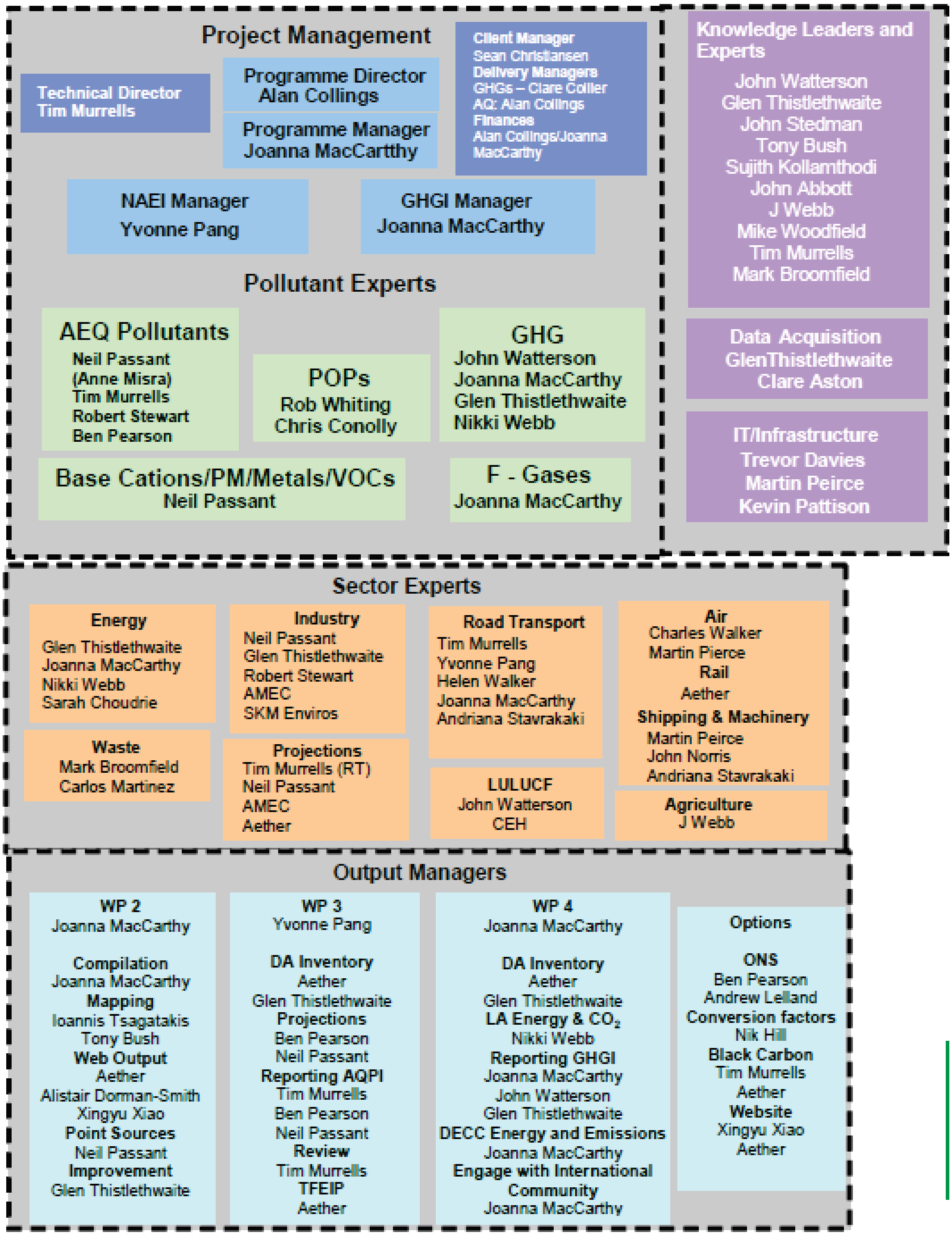


This determines the impact of uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. All analyses are consistent with the IPCC and EMEP/EEA good practice guidance. Uncertainties are assessed for each year's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

1.6.4 Staff Responsibilities and Roles

To allow an effective QA/QC system to be put in place and operated, staff roles must be clearly defined. Figure 1.10 gives an illustration of the way in which the UK emissions inventory team is organised.

Figure 1.10 Inventory Team Organisation and Responsibilities



This well-defined structure ensures that responsibilities are transparent.

1.7 Uncertainty Evaluation

Evaluation of uncertainty is carried out by a Monte-Carlo uncertainty assessment as indicated in section 1.6.3.

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 draft guidance produced by the UNECE Taskforce on Emission Inventories. This work is described in more detail by Passant (Passant NR (2002)). Uncertainty estimates are shown in Table 1.9. 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 1.9 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 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/PCDF	+/- >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_2, NO_x and NMVOC largely due to the nature of the major agricultural sources. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques. Hence emissions are affected by a large number of factors, which make the 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 and NMVOC, a few uncertain sources dominate the inventory.

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 highly uncertain, due to the relatively small number of emission factor measurements available and the highly variable nature of these values.

Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. The emission factors used in the inventory have been derived from 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, CO_2 and SO_2 which are also emitted mainly from major combustion processes.

1.7.3 Nitrogen oxides

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

From the above, one might expect the NO_x inventory to be very uncertain, however the overall uncertainty is in fact lower than for any pollutant other than SO_2. This is largely a result of two factors. First, while emission factors are uncertain, activity data used in the NO_x inventory is very much less uncertain. This contrasts with inventories for pollutants such as volatile organic compounds, PM_{10}, metals, and persistent organic pollutants, where some of the activity data are very uncertain. Second, the NO_x inventory is made up of a large number of independent emission sources with many of similar size and with none dominating (the largest source category contributes just 23% of emissions, and a further 14 sources must be included to cover 95% of the emission); reducing the resulting combined uncertainty in the national total. 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.

1.7.4 Non-Methane Volatile Organic Compounds

The NMVOC inventory is more uncertain than those for SO_2 and NO_x. 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, there is a reduced uncertainty in the national total, 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} has undergone considerable revision over the last few years of the NAEI and is now considered significantly improved. Nonetheless, the uncertainties in the emission estimates must still be considered high. These uncertainties stem from uncertainties in the emission factors themselves, the activity data with which they are combined to quantify the emissions and that in the size distribution of particle emissions from the different sources.

Emission factors characteristically are based upon a few measurements made on one emitting source, which is assumed to be representative of the behaviour of all similar sources. Emission estimates for PM_{10} are based whenever possible on measurements of PM_{10} emissions from the source, but sometimes measurements have only been made on the mass of total particulate matter and it is therefore necessary to convert this to PM_{10} - based either on the size distribution of the sample collected or, more usually, on size distributions given in the literature. 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.

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_2, NO_x or NMVOC.

The approach adopted for estimating emissions of the smaller particle sizes is currently the only one available, utilises US and Dutch data, and includes a number of assumptions and uncertainties. The approach depends on the PM_{10} emission rates estimated for each sector which themselves have great uncertainties. The emission estimates for the smaller particles will be even more uncertain for a given source given the additional uncertainties in the size fractions and the applicability of these to individual emission source sectors. The relevance of US and Dutch size fraction data to UK emission sources can also be questioned. Perhaps surprisingly, the inventories for the smaller particles are less uncertain overall than the PM_{10} inventory. This is because the most uncertain PM_{10} emissions are those from industrial processes, quarrying and construction, which emit significant quantities of PM_{10}, but these sources emit very little of the finer particulate fraction. Road transport is the dominant source of this sub-PM_{10} particulate fraction.

Estimates for total suspended particles (TSP) are calculated by applying scaling factors to the PM_{10} emissions data. The scaling factors are based on the US EPA factors (US EPA (2009).

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/PCDF, PCBs, PAHs). The issue is further exacerbated by a lack of good activity data for some important sources. The inventory for polychlorinated biphenyls and hexachlorobenzene are less uncertain than those for other persistent organic pollutants with new data from the POPs improvement programme. 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

Recent comparison of air concentrations with modelling of emission sources has suggested that some fugitive sources of metals may constitute a significant omission from emission inventories. The UK is investigating whether it is possible to estimate emissions of these sources, although currently our understanding is that no signatory country includes these sources in their emission estimates.

There are no other known omissions from the UK inventory.

1.8.2 Included Elsewhere

Sources that are unspecified within the NFR disaggregation for a specific sector are reported in categories such as 2 C 5 e - Other metal production. The list of sources included in these aggregated categories is reported in the additional information table within the 2012 CLRTAP submission[15].

1.8.3 Other Notation Keys

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

[15] http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envtzp7xq

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_2, NO_x, NMVOC, and NH_3) and additionally PM_{10}, $PM_{2.5}$, CO and a range of metals. Emissions of $PM_{2.5}$ are presented as limits will be 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 the time. The text highlights where there have been significant changes in emissions between 1980 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 a 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 in the NAEI is 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_2, NO_x, NMVOC, and NH_3 from 1980 to 2011. The emissions of NH_3 are much smaller than those of SO_2, NO_x, NMVOC and so they are presented on a separate axis. Emissions of SO_2 have declined substantially since 1980 and are now at their lowest since 1980. Emissions of NO_x and NMVOC increased gradually during the 1980s, but declined substantially since 1990 and are now at their lowest since 1980. Emissions of NH_3 have declined steadily since the mid-1980s, reaching a minimum in 2008.

Figure 2.1 Total UK emissions of SO_2, NO_x, NMVOC, and NH_3

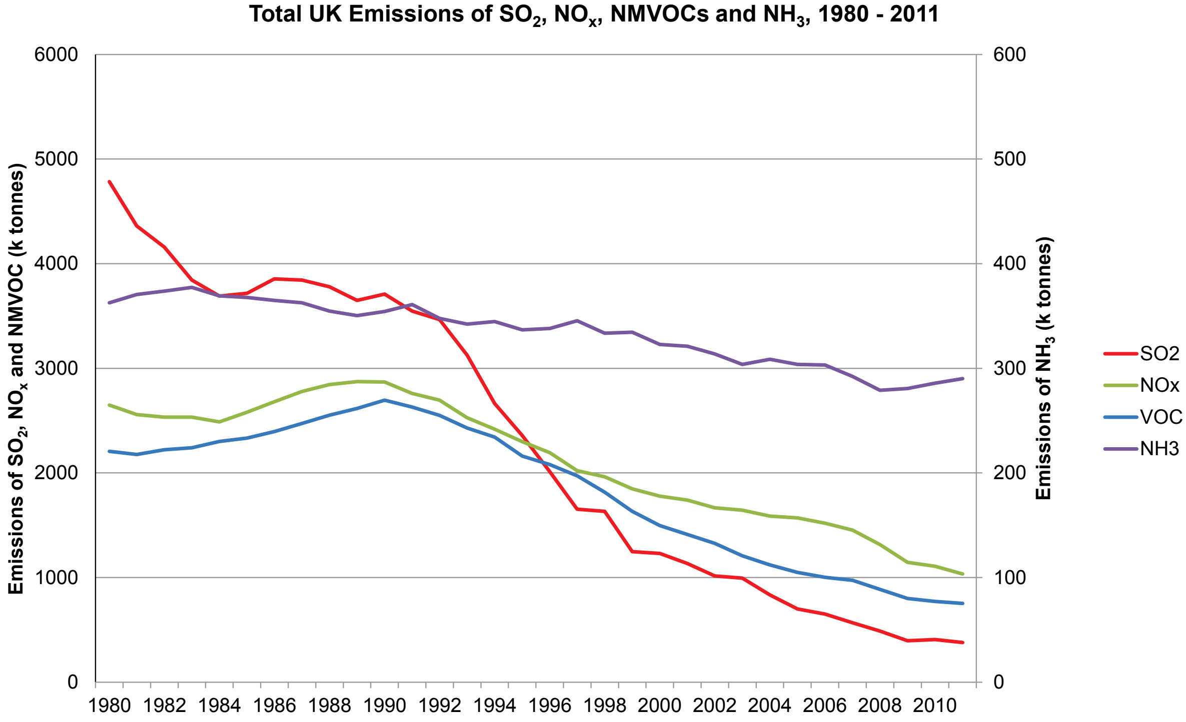


Table 2.1 shows the percentage changes in the emissions of NECD pollutants since 1980, and summarises the key factors and legislation responsible for the reductions in emissions. The impacts of these factors and legislation are discussed in greater detail, according to source, in the sections below this table.

Table 2.1 Changes in emissions of NECD pollutants since 1980

Pollutant	% change from 1980 to 2011	Key factors and legislation driving the decline in emissions
SO_2	-92%	• 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) • 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	-61%	• UK National Air Quality Strategy • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • Directive on industrial emissions 2010/75/EU (IED) • UK Pollution Prevention and Control (PPC) regulations • New air quality directive (Directive 2008/50/EC) • Implementation of the large combustion plant directive (LCPD, 2001/80/EC) • Series of Euro standards to limit vehicle tailpipe emissions, e.g. Euro 5 and Euro 6 Regulation (EC) No 715/2007 • LRTAP convention which includes measures to combat the effects of VOCs • 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

Pollutant	% change from 1980 to 2011	Key factors and legislation driving the decline in emissions
NMVOC	-66%	• UK Pollution Prevention and Control (PPC) regulations • Directive on Integrated Pollution Prevention and Control (IPPC) (Directive 2008/1/EC) • Directive on industrial emissions 2010/75/EU (IED) • Solvents Directive (99/13/EC) • New air quality directive (Directive 2008/50/EC) • Series of Euro standards to limit vehicle tailpipe emissions, e.g. Euro 5 and Euro 6 Regulation (EC) No 715/2007 • UK National Air Quality Strategy • LRTAP convention which includes measures to combat the effects of VOCs
NH_3	-20%	• 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) • 1999 Gothenburg UN/ECE Protocol to abate acidification, eutrophication and ground level ozone • LRTAP convention which includes measures to combat the effects of NH_3

2.1.2 Power Generation

Power generation was a key source for emissions of SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$, and Cd, Hg and Pb in 2011. However, there has been a substantial reduction in the magnitude of all these emissions from this source between 1980 and 2011 (see Table 2.2).

Table 2.2 Power Stations: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
SO_2	1A1a	44%	-94%
NO_x	1A1a	23%	-73%
CO	1A1a	4%	-37%
PM_{10}	1A1a	6%	-92%
$PM_{2.5}$	1A1a	5%	-89%
Cd	1A1a	6%	-95%
Hg	1A1a	23%	-84%
Pb	1A1a	5%	-97%

Figure 2.2 and Figure 2.3 show the emissions of a range of pollutants emitted from power stations between 1980 and 2011. 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 2.2 are presented in k tonnes and those in Figure 2.3 are presented in tonnes.

Figure 2.2 Total UK Emissions of SO_2, NO_x, CO, PM_{10} and $PM_{2.5}$ from power stations

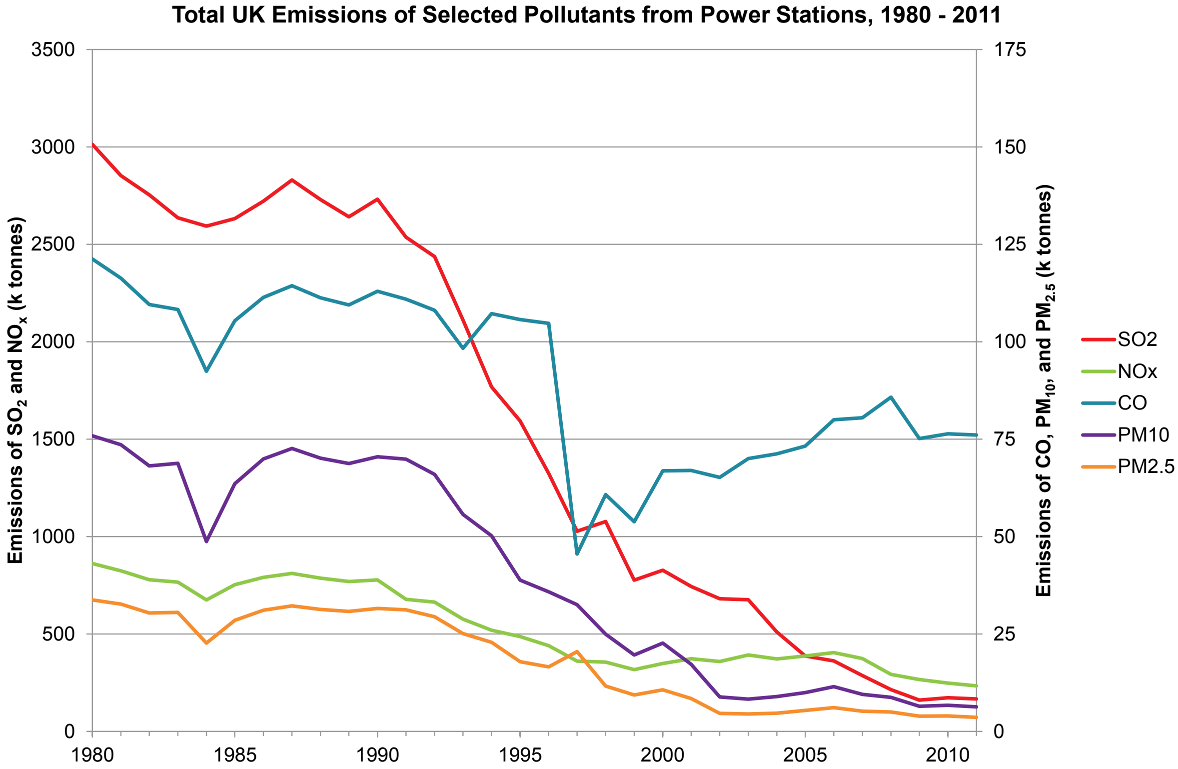
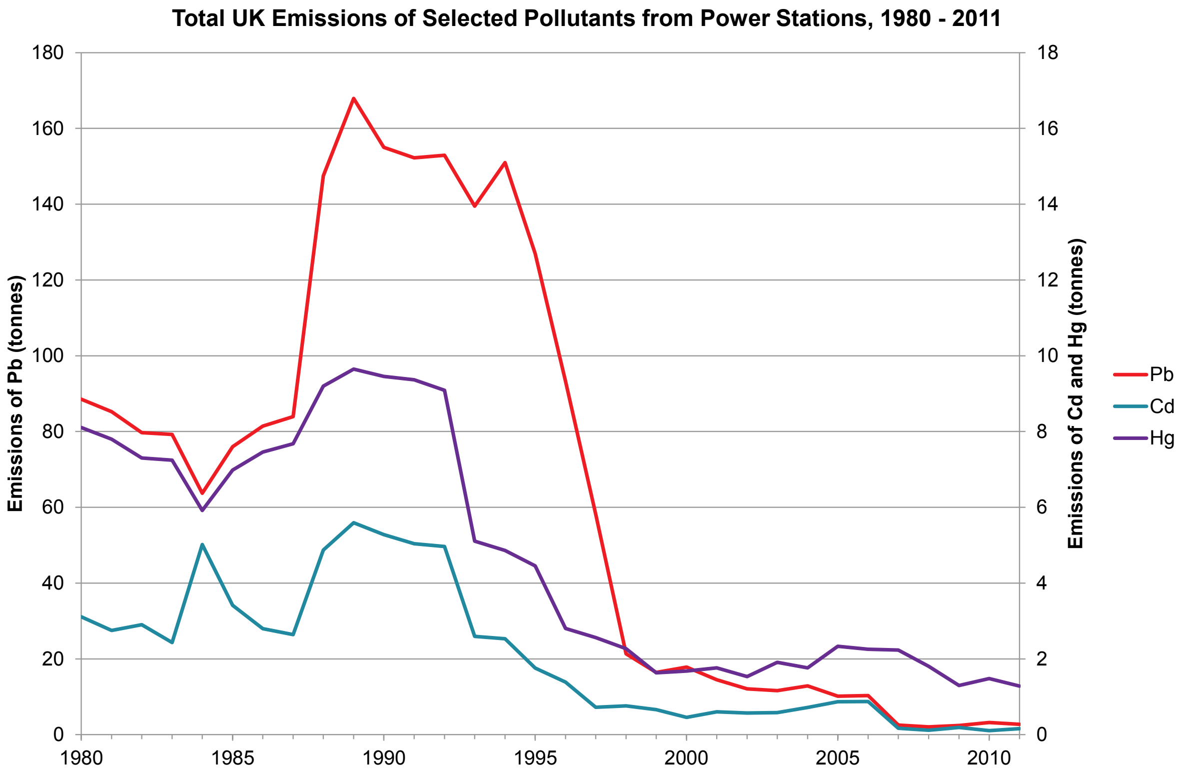


Figure 2.3 Total UK Emissions of Pb, Cd and Hg from power stations



Prior to 1989, the decline in emissions of SO_2, NO_x, 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. In 1984 the miners' strike led to a significant decrease in the use of coal for combustion in electricity generation, industry and the domestic sector. As a result there is a noticeable dip in emissions from coal-fired combustion sources in 1984.

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 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_2 emissions; this has accelerated the decline of 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 power stations has reduced SO_2 and particulate emissions further. Power station emissions are expected to fall further, primarily as a result of fuel switching, more CCGT stations and the implementation of the Industrial Emissions Directive (IED) leading to flue gas desulphurisation being fitted at more sites.

2.1.3 Residential and Commercial Sectors

Residential combustion was a key source for emissions of SO_2, NO_x, NMVOC, CO, PM_{10}, $PM_{2.5}$, and Cd, Hg and Pb emissions during 2011. However there has been a substantial reduction in the magnitude of all these emissions from this source between 1980 and 2011 (see Table 2.3).

Table 2.3 Residential: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
SO_2	1A4bi	9%	-85%
NO_x	1A4bi	3%	-66%
NMVOC	1A4bi	3%	-83%
CO	1A4bi	15%	-84%
PM_{10}	1A4bi	16%	-82%
$PM_{2.5}$	1A4bi	16%	-72%
Cd	1A4bi	7%	-57%
Hg	1A4bi	3%	-86%
Pb	1A4bi	7%	-87%

Figure 2.4 and Figure 2.5 show the emissions of a range of pollutants emitted from the residential and commercial sectors between 1980 and 2011. 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_2, NO_x, NMVOC, PM_{10} and $PM_{2.5}$ from the Residential and Commercial Sectors**

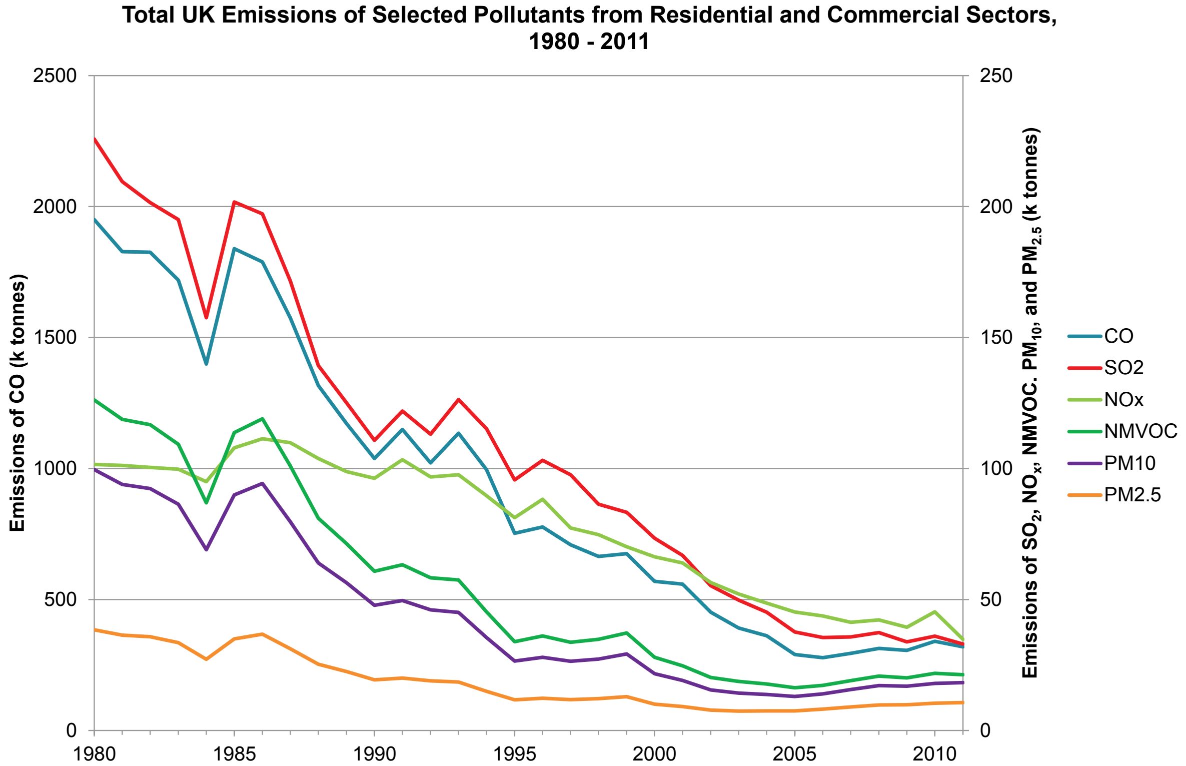
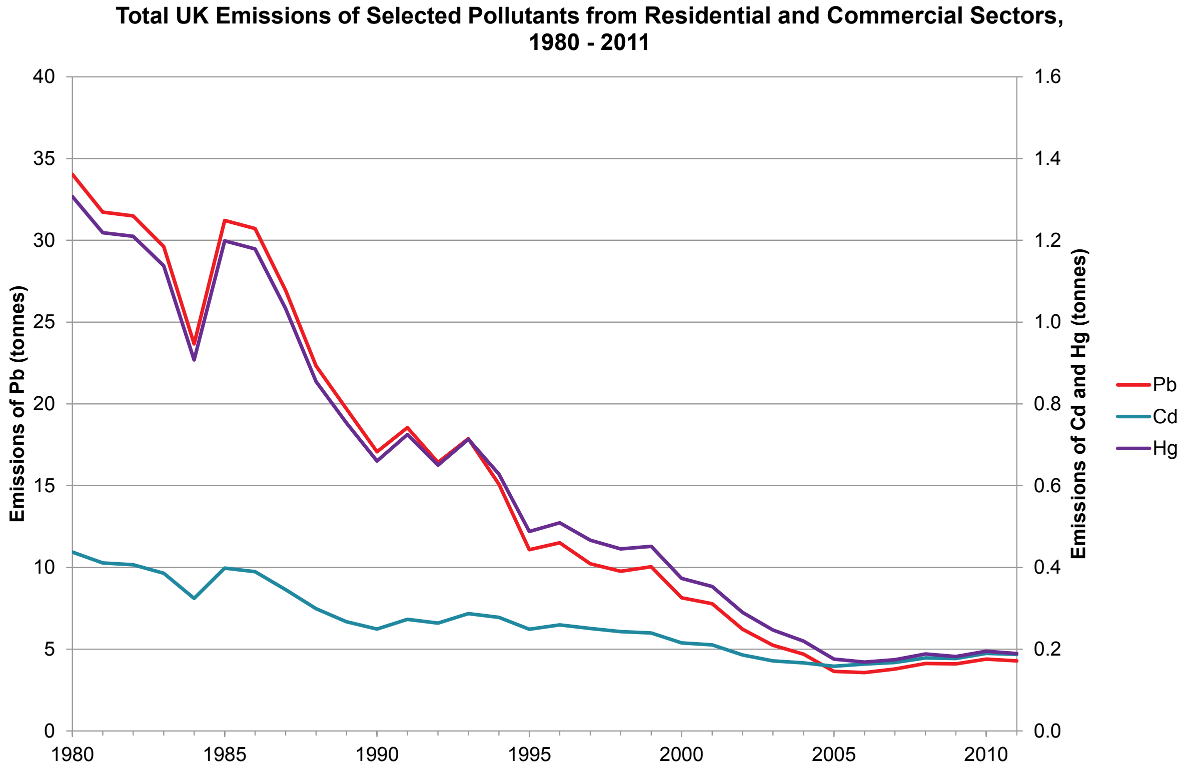


Figure 2.5 **Total UK Emissions of Pb, Cd and Hg from the Residential and Commercial Sectors**



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. In 1984 the miners' strike led to a significant decrease in the use of coal for combustion in electricity generation, industry and the domestic sector. As a result there is a noticeable dip in emissions from coal-fired combustion sources in 1984. 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 Acts and this has helped substantially reduce emissions of PM_{10}. Between 1980 and 2011, PM_{10} emissions from domestic and commercial and institutional combustion (1A4ai and 1A4bi) have fallen by 84% and 82%, respectively. Fuel switching from coal to gas and electricity has also occurred in the commercial sector. This trend in the NO_x emissions reflects this increased use of gas, and the decline in emissions of NO_x 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 (2D2) and the chemical industry (2B5a) are two of the key source categories for NMVOC emissions during 2011 (see Table 2.4). Emissions from the food and drink industry comprised 11% of the total NMVOC emission in 2011. The largest source is whisky maturation although animal feed manufacture, fat and oil processing, barley malting and bread baking are also important. Emissions from the sector peaked in 1980 before falling again to reach the lowest emissions in 1987. Since then, emissions have been generally increasing to 2011. The emission trends with time are primarily driven by production in these sectors.

Table 2.4 Industrial Processes: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
NMVOC	2B5a	3%	-85%
NH_3	2B5a	1%	-47%
CO	2B5a	1%	-68%
Hg	2B5a	12%	-93%
Pb	2B5a	7%	-96%
B[a]P	2B5a	1%	-35%
SO_2	2C1	2%	-20%
CO	2C1	8%	-28%
PM_{10}	2C1	3%	-6%
$PM_{2.5}$	2C1	3%	-16%
Cd	2C1	39%	20%
Hg	2C1	14%	124%
Pb	2C1	36%	-50%
B[a]P	2C1	2%	-55%
PCDD/ PCDF	2C1	18%	-52%
NMVOC	2D2	11%	2%

Figure 2.6 and Figure 2.7 show the emissions of a range of pollutants emitted from the chemical industry between 1980 and 2011. 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 NMVOC, CO, and NH_3 from the Chemical Industry

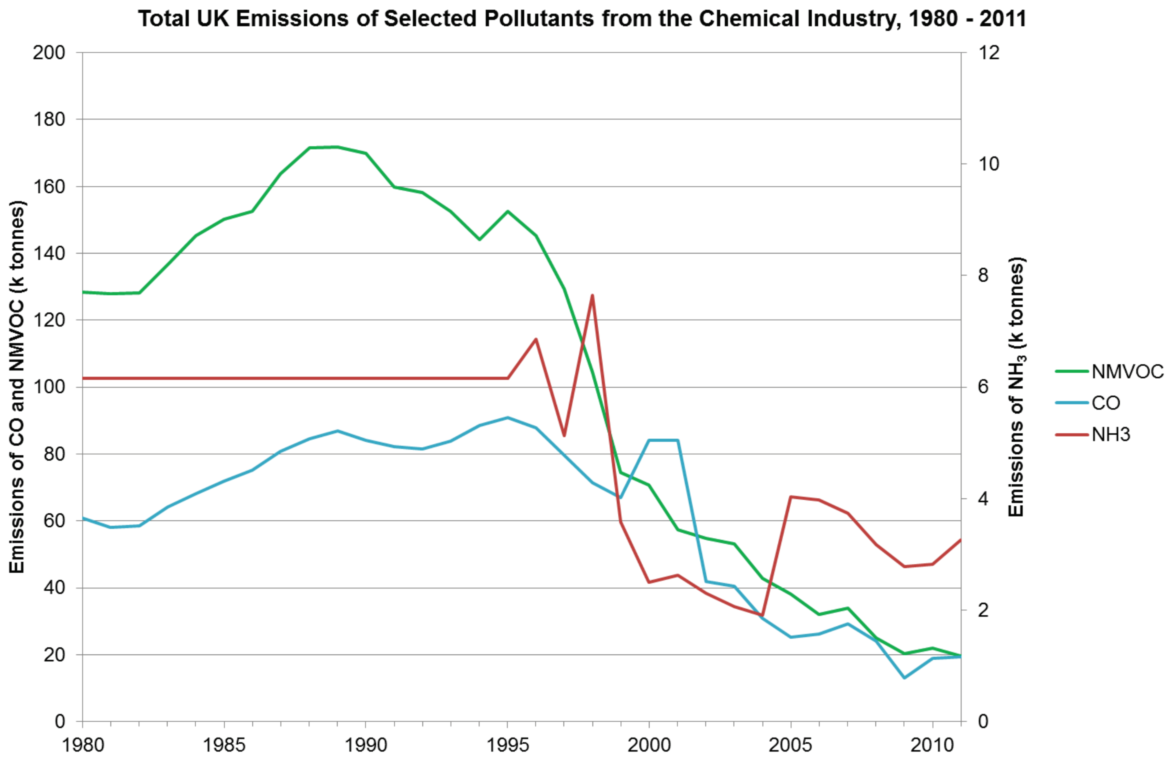
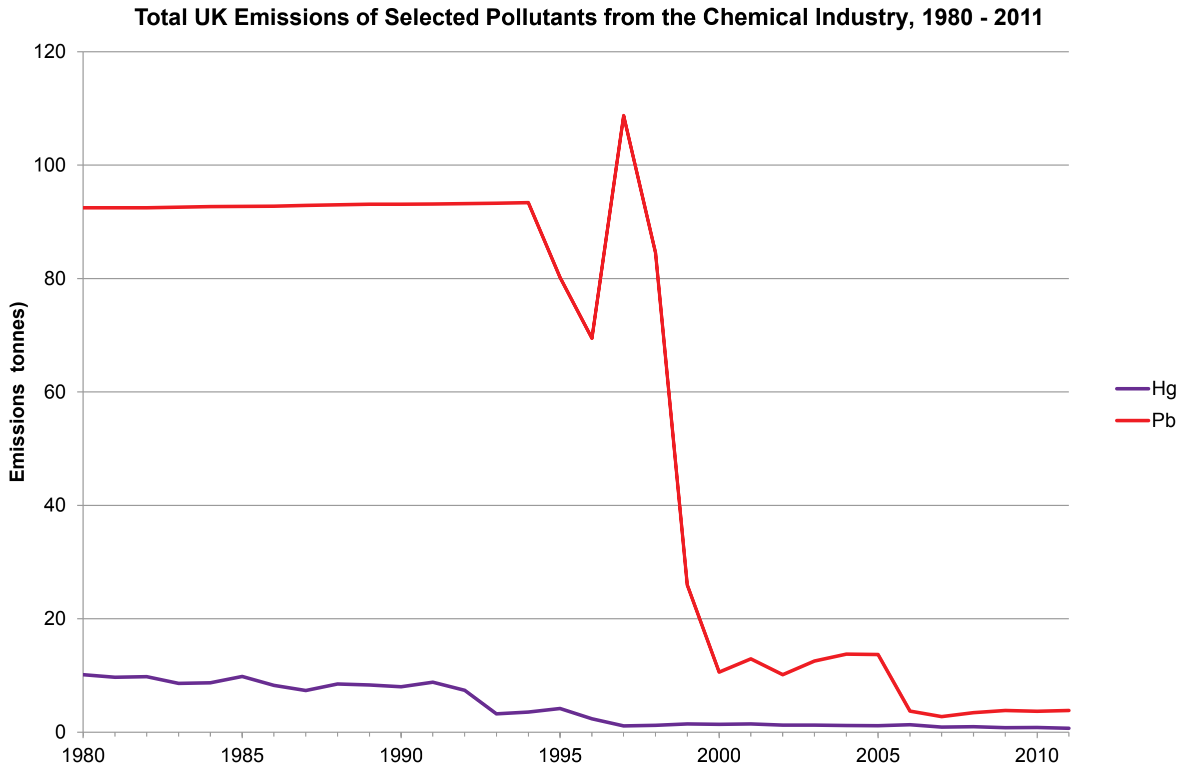


Figure 2.7 Total UK Emissions of Hg and Pb from the Chemical Industry



Emissions from the chemical industry grew steadily until 1989, since then tightening emission controls have led to a reduction in emissions. The overall reduction in emissions from the chemical industry of

NMVOC between 1980 and 2011 is 85%. The chemical industry is a key source category for CO, NH_3, Pb, Hg and benzo[a]pyrene.

Figure 2.8 and Figure 2.9 show the emissions of a range of pollutants emitted from the iron and steel industry between 1980 and 2011. 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 2.8 Total UK Emissions of CO, SO_2, PM_{10} and $PM_{2.5}$ from Iron and Steel

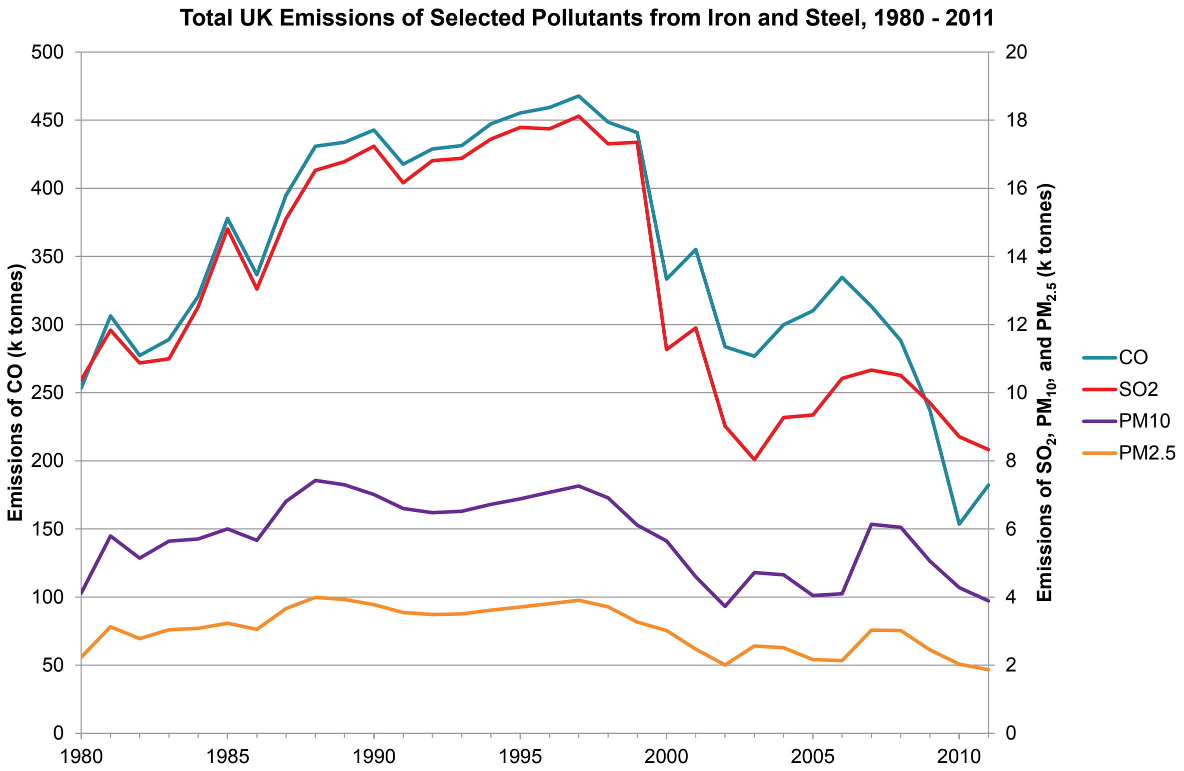
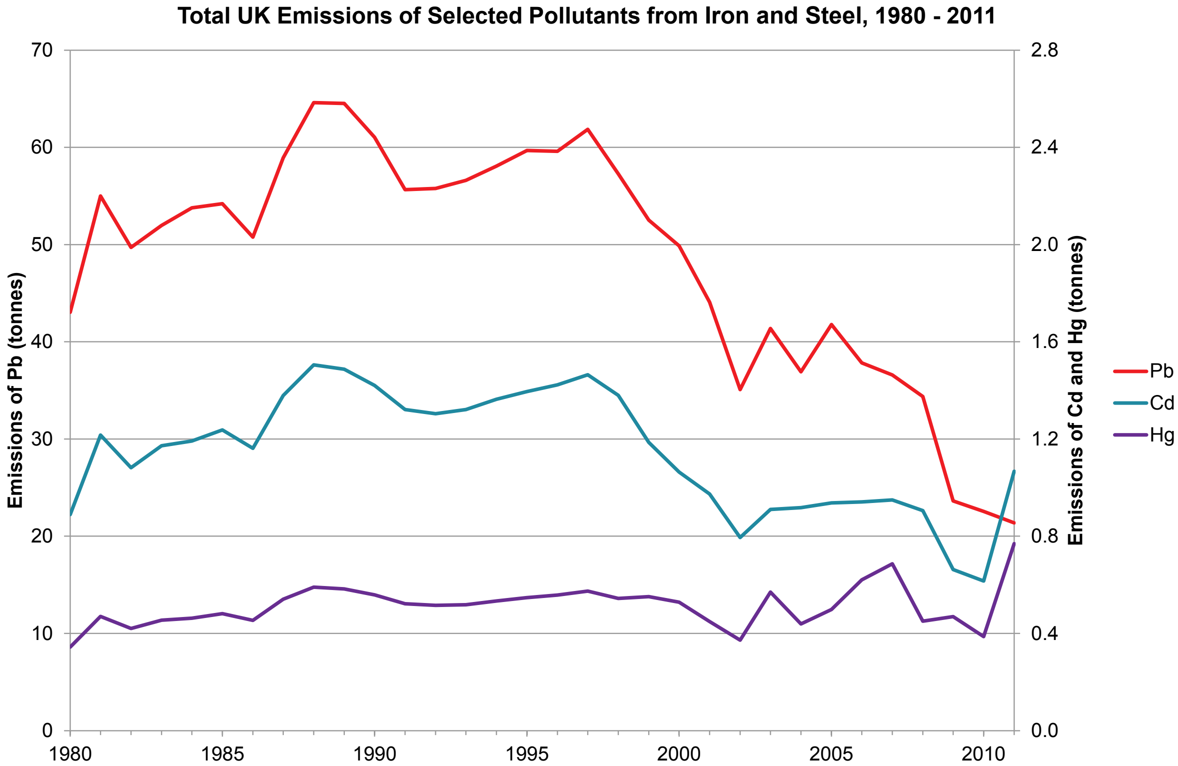


Figure 2.9 Total UK Emissions of Pb, Cd and Hg from Iron and Steel



Iron and steel production (2C1) is a key category for SO_2, CO, PM_{10}, $PM_{2.5}$, Pb, Cd, PCDD/PCDF, benzo[a]pyrene and Hg. Trends in emissions from these sources are summarised in Table 2.4. Metal production emissions have typically declined since 1980 in line with declining production, although emissions of heavy metals from this category can be variable from year to year, and 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; see 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
1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)
1A3bi	1 A 3 b i Road Transport, Passenger cars
1A3bii	1 A 3 b ii Road Transport, Light duty vehicles
1A3biii	1 A 3 b iii Road Transport, Heavy duty vehicles
1A3biv	1 A 3 b iv Road Transport, Mopeds & Motorcycles
1A3bv	1 A 3 b v Road Transport, Gasoline evaporation
1A3bvi	1 A 3 b vi Road Transport, Automobile tyre and brake wear
1A3bvii	1 A 3 b vii Road Transport, Automobile road abrasion
1A3c	1 A 3 c Railways

NFR Code	NFR Name
1A3dii	1 A 3 d ii National Navigation

Transport is a key source of CO, NH_3, NMVOC, NO_x, PM_{10} and SO_2 emissions in the UK; see Table 2.6.

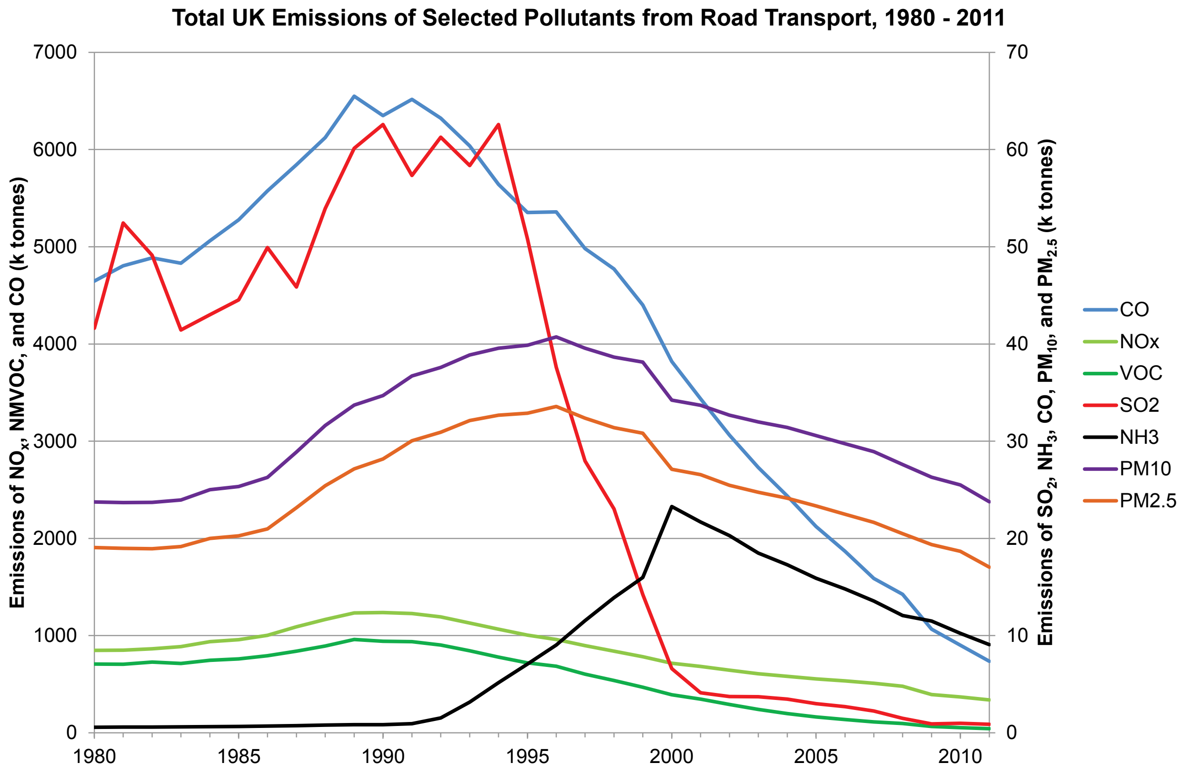
Table 2.6 Transport: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
SO_2	1A3dii	2.0%	-71%
NO_x	1A3bi	15%	-72%
NO_x	1A3biii	12%	-47%
NO_x	1A3bii	6%	-15%
NO_x	1A3c	4%	19%
NO_x	1A3dii	4%	-14%
NO_x	1A3ai(i)	1%	198%
CO	1A3bi	29%	-84%
CO	1A3bii	2%	-91%
CO	1A3biv	2%	-70%
CO	1A3dii	2%	184%
CO	1A3aii(i)	1%	-52%
CO	1A3biii	1%	-72%
PM_{10}	1A3bvi	8%	59%
PM_{10}	1A3bvii	4%	64%
PM_{10}	1A3bi	4%	80%
PM_{10}	1A3bii	3%	49%
PM_{10}	1A3dii	2%	-48%
PM_{10}	1A3biii	2%	-81%
PM_{10}	1A3c	1%	18%
$PM_{2.5}$	1A3bvi	7%	62%
$PM_{2.5}$	1A3bi	6%	80%
$PM_{2.5}$	1A3bii	5%	49%
$PM_{2.5}$	1A3bvii	4%	64%
$PM_{2.5}$	1A3dii	3%	-48%
$PM_{2.5}$	1A3biii	3%	-81%

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
$PM_{2.5}$	1A3c	2%	16%
NMVOC	1A3bi	3%	-93%
NMVOC	1A3dii	1%	110%
NMVOC	1A3bv	1%	-98%
NMVOC	1A3bii	1%	-89%
NMVOC	1A3biv	1%	-83%
NH_3	1A3bi	3%	1913%

Figure 2.10 shows the emissions of a range of pollutants emitted from the road transport sector (1A3b) between 1980 and 2011. Note that this chart uses two Y-axes and pollutants are assigned to an axis depending on the relative magnitudes of their emissions.

Figure 2.10 Total UK Emissions of CO, NO_x, NMVOC, SO_2, NH_3, PM_{10} and $PM_{2.5}$ Road Transport



Road vehicle emissions rose steadily from 1970 to a peak in 1989, reflecting the overall growth in road traffic in the UK. Road traffic is still growing over time but there has been a decline in emissions due to number of reasons. Since 1989, the requirement for new petrol cars to be fitted with three-way catalysts has reduced emissions of NO_x, CO and NMVOC. On the other hand, emissions of NH_3 from road transport have increased as a result of the increasing number of three way catalyst in the vehicle fleet. However, emissions are projected to fall across the next years as the second generation of catalysts (which emit less NH_3 than first generation catalysts) penetrate the vehicle fleet.

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 emissions. Fuel switching from petrol cars to diesel cars has reduced CO and NMVOC 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.

Further detailed information on Transport is covered in Chapter 5.

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
4A1	4 A 1 Enteric_Fermentation_Cows
4A10	4 A 10 Enteric_Fermentation_Deer
4A3	4 A 3 Enteric_Fermentation_Sheep
4A4	4 A 4 Enteric_Fermentation_Goats
4A6	4 A 6 Enteric_Fermentation_Horses
4A8	4 A 8 Enteric_Fermentation_Swine
4B12	4 B 12 Solid_Storage_and_Drylot
4B13	4 B 13 Other
4B1b	4 B 1 b Non-Dairy
4B3	4 B 3 Sheep
4B4	4 B 4 Goats
4B6	4 B 6 Horses
4B8	4 B 8 Swine
4B9a	4 B 9 a Laying hens
4B9b	4 B 9 b Broilers
4B9d	4 B 9 d Other poultry
4D1a	4 D 1 a Synthetic N-fertilizers
4D2c	N-excretion on pasture range and paddock unspecified
4F	4 F Field Burning Of Agricultural Wastes
4G	4 G OTHER (d)

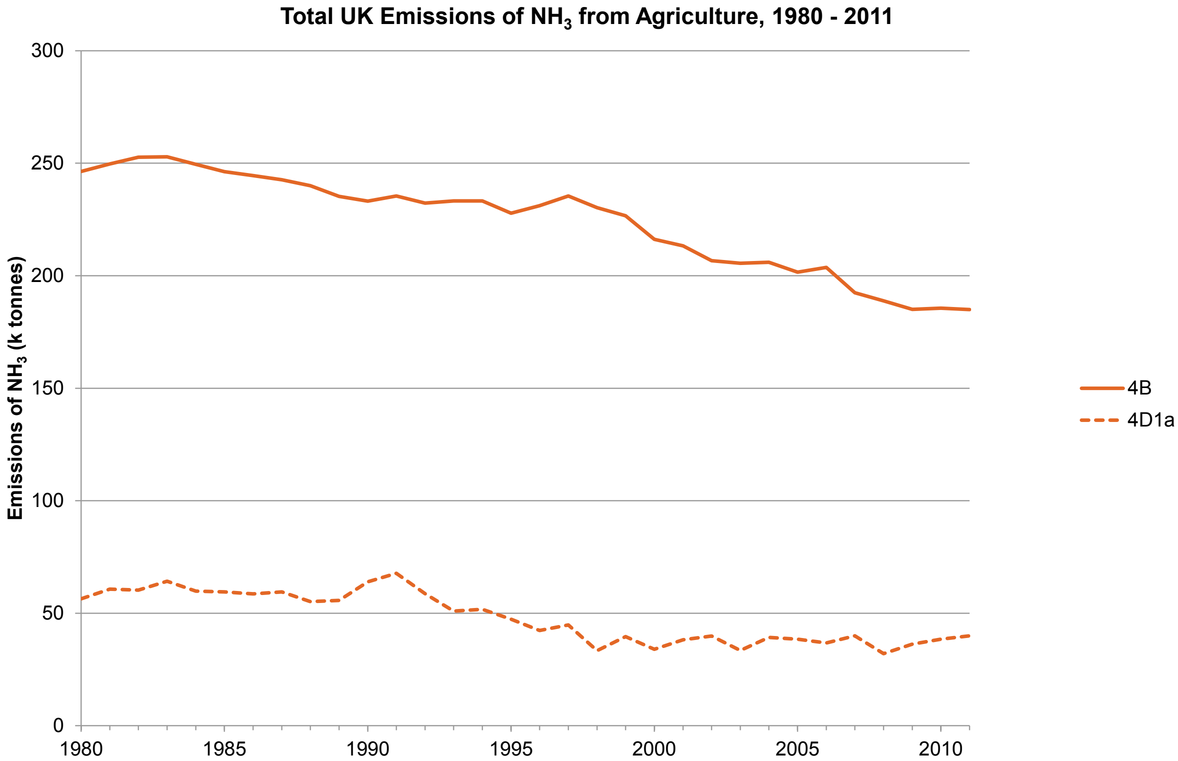
Table 2.8 Agriculture: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
NH_3	4B1a	23%	-18%
NH_3	4B1b	16%	-27%

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
NH_3	4D1a	14%	-29%
NH_3	4D2c	8%	-11%
NH_3	4B9d	8%	3%
NH_3	4B13	6%	-14%
NH_3	4B8	6%	-54%
NH_3	4B9a	3%	-58%
NH_3	4B6	1%	-
NH_3	4B3	1%	-16%
PM10	4B9b	5%	71%
PM10	4B9d	2%	8%
PM10	4B8	1%	-43%
PM2.5	4B9b	2%	71%
PM2.5	4B9d	1%	8%

Figure 2.11 shows the emissions of NH_3 emitted from two source categories in the agriculture sector between 1980 and 2011.

Figure 2.11 Total UK Emissions of NH_3 from Selected Sources in Agriculture



Agricultural sources with emissions from livestock and their wastes (NFR 4B) are the major source of NH_3 emissions, contributing 64% of total emissions in 2011. 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 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 4D1a), which also caused a decrease in emissions. Total NH_3 emissions from agriculture in 2011 represent a decrease of 25% on the 1980 emissions.

Field burning of agricultural waste (4F) was one of the key sources of CO and NMVOC emissions in 1980, contributing 5.4% and 2% of total emissions respectively. Emissions from the agricultural sector occur for NO_x, CO and NMVOC until 1993 only. During 1993, agricultural stubble burning was stopped in England and Wales and therefore emissions of NO_X, CO and NMVOC are no longer recorded post-1993.

2.1.7 Waste

Emissions of NO_x, CO and SO_2 from the waste sector have a negligible effect on overall UK emissions. Emissions of NMVOC from solid waste disposal on land i.e. landfill (6A) contribute approximately 4% of total emissions, but have declined substantially since 1980; see Table 2.9.

Table 2.9 Waste: Magnitude of Emissions, and Trends from 1980 to 2011

Pollutant	NFR Code	% of total emissions in 2011	% change from 1980 to 2011
NH_3	6D	5%	1155%
NH_3	6B	2%	1%
NH_3	6A	1%	1%
PM_{10}	6Ce	2%	<1%
$PM_{2.5}$	6Ce	3%	<1%
VOC	6A	4%	-60%

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 Total UK emissions and Key Sources: 2010 Significance and Trends, 1980-2011

Pollutant	Key sources during 2011		% of total emissions in 2011	% Change from 1980 to 2011
SO_x	1A1a	1 A 1 a Public Electricity and Heat Production	44%	-94%
	1A1b	1 A 1 b Petroleum refining	16%	-69%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	12%	-94%
	1A4bi	1 A 4 b i Residential plants	9%	-85%
	1A3dii	1 A 3 d ii National Navigation	2%	-71%
	2C1	2 C 1 Iron and steel production	2%	-20%
	1B1b	1 B 1 b Solid fuel transformation	2%	-77%
	2A7d	2 A 7 d Other Mineral products	2%	-43%
	1A2c	1 A 2 c Chemicals	2%	150%
	1A5b	1 A 5 b Other, Mobile (Including military)	1%	-13%
	1A2a	1 A 2 a Iron and Steel	1%	-93%

Pollutant	Key sources during 2011		% of total emissions in 2011	% Change from 1980 to 2011
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1%	-78%
	Overall change for all sources			**-92%**
NO_x	1A1a	1 A 1 a Public Electricity and Heat Production	23%	-73%
	1A3bi	1 A 3 b i R.T., Passenger cars	15%	-72%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	12%	-47%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	7%	-77%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	6%	-15%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction:	6%	-43%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	5%	27%
	1A3c	1 A 3 c Railways	4%	19%
	1A3dii	1 A 3 d ii National Navigation	4%	-14%
	1A4bi	1 A 4 b i Residential plants	3%	-66%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	3%	-64%
	1A5b	1 A 5 b Other, Mobile (Including military)	3%	-32%
	1A1b	1 A 1 b Petroleum refining	2%	-46%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	2%	-59%
	1A2c	1 A 2 c Chemicals	1%	1%
	Overall change for all sources			**-61%**
CO	1A3bi	1 A 3 b i R.T., Passenger cars	29%	-84%
	1A4bi	1 A 4 b i Residential plants	15%	-84%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	12%	71%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction:	10%	28%
	2C1	2 C 1 Iron and steel production	8%	-28%
	1A1a	1 A 1 a Public Electricity and Heat Production	4%	-37%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	3%	7%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	2%	-91%
	1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	2%	-70%
	1A4ci	1 A 4 c i Stationary	2%	156%
	1A3dii	1 A 3 d ii National Navigation	2%	184%
	2C3	2 C 3 Aluminum production	1%	-24%
	1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	1%	-52%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-14%
	2B5a	2 B 5 a Other chemical industry	1%	-68%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	1%	-72%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1%	39%

Pollutant	Key sources during 2011		% of total emissions in 2011	% Change from 1980 to 2011
	7A	7 A Other (included in national total for entire territory)	1%	-7%
	Overall change for all sources			**-74%**
PM_{10}	1A4bi	1 A 4 b i Residential plants	16%	-82%
	1A3bvi	1 A 3 b vi R.T., Automobile tyre and brake wear	8%	59%
	1A4ci	1 A 4 c i Stationary	7%	72%
	1A1a	1 A 1 a Public Electricity and Heat Production	6%	-92%
	4B9b	4 B 9 b Broilers	5%	71%
	2A7a	2 A 7 a Quarrying and mining of minerals other than coal	5%	-39%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction:	4%	-49%
	1A3bvii	1 A 3 b vii R.T., Automobile road abrasion	4%	64%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	4%	-74%
	1A3bi	1 A 3 b i R.T., Passenger cars	4%	80%
	2C1	2 C 1 Iron and steel production	3%	-6%
	3A2	3 A 2 Industrial coating application	3%	-41%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	3%	49%
	7A	7 A Other (included in national total for entire territory)	2%	-16%
	2A7d	2 A 7 d Other Mineral products	2%	-37%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	2%	-71%
	1A3dii	1 A 3 d ii National Navigation	2%	-48%
	4B9d	4 B 9 d Other poultry	2%	8%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	2%	-81%
	6Ce	6 C e Small scale waste burning	2%	0%
	1A1b	1 A 1 b Petroleum refining	1%	-70%
	1A3c	1 A 3 c Railways	1%	18%
	2G	2 G OTHER (Please specify in a covering note)	1%	-39%
	4B8	4 B 8 Swine	1%	-43%
	1B2c	1 B 2 c Venting and flaring	1%	-61%
	1A5b	1 A 5 b Other, Mobile (Including military)	1%	-19%
	2D3	2 D 3 Wood processing	1%	-60%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1%	-84%
	1A2c	1 A 2 c Chemicals	0%	1162%
	Overall change for all sources			**-65%**
$PM_{2.5}$	1A4bi	1 A 4 b i Residential plants	16%	-72%
	1A3bvi	1 A 3 b vi R.T., Automobile tyre and brake wear	7%	62%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	7%	-49%
	1A3bi	1 A 3 b i R.T., Passenger cars	6%	80%
	1A1a	1 A 1 a Public Electricity and Heat Production	5%	-89%

Pollutant	Key sources during 2011		% of total emissions in 2011	% Change from 1980 to 2011
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	5%	49%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	5%	-71%
	1A4ci	1 A 4 c i Stationary	5%	120%
	1A3bvii	1 A 3 b vii R.T., Automobile road abrasion	4%	64%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	3%	-71%
	1A3dii	1 A 3 d ii National Navigation	3%	-48%
	2A7d	2 A 7 d Other Mineral products	3%	-35%
	2C1	2 C 1 Iron and steel production	3%	-16%
	6Ce	6 C e Small scale waste burning	3%	0%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	3%	-81%
	2A7a	2 A 7 a Quarrying and mining of minerals other than coal	3%	-39%
	7A	7 A Other (included in national total for entire territory)	2%	-13%
	1A3c	1 A 3 c Railways	2%	16%
	3A2	3 A 2 Industrial coating application	2%	-41%
	4B9b	4 B 9 b Broilers	2%	71%
	1B2c	1 B 2 c Venting and flaring	1%	-61%
	1A5b	1 A 5 b Other, Mobile (Including military)	1%	-19%
	2D3	2 D 3 Wood processing	1%	-60%
	2G	2 G OTHER (Please specify in a covering note)	1%	-39%
	1A1b	1 A 1 b Petroleum refining	1%	-80%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1%	-76%
	1A2c	1 A 2 c Chemicals	1%	3964%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1%	-62%
	Overall change for all sources			**-60%**
NMVOC	3D2	3 D 2 Domestic solvent use including fungicides	18%	66%
	3D3	3 D 3 Other product use	12%	-34%
	2D2	2 D 2 Food and Drink	11%	2%
	3A2	3 A 2 Industrial coating application	5%	-66%
	1B2b	1 B 2 b Natural gas	4%	-12%
	3A1	3 A 1 Decorative coating application	4%	-37%
	1B2ai	1 B 2 a i Exploration Production, Transport	4%	-69%
	1B2c	1 B 2 c Venting and flaring	4%	-35%
	6A	6 A SOLID WASTE DISPOSAL ON LAND	4%	-60%
	1B2av	1 B 2 a v Distribution of oil products	4%	-65%
	1A3bi	1 A 3 b i R.T., Passenger cars	3%	-93%
	1A4bi	1 A 4 b i Residential plants	3%	-83%
	1B2aiv	1 B 2 a iv Refining / Storage	3%	-79%
	3B1	3 B 1 Degreasing	3%	-77%

Pollutant	Key sources during 2011		% of total emissions in 2011	% Change from 1980 to 2011
	2B5a	2 B 5 a Other chemical industry	3%	-85%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction	2%	-13%
	3D1	3 D 1 Printing	2%	-59%
	3C	3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	2%	-77%
	1A3dii	1 A 3 d ii National Navigation	1%	110%
	1A3bv	1 A 3 b v R.T., Gasoline evaporation	1%	-98%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-51%
	1A4ci	1 A 4 c i Stationary	1%	157%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	1%	-89%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	1%	-68%
	Overall change for all sources			**-66%**
NH_3	4B1a	4 B 1 a Dairy	23%	-18%
	4B1b	4 B 1 b Non-Dairy	16%	-27%
	4D1a	4 D 1 a Synthetic N-fertilizers	14%	-29%
	4D2c	N-excretion on pasture range and paddock unspecified	8%	-11%
	4B9d	4 B 9 d Other poultry	8%	3%
	4B13	4 B 13 Other	6%	-14%
	4B8	4 B 8 Swine	6%	-54%
	6D	6 D Other Waste (f)	5%	1155%
	1A3bi	1 A 3 b i R.T., Passenger cars	3%	1913%
	4B9a	4 B 9 a Laying hens	3%	-58%
	6B	6 B Waste-Water Handling	2%	1%
	4B6	4 B 6 Horses	1%	-
	2B5a	2 B 5 a Other chemical industry (Please specify the sources included/excluded in the notes column to the right)	1%	-47%
	Overall change for all sources			**-20%**

3. 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 *(except HCH)*	Power stations
		Miscellaneous industrial/commercial combustion (landfill gas, MSW only)[16]
1 A 1 b Petroleum refining	All CLRTAP pollutants *(except NH_3, HCB, HCH and PCBs)*	Refineries
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	All CLRTAP pollutants *(except HCB and HCH)*	Coke production
		Collieries – fuel combustion
		Gas production (downstream gas)[17]
		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, EUETS, operators	Major fuels: Operator-reported emissions data under IPPC. Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research)
Miscellaneous industrial/commercial combustion	AD x EF	DECC energy statistics, EUETS	MSW: Operator-reported emissions data under IPPC. LFG: default factors (USEPA, EMEP-EEA, UK-specific research)
Refineries	AD x EF	DECC energy statistics, EUETS	Major fuels: Operator-reported emissions data under IPPC, UKPIA Minor fuels: default factors (USEPA, EMEP-EEA, UK-specific research,

[16] Emissions from miscellaneous / commercial sources are only reported in 1A1a where MSW & landfill gas are burned to produce heat.

[17] 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
			UKPIA)
Coke production	UK model	DECC energy statistics, EUETS, ISSB	Major fuels: Operator-reported emissions data under IPPC, 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, EUETS	Default factors (USEPA, EMEP-EEA, UK-specific research)
Gas separation plant	AD x EF	DECC energy statistics, EUETS	EEMS and IPPC annual reporting by operators, UKOOA research, USEPA factors for PM_{10}
Upstream gas production	AD x EF	DECC energy statistics, EUETS	EEMS and IPPC 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, EUETS	EEMS and IPPC annual reporting by operators, UKOOA / other UK-specific research, USEPA PM_{10} factor
Solid smokeless fuel production	AD x EF	DECC energy statistics, EUETS	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 Classification of activities and sources

The NAEI utilises official UK energy statistics published annually in the Digest of UK Energy Statistics (DECC, 2012), hereafter abbreviated to DUKES. 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 3.1 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 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.

3.2 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), and Northern Ireland’s Inventory of Sources and Releases (ISR). 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 ISR is not available online but is supplied directly by the Northern Ireland Environment Agency (NIEA).

The emissions reported in the PI, SPRI and ISR 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). In some cases, it is therefore necessary to split the reported emissions data by fuel and/or sub-source. In general, this is done by estimating the split, although direct consultation with site operators and trade associations is conducted to achieve more accurate source-specific reporting in critically important cases, for example where reporting of emissions must be spread over more than one NFR category (such as the steelworks example mentioned above).

Fuel use data are primarily obtained from DUKES, with some deviations where alternative data are believed to be more reliable, such as industrial energy data from the EU Emissions Trading Scheme (EUETS) which has been used to revise energy data for some industry sectors such as power stations in recent years. In most cases where alternative, non-DUKES, data are used rather than data in DUKES for a given sector, we also make adjustments to our DUKES-based estimates for other sectors so that our estimate of total UK fuel demand is consistent with DUKES. Further information on these modifications to energy data are given in the next section.

Instead of the use of PI/SPRI/ISR data, emissions of some pollutants are estimated using literature emission factors and activity data from DUKES. 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/ISR is much lower than is the case for NO_x, for example. Many operators do not have to provide emissions data for these pollutants because these emissions are below minimum thresholds for reporting. This means that far fewer reported data are available from which to estimate emission factors, so any factors derived that way would be less representative and probably less reliable. The use of literature factors is therefore considered more defensible. The sectors and pollutants affected in this way 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.

3.3 Fuel consumption data

As stated previously, fuel consumption data are taken from DUKES, but with 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 are not considered as accurate as data available from alternative sources such as the EUETS;
- DUKES does not include data for a given source, or data in DUKES are not available in sufficient detail.

The most important of these deviations are as follows:

1) DUKES data for the quantity of fuel oil consumed by power stations are much lower than the quantity reported by process operators to the NAEI team and, more recently, quantities reported under the EU Emissions Trading Scheme (EUETS). Partly, 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.

2) Similarly, DUKES data for consumption of gas oil in power stations is also lower than data for recent years taken from EUETS. As with fuel oil, a re-allocation of gas oil is made so that the NAEI is consistent with the EUETS data for power stations, but also consistent with overall demand for gas oil, given in DUKES. The EUETS 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.

3) DUKES does not include any energy uses of petroleum coke, other than the burning of catalyst coke at refineries and recent data for petroleum coke burnt at power stations. Instead, consumption of petroleum coke is allocated to 'non-energy uses' in the commodity balance tables for petroleum products (although DUKES does include some information on energy use of petroleum coke in the notes accompanying the tables). The inventory agency include estimates of petroleum coke burnt by power stations (based on data from industry sources and the EUETS) which differ slightly from the data given in DUKES. We also include activity data for refinery use of petroleum coke from 2005 onwards that are based on EUETS data, rather than DUKES. We also include our own estimates for petroleum coke use as fuel in NFR 1A2 and 1A4. 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 are based on more detailed data sources than DUKES.

4) Since 2002, DUKES does not include any energy use of gases derived from Natural Gas Liquids (LPG and OPG) that are burned in boilers at gas separation plant, at oil terminals, as these data are no longer routinely provided to DECC by oil companies. Through the EUETS and EEMS, however, the use of OPG (mainly ethane) as a fuel at these sites is reported to the environmental regulatory agencies. The EUETS 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 EUETS data used to ensure completeness in 2010 and 2011.

5) 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, 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.

3.4 Methodology for power stations (NFR 1A1A)

NFR Sector 1A1a is a key source for NO_x, SO_2, CO, PM_{10}, Cd, Pb, Hg, HCB and PCDD/PCDF.

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 41 Mt of coal were burnt at 17 power stations during 2011, while approximately 9,400 Mtherms of natural gas were consumed at 44 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 3 large facilities, and gas oil or burning oil was used by 4 large and 8 small power stations.

One of the gas-fired power stations burns small quantities of sour gas as well as natural gas, although much larger quantities were burnt in the 1990s. Some coal-fired power stations have trialled use of petroleum coke in the past, and it has been used as a partial substitute for coal at a few sites. In the past, UK power stations have also burnt scrap tyres, Orimulsion, and coal slurry, but none currently does so.

Bio-fuels 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 25 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 currently 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 6C. There is also an EfW plant on the Isle of Man, a very small waste incinerator on the Isle of Scilly, and a large EfW plant on Jersey. The latter is a replacement for a waste incinerator which ceased operation in 2010. Currently, emissions from the waste incinerators on the Scilly Isles are also reported under 1A1, rather than 6C: this should be reviewed.

Landfill gas and sewage gas are also burnt to generate electricity. In 2011, 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 Inventory of Sources and Releases (ISR). 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 excluded sites will be relatively insignificant; hence emission estimates for the sector can be based on the emission data reported for individual sites:

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. However, good data are generally available on the capacity of each individual plant and fuel consumption data are available for most power stations, so it is then a relatively easy task to extrapolate the emissions data to cover non-reporting and excluded sites as well. This extrapolation of data does not add significantly to emission totals.

The methodology 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 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 EUETS 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, reporting of emissions in the PI, SPRI, and ISR is limited and/or highly variable. Therefore for emission estimates of POPs the PI/SPRI/ISR data are disregarded and emissions are calculated from literature emission factors and activity statistics. Emissions data for NMVOC and metals are quite limited and emission factors generated using these data can show large year-on-year variations, particularly for power stations 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 & ISR. Due to the small-scale of all of these sites, variation in emission factors for the sector does not lead to significant year-on-year variation in the total UK emission. However, the power stations methodology is reviewed each year, and revision of the methods for these more uncertain emission factors could be considered. The general approach described above is used for power stations burning coal, oils, natural gas and biomass as their primary fuel, with one exception in the case of the single straw-burning plant, all reported emissions are currently allocated to the straw.

All reported emissions from EfW plants and MSW incinerators are also assumed to be due only to the combustion of the MSW, so no account is taken of any fossil fuels used to support combustion. This means that there will be an insignificant inconsistency in the inventory, but this is expected to be very small and therefore not a priority for revision.

Emissions data are available back to 1988 in the case of NO_x and SO_2 from major fossil-fuel powered stations. For NO_x, emission factors from Stewart & Walker (1997) are used for the years prior to 1989, while in the case of SO_2, factors for 1970-1987 are based on information provided by coal suppliers. The emission factors for NO_x & 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 and SO_2, 1970-1996 for most other pollutants) are not reviewed each year. They 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. However, the methodologies lack transparency compared with those used to generate later emission factors and so the early factors are more uncertain. They are due for review, and improvement to methodological transparency is a priority.

Emissions data for EfW plant are available from the early 1990s, although the derived emission factors are quite variable for the early part of the time series and some derived factors are rejected as unreliable. Gaps in the time-series, and emissions factors prior to the early to mid 1990s are filled either by extrapolating back emission factors based on later emissions data, or by using literature factors.

An exception to the use of UK-derived factors is that emissions of some pollutants from landfill gas and sewage gas engines are estimated using literature emission factors from AP-42 (US EPA, 2009). However, emissions from these engines of NO_x and SO_2 (landfill gas only) are based on emission factors derived using UK data or based on emission limit values for UK processes. Some sites have reported emissions in the PI, SPRI & ISR in recent years but these data are not currently used as the scope of installation emission estimates because they include other emission sources (i.e. not only the power generating activities) and also the level of operator reporting does not currently provide complete sector coverage.

The NOx emission factor for engines burning landfill gas and sewage gas is based on engines being typically 3MW and complying with the regulatory emission limit values appropriate for this size of plant. The SO_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	1990-2011: O 1989: O/M 1970-1988: L
	SO_2	1990-2011: O 1988-1989: O/M 1970-1987: F
	HCl (coal only)	1993-2010: O 1992: O/M 1970-1991: E
	Pb	1997-2011: O 1990-1996: O/M 1970-1989: E
	CO, VOC, other metals, PM_{10}, HF	1997-2011: O 1993-1996: O/M 1970-1992: E

Fuels	Pollutant	Methodology
Sour gas	NO_x, SO_2	1992:2011: O 1970-1991: not occurring
	CO	1997:2011: O 1992-1996: L 1970-1991: not occurring
	VOC, PM10	1997:2011: O 1992-1996: O/M 1970-1991: not occurring
Coal slurry	NO_x, SO_2	1994:2011: O 1970-1993: not estimated separately, included with estimates for coal
	CO, VOC, HCl, metals, PM_{10}	1994:2011: O 1994-1996: O/M 1970-1993: not estimated separately, included with estimates for coal
Natural gas	NO_x	1997-2011: O 1992-1996: O/M 1970-1991: E
	SO_2	1997-2011: O 1993-1996: O/M 1970-1992: not estimated
	CO	1997-2011: O 1993-1996: O/M 1970-1992: E
	VOC, Hg, PM_{10}	1997-2011: O 1996: O/M 1970-1995: E
Gas oil	NO_x	1997-2011: O 1994-1996: O/M 1970-1993: L
	SO_2	1997-2011: O 1994-1996: O/M 1970-1993: F
	CO	1997-2011: O 1996: O/M 1970-1995: L
	VOC, metals, PM_{10}	1997-2011: O 1970-1996: L
Poultry litter	All	1997-2011: O 1992-1996: O/M 1970-1991: not occurring
Straw	All	2000-2011: O 1970-1999: not occurring
Landfill/sewage gas	All	1970-2011: 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

3.5 Methodology for refineries (NFR 1A1b)

NFR Sector 1A1b is a key source for SO_2, NO_x, PM_{10}, Cd, Ni, Pb, B[a]P, I[123-cd]P and PCDD/PCDF.

The UK currently has 11 oil refineries, three of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining eight 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, SO_2, and PM_{10} are supplied annually by process operators via the United Kingdom Petroleum Industry Association (UKPIA, 2012). These data split the emissions[18] 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). Emission estimates for the sector can be based on the emission data reported for individual sites:

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 1998-2011. Data for Scotland's refineries has been reported in the SPRI for the years 2002 and 2004-2011. Emissions data for NO_x and 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 and SO_2, and back to 1998 for other pollutants, while emission factors for earlier years are generated by extrapolation from 1990 data for NO_x and $SO_{2,}$ 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 is 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, in the 2011 dataset, 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, 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, 2012); however, the EUETS 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 EUETS and UKPIA emissions totals for carbon dioxide. Therefore the EUETS activity data for OPG are used in preference to DECC data, with amendments to the DUKES statistics back to 2004 inclusive.

[18] 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.

3.6 Methodology for other energy industries (NFR 1A1C)

NFR Sector 1A1c is a key source for SO_2, NO_x and CO. 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 2011, 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 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, 1970-2011

Process type	Period	No of plant
Coke ovens	2004-2011	6
	2003	7
	1993-2002	9
	1991-1992	10
	1970-1990	No data
Solid smokeless fuel manufacture	2006-2011	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 either the Pollution Inventory or the Scottish Pollutant Release Inventory. Emission estimates for the sector can be based on the emission data reported for individual sites:

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, or because a site is closed down partway through a year and therefore does not submit an emissions report. 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, where emissions are expected to occur mainly from combustion of coke oven gas (the main fuel used), with very minor contributions from the use of other fuels (blast furnace gas, colliery methane, natural gas) and fugitive emissions from the coke oven. The approach relies upon the use of literature emission factors to estimate emissions from the minor sources. These emission estimates for the minor sources are then subtracted from the reported emissions data, with the remainder being allocated as the emissions from the coke oven gas.

Emissions of other pollutants will either be significant both from combustion and process-related sources, or will predominantly occur from process sources. In the case of SO_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/PCDF, 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. 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 in injected to the UK pipeline network. The activity data for this source are taken primarily from DUKES; however, the EUETS reporting system also provides activity data for gas use in compressor stations since 2005, and in some years the EUETS data exceeds the gas allocation in DUKES. Therefore in the UK inventory we use the DUKES data unless EUETS data are higher; where we use the higher EUETS 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 2009 Guidebook and from UK industry research where it is available.

Upstream Oil and Gas Exploration and Production 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 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, SO_2, CO, VOC and GHGs (CO_2 and CH_4).

The activity data for the emission estimates are primarily taken from DUKES, except in instances where the data from EUETS and EEMS reporting systems indicate that the UK energy statistics are under-reporting the activity (see section 3.3. 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 or from UK industry research.

3.7 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 (EA, SEPA, NIEA) and reported via their respective inventories of pollutant releases – PI, SPRI and ISR - the data is subject to audit and review within established 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 & ISR contain well in excess of 100,000 individual emissions data covering thousands of sites, and that 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 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, and specific data inconsistencies are sometimes queried directly with the PI, SPRI & ISR teams, Site Inspectors or other technical experts within the regulatory agencies, to seek to resolve data-reporting errors and to ensure the use of correct data within UK inventory outputs.

3.8 Recalculations in NFR 1A1

The most significant recalculations since the 2012 submission in NFR 1A1 are:

- Reduced allocation of fuel oil / waste oil to power stations in 2010 by around 4%, lowering all emissions;
- Increased allocation of biomass to power stations in 2010 by around 16%, increasing all emissions, improving completeness in the inventory;
- Revisions to allocation of fuel use to refineries in recent years due to DUKES revisions and impacts of EUETS information, revising estimates of gas, petcoke and OPG use in the sector; the reductions of around 4% of petcoke use in 2010 combined with other fuel re-allocations led to overall sector reductions of around 2% in PM_{10} and SO_2, 3% in dioxins, 1.5% in NOx, . These revisions ensure a more consistent scope of emissions are reported for the sector across the time series, improving inventory completeness and accuracy;
- Revisions to the fuel allocations (natural gas, LPG, OPG) across the time series for the upstream oil and gas sector (see Section 3.3) due to data reconciliation between DUKES, EEMS and EUETS has led to increases in emissions from OPG use in recent years but greater reductions in estimated emissions from operator own natural gas use. Impacts on emissions vary between years and pollutants; for example, overall NO_X emissions from the upstream sector are lower by around 13% in 2010, 4% in 2000 and 2% in 1990. These improvements were driven by a need for greater data transparency and accuracy between energy and emissions data reported to DECC and to environmental regulatory agencies. There remain some uncertainties and limitations in transparency due to lack of source detail in oil and gas terminal emissions reporting, but the changes in estimation methodology and allocation of fuels to sources improves consistency across the UK inventory time series and improves completeness of the activity data.

4. NFR 1A2: Combustion in Industry

Table 4.1 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 and HCH)	Blast furnaces
		Iron and steel - combustion plant
1 A 2 b Non-ferrous metals	All CLRTAP pollutants (except HCH)	Non-ferrous metal (combustion)
1 A 2 c Chemicals	All CLRTAP pollutants (except HCH)	Ammonia production - combustion
		Chemicals (combustion)
1 A 2 d Pulp, Paper and Print	All CLRTAP pollutants (except HCH)	Pulp, paper & print (combustion)
1 A 2 e Food processing, beverages and tobacco	All CLRTAP pollutants (except HCH)	Food & drink, tobacco (combustion)
1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	All CLRTAP pollutants (except HCH)	Autogenerators
		Cement - non-decarbonising
		Cement production - combustion
		Industrial engines
		Lime production - non decarbonising
		Other industrial combustion
1 A 2 f ii Mobile Combustion in manufacturing industries and construction	All CLRTAP pollutants (except HCB, HCH and PCBs)	Industrial off-road mobile machinery

Table 4.2 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, EUETS, ISSB	Operator-reported emissions data under IPPC, plant-specific data from Tata Steel. Default factors (EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_2.
Iron and steel - combustion plant	UK model for integrated works; AD x EF	DECC energy statistics, EUETS, ISSB	Operator-reported emissions data under IPPC, plant-specific data from Tata Steel. Default factors (EMEP-EEA, USEPA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for 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 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 NOx emissions from combustion sources, Default factors (USEPA) for other pollutants.
Chemicals	UK model	DECC energy	Default factors (USEPA, EMEP-EEA,

NAEI Source Category	Method	Activity Data	Emission Factors
(combustion)	for activity allocation to unit type; AD x EF	statistics	HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_2.
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 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 SO_2.
Autogenerators	UK model for activity allocation to unit type; AD x EF	DECC energy statistics	Operator-reported emissions data under IPPC. Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_2.
Cement - non-decarbonising	AD x EF	Mineral Products Association clinker production data, EUETS	IPPC 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, EUETS	IPPC annual reporting by operators, default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for SO_2.
Industrial engines	AD x EF	DECC energy statistics	
Lime production - non decarbonising	AD x EF	EUETS data, with extrapolation across time-series using IPPC emissions data and production estimates from British Geological Survey.	IPPC 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, EUETS). EUETS data (OPG).	Default factors (USEPA, EMEP-EEA, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for 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)

4.1 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 are reported by operators which do not differentiate between combustion and process-related emissions (see Section 4.4) and so mapping of the NAEI source categories to NFR 1A2 is justified.

Emissions for combustion in manufacturing industries and construction are disaggregated on an industry sector basis to categories 1A2a to 1A2f 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 1A2f. Details of the methods used to disaggregate the fuel data are given in Section 4.3.

Almost all of the NFR source categories listed in **Table 4.1** are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

4.2 General approach for 1a2

NFR Sector 1A2a is a key source for SO_2 and Cd, 1A2c is a key source for PM_{10}, Pb, Cd, Hg, SO_2 and NO_X, 1A2d is a key source for Hg, while 1A2fi is a key source for NO_x, SO_2, CO, PM_{10}, Cd, Pb, Hg, B[a]P and PCDD/PCDF and 1A2fii is a key source for CO, Pb, Cd, NMVOC, PM_{10}, NO_X, B[a]P and PCDD/PCDF.

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 for NO_x but literature emission factors for other pollutants.

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 ISR. 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 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.

4.3 Fuel consumption data

As stated previously, 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 range of fuel use data for industrial use of fuels. Fuel use data for cement kilns are provided by the Mineral Products Association (MPA, 2012), and are also available from the EUETS. The MPA 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 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 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 used for stationary combustion within the sectors listed above, compared with the original data for those sectors, 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. Use of petrochemical feedstock off-gases (OPG) in combustion processes have been estimated for several major UK facilities using EUETS data, with a time series for such activities extrapolated based on plant capacity data. Emissions of air quality pollutants from this activity have been included in the UK inventory for the first time in the 2013 submission.

Emissions for manufacturing industries and construction are disaggregated by industrial sector for separate reporting to categories 1A2a to 1A2f for coal, fuel oil, gas oil and natural gas. Full details of the methods used to generate the activity data are given below.

4.3.1 Coal

DUKES contains data on the use of coal by subsector for the whole of the period 1990-2011, 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 short-fall in coal allocated to the mineral industry between 1997 and 1999, compared with the independent estimates for fuels used for cement and lime production which are available for use within the inventory. The independent estimates suggest a much more gradual change in coal consumption over this period.

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. Following this, we have concluded that most of 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 and the time series for the rest of the industry sector has been built around these. Although the lime sector has not been reviewed in detail, it is known that there were no closures over that period and there is no evidence to support any major changes in that industry either, so again the independently-derived estimates for the lime sector are 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 1A2f. 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 are then derived from the difference between the DUKES industry totals and the independent cement and lime data, with the split between the four industry sub-sectors being based on a linear interpolation between the splits in 1996 and 2000

4.3.2 Natural Gas

Fuel consumption data for 1A2a to 1A2e are taken directly from DUKES. 1A2f makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES. One small modification is to add the non-energy use estimate from DUKES into the industry total, and then take out the NAEI independent estimate for non-energy use, provided to the NAEI by plant operators. 1A2f also contains our independent estimates of consumption by the cement and lime industries, and 1A2c contains our independent estimates of consumption by ammonia producers. 1A2f is also used as a balance, where independent estimates of fuel consumption are not possible to reconcile with DUKES. For example, gas use in 1A1c for gas compressors is taken from EU ETS, and this exceeds the allocation for this source within DUKES, therefore some fuel is reallocated from 1A2f to 1A1c.

4.3.3 Fuel Oil

Fuel consumption data for 1A2a to 1A2e are taken directly from DUKES. 1A2f makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES.

4.3.4 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. Previously, we have made independent estimates of the consumption of gas oil in off-road transport and machinery, in trains, and in various other sectors and then used the difference between the consumption in those sectors, and the total consumption given in DUKES as our estimate for consumption of gas oil in stationary plant. This approach though is problematic in that the year-on-year variations in our estimates for other sectors, and the variations in the DUKES total lead to big variations in our estimates of stationary plant consumption from one year to the next, in a way that does not seem realistic. In the most extreme cases, our independent estimates for the transport and other sectors exceed the DUKES total for all gas oil, thus meaning that it is impossible to allocate any gas oil to stationary plant using this method.

As a result, a number of changes have been made to our methods for estimating the consumption of gas oil. A general discussion of the new methodology is given in Appendix 1 but the most important aspect relevant to NFR 1A2 is that independent estimates are now made of the gas oil used in stationary plant, and that estimates of usage in other sectors are now allowed to vary in order to maintain consistency with the total demand figures in DUKES, rather than varying the estimate for 1A2. In essence the revision has been to move from a methodology where the major use of fuel was fixed based on the independent estimates, to one in which at least a minimum value for the minor use is defined instead. This switch in approach ensures that there is always some gas oil allocated to 1A2.

The new estimates for consumption in stationary plant are based on data for the period 2005 to 2011. For these years, EUETS data suggests that most of gas oil consumed in stationary plant is used as a backup or secondary fuel, with natural gas being the primary fuel on the site. We have therefore assumed that consumption of gas oil is related to consumption of gas, and that we can therefore use the ratio of gas oil or gas in the EUETS data, to estimate the use of gas oil in non ETS plant, based on the consumption of gas in non-ETS stationary plant. The latter can be estimated with some confidence as the difference between total demand given in DUKES for each sector, and the total consumption given in EUETS (since there is no need to consider gas use in mobile equipment unlike the case of gas oil.) In this way, we have estimated consumption of gas oil in stationary plant for the agricultural, commercial, industrial and public sectors and these estimates form the minimum values allowed for these sectors. If our estimates for off-road vehicles and machinery and other sources are too small to account for all of the remaining gas oil, then we allow a higher volume of gas oil for stationary plant in order to maintain consistency with the UK demand figures in DUKES. If on the other hand, our estimates for off-road vehicles and machinery and other sources are bigger than the remaining gas oil, it is these estimates that are reduced in order to maintain consistency with the DUKES totals.

Once estimates for industrial gas oil use are finalised, these are then disaggregated across 1A2b to 1A2f using detailed sector-level data from DUKES.

4.4 Methodology for cement & lime kilns

The UK had 13 sites producing cement clinker during 2011. 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 2011. 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 ISR, hence emission estimates for the sector can be based on the emission data reported for the sites:

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 is 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 cement works will burn a variety of fuels, and many pollutants will be emitted from the use of each fuel, and from process sources as well. We consider that 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, are likely to burn a large variety of fuels like cement kilns, so reported emissions of CO and NO_x 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.

4.5 Methodology for blast furnaces

Emissions data for the period 2000-2011 are supplied by the process operator (Tata Steel, 2012). In the case of NO_x, 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. We assume the same emission factor 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, 2012); 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, and because some of the emissions that are reported prior to 1998 are very much lower than the emissions reported in subsequent years. It is possible that they may be underestimates.

4.6 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 (and which do not therefore report emissions in the PI, SPRI or ISR), 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:

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

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 ISR for the 'large combustion plant' and the methodology allows for these reported data to be used in the case of NO_x 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 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 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 (EMEP/ EEA, 2007) and UK emission factor surveys (Walker et al, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2012) 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.

4.7 Methodology for industrial gas combustion

Emissions from industrial gas combustion were previously estimated in the same manner as emissions from industrial combustion of coal, coke and oils (see Section 4.6). However, an alternative approach which was used initially to predict future emission factors for the sector suggested that the original approach overestimated emissions. The method has been used to generate aggregate emission factors for 2010 and 2011, with the emission factor calculated for 2010 used for all earlier years in the NAEI as well.

The new method differs from the old in that rather than dividing fuel use into consumption by different technologies, it is now split according to environmental regulation. For example, gas burnt by plant covered by the Large Combustion Plant Directive (LCPD) is separated from 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 plant as a result of their regulation. We assume 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 might therefore tend to overestimate emissions.

4.8 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 information and EU Emission Trading Scheme energy use data. As discussed above, there have been instances where such information has led to amendments to 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 ISR. Section 3.7 discusses QA/QC issues regarding these data.

4.9 Recalculations in NFR 1A2

The most significant recalculations since the 2012 submission in NFR 1A2 are:

- Inclusion of biomass use in the NFR 1A2f estimates for the first time in the 2013 inventory submission increases emissions of all pollutants across the time series, improving inventory completeness;
- Inclusion for the first time in the inventory of new estimates of OPG use within NFR 1A2f to reflect the practice of recovering process gases (OPG) in petrochemical facilities for combustion in boilers. Emissions of all pollutants are increased across the time series due to this improvement in inventory completeness. The increase in total UK NO_X emissions is 0.3% in 2010 due to this new source estimate.
- Revisions to assumptions and emission factors for the industrial off-road machinery source emissions in NFR 1A2fii have led to notable reductions in emission estimates for several pollutants across the time series, including a 12.5% reduction in CO, NO_X and PM_{10} in 2010 compared to the previous submission. In the overall UK inventory context, this represents around a 0.5% reduction in emissions for both NO_X and PM_{10};
- Revisions in allocation of fuel oil to NFR category 1A2fi for recent years has led to increases in emission estimates of all pollutants of over 200% in 2010, and in the UK inventory context this represents a 6% increase in Nickel, a 2.4% increase in Cadmium and a 0.7% increase in SO_2;
- Revisions to the emission factor for B[a]P applied to cement industry estimates within 1A2fi have led to increases in emission estimates for several years in the time series. In 2010, the impact of this revision was to increase source estimates four-fold which in the UK inventory context represented an increase of 0.3%, whereas impacts in other years were much less significant.
- Revised activity data for fuel oil use in iron and steel combustion plant in recent years led to reductions in emission estimates for most pollutants of around 86% in 2010, compared to the previous submission. In the UK inventory context, this represented a reduction in the 2010 estimates of 0.6% for Cd and 1.5% for Ni. Reductions in gas oil allocation of just under 7% were also evident for the same source in 2010;

5. NFR 1A3: Transport

Table 5.1 Mapping of NFR Source Categories to NAEI Source Categories: Transport.

NFR Category (1A3)	Pollutant coverage	NAEI Source category	Source of EFs
1A3ai(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	
1A3aii(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, HCH and PCBs)*	Petrol cars with and without catalytic converter (cold start, urban, rural and motorway driving)	UK factors of factors from COPERT 4 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	

NFR Category (1A3)	Pollutant coverage	NAEI Source category	Source of EFs
		driving)	
1 A 3 c Railways	All CLRTAP pollutants including PCDD/PCDF *(exceptNH_3,PAHs, HCB, HCH and PCBs)*	Rail - coal	UK factors
		Railways - freight	
		Railways - intercity	
		Railways - regional	
1 A 3 d ii National navigation (Shipping)	All CLRTAP pollutants *(except NH_3, HCH and PCBs)*	Marine engines	UK factors and EMEP inventory guidebooks
		Shipping – coastal	
		Inland waterways	
1A2fii Non-road mobile sources and machinery	All CLRTAP pollutants *(except HCB, HCH and PCBs)*	Industrial and construction mobile machinery	EMEP inventory guidebooks
1A4bii Non-road mobile sources and machinery	All CLRTAP pollutants *(except HCB, HCH and PCBs)*	Domestic house and garden mobile machinery	EMEP inventory guidebooks
1A4cii Non-road mobile sources	All CLRTAP pollutants *(except HCB, HCH and PCBs)*	Agricultural mobile machinery	EMEP inventory guidebooks
1A4ciii Non-road mobile sources	All CLRTAP pollutants *(except NH_3, HCH and PCBs)*	Fishing	UK factors and EMEP inventory guidebooks
1 A 5 b Other, Mobile (Including military)	All CLRTAP pollutants *(except HCB, HCH and PCBs)*	Aircraft - military	UK Literature sources
		Aircraft - support vehicles	
		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.

5.1 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 have been listed already in Table 3.3. The detailed NAEI source categories used in the inventory for transport are related to equivalent NFR source categories in Table 5.1 above.

Almost all of the NFR source categories listed in Table 5.1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

5.2 Aviation

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation 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.

In 2004, the simple method previously used to estimate emissions from aviation overestimated fuel use and emissions from domestic aircraft because only two aircraft types were considered and the default emission factors used applied to older aircraft. It is clear that more smaller modern aircraft are used on domestic and international routes. Emissions from international aviation were correspondingly underestimated. A summary of the more detailed approach now used is given below, and a full description is given in Watterson et al. (2004).

The current 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. In comparison with earlier methods used to estimate emissions from aviation, the current approach is much more detailed and reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also now included.

This method utilises data from a range of airport emission inventories compiled in the last few years by AEA (now Ricardo-AEA). This work includes 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 and representative of the fleets at those airports. Emissions of NOx and fuel use from the Heathrow inventory have been used to verify the results of this study.

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 made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights. In 2007, these recommendations for Heathrow were incorporated into the UK inventory and in the 2008 inventory they were incorporated into the UK inventory for all airports, along with further recommendations relating to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

For arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. In 2007, these recommendations for Heathrow were incorporated into the UK inventory and in the 2008 inventory they were incorporated into the UK inventory for all airports, along with further recommendations relating to: the interpolation to intermediate thrust settings; approach thrusts and times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

Since publication of the PSDH report, inventories at Gatwick and Stansted have been updated. These inventories incorporated many of the recommendations of the PSDH and have been used as a basis for the 2008 inventory.

For the 2009 inventory flights between the UK and overseas territories have been included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.

For the 2010 inventory all flights originating from the overseas territories, irrespective of destination, have been included in the inventory as have return flights from oil rigs.

Separate estimates have been 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.

In the current UK inventory there is a noticeable reduction in emissions from 2005 to 2006 despite a modest increase in aircraft movements and kilometres flown. This is attributable to the propagation of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in 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, there are reductions in both emissions and aircraft movements, in line with the economic downturn.

5.2.1 Emission Reporting Categories for Civil Aviation

Table 5.2 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 the reporting requirements to the LRTAP Convention have altered recently – the table contains the most recent reporting requirements.

Table 5.2 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

5.2.2 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 has been 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) have been calculated. The data covered all Air transport Movements (ATMs) excluding air-taxi.

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

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

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

  A summary of aircraft movement data is given in Table A 3.3.8 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 2012). 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.

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

Table 5.3 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	469.62	367.81	654.15	114.21
1991	454.57	335.27	643.25	106.58
1992	491.80	351.97	725.80	111.69
1993	502.90	362.83	737.68	116.63
1994	519.22	342.45	811.29	111.59
1995	540.74	355.42	851.62	115.64
1996	570.15	366.32	892.50	120.65
1997	595.78	377.38	969.19	125.89
1998	632.18	383.30	1053.96	132.72
1999	666.83	387.90	1120.39	136.25
2000	713.04	398.40	1193.15	142.70
2001	720.51	414.16	1208.59	153.50
2002	712.98	415.33	1200.17	152.65
2003	729.00	423.56	1251.83	155.59
2004	762.36	458.69	1356.88	166.59
2005	804.39	484.29	1448.79	177.51
2006	831.40	486.48	1517.07	179.36
2007	857.85	480.82	1572.29	175.79
2008	844.41	467.96	1558.33	172.23
2009	776.37	417.48	1441.29	156.38
2010	736.93	390.92	1396.04	145.40
2011	774.95	372.97	1486.65	141.92

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.

5.2.3 Emission factors used

The following emission factors were used to estimate emissions from aviation. The emissions of CO_2, SO_2 and metals depend on the carbon, sulphur and metal contents of the aviation fuels’. Emissions factors for CO_2, SO_2 and metals have been 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 5.4 Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2011 (kg/t)

Fuel	CO_2	SO_2
Aviation Turbine Fuel	859	0.84
Aviation Spirit	853	0.84

Notes
Carbon and sulphur contents of fuels provided by UKPIA (2012b)
Carbon emission factor as kg carbon/tonne

Military aviation only uses ATF

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 have been calculated from the International Civil Aviation Organization (ICAO) database. The cruise emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

Table 5.5 Average Non-CO2 Emission Factors for Civil and Military Aviation in kt/Mt, 2011

	Fuel	CH_4	N_2O	NO_x	CO	NMVOC
Civil aviation						
Domestic LTO	AS	1.55	0.10	3.78	1077.01	12.64
Domestic Cruise	AS	-	0.10	7.39	2.54	0.18
Domestic LTO	ATF	0.19	0.10	12.70	8.69	1.76
Domestic Cruise	ATF	-	0.10	14.40	2.40	0.51
International LTO	AS	1.79	0.10	2.19	1228.37	14.55
International Cruise	AS	-	0.10	7.13	0.84	0.03
International LTO	ATF	0.13	0.10	13.89	8.87	1.20
International Cruise	ATF	-	0.10	14.10	1.16	0.52
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

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

The basic approach to estimating emissions from the LTO cycle is as follows. 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.

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

The approaches to estimating emissions in the cruise are summarised below. 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.

5.2.6 Estimating emissions

The EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 1996) provides fuel consumption and emissions of non-GHGs (NO_x, 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 has been assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al*. (2004).

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

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

Where:

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

Emissions of SO_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.

5.2.7 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, casual uplift at civilian airports.

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

5.2.8 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 DECC 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 has been 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.

5.3 Railways (1A3c)

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

Summary of emission factors
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.

Summary of activity data
Gas oil consumption data from Office of Rail Regulation for passenger and freight trains for 2005-2009 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 class.

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

<u>Railways (stationary)</u>
The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported in chapter 6. These emissions are based on fuel consumption data from DECC (2012).

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

Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2011 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 / train kilometres travelled and UK-specific emission factors in grams per vehicle / train kilometre.

Gas oil consumption by passenger trains was obtained from the Office of Rail Regulation's (ORR's) National Rail Trends Yearbook (NRTY) for the years 2005 to 2009. No data was available for 2010 or 2011 or prior to 2005 and therefore fuel consumption for these years was estimated on the basis of the trend in train kilometres.

In the 2011 inventory for the first time, emission estimates for 2009 for passenger trains were obtained from the UK's Department for Transport Rail Emissions Model (REM) which covers all train movements on the UK rail network as engine kilometres by train class and by strategic route. This has resulted in a large improvement to the rail emission estimates as detailed information on the vehicle train classes in operation and new emission factors supplied by WS Atkins Rail were incorporated.

Emission estimates for other years were derived based on the changes in train kilometres provided in the NRTY, and a literature review and expert judgement were used to inform data on the changes to the kilometres undertaken by different train classes.

Gas oil consumption by freight trains was also obtained from ORR's NRTY for 2005-2009. As with the passenger train estimates, no data from ORR was available for 2010 or 2011 or prior to 2005 and therefore fuel consumption for these years were estimated on the basis of the trend in train tonne kilometres.

In 2011, the estimated fuel consumed by both passenger and freight rail showed an increase in comparison to 2009 as a consequence of increased train kilometres travelled.

Carbon and sulphur dioxide emissions are calculated using fuel-based emission factors and the total fuel consumed. Emissions of CO, NMVOC, NO_x 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 for different train classes from DfT's REM and extrapolations for 2010 and 2011;
- For freight trains: Train kilometre data taken from the NRTY and extrapolations to 2010 and 2011, with an assumed mix of locomotives and fuel consumption factors for different types of locomotive.

The emission factors shown in Table 5.6 are aggregate implied factors for trains running on gas oil in 2011, so that all factors are reported on the common basis of fuel consumption.

The passenger train emission factors have been modified in line with the REM; no revisions have been made to any of the freight emission factors which are provided in terms of g/km. However, for freight trains this leads to a change on a kt/Mt basis due to small changes to the fuel consumption estimates.

The emission factor for SO_2 has decreased from 1.44 kt/ Mt fuel in 2010 to 0.76 kt/ Mt fuel in 2011 in line with data from UKPIA (2012b) showing a reduction in the sulphur content of gas oil.

Table 5.6 Railway Emission Factors for 2011 (kt/Mt fuel)

	NO_x	CO	NMVOC	PM	SO_2
Freight	109.9	12.4	6.23	1.50	0.76
Intercity	38.9	8.4	3.03	3.5	0.76
Regional	47.2	8.4	2.58	1.36	0.76

5.4 Road Transport (1A3b)

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.

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).

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.

5.4.1 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 15 and 16 of the revised Guidelines on Reporting (ECE/EB.AIR/2008/4) 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 ±8% for both petrol and diesel consumption across the 1990-2011 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, not sold.

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.

5.4.2 Fuel-based emissions

Emissions of sulphur dioxide (SO_2) from road transport are calculated from the consumption of petrol and diesel fuels and the sulphur content of the fuels consumed. 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 from the Crown Dependencies are calculated elsewhere).

In 2011, 13.90 Mtonnes of petrol and 20.99 Mtonnes of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2010. It was estimated that of this, around 2.8% of petrol was consumed by inlands waterways and off-road vehicles and machinery and 0.5% used in the Crown Dependencies, leaving 13.45 Mtonnes of petrol consumed by road vehicles in the UK in 2011. Around 1.8% 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 20.56 Mtonnes of diesel consumed by road vehicles in the UK in 2011.

According to figures in DUKES (DECC, 2012), 0.098 Mtonnes of LPG were used for transport in 2011, a reduction from 0.106 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 (2012), 0.52 Mtonnes bioethanol and 0.82 Mtonnes biodiesel were consumed in the UK in 2011. On a volume basis, this represents about 3.3% of all petrol and 3.6% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.310 Mtonnes of mineral-based petrol (about 2.2% of total petrol that would have been consumed) and 0.715 Mtonnes of mineral-based diesel (about 3.4% of total diesel that would have been consumed).

Emissions of 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 5.7 for 2011 fuels based on data from UKPIA (2012b).

Table 5.7 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	SO_2 [a]
Petrol	0.010
Diesel	0.015

a 2011 emission factor calculated from UKPIA (2012b) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2011

Emissions of SO_2 and fuel-based pollutants such as the metals can be 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.

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 http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/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 5.8 for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 5.8 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km	Urban	Rural	Motorway

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
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 lorries (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. It should be noted that the publication of the Road Freight Statistics was delayed in 2012 and hence mpg factors for 2011 were not available in time for the inventory compilation. Data for overall fuel efficiency of HGVs in 2010 from DfT has been assumed for 2011.

Table 5.9 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2011 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a).

Table 5.9 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

g fuel/km	Rigid HGVs			Artic HGVs		
	Urban	Rural	Motorway	Urban	Rural	Motorway
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	252.9	208.4	222.3	373.2	290.0	295.6
2003	262.8	216.1	230.1	378.3	293.7	299.4
2004	253.9	208.6	221.8	365.0	283.2	288.7
2005	250.7	205.0	217.4	360.9	279.7	285.2
2006	261.9	213.1	225.5	363.4	281.4	286.9
2007	270.1	218.5	230.7	365.9	283.1	288.7
2008	279.6	226.0	238.5	379.8	293.5	299.3
2009	281.8	228.0	240.8	381.1	294.3	300.1
2010	285.3	229.9	242.5	384.9	296.9	302.7
2011	284.8	229.2	241.7	384.1	296.0	301.8

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, 2012b). 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, i.e. a reduction in fuel efficiency over the period from 1998/9 to 2009/10. However, there is a small improvement in fuel efficiency between 2009/10 and 2010/11.

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 2010/11. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2010/11 figures were used for the 2010 calendar year and superceded estimates for 2010 made last year when these data were not available. As there are no corresponding BSOG data to use for 2011, factors were estimating based on trends in the average fuel consumption factor for urban buses implied by DfT/TRL speed functions for different bus classes and the change in the bus fleet between 2010 and 2011. This produced a fuel efficiency scaling factor that could be applied to the factor for 2010.

Table 5.10 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2011 for urban, rural and motorway conditions based on this method.

Table 5.10 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
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	309.5	198.6	234.1
2005	324.4	208.1	245.6
2006	319.2	204.7	241.6
2007	327.6	209.7	247.7
2008	340.7	217.8	257.3
2009	341.6	217.9	257.7
2010	338.0	215.2	254.8
2011	337.8	214.8	254.4

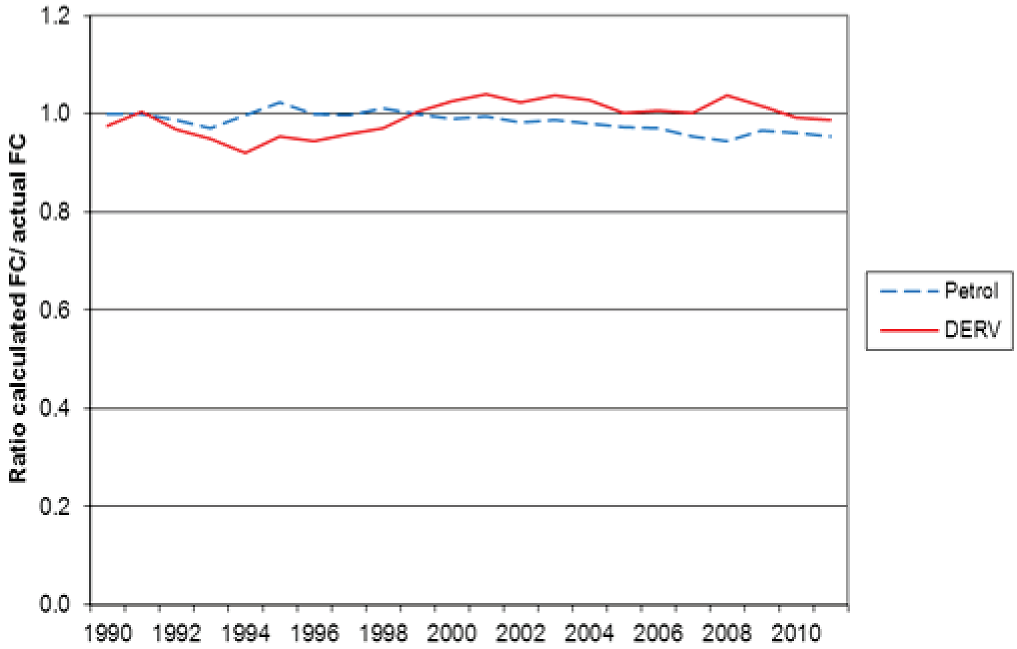
Fuel reconciliation and normalisation

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 5.1 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 2011, the bottom-up method underestimates petrol and diesel consumption by 4.5% and 1.2% respectively. This is considered well within the uncertainty of the factors used to derive the bottom-up estimates.

Figure 5.1 **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 are 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 4.5% to align with fuel sales in 2011. 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 652 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.

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 2011.

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.

5.4.3 Traffic-based emissions

Emissions of the pollutants NMVOCs, NO_x, 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 its engine runs on, the driving profile 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 drive cycle 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 http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/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 and the emission results 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, 2012c). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2011 inventory, taking into account any revisions to historic data. In particular, during 2012 DfT revised their vehicle km estimates for minor roads over the time series from 2000-2010 as a result of a new benchmarking exercise on the traffic census data collected over these years using more up-to-date information on traffic flows on minor roads. Additional information discussed later was used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2011a). These provided a consistent time-series of vehicle km data for all years up to 2010. Data for 2011 was not available for this year's inventory and were derived using change factors provided by DRDNI (2012a). Data for 2010 has been revised slightly upward for artic HGVs and buses and downward for LGVs, however, the changes were within 1%. 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. There has been a downward revision to the motorcycle vehicle km data for Northern Ireland across the time series as updated GB licensing statistics have been used in 2011 inventory. 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, 2012b).

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 2011 as shown in Table 5.11.

Table 5.11 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2005	2009	2010	2011
Petrol cars	urban	142.2	137.9	135.1	119.9	105.2	99.5	96.7
	rural	141.1	134.1	134.2	127.3	113.4	109.1	105.0
	m-way	49.2	48.4	53.0	48.8	43.4	41.7	39.7
Diesel cars	urban	5.8	17.2	26.1	40.8	52.8	54.1	57.2
	rural	6.1	18.0	28.3	47.6	64.1	65.8	70.0
	m-way	2.8	8.5	14.6	25.1	33.2	33.5	36.6
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.4	1.3	1.2
	rural	11.4	8.3	5.0	2.3	1.8	1.6	1.5
	m-way	3.9	3.2	2.0	0.9	0.7	0.6	0.6
Diesel LGVs	urban	5.7	10.2	15.5	21.2	22.2	22.6	23.0
	rural	6.1	11.5	18.8	26.0	29.1	29.5	29.5
	m-way	2.0	4.4	7.4	10.5	11.5	11.4	11.9
Rigid HGVs	urban	4.5	3.7	3.9	4.0	3.3	3.2	3.1
	rural	7.1	6.8	7.2	7.5	6.7	6.6	6.4
	m-way	3.7	3.7	4.2	4.2	4.0	4.1	3.8
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	5.0	5.0
	m-way	4.7	6.0	7.4	7.9	7.3	7.5	7.5
Buses	urban	2.4	2.9	3.0	3.2	3.0	3.1	2.9
	rural	1.7	1.5	1.7	1.5	1.6	1.6	1.4
	m-way	0.6	0.5	0.5	0.5	0.4	0.5	0.4
M/cycle	urban	3.3	1.9	2.3	2.9	2.7	2.5	2.4
	rural	2.0	1.6	2.0	2.2	2.1	1.8	2.0
	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**	**516.1**	**507.9**	**509.0**

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 5.11 shows the speeds used in the previous and 2011 inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2011.

Table 5.12 Average Traffic Speeds in Great Britain

		Lights kph	Heavies 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
Connurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	20
	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 (2012d, pers comm) for defining the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) 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. 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 DA-country specific vehicle licensing data (hereafter referred as DVLA data) to define regional variation (DfT, 2010a). 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, 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 DA 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 two years of ANPR data (2010 and 2011) 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 5.11.

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 5.13 shows the regulations that have come into force up to 2011 for each vehicle type. The year 2011 saw the introduction of Euro 5 standards for medium and large-sized vans. 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 5.13 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
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 and it was important to consider how the trends observed in these limited years of ANPR data availability could be rolled back 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 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.

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, 2012e). 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, 2008b).

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 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. 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. In 2011, the assumptions for artic (34-40t and 40-50t) have been updated for the whole time series based on further information available from DfT’s licensing statistic (DfT, 2012e).

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, 2012).

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 motorcycles on motorways are the type more than 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 are not Type Approved and do 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 repair rate is taken into account for Euro 3 and above petrol LDVs from mid-2009 assuming all failed vehicles are rectified properly.

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.

Prior to 2010 inventory, it was assumed that a proportion of all new petrol cars sold in the UK would meet Euro 4 standards prior to the mandatory date required by the Directive i.e. in year 2006 for new registrations (DfT, 2004). However, this assumption has since been updated with Euro 4 petrol cars only introduced from year 2006 onwards as set by the Directive. This is in light of the recent study by King's College and AEA (Carslaw et al., 2011) indicating on the basis of ANPR data and manufacturers' information a lower proportion of Euro 4 cars on the road than previously implied by the inventory.

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, CO and NMVOCs emissions.

Emissions from HGVs and buses 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, but the measures can have an indirect effect on greenhouse gas emissions.

The effect of the Low Emission Zone 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. 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.

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, CO, NMVOCs, $PM_{10}/_{2.5}$

Emission factors for NO_x were revised in the 2010 inventory as recent evidence has shown that there is lack of consistency between the trends in the road transport NO_x emissions inventory and trends in ambient roadside concentrations of NOx (Carslaw et al., 2011). Moreover, the previous emission factors for some vehicle classes do not seem to reflect real-world NO_x emissions, especially for more modern diesel vehicles (Euro 3+). NO_x emission factors from the COPERT 4 v8.1 model (which remain the same in COPERT 4 v9.0) are now used in the inventory to reflect recent evidence on the performance of vehicle NO_x emissions under real-world conditions. 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/.

Emission factors from COPERT 4 v9.0 for total hydrocarbons (THC) and PM have been adopted in the 2011 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 2009 EMEP/EEA Emissions Inventory Guidebook (EEA, 2010). For NO_x, there are separate emission functions available for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NOx 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 TRL/DfT (Boulter et al., 2009) emission factors for CO are continued to be used in the 2011 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.

Table 5.22, Table 5.23, Table 5.24 and Table 5.25 summarise the baseline COPERT 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 50,000km 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 5.12. 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 low urban speed end of the range. The 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 NO_x emission factors for diesel heavy duty vehicles where Euro V vehicles equipped with SCR can show higher factors for NO_x 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, 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 (2012) 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 fitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO and NMVOC emissions beyond that required by Directives. Emissions from 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 5.14.

Table 5.14 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 5.15

Table 5.15 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

Ammonia emissions from combustion sources are usually small, but significant levels can be emitted from road vehicles equipped with catalyst devices to control NO_x emissions. Similar to N_2O, ammonia emissions are an unintended by-product of the NO_x reduction process on the catalyst and were more pronounced for early generation petrol cars with catalysts (Euro 1 and 2). Factors for later petrol vehicle Euro standards and for diesel vehicles are much lower.

The emission factors for NH_3 for all vehicle types are based on the recommendation of the EMEP/EEA Emissions Inventory Guidebook (EEA, 2007) 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 5.26 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 http://www.dft.gov.uk/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/EEA, 2009); and
- Expert judgement.

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

Emission factors have been specified by vehicle type and Euro standard for all 16 PAHs. An example of factors for benzo[a]pyrene is shown in Table 5.27.

There are various other pollutants such as metals that are emitted from vehicles because of their presence in the fuel. Emissions depend on the concentrations of these components in the fuel and are calculated from fuel-based emission factors such as described earlier for SO_2. The emission factors are referred to elsewhere in this report.

Pollutant speciation

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

Nitrogen oxides are emitted in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). The fraction emitted directly as NO_2 (f-NO_2) is of particular interest for air quality modelling and the inventory is required to provide estimates of the fraction emitted as NO_2 for different vehicle categories. 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 5.16. These should be used in conjunction with the NO_x emissions calculated by the inventory to derive the corresponding emissions of NO_2.

Table 5.16 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
Petrol cars	0.040	0.040	0.040	0.035	0.032	0.031
Diesel cars	0.110	0.110	0.113	0.221	0.418	0.420
Petrol LGVs	0.040	0.040	0.040	0.037	0.034	0.034
Diesel LGVs	0.110	0.110	0.110	0.202	0.432	0.446
Rigid HGVs	0.110	0.110	0.110	0.128	0.128	0.125
Artic HGVs	0.110	0.110	0.110	0.132	0.125	0.119
Buses and coaches	0.110	0.110	0.110	0.124	0.127	0.125
Motorcycles	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 (2007), 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 VOCs emitted and the chemical speciation of emissions differs for different sources. The NMVOC speciation in the inventory is discussed elsewhere, but the speciation of NMVOCs emitted from vehicle exhausts is taken from EMEP/EEA Emissions Inventory Guidebook (2007).

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). Their 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 (EEA, 2007). However, it was also acknowledged that such an update can only be undertaken once the ARTEMIS model and/or COPERT 4 have been finalised and that at the time of their study it was not possible to give definitive emission factors for all vehicle categories.

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

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

Cold start emissions are calculated from the formula:

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

where

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

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

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

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

where

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

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

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, 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 (EEA, 2007). 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 5.17. There are no cold start factors for HGVs and buses.

Table 5.17 Cold Start Emission Factors for NH3 (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.

5.4.4 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 (EEA, 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 more detailed vehicle categories and technologies than the previous method 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 (2012), 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 2011 is shown for petrol cars and motorcycles in Table 5.18. The units are in g per vehicle per day.

Table 5.18 Fleet-average emission factor for evaporative emissions of NMVOCs in 2011

g/vehicle.day	2011
Petrol cars	0.75
Motorcycles	1.63

5.4.5 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/EEA, 2007) 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 5.19 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.

Table 5.19 Emission factors for PM_{10} from tyre and brake wear

mg PM_{10} /km		Tyre	Brake
Cars	Urban	8.74	11.68
	Rural	6.80	5.53
	Motorway	5.79	1.36
LGVs	Urban	13.80	18.22
	Rural	10.74	8.62
	Motorway	9.15	2.12
Rigid HGVs	Urban	20.74	51.00
	Rural	17.39	27.14
	Motorway	13.98	8.44
Artic HGVs	Urban	47.07	51.00
	Rural	38.24	27.14
	Motorway	31.49	8.44
Buses	Urban	21.18	53.60
	Rural	17.39	27.14
	Motorway	13.98	8.44
Motorcycles	Urban	3.76	5.84
	Rural	2.92	2.76
	Motorway	2.49	0.68

PM emissions from road abrasion are estimated based upon the emission factors and methodology provided by the EMEP/EEA Emissions Inventory Guidebook (EMEP/EEA, 2009). 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 5.20. 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 5.20 Emission factors for PM_{10} from road abrasion

mg PM_{10}/km	Road abrasion
Cars	7.5

mg PM_{10}/km	Road abrasion
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 5.21.

Table 5.21 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 resuspension of deposited material on the road surface by the movement of vehicles. Inventory guidelines do not require an estimate for resuspension 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 resuspension to PM air quality requires more sophistication than a basic inventory approach can provide, taking into account the local conditions.

Table 5.22 NOx 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		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	0.35	0.31	0.52
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

[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		Urban	Rural	Motorway
	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	0.51	0.49	0.73
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
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
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
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 5.23 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		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.299	0.818	0.711
	Euro 1	0.154	0.115	0.119
	Euro 2	0.061	0.045	0.044
	Euro 3	0.014	0.017	0.033
	Euro 4	0.012	0.014	0.019
	Euro 5	0.012	0.014	0.019
Diesel cars	Pre-Euro 1	0.122	0.078	0.055
	Euro 1	0.052	0.032	0.029
	Euro 2	0.045	0.029	0.019
	Euro 3	0.020	0.012	0.010
	Euro 4	0.009	0.006	0.006
	Euro 5	0.009	0.006	0.006
Petrol LGVs	Pre-Euro 1	1.403	0.475	0.884
	Euro 1	0.175	0.082	0.099

g HC/km		Urban	Rural	Motorway
	Euro 2	0.042	0.020	0.024
	Euro 3	0.025	0.011	0.014
	Euro 4	0.011	0.005	0.006
	Euro 5	0.011	0.005	0.006
Diesel LGV	Pre-Euro 1	0.120	0.101	0.118
	Euro 1	0.120	0.101	0.118
	Euro 2	0.120	0.101	0.118
	Euro 3	0.074	0.063	0.073
	Euro 4	0.028	0.023	0.027
	Euro 5	0.028	0.023	0.027
Rigid HGVs	Pre-Euro I	0.825	0.538	0.371
	Euro I	0.422	0.294	0.220
	Euro II	0.282	0.193	0.142
	Euro III	0.260	0.176	0.128
	Euro IV	0.037	0.029	0.027
	Euro V	0.023	0.018	0.015
Artic HGVs	Pre-Euro I	0.683	0.463	0.341
	Euro I	0.635	0.436	0.323
	Euro II	0.418	0.284	0.208
	Euro III	0.386	0.263	0.193
	Euro IV	0.059	0.044	0.039
	Euro V	0.036	0.027	0.023
Buses & coaches	Pre-Euro I	1.099	0.812	0.311
	Euro I	0.488	0.358	0.316
	Euro II	0.334	0.248	0.209
	Euro III	0.310	0.237	0.207
	Euro IV	0.047	0.038	0.033
	Euro V	0.028	0.024	0.021
Mopeds, <50cc, 2st	Pre-Euro 1	13.910		
	Euro 1	2.730		
	Euro 2	1.560		
	Euro 3	1.200		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.521	7.442	
	Euro 1	2.362	2.863	
	Euro 2	1.254	1.521	
	Euro 3	0.784	0.948	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.595	1.302	1.726
	Euro 1	0.896	0.793	0.807
	Euro 2	0.394	0.432	0.577
	Euro 3	0.246	0.270	0.362

Table 5.24 PM_{10} Emission Factors for Road Transport (in g/km)

g PM/km		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	0.170	0.132	0.160
	Euro 1	0.054	0.069	0.099

g PM/km		Urban	Rural	Motorway
	Euro 2	0.043	0.040	0.048
	Euro 3	0.028	0.032	0.042
	Euro 4	0.027	0.024	0.025
	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	0.289	0.318	0.349
	Euro 1	0.062	0.084	0.141
	Euro 2	0.062	0.084	0.141
	Euro 3	0.042	0.057	0.094
	Euro 4	0.022	0.030	0.049
	Euro 5	0.001	0.002	0.003
Rigid HGVs	Pre-Euro I	0.358	0.291	0.275
	Euro I	0.230	0.184	0.177
	Euro II	0.112	0.122	0.144
	Euro III	0.115	0.089	0.083
	Euro IV	0.027	0.023	0.024
	Euro V	0.025	0.020	0.018
Artic HGVs	Pre-Euro I	0.481	0.420	0.271
	Euro I	0.374	0.326	0.199
	Euro II	0.202	0.212	0.261
	Euro III	0.187	0.144	0.132
	Euro IV	0.043	0.034	0.032
	Euro V	0.043	0.033	0.030
Buses & coaches	Pre-Euro I	0.453	0.340	0.272
	Euro I	0.268	0.214	0.199
	Euro II	0.144	0.129	0.124
	Euro III	0.139	0.111	0.105
	Euro IV	0.034	0.027	0.029
	Euro V	0.030	0.023	0.020
Mopeds, <50cc, 2st	Pre-Euro 1	0.188		
	Euro 1	0.076		
	Euro 2	0.038		
	Euro 3	0.011		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.200	0.200	
	Euro 1	0.080	0.080	
	Euro 2	0.040	0.040	
	Euro 3	0.012	0.012	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.017	0.020	0.020
	Euro 1	0.017	0.020	0.020
	Euro 2	0.004	0.005	0.005
	Euro 3	0.004	0.005	0.005

Table 5.25 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13

g CO/km		Urban	Rural	Motorway
	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
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
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
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 5.26 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

mg/km	Standard	Urban	Rural	Motorway
	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
	Euro V	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
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
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 5.27 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

g B(a)P/km	Standard	All road types
	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
	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
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
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
Mopeds, <50cc, 2st	All	1.01E-06
Motorcycles, >50cc, 2st	All	1.01E-06
Motorcycles, >50cc, 4st	All	3.02E-06

5.5 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.

Summary of Methodology
A Tier 2/3 methodology is used for calculating emissions from domestic coastal navigation, inland waterways, fishing and international marine bunkers using vessel, engine and fuel-specific, and in some case, movement specific emission factors and activity data.

Summary of emission factors
For domestic coastal shipping, fishing, military and international marine bunker emissions, the emission factors are taken from the study by Entec (2010), originating from Lloyds Register Engineering Services and a study by IVL for different vessel, fuel and movement types. These were supplemented by factors from the EMEP/EEA Emissions Inventory Guidebook. For inland waterway vessels, engine and fuel-specific emission factors were taken from the EMEP/EEA Emissions Inventory Guidebook.

Country-specific factors for SO_2 are based on considerations by Entec on the types of fuels used to comply with MARPOL Annex VI requirements and operations in Sulphur Emission Control Areas, as well as data from UKPIA on the sulphur content of marine fuels provided for more recent years.

Summary of activity data
Detailed shipping vessel movement data provided by Entec (2010) were used for 2007. Port movement data from DfT Maritime Statistics were used to estimate trends for other years. For inland waterways, bottom-up estimates from population and hours of use of vessels in 2008/2009 were used and various proxy statistics used as activity drivers for different groups of vessel types to estimate fuel consumption in other years. UK fishing statistics were used to estimate fuel consumption from UK fishing activities and fuel consumption data provided by the MoD were used for naval shipping. A reconciliation with total gas oil and fuel oil consumption statistics given in DUKES was used to estimate fuel consumption by UK international maritime bunkers.

Methodology details
The method for estimating domestic coastal shipping is centred around a procedure developed by Entec (now AMEC) 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 which the UK is responsible, including fishing activities and vessel movements between the UK and overseas territories. The latter were included for the first time in this version of the inventory.

The balance in total marine fuel consumption is used to define emissions from international marine bunkers following a Tier 2 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, 2012). 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 believed 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 2011.

According to emission reporting guidelines, emissions from domestic coastal shipping are included in national totals, whereas emissions for international marine are not, but are reported as a Memo item for information. To meet the overall requirements for reporting emissions from shipping to CLRTAP, the method adopted for the UK inventory uses the results from Entec for coastal shipping based on movement data for domestic journeys while at the same time using an estimation for international marine that retains consistency with total marine fuels data reported in DUKES after also accounting for other uses of marine fuels for purposes where the UK is responsible for emissions. Emissions from naval shipping continue to be based on fuel consumption data reported by the MoD. Estimates of emissions from inland waterways and fishing are reported separately.

Following comments made by reviewers during the In-Country Review of the UK's Greenhouse Gas Inventory in 2012, emissions from UK fishing activities in waters outside the Entec study area and emissions from vessel movements between the UK and overseas territories have been included for the first time.

This leads to a revision in the method used for international marine bunker emissions in order to maintain the overall marine fuel balance with DUKES. The overall approach can be summarised as follows:

- Fuel consumption and emissions for domestic journeys are taken from the Entec study based on detailed movement data for 2007. Entec provided an uplift to their bottom-up estimates to take account of missing vessel movements
- Fuel consumption and emissions for fishing vessels in UK waters are taken from the Entec study and reported separately under 1A4ciii
- Estimates for domestic coastal shipping fuel consumption and emissions backcast to 1990 and forecast to 2011 are used
- Fuel consumption and emissions are calculated separately for naval shipping from data provided by the MoD
- Fuel consumption and emissions are calculated separately for inland waterways from estimates of vessel population and activities
- Fuel consumption and emissions are calculated separately for fishing which takes place in non-UK waters by UK vessels
- Fuel consumption and emissions are calculated separately for shipping movements between the UK and Overseas Territories
- A reconciliation with fuels data in DUKES is made whereby the ***difference*** between the sum of the currently reported fuel deliveries for marine bunkers and national navigation in DUKES and the sum of the fuel consumption estimate for domestic coastal shipping taken from Entec, and the fuel consumption estimates for naval shipping, the UK's inland waterways, fishing outside UK waters and shipping movements between the Overseas Territories, is assigned to international shipping.

Details in the approach for the elements of these parts of the inventory for navigation are given in the following sections, including the methodologies for inland waterways, naval shipping, 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.

Estimation for Domestic Coastal Shipping Emissions in 2007 (1A3dii)

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).

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, SO_2, PM and NMVOCs. For NO_x, 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. Emission factors for SO_2 depend on the sulphur content of the fuel. Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table 5.28 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%

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 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, including CH_4 and N_2O, emission factors in units g/kg fuel were taken from the EMEP/EEA guidebook.

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 emissions to be allocated to the NFR category 1A3dii Domestic Water-borne Navigation separate from 1A3di International Water-borne Navigation (International bunkers), according to NFR Source Categories:

Table 5.29 NFR Navigation Source Category and description

1A3di International Water-borne Navigation (International bunkers)	Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Includes emissions from journeys that depart in one country and arrive in a different country.
1A3dii Domestic Water-borne Navigation	Emissions from fuels used by vessels of all flags that depart and arrive in the same country

Emissions from domestic navigation (1A3dii) are included in the national totals, emissions from international navigation (1A3di) are not included in national totals, but are reported as a Memo item for information.

It should be noted that the gridded inventory developed by Entec also included fuel consumption and emissions from passing vessels not calling at UK ports. These emissions from transit vessels are not included in the UK inventory. The Entec inventory also 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. 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 are described later.

Estimating the Time Series in Domestic Coastal Shipping Emissions from 1990

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 2011 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
- Changes in emission factors.

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 1990-2011.
- 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 1990-2011
- 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, 2012).

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. These were trends in ports traffic (tonnes cargo) for domestic movements, international sea passenger numbers and fish landings which showed declining activity. However, in the period between 2007 and 2009, almost all statistics showed a decreasing level of activity. Between 2009 and 2011 there was little change in these statistics. The small changes resulted in an overall decreasing trend in fuel consumption from 2010 to 2011.

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. However, other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2011 time-series. Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007. Information from UKPIA and DECC shows that fuel oil is still used for marine consumption.

As far as changes in emission factors are concerned, the main consideration was in changes in factors for NO_x and SO_2 over time. The issue for NO_x was the proportion of pre- and post-2000 engines installed on ships since engines installed after January 2000 must comply with the NO_x Technical Code. 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.

SO_2 factors are based on the sulphur content of each type of fuel. Prior to 2007, 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.

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 2011. These are below the global MARPOL limit on sulphur content for marine fuels outside SECAs of 4.5% (up to January 2012).

Emission factors for PM were varied each year according to changes in fuel sulphur content using a relationship taken from Lloyd's. For all other pollutants, emission factors remained constant over the time-series.

Emissions from 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, 2012). Data are provided on a financial year basis so adjustments were made to derive figures on a calendar year basis.

Implied emission factors derived for international shipping vessels running on marine distillate (MGO and MDO) from the Entec (2010) study were assumed to apply for military shipping vessels.

Emissions from Inland Waterways (1A3dii)

The CLRTAP Guidelines specify that category 1A3d Waterborne Navigation should include not only fuel used for marine coastal shipping, but also 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. It was therefore necessary to use a Tier 3, bottom-up approach based on estimates of population and usage of different types of inland waterway vessels to estimate their emissions. In the UK, all emissions from inland waterways are included in domestic totals whereas in some other countries, vessels on inland waterways could be classed as international since they pass between countries.

The methodology applied to derive emissions from the inland waterways sector for the 2011 inventory 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 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. As a result, around 90 kt of DERV and 90 kt of petrol previously assigned to the road transport sector for 2009 in the 2009 inventory are now allocated to inland waterways.

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.

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 – 2011:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on "Recreation and culture"; http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html. No data were available for this dataset after 2009, therefore a second dataset was used to estimate the activity in 2010-11: OECD.Stat data: http://stats.oecd.org/Index.aspx?QueryId=9189# - 'Final consumption expenditure of households, UK, 1990-2011', P31CP090: Recreation and culture);.
- Commercial passenger/tourist craft – Visit England, Visitor Attraction Trends in England 2011, Full Report, http://www.visitengland.org/insight-statistics/major-tourism-surveys/attractions/Annual_Survey/, Slides 10&12: "Total England Attractions"
- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table PORT0104 - All UK port freight traffic, foreign, coastwise and one-port by direction; http://www.dft.gov.uk/statistics/releases/port-freight-statistics-2010-final-figures/; and
- Freight – DfT Waterborne Freight in the United Kingdom, Table DWF0101: Waterborne transport within the United Kingdom, 1990 – 2010; Goods lifted - UK inland waters traffic - Non-seagoing traffic – Internal http://www.dft.gov.uk/statistics/releases/waterborne-freight-in-the-uk-2010

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 5.30 shows the trend in fuel consumption by inland waterways from 1990-2011 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. The fuel-based emission factors used for all inland waterway vessels were taken from the EMEP Emissions Inventory Guidebook and implied factors for 2011 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.

Table 5.30 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	3.82	0.59	27.6	22.0	11.2
1991	86.5	3.44	0.62	28.8	22.6	11.7
1992	86.9	3.76	0.68	31.5	24.1	12.8
1993	88.4	4.07	0.74	34.3	25.5	13.9
1994	92.8	4.52	0.80	37.0	27.0	15.0
1995	94.3	4.20	0.85	39.8	28.5	16.1
1996	94.9	3.63	0.91	42.5	29.9	17.2
1997	95.2	3.06	0.97	45.3	31.1	18.3
1998	95.8	2.74	1.03	48.0	32.2	19.4
1999	95.5	2.74	1.09	50.7	33.6	20.5
2000	96.1	2.74	1.15	53.5	34.8	21.6
2001	94.5	2.71	1.21	56.2	35.9	22.8
2002	96.0	2.52	1.30	60.4	38.7	24.4
2003	96.4	2.02	1.39	64.6	41.0	26.1
2004	98.8	1.65	1.48	68.8	43.2	27.8
2005	100.2	2.16	1.57	72.9	45.2	29.5
2006	101.1	2.26	1.66	77.1	47.6	31.2
2007	101.7	2.14	1.75	81.3	49.9	32.9
2008	100.3	2.35	1.84	85.5	52.2	34.6
2009	94.6	2.08	1.93	89.6	54.8	36.3
2010	97.0	1.87	1.98	92.2	56.3	37.3
2011	99.0	1.87	2.00	93.2	57.2	37.7

<u>Emissions from Deep Sea Fishing in Sea Territories outside UK Waters (1A4ciii)</u>

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), 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 have been estimated for the first time 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.

<u>Approach</u>

The Marine Management Organisation (MMO) produces a report annually on the UK fishing industry[20] entitled "*The UK Fishing Industry 2011: Landings*"[21]. This is classed as a National Statistics Publication. This report gives the tonnes of fish landing into the UK and abroad by UK vessels by **area of capture**. The areas of capture are listed in terms of the ICES[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 1994-2011 (see for example, Table 8 in the 2011 MMO Landings report).

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
- 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

i) Number of vessel trips

According to the MMO Landings report (Table 8), the fish catches in the non-UK ICES areas are mainly of Pelagic fish such as mackerel and herring (Table 6). These are also mainly caught by the largest vessels, over 24m (Table 10).

A publication by Borges et al[23] on Dutch commercial fishing operations by pelagic trawlers indicated that a small number of very large-sized trawlers (factory trawlers) catch on average **155 tonnes**

[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] http://www.marinemanagement.org.uk/fisheries/statistics/documents/ukseafish/2011/landings.pdf

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

[23] L Borges et al, "What do pelagic freezer-trawlers discard?", ICES Journal of Marine Science, 65: 605–611(2008), http://icesjms.oxfordjournals.org/content/65/4/605.full.pdf

pelagic fish per vessel per trip based on data for 2005. These are vessels that are over 100m in length with an engine size close to 6,000kW making them similar in size to a bulk carrier ship.

The MMO Landings data for 2011 indicates that 39,500 tonnes fish were caught in the non-UK ICES areas in 2011. Assuming the UK vessels have the same trawling capacity as the Dutch fleet, then this would require **255 vessel trips** per year in 2011.

Although a very rough estimate, this is consistent with information on a Greenpeace website which states that there are 47 pelagic fishing vessels in the UK. If 255 vessel trips are made per year, this would imply each vessel does around 5-6 trips per year.

The Borges et al study stated that the Netherlands has some of the largest fishing vessels in the world. If the UK vessels are generally smaller then they will require more than the 255 trips to the non-UK ICES areas estimated above to make the total catch reported. However this will be offset by the fact that their engine sizes and hence fuel consumption rates would be lower.

According to Table 3 in the MMO Structure and Activity report, the average engine size of the >24m fleet of vessels in the UK is 1,206 kW which is considerably less than the engine size of the factory trawlers in the Dutch fleet. The largest vessels in the UK fleet are in Scotland (142 vessels >24m, with an average engine size of 1,350 kW). It is possible that very large vessels make up a sub-set of these figures.

For the purpose of these estimates, 255 vessel round-trips was assumed to the non-UK ICES areas in 2011 in conjunction with an assumed engine power for these vessels of 5,800kW. Fish landings for these non-UK ICES areas in other years from the MMO reports were used to calculate number of round-trips in other years.

ii) Distances covered to/from the non-UK ICES sea areas

The MMO information was used to split the tonnes fish landings from the non-UK ICES areas between each area in each year. The tables in the MMO Landing reports indicate that the major areas of capture by UK fishing vessels in the non-UK ICES areas are the north Norwegian coast and ‘other areas’. The MMO reports do not specify what ‘other areas’ refer to, but Chart 18 in the MMO Landings report indicates that Spain and Morocco are major areas outside UK waters receiving landings of pelagic fish from UK vessels. It was therefore assumed that the landings to the UK from ‘other areas’ are from off the coast of Morocco which is known to be an important fishing area.

Detailed landings data to accompany Chart 17 in the MMO Landings report indicate that 81% of landings of pelagic fish are to major ports in Scotland (Peterhead, Lerwick and Fraserburgh) with 11% to major ports in the south-west of England (mainly Plymouth, Newlyn and Brixham) and the rest to other ports.

It was assumed that all 11% of the landings to the south-west of England were captured in the ‘other areas’ (designated as Morocco). Peterhead and Lerwick were assumed to take the remaining percent of the landings captured from Morocco and all the landings captured off the coast of Norway and the other minor areas. The Peterhead/Lerwick split was taken to be 65%/35% for all the areas of capture based on MMO data.

This information on landings was used to split the total number of vessel trips from the UK (calculated above) to each of the non-UK ICES sea areas between the “representative” UK ports of Peterhead, Lerwick and Plymouth.

To calculate trip distances, certain central positions were allocated to each area of capture. Distances from the relevant UK port to these positions are shown below:

Approx distances to points in each sea area in km

	Peterhead	Lerwick	Plymouth
Barents Sea/Murman Coast (I)	1923	1730	

Norwegian Coast (IIa)	1000	750	
Bear Island & Spitzbergen (IIb)	2600	2300	
Bay of Biscay (VIII)	2000	1875	660
East Coast of Greenland (XIV)	1800	1700	
North Azores (XII)	3000	3000	
Other Areas [(a)]	2900	2900	1700

Using the return port-sea area distances and the number of return trips made, split between each combination of UK port-to-sea area, the total distances travelled per year by all UK fishing trips to the non-UK ICES areas were calculated for each year.

iii) Average vessel speed

An average cruise speed of 25 kph was used for the fishing vessels travelling between the UK port and area of fish capture. This is taken from the EMEP Inventory Guidebook section on marine navigation.

Using this speed with the trip distances calculated above, the total time taken to travel the distances calculated above was derived for each year.

iv) Rated engine power

A rated engine power of 5,800 kW was used for all vessels, consistent with the calculation of number of vessel trips above.

A weighted average engine load factor of 0.46 was used. This was based on an assumption that the vessel would be operating under different loads for different parts of a day. The assumptions were: 5 hrs/day at 80% load, 11 hrs day at 50% load, 8 hrs/day at 20% load.

Fuel consumption

A specific fuel consumption factor of 203 g/kWh was used to calculate total fuel consumption by UK vessels travelling to and returning from the non-UK ICES sea area 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.

The fuel used whilst actively fishing in the non-UK areas was calculated by assuming each vessel spends 4 days actively fishing once it has reached its sea area. This was used in conjunction with the same engine power, load information and fuel consumption factor as above to calculate total fuel consumption for all UK vessels whilst actively fishing in these sea areas.

Note that using other information in the MMO reports on total fishing effort in combination with the vessel trip information and landings used here implies that the average time spent fishing is around 3-4 days, consistent with this assumption.

The total fuel consumption for fishing by UK vessels in non-UK ICES areas is the sum of the total fuel consumed during the fishing activity and the total fuel consumed travelling to and from the area of capture.

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.

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 have been estimated for the first time 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.

Approach
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 2011.

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 Emissions Inventory Guidebook 2009[24].

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. The estimates were summed for all voyages between the UK and each OT and separately for both for the UK inward and UK outward journeys. For example, the total fuel consumed by all movements from the UK to Gibraltar and from Gibraltar to the UK were estimated separately.

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[25]. 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[26]. 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 2011.

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[24] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009
[25] http://www.gibraltarport.com/cruise/schedules
[26] 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

The same source of information as described above was used to define the distances travelled, cruise speed, engine power and fuel consumption factor to calculate total fuel consumption by cruise ships between the UK and each OT. The information for passenger ships was taken from the EMEP Guidebook.

No cruise ship information was available before 1999 from either DfT or the individual OT port authorities. Trends in the total number of passengers on cruises beginning or ending at UK ports between 1990 and 1999 published in DfT's Maritime Statistics (from Table 3.1(a) UK international short sea passenger movements, by port and port area: 1950 – 2009) were used to define the trend in fuel consumption by cruise ships between the UK and OTs over these years.

The total fuel consumed by vessels moving between the UK and each OT was calculated as the sum of all fuel consumed by freight and passenger vessels. This was calculated separately for movements from the UK to each OT and from each OT to the UK.

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.

Estimation of International Shipping Emissions from 1990 (1A3di)
Emissions from international marine bunkers are calculated, but reported as a Memo item and not included in the UK totals.

The study by Entec provided a time-series in fuel consumption and emissions from vessels involved in international movements, i.e. those arriving at UK ports from overseas and those leaving UK ports to voyage overseas. However, when adding the estimates of fuel consumption from international movements to fuel consumed by domestic movements (UK port-to-UK port), the sum is different to the total fuel supplied to international marine bunkers and consumed by national navigation in DUKES. This is illustrated in Table 5.31 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. 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 5.31 Total consumption of marine fuels for domestic and international shipping calculated by the Entec method compared DUKES for 2007

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.

The key point is that for emission reporting 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:

International shipping fuel consumption = (total DUKES fuel consumption – Entec domestic shipping fuel consumption – naval fuel consumption – inland waterways fuel consumption – fishing vessels outside UK waters fuel consumption – shipping vessels travelling from the UK to overseas territories fuel consumption)

This implies that the total marine fuel consumption by all marine activities covered in the inventory is considered a “closed” system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic coastal shipping, fishing, naval and inland waterways, voyages to overseas territories, fishing outside UK waters) is consistent with the total amount of gas oil and fuel oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES as can be seen in Table 5.32.

Table 5.32 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.

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.534	0.942
	International	1.035	0.627
	Total	1.569	1.569
	% domestic	34%	60%
Fuel oil	Domestic	0.122	0.569
	International	1.918	1.471
	Total	2.040	2.040
	% domestic	6%	28%

The DUKES figure for gas oil (international) has consumption by military vessels excluded. This table differs from the corresponding table in last year’s (2010) inventory report because fuel used for fishing in non-UK waters and voyages from UK to OTs are included in domestic consumption.

The inclusion of fuel used for deep sea fishing in non-UK waters and fuel used for voyages from the UK to OTs in the inventory increased the domestic shipping fuel proportion compared with last year’s

(2010) inventory, but the table still shows how the inventory implies a smaller proportion of fuel is used for domestic activities (as defined for inventory reporting) than is implied by DUKES.

Following this revised approach, 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).

This approach was used to estimate international shipping fuel consumption and emissions for all years back to 1990.

Estimation of Domestic and International Shipping Emissions from 1970-1990

For years prior to 1990, the implied emission factors and fuel types used for navigation are assumed to be the same as for 1990. Implied emission factors in g/kg fuel were developed for domestic, international and fishing vessels for gas oil and fuel oil.

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).

Summary of fuel consumption for UK marine activities

Table 5.33 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. 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 5.33 Fuel consumption for UK marine derived from inventory method

	Gas oil				Fuel oil		
ktonnes fuel	Domestic coastal and military	Fishing	Inland waterways	International bunkers	Domestic coastal and military	Voyages from UK to OTs	International bunkers
1990	0.609	0.025	0.090	1.595	0.35	0.008	1.124
1991	0.626	0.025	0.090	1.655	0.34	0.008	1.057
1992	0.588	0.025	0.091	1.681	0.34	0.008	1.087
1993	0.540	0.025	0.093	1.597	0.33	0.009	1.134
1994	0.521	0.025	0.097	1.526	0.35	0.009	0.941
1995	0.535	0.026	0.098	1.358	0.37	0.009	1.187
1996	0.540	0.034	0.099	1.574	0.37	0.009	1.249
1997	0.559	0.041	0.098	1.496	0.36	0.010	1.560
1998	0.450	0.038	0.099	1.791	0.37	0.011	1.406
1999	0.479	0.034	0.098	1.452	0.37	0.011	0.865
2000	0.461	0.032	0.099	1.462	0.35	0.012	0.618
2001	0.430	0.030	0.097	1.618	0.33	0.011	0.530
2002	0.413	0.029	0.098	1.209	0.35	0.008	0.452
2003	0.439	0.029	0.098	1.416	0.34	0.009	0.566
2004	0.469	0.028	0.100	1.319	0.34	0.010	0.925
2005	0.443	0.029	0.102	1.235	0.36	0.009	1.155
2006	0.427	0.038	0.103	1.652	0.34	0.013	1.468
2007	0.662	0.042	0.104	1.035	0.10	0.019	1.918
2008	0.649	0.074	0.103	0.860	0.10	0.011	2.448
2009	0.629	0.049	0.097	0.879	0.09	0.009	2.260
2010	0.616	0.064	0.099	0.803	0.09	0.011	1.845
2011	0.594	0.037	0.101	0.832	0.09	0.011	2.139

Summary of emission factors for UK marine activities

Table 5.34 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2011. The units are in g/kg fuel and are implied by the figures in the Entec study and fuel sulphur content.

Table 5.34 2011 Inventory Implied Emission Factors for Shipping

Fuel	Source	NO_X	SO_2	VOC	PM_{10}	CO
		g/kg	g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.44	20.00	2.82	1.95	7.40
	Fishing	57.97	2.02	2.04	1.32	7.40
	International	69.33	20.00	2.74	1.85	7.40
Fuel Oil	Domestic	70.57	17.60	3.52	6.56	7.40
	International	77.71	27.60	2.92	6.75	7.40

Table 5.35 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2011.

Table 5.35 2011 Inventory Emission Factors for Inland Waterway Vessels

Fuel	NO_X	SO_2	VOC	PM_{10}	CO
	g/kg	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.0154	4.72	4.12	10.9
Gas Oil	42.5	0.02	4.72	4.12	10.9
Petrol	9.0	0.0096	50.0	0.036	300

5.6 Other Sectors (1A4)

The mapping of NAEI categories to 1A4 Other Sectors is shown in Section A3.2. For most sources, the estimation procedure follows that of the base combustion module using DECC reported fuel use data and emission factors from section 5.3. 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 5.7 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.

5.7 Other

Emissions from a variety of off-road mobile machinery sources are included in 1A2fii, 1A4bii, 1A4cii, 1A3e. 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. .

5.7.1 Estimation of Other Off-Road Sources (1A2fii, 1A4bii, 1A4cii, 1A3e)

Summary of Methodology

A Tier 3 methodology is used for calculating emissions from individual types of mobile machinery.

Summary of emission factors
Machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from EMEP/CORINAIR Guidebook (1996). Emission factors for more modern machinery based on engine or machinery-specific emission limits established in EU Non-Road Mobile Machinery Directive.

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.

The mapping of these categories to the appropriate NFR code is shown in Table 6.1. Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

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. Therefore, other activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2011.

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 5.36.

For domestic house and garden machinery, trends in number of households are used (CLG, 2011), for airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2012), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2012) are used.

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/CORINAIR (1996) 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).

Table 5.36 Activity drivers used for off-road machinery in the industry and construction sector.

Category	Driver source	Machinery types
Construction	ONS construction statistics. The value of all new work (i.e. excluding repair and maintenance work) at constant (2005) prices and seasonally adjusted. Taken from the Construction Statistics Annual. The 2012 Annual did not include the seasonally adjusted output, therefore the non-seasonally adjusted figures were used and scaled to ensure time series consistency. http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-260307	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook	bore/drill rigs
		off highway trucks*

Category	Driver source	Machinery types
	data, BGS 2012.	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

5.8 Recalculations in transport sources

Rail

The recalculations for rail primarily stem from the incorporation of information from the detailed UK's Department for Transport strategic Rail Emissions Model (REM) for the first time. This contains detailed information on the vehicle kilometres undertaken by each class of passenger train as well as new emission factors. Estimates for the freight sector remain largely unchanged, with a minor revision to infrastructure activity.

The recalculations were undertaken as part of the inventory improvement programme aimed at addressing comments from reviewers of the greenhouse gas inventory in 2011 to "*improve the completeness and transparency of reporting category-specific emissions for railway*s". The inventory for this sector now has greater traceability through direct links to the UK's Rail Emissions Model at the Department for Transport under development for national transport policy.

The effect of these changes on the calculations of rail emissions in 2010 compared with the previous inventory is summarised as follows:

Total rail fuel consumption is unchanged, but there is a significant redistribution of fuel from use by Intercity trains to regional passenger trains.

There is a small (4%) increase in overall 2010 NOx emissions; this is because there is an increase in the NOx emission factor for regional trains compared with those previously used.

There is a very large increase (94%) in overall 2010 PM emissions; this is due to a very large increase in mean emission factor for Intercity trains (particularly Class 43 diesel locomotives) compared with those used previously and a smaller (but still large) increase in the factors for regional trains.

There is a large decrease (56%) in overall 2010 CO emissions; this is due to a very large decrease in CO factors for regional trains.

There is a large decrease (32%) in overall 2010 NMVOC emissions; this is due to a large decrease in NMVOC factors for regional trains.

Road transport
There have been a number of improvements made to the road transport inventory and the key changes are summarised as follows:

- Revised emission factors for PM_{10} and total hydrocarbon (THC) for all vehicle types and the associated emission degradation methodology for light duty vehicles based on COPERT 4 (v9.0);
- Revised 2000-2010 minor road vehicle km estimates for England and Wales as a result of a benchmarking exercise planned in 2010 by DfT;
- Revised 2010 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development;
- Revised assumption on the distribution of vehicle km between artic 34-40t and 40-50t weight classes across the whole time series, based on bespoke licensing statistics provided by the DfT;
- Updated London bus fleet composition data as provided by Transport for London in July 2012;
- Revised DUKES data for petrol and diesel sales (2007-2010), in particularly for petrol sales in 2010 (3% lower compared to the value used in 2010 inventory);
- Corrected NO_x emission factors for small LGVs N1 (I) which are now based on medium sized-car emission factors.

For pollutants calculated from fuel consumption, these changes have affected the distribution of fuel consumption and hence emissions between vehicle types. Total fuel-related emissions from road transport between 2007 and 2010 are slightly lower compared to the 2010 inventory, due to revised DUKES data for petrol and diesel sales as mentioned above. It should be noted that estimates of fuel consumption calculated for individual types of vehicles are normalised so the total adds up to the DUKES figures for petrol and diesel consumption (corrected for off-road consumption). For other pollutants where emissions are not directly related to fuel consumption, the changes in methods, activity data and emission factors alter the total emissions for road transport reported in each year.

Shipping
Emission estimates for UK deep-sea fishing activities in non-UK waters and emissions from vessel movements between the UK and overseas territories have been included for the first time for the first time. This led to a revision in the fuel consumption and emissions attributed to international marine bunkers in order to retain the overall marine fuel balance with figures in DUKES.

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

Table 6.1 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 *(except HCH)*	Miscellaneous industrial & commercial combustion
		Public sector combustion
		Railways - stationary combustion
1 A 4 b i Residential: Stationary plants	All CLRTAP pollutants *(except HCB and HCH)*	Domestic combustion
1 A 4 b ii Residential: Household and gardening (mobile)	All CLRTAP pollutants *(except HCB , HCH and PCBs)*	House and garden machinery
1 A 4 c i Agriculture/Forestry/Fishing : Stationary	All CLRTAP pollutants *(except HCB and HCH)*	Agriculture - stationary combustion
1 A 4 c ii Agriculture/Forestry/Fishing : Off-road vehicles and other machinery	All CLRTAP pollutants *(except HCB, HCH and PCBs)*	Agricultural engines
		Agriculture - mobile machinery
1A 4 c iii Agriculture/Forestry/Fishing : National fishing	All CLRTAP pollutants *(except NH_3, PCDD/ PCDF, HCB, HCH, PCBs and)*	Fishing vessels

Table 6.2 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 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 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 SO_2.
Domestic combustion	UK model for	DECC energy	Default factors (USEPA, EMEP-EEA,

NAEI Source Category	Method	Activity Data	Emission Factors
	activity allocation to unit type; AD x EF	statistics	IPCC, HMIP, UK-specific research). Fuel analysis (UKPIA, others) for 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 utilisation. Fuel analysis (UKPIA) for 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 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 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 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 SO_2.

6.1 Classification of activities and sources

The NAEI utilises energy statistics published annually in the Digest of UK Energy Statistics (DECC, 2012). The source categories and fuel types used in the NAEI therefore reflect those used in DUKES.

Table 3.2 lists the fuels used in the inventory.

Table 6.1 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 6.1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

6.2 General approach for 1A4

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

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.

6.3 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.

6.4 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 ISR 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 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 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 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, 2009) and UK emission factor surveys (Walker *et al*, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2012) 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. 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/GJ
- 1990-2004 — 24 g NO_x/GJ
- 2005-2011 — 19 g NO_x/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/GJ, 1 in 15 of these boilers are replaced in 1990 with new boilers that emit 24 g NO_x/GJ and that by 2004 all boilers emit 24 g NO_x/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. A similar approach might be worthwhile for other fuels to reflect changes in the use of fuels over time, and improvements in technology, but as for gas, the method would necessarily need to be simplistic and rely on assumed values for the proportions of different types of appliance.

6.5 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 ISR. Section 3.7 discusses QA/QC issues regarding these data.

6.6 Recalculations in NFR Sector 1A4

- A new source has been added to the 2013 submission for charcoal use in the domestic sector. This is based on FAOSTAT activity data and emission factors taken from the 1996 IPCC Guidelines.
- Activity data for straw combustion in agriculture has been revised in DUKES, leading to a small increase in emissions, notably for dioxins, PM_{10} and CO.
- Emissions from fishing vessels have increased due to the inclusion of fishing outside of UK territorial waters.

7. NFR 1B1 & 1B2: Fugitive Emissions from Fuels

Table 7.1 Mapping of NFR Source Categories to NAEI Source Categories: Fugitive Emissions from Fuels.

NFR Category (1B1)	Pollutant coverage	Source
1 B 1 b Solid fuel transformation	All CLRTAP pollutants *(except Se, HCB and HCH)*	Charcoal production
		Coke production
		Iron and steel flaring
		Solid smokeless fuel production
1 B 2 a i Exploration, production, transport	NO_x, NMVOC, SO_2 and CO	Upstream Gas Production - Gas terminal storage
		Upstream Gas Production - Offshore Well Testing
		Upstream Gas Production - process emissions
		Gasification processes
		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 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	NMVOC	Gas transmission network leakage
		Gas distribution network leakage
		Gas leakage at point of use
1 B 2 c Venting and flaring	NO_x, NMVOC, SO_2, Particulate Matter and CO	Upstream gas production - gas flaring
		Upstream gas production - gas venting
		Upstream oil production - gas flaring
		Upstream oil production - gas venting
		Refineries - flares

Table 7.2 Summary of Emission Estimation Methods for NAEI Source Categories in NFR Category 1B1

NAEI Source Category	Method	Activity Data	Emission Factors
Charcoal production	AD x EF	FAOSTAT	Default factors (IPCC 1996)
Coke production	UK I&S model, AD x EF	DECC energy statistics, ISSB, EUETS	Operator data reported under IPPC, Tata Steel, SSI, default factors (USEPA, EIPPCB)
Iron and steel flaring	UK I&S model, AD x EF	DECC energy statistics, EUETS, Tata Steel	Default factors (EMEP-EEA)
Solid smokeless fuel production	UK model for SSF production, AD x EF	DECC energy statistics	Operator data reported under IPPC, default factors (EMEP-EEA, 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			
Upstream Oil Production - process emissions			
Upstream Oil Production - Oil terminal storage			
Upstream Gas Production - Offshore Well Testing	AD x EF	EEMS, Oil and Gas UK, 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			
Upstream Oil Production - Offshore Oil Loading			
Upstream Oil Production - Onshore Oil Loading			
Gasification processes	AD x EF	DECC energy statistics	Operator reported emissions under IPPC
Petroleum processes	AD x EF	DECC energy statistics	Operator reported emissions under IPPC
Refineries – Drainage, General, Process, Tankage	Operator reported emissions	UKPIA, DECC energy statistics	Operator reported emissions under IPPC, 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	UK Distribution, Northern Gas Networks, Scotia Gas, Phoenix Gas, Wales and West Utilities	Annual gas compositional analysis by the GB gas network operators.
Gas distribution network leakage			
Gas leakage at point of use	UK model	DECC energy	Leakage % of total by end user

NAEI Source Category	Method	Activity Data	Emission Factors
		statistics	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, UKPIA data for all refinery sources.

7.1 Classification of activities and sources

The following NFR source categories are key sources for major pollutants: 1B1b, 1B2a(i), 1B2a(iv), 1B2a(v), 1B2b, 1B2c. 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;
- refinery activity estimates from UKPIA;
- upstream oil & gas activity data from the EEMS reporting system managed by the DECC Offshore Inspectorate; and
- gas leakage data provided annually by the gas supply network operators in the UK.

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
- Annual sampling and analysis, e.g. to determine fuel composition
- Calculations that utilise fuel qualities and UK temperature data, e.g. to determine fugitive / tank breathing / evaporative losses

7.2 NFR 1B1b: Solid fuel transformation

NFR Sector 1B1b is a key source for SO_2 and B[a]P, as well as for a range of heavy metals including Cd, Pb, Cr and Ni. The main source of emissions of these pollutants is coke production, although smokeless solid fuel production is the more significant source of cadmium emissions.

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 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, 2009), BREF notes, US EPA AP-42 (US EPA, 2009) 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. 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 emissions in one of the Pollution Inventory (PI), the Scottish Pollutant Release Inventory (SPRI), or Northern Ireland's Inventory of Sources and Releases (ISR). Emission estimates for the sector can be based on the emission data reported for individual sites i.e.

$$\text{Emission} = \Sigma \quad \text{Reported Site Emissions}$$

There are 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. 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.

7.3 NFR 1B2: Fugitive emissions from oil & gas industries

NFR Sector 1B2ai, iv and v are all key sources for NMVOC, 1B2b is a key source for NMVOC only whilst 1B2c is a key source for NMVOC and PM_{10}.

Around 4% of total UK NMVOC emissions in 2011 arise from oil loading and unloading activities at offshore installations and onshore terminals (1B2ai), a further 3% from refinery operations (1B2aiv), and 4% from oil distribution (1B2av), primarily from vehicle refuelling at petrol stations. Refinery processes and fugitive releases in oil distribution are also a key source for non-CLRTAP pollutants such as benzene and 1,3-butadiene.

Natural gas leakage from the public supply network (1B2b) accounts for another 4% of UK NMVOC emissions in 2011, whilst flaring and venting in oil and gas production installations (1B2c) accounts for another 4% of NMVOC emissions and just under 1% of PM10 emissions.

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, individually 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.

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, CO2, CH4, CO, NOX, SO2 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 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 VOCs 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, 2012), 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 11 UK refineries that are currently operating. Annual estimates have been provided by UKPIA since 1993, with 1993 data assumed to be representative of earlier years in the time series.

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 VOC 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: Transco, UKD, Scotia Gas, Northern Gas Networks, Wales and West, Phoenix gas. 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 (UKD);
- Losses from Low Pressure Distribution Network (UKD, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas); and
- Other losses, from Above Ground Installations and other sources (UKD).

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
- Numbers of appliances in the UK in these sectors
- 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)

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, whilst refinery flaring estimates are generated by operators and reported annually to the inventory agency via UKPIA. 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).

7.4 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 provides emission estimation guidance for all operators to assist in the completion of EEMS and EUETS 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 Oil and Gas UK EEMS dataset for 1998 onwards. Emission estimates for earlier years (i.e. pre-EEMS) are estimated based on industry studies (Oil and Gas UK 1995, 1998) which were revised and updated in 2005 (UK Oil and Gas, 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. The dataset provided in 2012 by DECC provides a more consistent time-series of data for the range of activities within this sector. However, whilst the EEMS data quality appears to be improving over recent years, the completeness of emissions reported via the EEMS reporting system is still subject to uncertainty as reporting gaps for some sites are still evident. The Inventory Agency continues to work with the regulatory agency, DECC, in the continued development of emission estimates from this sector.

During the latest inventory cycle, a review of data consistency and completeness across the time series was undertaken. This was prompted by a need to improve transparency and reconcile data on energy and emissions reported to DECC and the UK environmental regulatory agencies, comparing and aligning data from DUKES, EEMS and EUETS. The review of data and consultation with data providers within the DECC energy statistics team and DECC Offshore Inspectorate led to some systematic changes in estimates for the upstream oil and gas sector, most of which are covered in NFR sector 1A1. However, some re-allocations between the upstream oil and upstream gas sectors, as well as gap-filling for under-reports and non-reports within the EEMS system also impact in NFR 1B estimates of process and fugitive releases.

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 time series consistency of the gas leakage from transmission and distribution was reviewed in the latest inventory cycle and this has led to revisions in the 2013 submission for data in the 1990s and early 2000s. Stakeholder consultation with the gas network operators clarified that the assumptions regarding leakage rates should be interpolated between two large industry leakage surveys, one in 1992 and one in 2002, upon which the leakages estimates for that time period are based. In previous submissions, the assumptions from the earlier survey had been extrapolated forwards until the analysis of the 2002 survey findings were applied from 2003 onwards, which had led to a step-change in inventory estimates between 2002-2003 which did not reflect the actual UK trend for this source.

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 enables a degree of internal consistency checking.

7.5 Recalculations in NFR sectors 1B1 and 1B2

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

- The inclusion of emission estimates from charcoal production for the first time in the 2013 submission has improved completeness of the UK inventories, adding emissions across the time series for CO, NOX and NMVOC;
- The reporting of gas leakage in NFR 1B2b is now presented at a more detailed level, as the estimates of NMVOC from transmission and distribution are now reported separately, improving transparency. Furthermore, the revision to gas leakage at the point of use to include releases of NMVOCs from gas leakage from cooking appliances in the residential and commercial sector has improved inventory completeness, although the impact on the UK inventory is minor;
- Improvements to the allocation and completeness of upstream oil and gas flaring estimates has led to increases in emission estimates for all pollutants in 2010 for gas flaring in upstream production, ranging from a 7% increase for NOx to a 19% increase for NMVOC. This was

partially offset by a small reduction in flaring emission estimates of CO, NOx and PM_{10} for the upstream oil sector;

8. NFR 2: Industrial Processes

Table 8.1 Mapping of NFR Source Categories to NAEI Source Categories: Industrial Processes.

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 4 Soda Ash Production and use	Particulate Matter and CO	Chemical industry - soda ash	Operator reporting under IPPC
2 A 6 Road Paving with Asphalt	NMVOC, Particulate Matter, PCDD/ PCDF, benzo[a]pyrene and benzo[k]fluoranthene	Bitumen use	Literature factors, predominantly from USEPA AP-42 with some UK-specific reference sources for dioxins, metals.
		Other industry - asphalt manufacture	
2 A 7 a Quarrying and mining of minerals other than coal	Particulate Matter, Pb and Zn	Dewatering of lead concentrates	
		Quarrying	
2 A 7 b Construction and demolition	Particulate Matter	Construction	
2A 7 c Storage, handling and transport of mineral products		Cement & concrete batching	
2 A 7 d Other Mineral products (Please specify the sources included/excluded in the notes column to the right)	All CLRTAP pollutants *(except NO_x, PAHs, HCB, HCH and PCBs)*	Brick manufacture - non Fletton	Literature factors (USEPA AP-42, HMIP)
		Brick manufacture - Fletton	Operator reporting under IPPC & UK-specific factors / research for dioxins (HMIP) and PM_{10} from glass sector
		Coal tar and bitumen processes	
		Glass - container	
		Glass - continuous filament glass fibre	
		Glass - domestic	
		Glass - flat	
		Glass - frits	
		Glass - glass wool	
		Glass - lead crystal	
		Glass - special	
		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	Nitric acid production	Operator-reported activity and emissions
2 B 5 a Other chemical industry	All CLRTAP pollutants *(except benzo[b] fluoranthene, Indeno (1,2,3-cd) pyrene, HCH 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	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Chemical industry - picloram production	
		Chemical industry - sodium pentachlorophenoxide	
		Chemical industry - trichloroethylene	
		Chemical industry - alkyl lead	Operator reporting under IPPC & literature factors for dioxins (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 & literature factors for dioxins (HMIP), PAHs and metals from some sources
		Chemical industry - reforming	
		Chemical industry - sulphuric acid use	
		Chemical industry - tetrachloroethylene	
		Chemical industry - titanium dioxide	
		Coal tar distillation	
		Solvent and oil recovery	
		Sulphuric acid production	
2 C 1 Iron and steel production	All CLRTAP pollutants *(except NH_3, HCB and HCH)*	Basic oxygen furnaces	Operator reporting under IPPC, plus additional operator reporting and literature sources for metal emissions and VOCs (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 3 Aluminium	All CLRTAP pollutants	Alumina production	Literature factors (UK

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
production	*(except NMVOC, NH_3,Se HCH and PCBs)*		research)
		Primary aluminium production - anode baking	Operator reporting under IPPC, 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	
		Secondary aluminium production	Operator reporting under IPPC, literature sources for dioxins where no reported emissions (HMIP)
2 C 5 a Copper production	Particulate Matter, CO, Heavy Metals *(except Cr and Se)* and PCDD/ PCDF	Copper alloy and semis production	
		Secondary copper production	
2 C 5 b Lead production	SO_2, Particulate Matter, CO, Heavy Metals *(except Cr and Ni)* and PCDD/ PCDF	Lead battery manufacture	
		Secondary lead production	
2 C 5 c Nickel production	Ni and PCDD/PCDF	Nickel production	
2 C 5 d Zinc production	Particulate Matter, CO, Heavy Metals *(except Se)* and PCDD/ PCDF	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 5 e Other metal production	NH_3, Particulate Matter, CO, Heavy Metals and PCDD/ PCDF	Foundries	
		Magnesium alloying	
		Other non-ferrous metal processes	Operator reporting under IPPC
		Tin production	Literature factors (HMIP, UK industry research)
2 D 1 Pulp and Paper	NH_3	Paper production	
2 D 2 Food and Drink	NMVOC and NH_3	Bread baking	
		Brewing - fermentation	Literature factors, mainly from UK industry research, some EMEP/EEA factors for VOCs
		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 VOCs
		Other food - margarine and other solid fats	
		Other food - meat fish	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		and poultry	
		Other food - sugar production	Operator reported data under IPPC
		Spirit manufacture - casking	Literature factors, mainly from UK industry research, some EMEP/EEA factors for VOCs
		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 D 3 Wood processing	NMVOC and Particulate Matter	Wood products manufacture	Literature factors (USEPA AP-42)
2 F Consumption of POPs and heavy metals	PCDD/ PCDF, HCH, PCBs	Capacitors	Literature factors (Dyke et al)
		Fragmentisers	
		Previously treated wood	
		Transformers	
2 G OTHER	Particulate Matter	Other industry - part B processes	Literature factor from UK research

8.1 Classification of activities and sources

Table 8.1 relates the detailed NAEI source categories to the equivalent NFR source categories. A number of these NAEI source categories are only used to describe emissions of greenhouse gases and the methodologies used to produce estimates for these categories will therefore not be covered in this report.

The following NFR source categories are key sources for major pollutants: 2A7a, 2A7d, 2B5a, 2C1, 2C3, 2C5a, 2C5b, 2C5e, 2D2 and 2G. Description of the inventory methodology will focus on these categories.

8.2 Activity data

Activity data for some of these sources is readily available from national statistics published, for example, by the Office of National Statistics (ONS). Other suppliers of data include the Iron & Steel Statistics Bureau, the British Geological Survey, and trade associations such as the Mineral Products Association and the Scotch Whisky Association.

Suitable activity data are not available for all sources however, and in the cases of processes such as the manufacture of all chemicals, most mineral industry processes, certain types of secondary non-ferrous metal processes, foundries, and pulp and paper industry processes, activity data must be estimated by Ricardo-AEA. Some data available from ONS are used in the derivation of these estimates – for example they publish very detailed data on production by industry sectors. These data are not complete, since confidential data are suppressed, and are sometimes only available in terms of sales value or number of items produced and so various assumptions are necessary in order to derive activity suitable for use in the inventory.

In a few cases where emissions data are available directly (for example from the Pollution Inventory) 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.

8.3 Methodology for mining and quarrying (NFR 2A7a)

NFR Sector 2A7a is a key source for PM_{10}.

The UK has relatively few underground mines and most minerals in the UK are extracted from quarries. Production is dominated by aggregate minerals, clays and industrial minerals and production of metalliferous ores is 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 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). Emission factors are available for numerous different types of sources within the mining and quarrying industries including initial processing of minerals e.g. crushing & grinding. Overall emissions are calculated and an overall emission factor calculated by dividing this emission by total UK production of mined/quarried products. The uncertainty of the emission estimates is considered to be high, but alternative data have not been found.

8.4 Methodology for other mineral processes (NFR 2A7d)

NFR Sector 2A7d is a key source for SO_2 and PM_{10}.

Glass production can be sub-divided into a number of types, the most important in the UK being flat glass, container glass, glass wool, and continuous filament glass fibre. Production of special glass and domestic glass (including lead glass), has declined in recent years and are now trivial.

Brick manufacture can be divided into Fletton and non-Fletton types. Fletton bricks are made from the Lower Oxford Clay, which contains a high proportion of both carbonaceous material and sulphur, which increases emissions of organic emissions and SO_2 respectively.

Most emissions from these industries are relatively trivial, the exception being emissions of SO_2 from Fletton bricks. The UK had just one Fletton brickworks in 2011, after the closure of another site in 2009. Both sites had to report emissions to the PI and these data are the basis of emission estimates. The SO_2 emitted will be caused both by the sulphur in the clay, but also by use of fossil fuels containing sulphur in the kilns. One plant uses natural gas as a fuel, the other, closed, site used coal, and so only the latter should have fuel-related SO_2 emissions. Ricardo-AEA estimate the use of coal at this plant and then calculate a combustion-related SO_2 emission using this fuel consumption estimate and the NAEI factor for industrial combustion of coal. The difference between this combustion-related emission estimate and the actual reported emission for the site is assumed to be due to sulphur from the clay. All of the SO_2 emissions from the site using natural gas are assumed to be from the clay used there. A similar approach is used for PM_{10}.

The activity data for glass production and brick-making are largely Ricardo-AEA estimates and are uncertain, although they are based on available national statistics such as total numbers of bricks produced, and the annual production of some glass sub-types. Emission factors are also uncertain, although the uncertainty is thought to be less than for processes reporting under 2A7.

8.5 Methodology for chemical processes (NFR 2B5a)

NFR Sector 2B5a is a key source for NMVOC, Pb, Hg and Cd.

The UK has a large and varied chemical industry and processes and required to report emissions in the PI, SPRI or ISR. 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 to occur from combustion processes, but this has been minimised by identifying the nature of the chemical processes carried out at each site, as well as whether combustion processes are also present, and then only including reported emissions only for those sites which there is at least a high probability that emissions are process-related.

Because emission estimates for chemical industry processes are based on reported emissions data, the quality of the national emission estimates depends upon the quality of the reported data. In general, the emissions data in the PI, SPRI & ISR are subject to the appropriate regulator’s QA/QC procedures and the data are assumed to be generally of good quality. For NMVOC emissions data, however, there is an additional issue with the interpretation of the reported data. 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, variations in reporting 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/ISR data with some ‘gaps’ being filled (by using reported data for the same process in other years) and other reported data being ignored on the grounds that the emissions have already been reported somewhere else. This means that the national emission estimates for NMVOC from chemical processes are more uncertain than most other national estimates based on PI/SPRI/ISR data.

Emission estimates for HCB from NFR 2B5a have historically related to the manufacture of tetrachloroethylene and trichloroethylene. The UK’s sole manufacturer of these goods ceased production in early 2009, and hence emissions of HCB from NFR 2B5a are assumed to be zero for 2009 onwards.

8.6 Methodology for iron & steel processes (NFR 2C1)

NFR Sector 2C1 is a key source for SO_2, CO, PM_{10}, Pb, Hg, Cd and PCDD/PCDF.

UK iron and steel production may be divided into 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 is lost and the carbon content of this gas is reported under CRF 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, some losses occur and these losses are reported with blast furnace gas losses under CRF 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 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 2011 from the operator 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 the earlier part of the time series for processes at integrated and electric arc steelworks are filled by extrapolation back of later emission factors

8.7 Methodology for aluminium processes (NFR 2C3)

NFR Sector 2B5a is a key source for CO, Pb, Cd, PCDD/PCDF and benzo[a]pyrene.

The UK had two primary aluminium producers at the end of 2011, following the closure of a large producer towards the end of 2009, and a larger number of secondary aluminium processes. The remaining large primary aluminium producer closed in early 2012, leaving only a small works. All of the operational primary aluminium sites in 2011, as well as the site closed in 2009, used the pre-baked anode process, and anodes were baked at two sites in the UK (one since the 2009 closure). All of the primary sites and all of the largest secondary processes report emissions in the PI, SPRI, and ISR (some small aluminium processes may be regulated by local authorities in England, Wales or Northern Ireland, and therefore do not report emissions in the PI or ISR, but emissions from these sites should be trivial due to the small scale of the processes).

Primary aluminium emission estimates for CO, other gaseous pollutants, and PM_{10} are based on a bottom-up approach using emissions reported in the PI, ISR & SPRI for the period 1997-2011, with the 1997 factor also used for earlier years. Emission factors for Cd and other metals are taken from van der Most et al, 1992.

Emission estimates for secondary production are also based on a bottom-up approach using data reported in the PI, ISR & SPRI and covering the period 1998-2011 with the 1998 factors used for earlier years as well. The relatively small-scale nature of many of the secondary aluminium processes means that emissions are quite often unavailable from the PI/SPRI/ISR, sometimes it being indicated that emissions are below the threshold for reporting, though in other cases, no information is provided at all. The standard method used in the UK inventory for incorporating emissions data from the PI/SPRI/ISR involves using reported data and then filling ‘gaps’ in the data using data reported by other processes or, where available, data for the same process in another year. While this approach works well for many industrial sectors, it has, due to increases in reporting thresholds in recent years for many pollutants such as metals, led to problems with sectors such as secondary aluminium production, other non-ferrous processes (see following section) as well as some waste disposal processes. Typically, the derived emission factors show high year-to-year variability that is probably not realistic, and this high variability is due to the large extent of the gap filling that is needed.

The standard approach will therefore need to be reviewed and possibly revised for these smaller processes to ensure a more realistic time series of emission factors that is less sensitive to small variations in the limited data available from the regulators’ inventories.

8.8 Methodology for non-ferrous metal processes (NFR 2C5)

NFR Sector 2C5 is a key source for Pb, Hg, Cd and PCDD/PCDF.

UK production of many non-ferrous metals has been relatively small for many years and has declined further in recent years with the closure of the only primary lead/zinc producer in 2003 and the only secondary copper production process in 1999. Processes currently operating include a lead refinery, a nickel refinery, various secondary lead processes, including three processes recovering lead from automotive batteries, and various zinc and copper processes (such as production of alloys).

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. Some smaller non-ferrous metal processes may be regulated by local authorities in England or Wales and therefore not report emissions in the PI or ISR, but emissions from these sites should be trivial due to the small scale of the processes.

The emission factor time series for many of these non-ferrous metal sectors suffer from the same issues noted for secondary aluminium, i.e. implied emission factors are highly variable due to the limited nature of the operator-reported emissions data. The approach used will be reviewed and modified if necessary. Emission estimates for metals and persistent organic pollutants are particularly affected by this issue and the emission factors for these pollutants are therefore most uncertain.

8.9 Methodology for food and drink processes (NFR 2D2)

NFR Sector 2D2 is a key source for NMVOC.

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, 2009).

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 estimated to be among the most uncertain sources within the NMVOC inventory.

8.10 Methodology for other processes (NFR 2G)

NFR Sector 2G is a key source for PM_{10}.

Numerous scale-scale processes are regulated by local authorities in the UK and many of these processes have the potential to emit dust. Emission estimates rely on a UK-specific methodology based on use of limited site-specific emissions data, extrapolated to a UK level emission estimate on the basis of plant numbers. The estimates are highly uncertain, but alternative approaches are not available for many of these process types and, where alternatives such as literature factors are available, suitable activity data often is not. The methodology for this source category is reviewed periodically and improvements made where possible.

8.11 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 ISR. Section 3.7 discusses QA/QC issues regarding these data.

There are numerous instances where data from EUETS 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.

8.12 Recalculations in NFR 2

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

- Emission estimates from foundry castings (NFR 2C5e) in 2010 have been revised based on revised production data for 2010 from ONS, 2012. Emissions of metals, dioxins and PM_{10} are over 20% higher than in the previous submission for this source, and in the UK context this has increased total UK estimates in 2010 of Cr (up 0.9%), Hg (up 0.6%) and Pb (up 0.9%);
- Revisions to operator-reported emissions in the PI/SPRI/ISR have led to increased estimates for VOC from the chemical industry under NFR 2B5a, which are 19% higher in 2010 compared to the previous submission. In the UK context, this has increased total VOC emissions in 2010 by 0.5%. Revisions to data for other pollutants are also evident for this source category in 2010, including a 10% increase in CO and a 22% reduction in Pb compared to the previous submission;
- Revisions to emission estimates for Zinc emissions from process releases in Zinc oxide production (NFR 2C5d) have been made for the early part of the time series, to provide an improved estimate of industry emissions, increasing the overall UK Zinc inventory estimates by 0.8% in 1990;

9. NFR 3: Solvent and Other Product Use

Table 9.1 Mapping of NFR Source Categories to NAEI Source Categories: Solvent and Other Product Use

NFR Category (3A)	Pollutant coverage	NAEI Source Category	Source of EFs
3 A 1 Decorative coating application	NMVOC	Decorative paint - retail decorative	UK industry data
		Decorative paint - trade decorative	
3 A 2 Industrial coating application	NMVOC and Particulate Matter	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	
		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	
3 A 3 Other coating application		Industrial coatings - metal packaging	
3 B 1 Degreasing	NMVOC	Leather degreasing	UK industry data and country-specific factors
		Surface cleaning - 111-trichloroethane	
		Surface cleaning - dichloromethane	
		Surface cleaning - hydrocarbons	
		Surface cleaning - oxygenated solvents	
		Surface cleaning – tetrachloroethylene	
		Surface cleaning - trichloroethylene	
3 B 2 Dry cleaning		Dry cleaning	
3 C Chemical products, manufacture and processing	NMVOC and Particulate Matter	Coating manufacture - adhesives	UK industry data and country-specific factors
		Coating manufacture - printing inks	
		Coating manufacture - other coatings	
		Other rubber products	
		Tyre manufacture	Operator-reported data
		Paper coating	
		Textile coating	
		Leather coating	
		Film coating	
3 D 1 Printing	NMVOC	Printing - heatset web offset	UK industry data and
		Printing - metal decorating	

NFR Category (3A)	Pollutant coverage	NAEI Source Category	Source of EFs
		Printing – newspapers	country-specific factors (BCF)
		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	
3 D 2 Domestic solvent use including fungicides	NMVOC and NH_3	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	
3 D 3 Other product use	NMVOC, PAHs	Industrial adhesives - pressure sensitive tapes	Operator-reported data
		Seed oil extraction	
		Industrial adhesives - other	UK industry data and country-specific factors (HMIP, Giddings et al)
		Other solvent use	
		Road dressings	
		Creosote use	
		Wood impregnation - creosote	
		Wood impregnation - general	
		Wood impregnation - LOSP	

9.1 Classification of activities and sources

Table 9.1 relates the detailed NAEI source categories to the equivalent NFR source categories.

9.2 Activity statistics

Emission estimates for NFR sector 3 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.

9.3 Methodology for solvent use (NFR 3)

All source categories within NFR sector 3 are key sources for NMVOC except for 3B2 and 3A3. NFR Sector 3A2 is also a key source for PM_{10}.

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 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 9.2 shows how estimates have been derived for each NAEI source category.

Table 9.2 Methods for Estimating Emissions from Solvent and Other Product Use.

NAEI Source Category	General method
Aerosols (car care, cosmetics & toiletries, household products) Agrochemicals use Decorative paint - retail decorative Decorative paint - trade decorative Dry cleaning Industrial adhesives (general) Industrial coatings - agricultural and construction Industrial coatings - aircraft Industrial coatings - commercial vehicles Industrial coatings - high performance Industrial coatings – marine Industrial coatings - metal & plastic Industrial coatings - vehicle refinishing Industrial coatings – wood Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner)	Solvent consumption data for the sector, assumption that little or no solvent is recovered or destroyed.

NAEI Source Category	General method
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.

9.4 Source specific QA/QC and verification

This source category is covered by the general QA/QC of the NAEI in section 1.6.

9.5 Recalculations in NFR 3

The most significant recalculations in NFR 3 since the previous submission are:

- Emission estimates of VOC from dry cleaning (NFR 3B2) have been improved across the time series based on new industry data which indicated that emissions from modern dry cleaning machines were lower than assumed in the previous modelled estimates.. Emissions of VOCs are now estimated to be around 40% lower in 2000 and 80% lower in 2010 than in the previous submission for this source. This revision has reduced the total UK VOC inventory estimate in 2010 by 0.5%;
- Solvent use and VOC emissions have been revised for surface cleaning sources under NFR 3B1, based on new industry estimates. Lower emissions are estimated for 2010 for use of dichloromethane, tetrachloromethane and trichloroethylene, with increased estimates from

use of oxygenated solvents and hydrocarbons. The overall impact of these revisions in this sector is a reduction in VOC emission estimates in 2010 of 15%, which lowers the total UK inventory of VOC by 0.5%.

10. NFR: 4 Agriculture

10.1 Classification of activities and sources

Table 10.1 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 10.1 Mapping of NFR Source Categories to NAEI Source Categories: Agriculture

NFR Category	Pollutant coverage	NAEI Source	Source of EFs
4 B 1 a Cattle Dairy	NH_3 and Particulate Matter	Agriculture livestock - dairy cattle	UK factors
		Agriculture livestock - dairy cattle wastes	
4 B 1 b Cattle Non-Dairy		Agriculture livestock - other cattle	
		Agriculture livestock - other cattle wastes	
4 B 3 Sheep	NH_3	Agriculture livestock - sheep goats and deer wastes	
4 B 6 Horses	NH_3	Agriculture livestock - horses	
4 B 8 Swine	NH_3 and Particulate Matter	Agriculture livestock - pigs	
		Agriculture livestock - pigs wastes	
4 B 9 a Laying hens		Agriculture livestock - laying hens	
		Agriculture livestock - laying hens wastes	
4 B 9 b Broilers	Particulate Matter	Agriculture livestock - broilers	
		Agriculture livestock - broilers wastes	
4 B 9 d Other poultry	NH_3 and Particulate Matter	Agriculture livestock - other poultry	
		Agriculture livestock - other poultry wastes	
4 B 13 Other	NH_3	Domestic pets	
		Non-agriculture livestock - horses wastes	
4 D 1 a Synthetic N-fertilizers	NH_3	Agricultural soils	Literature sources
		House and garden machinery	
4D2c N-excretion on pasture range and paddock unspecified		N-excretion on pasture range and paddock unspecified	
4 F Field Burning Of Agricultural Wastes	NH_3 (NOx, NMVOC, Particulate Matter, PCDD/PCDF, PAHs, PCBs for 1990-1992 only)	Field burning	UK factors
4 G OTHER	Particulate Matter, HCB	Agricultural pesticide use - chlorothalonil use	
		Agricultural pesticide use - chlorthal-dimethyl use	
		Agricultural pesticide use -	

NFR Category	Pollutant coverage	NAEI Source	Source of EFs
		quintozine	
		Agriculture - agrochemicals use	

The following NFR source categories are key sources for major pollutants: 4B1a, 4B1b, 4D1a, 4D2c, 4B13, 4B9d, 4B8, 4B9a, & 4B6. Description of the inventory methodology will focus on these categories.

10.2 Activity statistics

National statistics on livestock numbers and weights are obtained from census statistics provided by each devolved administration (England, Scotland, Wales and Northern Ireland). The UK total is derived as the sum of the DA values. Proportion of animals in each housing type - cattle from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), pigs from Sheppard (1998, 2002). Proportion of pigs outdoors from Sheppard (1998, 2002). Poultry housing and % manure dropped outdoors provided by A Elson (ADAS).

Manure output values per animal are from Smith and Frost (2000) and Smith et al., (2000). N excretion values are derived from Cottrill, B.R. and Smith,K.A. (2007) 'Nitrogen output of livestock excreta', Final report, Defra Project WT0715NVZ, June 2007. Manure TAN[27] contents from expert opinion. Proportion of waste produced as slurry or FYM from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith et al., 2000c, 2001a, 2001b).

Proportion of pig or cattle manure applied to grassland and arable, proportion applied in summer (May-July), proportion applied by injection or irrigated and proportion incorporated within 1d or 1wk of application obtained from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith et al., 2000c, 2001a, 2001b).

Fertiliser usage in England, Wales and Scotland derived from 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).

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

10.3 Methods for estimating emissions

Agricultural sources are the most significant emission sources in the UK ammonia inventory. The methodology is described in detail in (Misselbrook et al., 2012). A summary of the methodology is given below for completeness.

The estimate of NH_3 emission from UK agriculture for 2011 was made using the spreadsheet version of the National Ammonia Reduction Strategy Evaluation System (NARSES) model (file: NH3inv2011_NARSES_261112_FINAL_corrected.xls). NARSES models the flows of total nitrogen and total ammoniacal N (TAN) through the livestock production and manure management system, with NH_3 losses given at each stage as a proportion of the TAN present within that stage (Webb and Misselbrook, 2004). NARSES was first used to provide the 2004 inventory estimate for UK agriculture, replacing the previously used UK Agricultural Emissions Inventory model (UKAEI). NARSES brings improvements over the UKAEI model in that emission sources are linked, such that changes in an upstream source will be reflected downstream, it has an internal accounting check that not more than 100% of TAN excreted can be emitted, it can incorporate trends in N excretion by certain livestock classes (e.g. dairy cattle, pigs, poultry) and it is much better suited to scenario testing. The NARSES model was therefore used to provide the NH3 emissions estimate for UK agriculture for 2011. Emissions from fertiliser use within agriculture are estimated using a simple process-based model as

[27] total ammoniacal nitrogen

described by Misselbrook et al. (2004), which has been incorporated into the NARSES spreadsheet model.

10.4 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 1980 - present year) and the reasons for any large deviations 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 and Defra for further checking prior to inclusion in the UK NAEI.

10.5 Recalculations in NFR4

a) Inclusion of 2011 livestock numbers
Headline changes from 2010 are:

- Cattle – a 1.7% decline in total cattle numbers (1.8% decline for dairy cows)
- Pigs – a 0.6% decline in pig numbers
- Sheep – a 1.8% increase in sheep numbers
- Poultry – a 0.8% decline in total poultry numbers, with a 1.1% decrease in the laying flock and a 2.7% decrease in broiler numbers

b) Inclusion of 2011 N fertiliser use
Data were derived from BSFP for crop year 2011 for England, Wales and Scotland and from DARD statistics for Northern Ireland.

Total fertiliser N use declined by 0.6% between 2010 and 2011, and there was a further increase in the proportion applied as urea (up from 22% in 2010 to 25% in 2011). The increase in urea use outweighed the overall decline in total fertiliser N use, resulting in an increase in emissions from fertiliser applications to land.

c) Poultry litter incineration
Data on tonnages of poultry litter incinerated at power stations were obtained from EPR Ltd, with an estimated total of 572,000 t incinerated in 2011, a decline of 98,000 t on the previous year.

d) Revision of livestock housing emission factors
New data on ammonia emissions from cattle and finishing pigs housed on straw were incorporated from Defra project AC0102. This has impacted the full emissions time series. In addition, the derivation of all existing emission factors, expressed as a percentage of TAN excreted in the house, were reviewed partly as there had been historical revisions to N excretion estimates for some livestock categories and partly because the original derivation had not been clearly documented. Full derivation of emission factors is given in the Appendix of Misselbrook et al. (2012), but the changes for those relevant to livestock housing and their impact on the emission total are given in **Table 10.2**. Emission factors for cattle housing, in particular, changed substantially, with revised values being much lower. This was mostly because of revising downwards the values (expressed as %TAN) derived from Defra projects WA0632/AM0110, project WA0722 [28] and the value from Hill (2000). These values had previously stood out as being much greater than those from most other studies.

e) Revision to N excretion estimate for sheep
Corrections were made to the N excretion estimates used for ewes and lambs across the full time series. The values previously used were from Defra project WT0715NVZ, but the value given there for ewes includes an amount for lambs from birth to 40kg. Therefore the value for ewes alone has been corrected according to that given by Smith and Frost (2000) of 9.0 kg N per ewe per year. For lambs, the daily output from Smith and Frost (2000) has been multiplied by the average lifespan of lambs of

[28] Defra projects – final reports are available from Defra (WA0632 - Ammonia fluxes within solid and liquid manure management systems; AM0110 - Additional housing measurements for solid vs. liquid manure management systems; WA0722 - Ammonia emission from housed dairy cows in relation to housing system and level of production).

8.1 months as derived from a recent survey by Wheeler et al. (2012), giving an estimated 1.6 kg N per lamb per year.

f) Agriculture - stationary combustion

Emissions from this source was misallocated to 4G in 2010 inventory and it is now included under 1A4ci.

Table 10.2 Revisions to emission factors used for livestock housing

Source	Previous EF (%TAN)	Revised EF (%TAN)	Impact on inventory (kt NH_3)
Cattle on slurry	31.5	27.7	-1.6
Cattle on straw	22.9	16.8	-2
Calves on straw	7.6	4.2	-0.6
Dry sows on slats	13.0	22.9	0
Dry sows on straw	25.0	43.9	+0.2
Farrowing sows on slats	19.0	30.8	+0.1
Farrowing sows on straw	25.0	43.9	0
Boars on straw	25.0	43.9	0
Finishing pigs on slats	33.2	29.4	-0.2
Finishing pigs on straw	22.4	26.6	+0.4
Weaners on slats	14.8	7.9	-0.1
Weaners on straw	26.2	7.2	-0.1
Layers – deep-pit	37.4	35.6	-0.1
Layers - belt-clean	16.5	14.5	0
Broilers	8.1	10.5	+0.6
Turkeys	19.2	36.6	+0.8
Other poultry	17.5	14.1	-0.5

11. NFR 6: Waste

Table 11.1 Mapping of NFR Source Categories to NAEI Source Categories: Waste

NFR Category (6)	Pollutant coverage	NAEI Source Category	Source of EFs
6 A Solid waste disposal on land	NMVOC, NH_3, Hg, PCDD/ PCDF and PCBs	Landfill	UK model and assumptions (NMVOC), UK industry research (NH_3, PCBs, PCDD/Fs)
		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	
6 B Waste-water handling	NH_3	Sewage sludge decomposition	UK industry research
6 C a Clinical waste incineration (d)	All CLRTAP pollutants *(except NH_3,Se, Indeno (1,2,3-cd) pyrene , HCH)*	Incineration - clinical waste	Operator reporting under IPPC and literature factors (EMEP/EEA, HMIP, USEPA)
6 C b Industrial waste incineration (d)	All CLRTAP pollutants *(except Se, Indeno (1,2,3-cd) pyrene and HCH)*	Incineration - chemical waste	
		Incineration - sewage sludge	
		Other industrial combustion	
		Regeneration of activated carbon	
6 C c Municipal waste incineration (d)		Incineration	
6 C d Cremation	NO_x, NMVOC, SO_2, Particulate Matter, CO, Hg, PCDD/ PCDF and benzo[a] pyrene	Crematoria	UK research (CAMEO) and literature factors (EMEP/EEA, HMIP)
		Foot and mouth pyres	UK research and literature sources (Stewart et al, Passant)
		Incineration - animal carcases	
6 C e Small scale waste burning	NO_x, NMVOC, Particulate Matter, CO, POPs *(except HCB and HCH)*	Agricultural waste burning	
		Small-scale waste burning	
		Combustion of treated wood	
6 D OTHER WASTE (f)	NH_3, PCDD/ PCDF and PCBs	Accidental fires – vehicles (PDCC/Fs)	Literature factors (Wichmann, CEH, Dyke et al)
		Composting (NH_3)	
		Anaerobic Digestion (NH_3)	
		RDF manufacture (PCB)	

11.1 Classification of activities and sources

Table 11 1 relates the detailed NAEI source categories for waste used in the inventory to the equivalent NFR source categories. All NFR 6 source categories are key sources for one or more pollutants in the UK inventory in 2011 (except 6Cc, as there has been no MSW incineration in the UK since 1996):

- 6A is a key source for NMVOC and Hg
- 6B is a key source for NH_3
- 6Ca is a key source for PCDD/Fs, Hg and Pb
- 6Cb is a key source for PCDD/Fs
- 6Cd is a key source for PCDD/Fs and Hg
- 6Ce is a key source for PCDD/Fs, B[a]P and PM10
- 6D is a key source for PCDD/Fs and NH3, NFR

11.2 Activity statistics

Waste-derived fuels used for electricity and heat generation are reported in DUKES (DECC, 2012) 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 is more comprehensive and the inventory agency obtain 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.

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.

11.3 Methods for estimating emissions

NFR 6A: 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 estimates of Local Authority controlled and Commercial & Industrial waste disposed to UK landfills;
- An estimate of the annual disposal to different types of landfills, ranging from old (now closed) landfills with no gas collection and control, to modern engineered landfills with gas management systems, gas flares and (in some cases) 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 elution from landfill waste and then applies factors to represent:

- the methane capture efficiency (based on the landfill gas collection efficiency averaged over modern and closed landfills);
- the methane flared or used in landfill gas engines;
- the methane oxidised in the surface layers of the landfill.

Combining the total methane generation estimate with the methane captured and oxidised derives an estimate for the total methane emitted to atmosphere annually from UK landfills.

Using the model outputs, estimates of NMVOC are calculated by assuming a fixed ratio of NMVOC to methane in landfill gas emissions, where:

NMVOC mass emission = Methane mass emission x 0.042 (Broomfield, 2011).

Emissions of dioxins are based on the activity estimates derived within the MELMod landfill model for methane escaping and methane flared at landfills, applying emission factors derived from research by 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 analysis by the Centre of Ecology and Hydrology (CEH, 2012).

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 6 B: Waste-water handling
The emission estimate for ammonia from sewage treatment & disposal is based on research by the Centre of Ecology and Hydrology (CEH, 2011). The approach uses factors of kt NH3-N per Mt sewage sludge and activity data estimates based on a time series of sewage sludge generated in the UK from an earlier (2004) CEH study of OFWAT annual reports by UK water companies, extrapolated based on ODPM housing numbers for more recent years.

NFR 6 C: 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). The operator-reported emissions are used directly in the national inventory. Where pollutants are reported to the PI/SPRI/ISR as “Below Reporting Threshold”, the inventory agency generates estimates for the emissions based on previous plant performance, activity data for waste burned and/or emission factors.

Where emissions data reported to the PI are incomplete (across sites, pollutants and/or years) the inventory agency generates estimates using estimates of waste burnt at each site as a basis together with emission factors or other reported data. 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 (Environment Agency, 2012), supplemented using literature-based emission factors, largely taken from the EMEP/EEA Emission Inventory Guidebook (EEA, 2009). The quantity of waste burnt annually is also estimated, these estimates being based on active UK sites and assumed capacity.

Emissions from **chemical waste incinerators** are estimated based on analysis of data reported to the Pollution Inventory (Environment Agency, 2012) with the exception of benzene and poly aromatic 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 (Environment Agency, 2012) and Scottish Pollutant Release Inventory (SEPA, 2012), supplemented with the use of literature-based emission factors where the IPPC-reported data are incomplete. Emissions of NOx 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 (EEA, 2009). The quantity of waste burnt annually is estimated based on annual activity data from environmental regulators (Defra, 2012 and SEPA, 2012) 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 animal carcass incinerators from the Pollution Inventory (Environment Agency, 2012) 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 (2012). Mercury emission estimates are based on calculations using UK population (ONS, 2012) 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 that 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 required that all such plant were either closed down or converted to Energy from Waste plant, 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 after a national waste burning habits survey of a 1000 UK households completed in 2010 (Whiting et al 2011).

The emission factors for emissions of copper, chromium and arsenic from treated wood are taken from a UK study (Passant, 2004). Emissions of dioxins 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). Emissions of NOX, PM10 and VOCs 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 and US research (USEPA, 2004 and Perry, 2002).

NFR 6D: Other Waste

Emissions of PCDD/Fs from accidental vehicle fires are based on activity data from UK fire service reporting, together with literature emission factors (Wichmann et al, 1995). Emissions of ammonia from composting and anaerobic digestion are based on national statistics for these activities and research conducted by the Centre of Ecology and Hydrology (CEH, 2012). Emissions of PCB from RDF manufacture are estimated by the inventory agency based on UK research (Dyke et al, 1997).

11.4 Source specific QA/QC and verification

Many of the emission estimates reported in NFR 6 are based on facility-specific emissions reported to the PI, SPRI and ISR, under IPPC/EPR regulation. Section 3.7 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 first and fore-most to estimate methane emissions from landfills. The methane estimates in the UK inventory (as reported to the UNFCCC) is subject to verification analysis against observed trends in UK ambient methane concentrations, using air sampling and analysis combined with back-trajectory Langrangian modelling of air mass movements. The results of this verification analysis are discussed in the UK's National Inventory Report to the UNFCCC.

11.5 Recalculations in NFR6

The most significant recalculations since the 2012 submission in NFR 6 are:

- Ammonia emission estimates from anaerobic digestion have been included in the UK inventory for the first time in this submission, reported in NFR 6D. This reflects the recent growth in this activity in the UK. The activity for AD has increased 15-fold between 2008 and 2011 alone;
- Revisions to operator-reported emissions to the PI/SPRI/ISR and revisions to inventory agency assumptions to address gaps in operator reporting (e.g. due to new data reported for 2011), has led to revisions to emission estimates in NFR 6Ca (clinical waste incineration) in 2010, including increases of around 60% for both dioxins and lead, and reductions of 28% for cadmium and 9% for mercury. The revision to lead represents a 1% increase in the 2010 lead inventory for the UK, whilst the mercury revision is a reduction of 0.5% on the 2010 UK inventory total;
- New emission estimates for ammonia from sewage sludge decomposition have been derived by CEH, which lower the UK estimates by around 15% per annum, which in 2010 represented a 0.3% reduction in the total UK NH3 inventory;
- Revisions to mercury emission estimates from crematoria in 2010 based on revised data on CAMEO scheme impacts increased emissions by just over 1%. This is a relatively minor revision, but it increased the UK inventory by 0.2% which reflects the significance of this source in the UK context and therefore the importance of the CAMEO scheme and to reflect scheme impacts accurately in future.

12. Other

Table 12.1 Mapping of NFR Source Categories to NAEI Source Categories: Other Sources

NFR Category (7)	Pollutant coverage	NAEI Source Category	Source of EFs
7 A Other (included in national total for entire territory)	NO_x, NMVOC, Particulate Matter, CO, and POPs (except HCB and HCH)	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/F, PCBs	Bonfire night	UK Factors
	PAHs, PCDD/F, NH_3	Cigarette smoking	Stockholm Convention Toolkit for PCDD/F and literature factors for PAHs and NH_3
	CO, Cu, K, Mg, Na and Particulate Matter	Fireworks	Emission Agency estimates based on industry
	NH_3	Infant emissions from nappies	UK Factors

12.1 Classification of activities and sources

NFR source category 7 is a key source for CO, PM_{10}, PCDD/PCDF and benzo[a]pyrene.

12.2 Activity Statistics

NFR category 7 – 'Other' captures those sources not covered in other parts of the inventory. National fire statistics produced by the UK's Office 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, this includes disaggregation for 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 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.

12.3 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) but does not provide further detail on scale of the fire or quantity of material destroyed. Therefore 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) and then makes assumptions based on the scale of the fire for how much property has been destroyed. The profile is then applied to the UK fire statistics to allow the inventory agency to provide activity data in the form of material burnt, which will cover a range of materials (wood, plastic, glass and metal). 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 poly aromatic hydrocarbons (PAHs), which make use of UK research by Coleman (2001) supported by UK ambient monitoring data.

Bonfire Night
The celebration of bonfire night in the UK (5th November) is treated as a separate source from other domestic burning events due to the large scale organised nature of the event 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 in 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/PCDF) are used to generate emission estimates.

Cigarettes
National statistics from the monthly digest 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. For estimates of PCDD/F the factors are taken from 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, 2011). 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.

12.4 Source specific QA/QC and verification

Many of the emission estimates reported in NFR 7 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.

12.5 Recalculations in NFR 7

There has only been one significant recalculation to the sources under NFR 7 this year:

- Revisions made to the ammonia estimates for infant's nappies based on continuing research and review by the Centre for Ecology and Hydrology (2012)

13. 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/ISR).

In recent years, the impact of EUETS 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.

13.1 NOx

NOx emissions have been revised up by 1kt (0%) in 2010. This is made up of a number of small changes to emissions, to revise categories both up and down, as well as the introduction of some new sources. The top contributors to this change are:

- + 3.85kt from regional railways
- + 3.66kt from OPG use in the other industry sector. This is a result of filling a gap in emissions data identified during the UNFCCC review of the UK GHG inventory
- + 3.45kt from fishing vessels, to include fishing from outside of UK territorial waters
- - 7.45kt from natural gas use for upstream oil production
- - 7.15kt from gas oil use in industrial off-road mobile machinery (model improvements to correct the split between gas oil and DERV use)

13.2 CO

CO emissions have been revised up by 116kt (5%) in 2010. The top contributors to this change are summarised below.

- +100.92kt from biomass use in other industrial combustion (new source to ensure completeness of energy balance for biomass fuels)
- +22.21kt from charcoal use in the domestic sector (new source, based on FAOSTAT data, to improve completeness of the inventory)
- +3.67kt from wood combustion in power stations, based on revised activity data from plant operators, ETS.
- -6.28kt from cars – cold start
- -5.65kt from railways – regional (new emission factors and other rail improvements)
- -4.40kt from petrol cars – urban driving
- -3.24kt from gas oil use in industrial off-road machinery (model improvements to correct the split between gas oil and DERV use)

13.3 NMVOC

Emissions of NMVOC have been revised down by 17kt (2%) in 2010. The main changes are summarised below.

- -7.62kt from cars – cold start
- -4.14kt from surface cleaning and -3.66kt from dry cleaning, based on new research in 2012
- +4.07kt from chemical industry – general, based on revisions to PI data and gap filling to account for missing sites
- +1.61kt from offshore oil loading

13.4 SO_2

Emissions of SO_2 have been recalculated by less than 1kt and by less than 1% in 2010. There have been no large recalculations to any categories.

13.5 NH_3

Emissions of NH_3 have been revised up by 1kt (0%). The main change has been the inclusion of anaerobic digestion as a new source (+5.78kt), but this has been largely offset by decreased estimates for cattle (-4.25kt).

13.6 PM_{10}

Emissions of PM_{10} have been revised up by 2kt (2%) in 2010. This is made up of a number of small changes, including:

- +0.64kt from biomass use for other industrial combustion (new source)
- +0.48kt from intercity railways, as part of the rail improvement work
- +0.35kt from straw combustion in agriculture (DUKES revision)
- -0.62kt from gas oil use in industrial off road machinery

13.7 Metals

Emissions of Pb have been revised up by 2 tonnes (3%) in 2010. This change is mostly from foundries and clinical waste incineration (+0.6 tonnes and +0.7 tonnes, respectively). Foundry emissions have been revised due to the use of updated PRODCOM data (in place of provisional estimates). Clinical waste incineration emission changes are due to data revisions in the PI and changes to gap filling assumptions.

Emissions of Cd have been revised up by 3% (<0.1 tonnes) in 2010. The main contributors to this change are an increase of 0.06 tonnes from fuel oil use in other industry, and 0.04 tonnes from biomass use in other industry (new source).

Hg emissions have been revised up by 3% (<0.1 tonnes) in 2010. The main contributors are 0.09 tonnes from biomass in other industry (new source) and 0.04 tonnes from foundries. Recalculations to Cr and Zn emissions have also been dominated by these sources. Total emissions of Cr have been revised up by 2% (0.4 tonnes) in 2010, and Zn emissions have been revised by 3 tonnes (1%) in 2010.

As emissions have been revised up by 2% (0.2 tonnes) in 2010. This increase is dominated by the inclusion of biomass in other industry.

Ni emissions have been revised by 5 tonnes (6%) in 2010. This is mostly due to increased emissions from fuel oil use in other industry (DUKES revision).

Cu and Se emissions have not been significantly revised.

13.8 POPs

Emissions of PCDD/PCDF have been revised by 1% (1g TEQ) in 2010.

The main changes are increases of 1.08g TEQ from agricultural combustion of straw (DUKES revision) and 0.56g TEQ from clinical waste incineration. These changes have been partially offset by a number of small changes to other sectors.

Emissions of Benzo[b]fluoranthene have been revised up by 7% (0.2 tonnes) in 2010. The main changes have been to road transport.

There have not been significant changes to emissions of other POPs.

13.9 Planned improvements

A number of improvements to the inventory are planned although it is anticipated that not all improvements will be incorporated for the next version of the inventory.

<u>NFR 1</u>
1A
Research to improve activity data should be considered, looking at source allocation and emission factors for biomass combustion and co-firing across all sources.

A review of the sulphur content of coal is recommended, focussing on imported coal to ensure that the inventory accurately reflects current data.

Research into or development of emission factors for PCDD/F for combustion of biogases is recommended.

1A1a
Currently, emissions from the waste incinerators on the Scilly Isles are reported under 1A1, rather than 6C but this will be reviewed for the next version of the inventory.

1A1, 1B
Further review of the upstream oil and gas reporting system is expected in the next cycle. The regulator, DECC Offshore Inspectorate, has commissioned a review of the EEMS reporting system (currently underway) and findings from previous quality checking routines should be taken forward into the next cycle of EEMS reporting. This may lead to retrospective changes to reported data, where new research / factors are agreed for specific activities, for example.

1A2
It is recommended that estimates of fuel use in the chemical and petrochemical industry be reviewed, and that the precise fuels used (NGLs, LPG, OPG) be reviewed to assess the most appropriate EFs for AQ pollutants.

The iron and steel sector model used in the UK inventory may be revised to address data reporting inconsistencies between the UK energy statistics and EUETS.

1A2, 1A4
Seek more detailed data on specific industrial and commercial sectors, to improve understanding of UK stock of combustion units and allocation of fuel use to different types of combustion appliance, in order to improve the UK inventory combustion model that derives aggregate EFs for NOx, PM_{10}, VOC, CO.

1A3
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 emission factors for diesel vehicles from the COPERT 4 v10 model released late in 2012, together with possible further changes in the Spring 2013 release of COPERT.

A watching brief is kept on developments in emission factors and activity data for all modes of transport. Potential improvements are summarised as follows:

1A3a – Aviation
Recent updates in the airport specific inventories for Heathrow and Gatwick airports, taking account of detailed movement and operational data, could be incorporated into the UK inventory.

1A3b – Road transport
- Emission factors for Euro 5/V diesel vehicles, based on the recommendations of COPERT and/or other major reviews
- Update factors for metal emissions from fuels and lubricants used for road transport and in tyre and brake wear, following recommendations of COPERT and inventory guidebooks.
- Include new emission factors and fleet data on hybrid and other alternative vehicle technologies and fuels

1A4
Addition of new estimates for HCB emissions from combustion sources, where these are missing the UK inventory, including some sources that have been highlighted by a recent EEA review as being large sources in other EU countries, such as coal use in domestic sector

<u>NFR 2</u>
A review of AD for bricks and ceramics to address current time series in UK which is evidently inconsistent year-to-year when using ONS statistics for production

Review of emission factors for cement industry, for PAHs, POPs and metals. Current estimates are sensitive to a handful of operator-reported data, and the gap-filling needed to generate sector-wide estimates is extensive in some years and therefore the time series is uncertain.

<u>NFR 4</u>
Revisions of intensive agriculture emission factors to reflect time series and changes to waste handling and housing management practices, and consider adding VOC estimates from intensive agriculture sources (pig and poultry) using USEPA factors and/or data from IPPC regulation of farms. This also applies for PM10.

<u>NFR 6</u>
Planned improvements in this source sector include:

- New emission estimates for methane from industrial waste water treatment have been derived using IPCC methodology and UK activity statistics for a number of UK economic sectors (chemical industry, food and drink industry). Further work is needed to assess the emissions of other pollutants such as ammonia from this source;
- Review and update of the mercury in product emissions to waste and landfill, this will include review of the existing literature factors and trends based on Wenborn *et al,* 1998 against more recent updates to European and Global estimates, including the studies carried out by Pacyna in 2006 and 2010. It is intended to make use of the new research to sense check and revise existing estimates accordingly.
- Further work is recommended to review available UK surveys and information for small-scale waste burning, to reduce the uncertainties associated with the emission factors for this source, which is a key source for dioxins and furans, PM_{10} and PAHs.
- Review and update of the PAH emission factors associated with the incineration sector to ensure the most suitable post-WID factor data is in use. This is needed to ensure that the emission estimates for PAH reflect modern plant operation
- A review of the ammonia emission estimates (source data, methods, alternative approaches) for emissions from waste water and sewage sludge treatment and disposal is recommended, to develop a time series that reflects the changing estimates of UK protein consumption and data on different water treatment and disposal methods.
- Review of method for waste incineration emissions where emission factors are reliant on data from the PI which is frequently reported as below reporting threshold

NFR 7
Review new EA report on emission factors from accidental fires, and to ensure full, accurate use of restructured DCLG fire statistics. DCLG fire statistics have changed format over recent years and no longer integrate into the inventory methodology.

13.10 Horizon Scanning

13.10.1 IMPACTS OF POTENTIAL CHANGES TO CLRTAP REPORTING

Introduction
The UN/ECE Gothenburg and Heavy Metals Protocols have recently been reviewed and updated. Following on from revisions to these protocols, the emissions reporting Guidelines associated with the CLRTAP are in the process of being reviewed and updated. This will have a number of implications for submissions under the LRTAP Convention. Whilst many of these changes are currently at the discussion stage and are not finalised, it is sensible to consider potential implications for the Air Quality Pollutant Inventory.

Most of the proposed changes will be discussed at the 2013 meeting of the Taskforce on Emission Inventories and Projections (TFEIP2013). The UK emissions inventory team will be represented at this meeting and can therefore contribute to the discussions.

Recommendations from TFEIP2013 will then be discussed at the 2013 meeting of the EMEP Steering Body and, again, the UK will be represented at this meeting, allowing input into the decision making process.

Confirmed and Potential Changes to LRTAP Reporting
EMEP Grid: The EMEP grid has been changed to a lat-long grid with a 0.1° x 0.1° resolution. Official reporting on this new grid is several years away, however Parties will be requested to voluntarily provide gridded emissions data on the new grid system from 2013 onwards.

The UK emissions inventory team are already aware of these changes to the gridded emissions, and are in a position to provide the gridded data on the new EMEP grid from 2013 onwards.

Adjustments: A new system has been put in place to allow best science emission inventories to differ from the emission estimates that are used for compliance purposes.

The UK emissions inventory team are aware of this new process, and consequently would be able to capture and present the information required for an adjustment application should the UK consider this necessary. However, it will be sensible to review the current inventory systems to ensure that they are able to provide the information to support an adjustment application in an efficient way.

Changes to Pollutants
Addition of BC: The reporting of BC is already encouraged under the CLRTAP's Gothenburg Protocol and may be required under the NECD in the future.
The UK Government were aware of this possibility and have already funded the first BC emission inventory for the UK. This will shortly be reviewed by Defra. It will be sensible to review whether there have been any changes to the methodologies and emission factors in the finalised EMEP/EEA Emissions Inventory Guidebook chapters before BC is included in formal UK submissions.

Removal of HCH: HCH will be removed from the reporting requirements.
The UK Government may wish to remove this from the annual inventory compilation if it considers that there are no users of the emissions data.

Possible Removal of Non-Priority Metals: The non-priority metals (As, Cr, Cu, Ni, Se, Zn) are under consideration for removal. It is likely that justification will be given for retaining the reporting of these pollutants, but perhaps reporting will be amended to every five years.

It would be sensible for the UK Government to liaise with the scientific community in the UK to form a view on whether there is a clear need to retain the emissions reporting of these metals at an annual resolution.

Changes to the NFR Sector Categories: Some minor amendments will be made to the NFR category system. This is to address current gaps, ensure continued alignment with the CRF (GHG reporting system) as far as possible, and improve the clarity regarding which “natural” sources should be reported.
Some minor changes may be required to the UK’s centralised emissions database to ensure that data is output in the correct format, but this is expected to be straightforward. Some sources may be newly itemised in the updated reporting structure. However, at present the UK inventory team are not aware of any issues that might be caused with the structures that currently underpin the UK emissions inventory.

Changes to the GNFR (Gridded Sectors): Some changes to the GNFR are likely, but details are yet to be discussed.
The mapping experts in the UK emissions inventory team will ensure that their views are expressed at TFEIP2013.

Changes to the Reporting Years: It has been suggested that the reporting years are changed so that emission estimates are required for Protocol base years, and from 1990 onwards. Emission estimates from 1980-1989 might not be reported, or it might be suggested that they are only updated every five years.
The UK emissions inventory team will consult with the users of emissions data to forma view on whether this would have any adverse impacts.

Changes to the reporting Deadline: EMEP’s Centre on Emission Inventories and Projections (CEIP) has suggested that the reporting deadline is moved to an earlier date – perhaps mid-January. This is to give them more time to process the increased amount of gridded data that is being submitted.
The UK inventory team will provide their input to discussion at TFEIP2013 after reviewing the practicalities associated with reporting emissions data to an earlier deadline.

Suggested Short-term Actions (within the next ~12 months)
The UK emissions inventory team have been involved with preliminary discussions regarding potential changes to the LRTAP reporting, and there will be opportunities to discuss any changes at the TFEIP2013 and also the 2013 meeting of the EMEP Steering Body. So the most important action will be for the UK Government and the emissions inventory team to consult with stakeholders prior to these meetings. It will then be possible to make effective contributions to the discussions during TFEIP 2013 and the 2013 meeting of the EMEP Steering Body.

It will also be sensible to review current inventory systems and platforms in the context of the introduction of the Adjustments mechanism. Should the UK wish to apply for an Adjustment it will be essential that robust supporting information can be provided with the application.

Longer-term Actions (>12 months)
There are number of recent initiatives and reviews which may require some longer-term changes to the UK emissions inventory.

Fine time resolution emission estimates: There is increasing interest in how the modelling community use annual emission estimates in their models, and a call for methodologies to be made more transparent.
The UK inventory team has recently updated the AQPI time profiles, and are therefore well placed to contribute to this developing area.

Scenario based historic emission estimates: The research community in the UK are interested to understand the potential impacts on emissions estimates of using the output from research, before it is incorporated into official UK emission estimates. There is therefore the call for a UK inventory system that is more flexible, and scenario based.

This would be a new considerable undertaking, and the UK Government will need to give this careful consideration before deciding whether this initiative warrants funding.

14. Projections

Projected emissions for the four National Emission Ceiling Directive (NECD) pollutants are compiled by the NAEI team in Ricardo-AEA to enable comparisons with international commitments to be assessed. Emission projections are submitted under the CLRTAP every 5 years, with the latest dataset (at the time) being provided in February 2012. It should be noted that the UK projections submitted under the NECD (31st Dec 2011) and CLRTAP (15th Feb 2012) are based on the 2009 UK inventory. A summary of the methodology, activity data forecasts and future emission factors relating to this set of projections is outlined in the 2012 Informative Inventory Report (Passant et al., 2012).

For the 2013 LRTAP submission, actual emissions data were available up to year 2011 and thus no emission projections were submitted. Further information on the most recent UK projections up to 2030 can be found on the NAEI website[29].

14.1 UK air quality emission commitments

The UK has made commitments under the Gothenburg Protocol and the more stringent National Emissions Ceilings Directive (NECD) to reduce emissions of NO_x, SO_2, NMVOCs and NH_3 by 2010. The revised Gothenburg Protocol (in May 2012) now also sets emission reduction commitments for the same four pollutants and for $PM_{2.5}$ to be achieved in 2020 and beyond. The target emissions are provided in Table 14.1 below together with the UK's actual emissions in 2010 and 2011 (the latest year available). The data shows that the NH_3, SO_2, NO_x and NMVOC ceilings have been met in 2010 and 2011.

Table 14.1 The UK's final 2010 and 2011 (as reported in 2013 LRTAP submission) and targets for 2010 (and 2020) that the UK is committed to.

Pollutant	Emissions (kt) reported in 2013			Targets for 2010		Revised Gothenburg Protocol	
	2005	2010	2011	Gothenburg Protocol target in 2010 (kt)	NECD Emissions ceiling target in 2010 (kt)	Emission reduction commitments between 2005 and 2020	Gothenburg Protocol target in 2020 (kt)
NO_x	1,570	1,107	1,033	1,181	1,167	55%	707
SO_2	700	407	379	625	585	59%	287
NMVOCs	1,049	771	752	1,200	1,200	32%	714
NH_3	304	286	290	297	297	8%	279
$PM_{2.5}$	84	70	67	N/A	N/A	30%	59

[29] Misra et al. (2012) UK Emission Projections of Air Quality Pollutants to 2030 (http://uk-air.defra.gov.uk/reports/cat07/1211071420_UEP43_(2009)_Projections_Final.pdf)

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