UK Informative Inventory Report (1980 to 2009)

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March 2011

Executive Summary

This is the 6th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) team. The report is compiled to accompany the UK's 2011 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 since 1980.

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

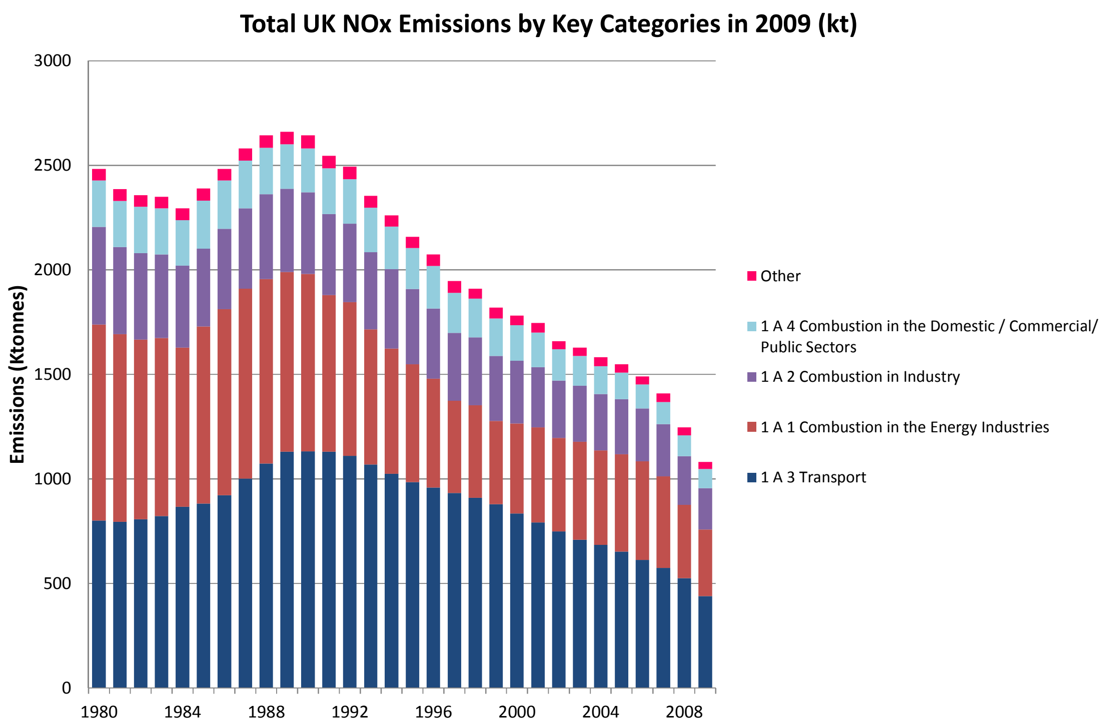
- nitrogen oxides, carbon monoxide, ammonia, sulphur dioxide, non-methane volatile organic compounds, particulate matter and heavy metals (1980 to 2009); and
- persistent organic pollutants (1990 to 2009).

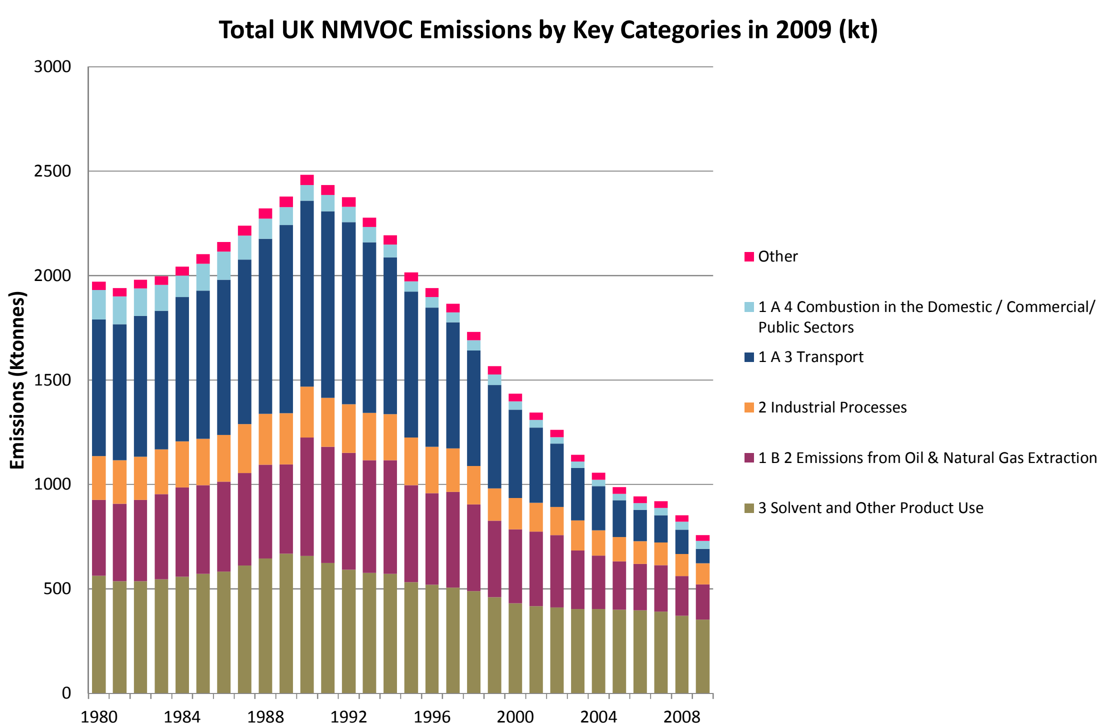
As part of the commitments to the CLRTAP, countries are also required to submit emission projections for nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and ammonia (NH_3) (under the Gothenburg Protocol).

Selected pollutants under the CLRTAP are also covered under the Directive 2001/81/EC of the European Parliament and the Council 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). These emission projections are compiled and reported as part of the UK inventory programme. In addition to the pollutants listed above, the NAEI compiles the Greenhouse Gas (GHG) inventory for the six gases covered under the UN Framework Convention on Climate Change (UNFCCC); Carbon dioxide, Methane, Nitrous oxide, Hydrofluorocarbons, Perfluorocarbons and Sulphur hexafluoride.

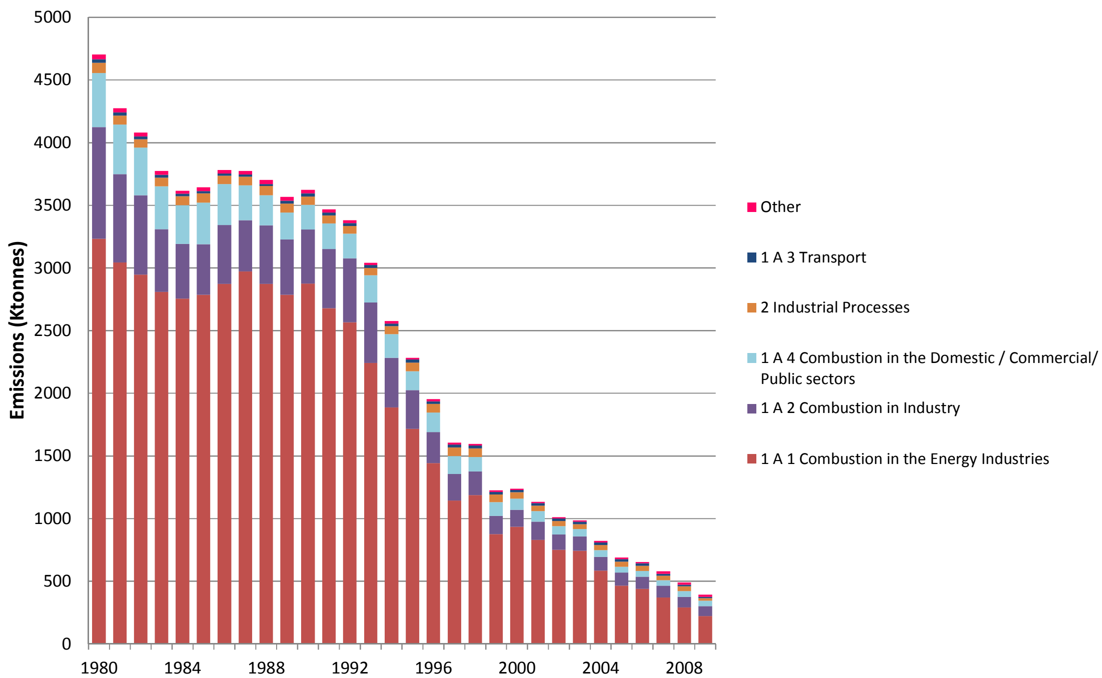
[1] See http://www.ceip.at/reporting-instructions/reporting-programme/ for reporting requirements set up by TFEIP/UNECE Guidelines for estimating and reporting emissions data under LRTAP.

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), 1980-2009 (kt)

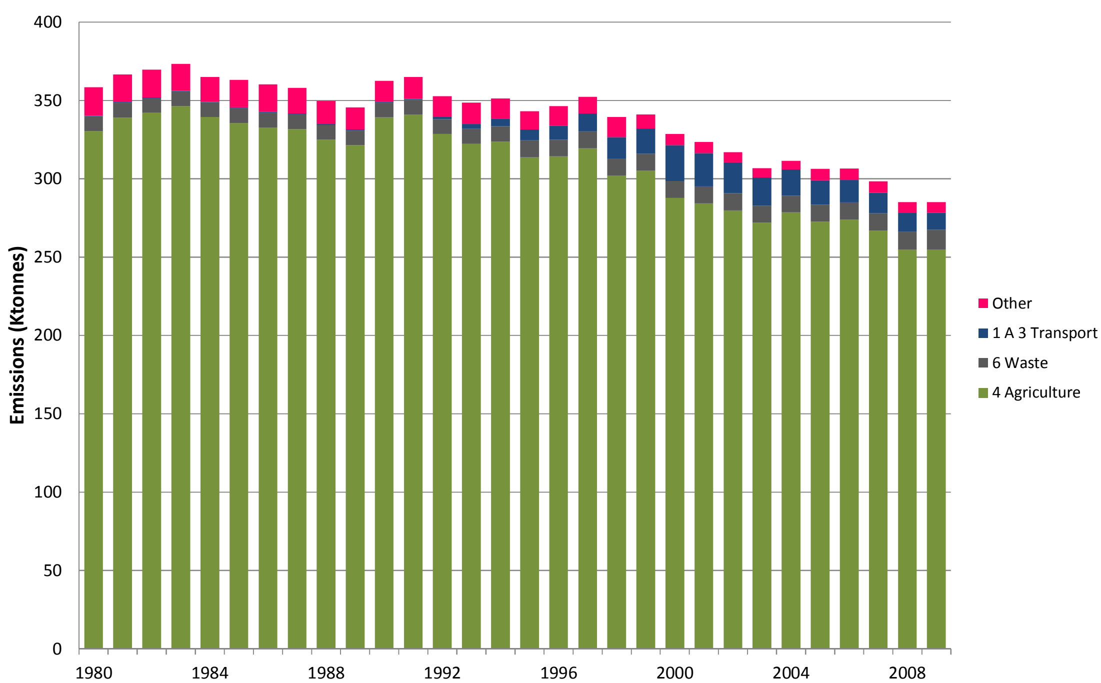




Total UK SO_2 Emissions by Key Categories in 2009 (kt)



Total UK NH_3 Emissions by Key Categories in 2009 (kt)



Reductions in the emissions of headline pollutants between 1980 and 2009 are summarised in the table below.

Table ES-1 Air Quality Pollutant Emission Reductions between 1980 and 2009

Pollutant	% Change from 1980 to 2009
NO_x	-57%
SO_2	-92%
NH_3	-21%
NMVOC	-63%
CO	-73%
PM_{10}	-64%

In principle, the emissions inventory attempts to make estimates of all known emissions to air, at as high a level of disaggregation as is possible. However, in accordance with international guidelines 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 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).
- 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.

The national totals reported for the UK in the CLRTAP and the UNFCCC submissions differ, as the sources included in the national totals differ under the CLRTAP[2] and the UNFCCC reporting guidelines. The historic data submitted under the NECD in December 2010 are provisional data only. The inventory team has made some further improvements to the data since the 2010 NECD submission[3]. Thus, for NECD and CLRTAP the submission totals differ slightly. 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 2009;
- Outline the latest emission projections for National Emission Ceiling Directive air quality pollutants, to 2010;

[2] Includes the United Kingdom (England, Scotland, Wales, Northern Ireland) and Gibraltar
[3] The individual sources feeding into the on- and offshore gas categories were further disaggregated. New sources were added after the 31st December 2010 affecting NFR codes 1A1c, 1B2ai, 1B2c.

- 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.

The information contained in this report is derived from the UK emissions inventory which includes the UK Greenhouse Gas inventory, used for reporting to the UNFCCC. The compilation of the inventories for the pollutants reported to the CLRTAP and the UNFCCC are strongly linked; they are based on many common activity data and share many common data sources, data management, 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 and emissions are available from http://www.naei.co.uk/data_warehouse.php. The complete 2011 UK CLRTAP submission templates are available from the European Environment Information and Observation Network (EIONET) under http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envtvpebw.

Any revisions to inventory compilation methodologies for key pollutants and key sectors between the 2010 and 2011 CLRTAP submission are discussed in Chapter 13, whilst the changes in emission estimates due to revisions in source data or estimation methodology are summarised in Appendix.1. 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 2008) have been addressed in the 2010 inventory. The 2010 UK CLRTAP submission was also subject to review as part of the stage 3 review process organised by Centre on Emission Inventories and Projections on behalf of the European Environment Agency. Comments and recommendations from the expert review team have been incorporated into the 2011 submission where feasible, see Chapter 13.

Planned improvements for future national inventory compilation cycles are discussed in section 13.8.

In addition, Table ES-2 gives an overview of differences in the 2011 submission compared to the 2010 CLRTAP submission. The differences vary from pollutant to pollutant due to the different key sources for the pollutants. For example, the increase in carbon monoxide (CO) emissions is driven primarily by changes in the road transport sector. The difference between the 2009 and 2010 submission is considerably higher for CO than for other pollutants, due to the significant methodology revisions in the road transport sector.

The changes in metal emissions are driven by revisions to operator-reported emissions data from individual installations. Changes in the persistent organic pollutants (POPs) estimates are due to revised activity data in the Digest of United Kingdom Energy Statistics (DUKES), and Renewable Energy Statistics (RESTATs). Hexachlorobenzene (HCB) emissions have decreased significantly due to the revision of the emission factor of HCB in chlorothalonil from agricultural pesticide use from 40ppm to 8ppm as part of the POP inventory improvement. NO_x, SO_2, NH_3 and NMVOC emission recalculations are mainly due to improvements to the estimation methodologies for the shipping and road transport sectors.

Table ES-2 UK Inventory Recalculations, Comparing the 2010 and 2011 CLRTAP Submissions

Pollutant	**2010 Submission**	**2011 Submission**		**Unit**	**Comment/Explanation (changes between the 2010 and 2011 CLRTAP Submissions)**
	2008	**2008**	**2009**		
NO_x	1403	1252	1086	kt	The reduction in NO_x emission between the two submission years is due to: revision in the NO_x emission factor for domestic gas combustion, updates to the relative mileage and fleet split numbers within the road transport sector, and incorporation of new factors for detailed vessel types and shipping movements (Entec, 2010)
CO	2822	2881	2277	kt	Updated activity data for straw used as a fuel by the agricultural sector, peat and petroleum coke used as domestic fuels, and petrol used in off-road vehicles & mobile machinery all contributed to an increase in emission estimates in the latest inventory. Vehicle-km split between buses and coaches on urban and rural roads has been updated and the percentage of petrol LGV sales has been updated with actual data contributing to the increase in emissions.
NMVOC	942	929	826	kt	Slightly lower estimates in the latest inventory stem from revisions to the relative mileage and fleets split numbers within the road transport sector and incorporation of new factors for detailed vessel types and shipping movements (Entec, 2010).
SO_2	512	498	397	kt	The overall change in UK SO_2 emission estimates is small, but there have been a range of recalculations affecting SO_2 data including: • Revisions to the activity data for domestic pet coke combustion; • Updates to relative mileage and fleet split numbers within the road transport sector. • Revisions to activity data and underlying assumptions in agricultural mobile machinery fuel use; • Incorporation of new factors for detailed vessel types and shipping movements from Entec (2010) study.
NH_3	282	288	288	kt	Inclusion of 2009 fertiliser use data, inclusion of 2009 livestock numbers, revision of livestock housing data and correction of minor errors in the manure management input data all contributed to a slight increase in NH_3 emissions. Revised livestock data also indicated an increase in UK horse population, which has led to revised estimates for ammonia from horse wastes.
TSP	NR	225	209	kt	TSP is reported for the first time in the 2011 submission.
PM_{10}	133	129	119	kt	Revised shipping inventory based on new activity data and emission factors, small revisions to Road Transport and a revision to activity data for off-road mobile machinery petrol use contributed to a slight decrease in overall emissions in the 2011 submission.
$PM_{2.5}$	83	76	70	kt	Revised shipping inventory based on new activity data and emission factors, small revisions to Road Transport and a revision to activity data for off-road mobile machinery petrol use contributed to a slight decrease in overall emissions in the 2011 submission.
Pb	67	73	60	tonnes	Revised activity data for waste oils used as an industrial fuel increased emissions in the 2011 submission.
Cd	3	3	2	tonnes	No significant changes.
Hg	6	6	7	tonnes	No significant changes. Small revisions stem from a change in the estimation methodology for clinical waste incineration.

Pollutant	2010 Submission	2011 Submission		Unit	Comment/Explanation (changes between the 2010 and 2011 CLRTAP Submissions)
	2008	2008	2009		
As	13	14	13	tonnes	No significant changes. Small revisions to activity data for waste oils used as industrial fuel and petroleum coke used as domestic fuel have slightly increased the emission estimates.
Cr	29	29	26	tonnes	No significant changes.
Cu	60	61	52	tonnes	No significant changes. Small revisions to activity data for both waste oils used as an industrial fuel and for fireworks have slightly increased the emission estimates.
Ni	99	113	83	tonnes	Emissions increased in the 2011 submission due to a revised time series of activity data for petroleum coke used as an industrial fuel and as a domestic fuel, and also due to a revision to metal emission reported by one UK refinery.
Se	36	36	31	tonnes	No significant changes.
Zn	277	368	339	tonnes	Significant revision to the industrial combustion of lubricants. In the inventory for the previous few years, we have believed that the road stone coating industry had to stop using waste oil as a fuel because they would otherwise need to comply with the Waste Incineration Directive (WID). That turns out not to have been the case and so this year we put in an estimate of the sector's use of waste oil so the activity data went up a lot. The analyses we've done suggest that waste oils have high zinc contents so this has a big impact on the inventory.
HCH	9856	9954	8760	kg	No significant changes.
PCB	998	1001	906	kg	No significant changes.
PCDD/PCDF	236	201	193	grams TEQ	Correction of emission estimate for secondary lead production has led to a reduction in emissions in the 2011 submission.
Benzo[a]pyrene	4	3	3	tonnes	Changes due to review of the DfT/TRL 2009 published RT Efs and factors in the COPERT 4/Emissions Inventory Guidebook.
Benzo[b]fluoranthene	3	3	3	tonnes	Changes due to review of the DfT/TRL 2009 published RT Efs and factors in the COPERT 4/Emissions Inventory Guidebook.
Benzo[k]fluoranthene	2	1	1	tonnes	Changes due to review of the DfT/TRL 2009 published RT Efs and factors in the COPERT 4/Emissions Inventory Guidebook.
Indeno(1,2,3-cd)pyrene	2	1	1	tonnes	Changes due to review of the DfT/TRL 2009 published RT Efs and factors in the COPERT 4/Emissions Inventory Guidebook.
HCB	91	58	33	kg	Emissions decreased due to the revision of emission factor of HCB in chlorothalonil from agricultural pesticide use, which was revised from 40ppm to 8ppm as part of POP inventory improvement. The list of IPPC sites was also reviewed and amended.
PCP	NR	NR	NR	kg	Not reported.
SCCP	NR	NR	NR	kg	Not reported.

NR: Not Reported

A number of improvements to the inventory are planned, although it is unlikely that all improvements will be incorporated in the next version of the inventory. The following sectors are expected to be the focus of future improvements:

- **Fugitive emissions from oil and gas industries;**
- **Road Transport;**
- **Rail;**
- **Inland waterways;**
- **Aviation;**
- **Industrial Process Emissions.**

(I) CONTACTS AND ACKNOWLEDGEMENTS

This work forms part of the evidence project of the Atmosphere and Local Environment Programme (ALE) of the Department for Environment, Food and Rural Affairs under contract AQ0711.

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 North Wyke 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 AEA on behalf of Defra: http://www.naei.org.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
AEA	UK Inventory compiler (AEA Group)
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	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
Mtonnes	Megatonne
Mtherms	Megatherms
NFR	Nomenclature for Reporting
NAEI	National Air 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	
Polychlorinated dibenzo-p-dioxins/ Polychlorinated dibenzofurans	PCDD/PCDF
Polychlorinated Biphenyls	PCB
Lindane (gamma-HCH)	HCH
Pentachlorophenol	PCP
Hexachlorobenzene	HCB
Short-chain chlorinated paraffins	SCCP
Polychlorinated Naphthalene	PCN
Polybrominated diphenyl ethers	PBDE
Sodium	Na
Potassium	K
Calcium	Ca
Magnesium	Mg

Contents

1. Introduction

1.1 NATIONAL INVENTORY BACKGROUND

1.1.1 UK Inventory Reporting Scope: Pollutants & Timeseries

The UK emissions inventory estimates annual pollutant emissions from 1970 to the most current inventory year for the majority of pollutants. A number of pollutants are estimated from 1990 or 2000 to the most current inventory year due to the lack of adequate data prior to the later date. The scope of pollutants and years for which they are compiled are reported in Table 1-3.

Inclusion of new pollutants in the inventory is usually driven by legislation. However, the UK government is pro-active in this area and the inventory includes emissions of 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 example reporting emissions of base cations allows the modelling community to better estimate the impacts of acidic gases. Pollutants that have to be reported to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) are highlighted in Table 1-1.

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.

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 upper limits for each Member State for the total emissions in 2010. These pollutants are responsible for acidification, eutrophication and ground-level ozone pollution. The Member States are required to prepare and annually update national emissions inventories and emissions projections for 2010 for these pollutants.

The revision of the NECD is part of the implementation of the Thematic Strategy on Air Pollution. The proposal to amend the NECD is still under preparation and may set emission ceilings to be reached by 2020 or even 2030 for the four already regulated substances and the primary emissions of $PM_{2.5}$. The revision of the NECD target has been delayed and is not expected till 2013.

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 emission ceilings of this protocol are equal or less ambitious than those in the NECD. The pollutants required for reporting under the CLRTAP are listed in Table 1-1.

Table 1-1 Summary of reporting requirements for estimating and reporting emissions under the CLRTAP[4]

Group	**Pollutant**	**Required reporting years**	**Reported years in 2011 UK submission**
Main Pollutants	Nitrogen Oxides	1980-2009	1980-2009
	Sulphur Dioxide		
	Carbon Monoxide		
	Non-Methane Volatile Organic Compounds		
	Ammonia		
Particulate Matter	Particulates < 10 µm	2000-2009	1980-2009
	Particulates < 2.5 µm		
	Total Suspended Particulates		
Priority Heavy Metals	Lead	1990-2009	1980-2009
	Cadmium		
	Mercury		
Other Heavy Metals	Copper	1990-2009	1980-2009
	Zinc		
	Nickel		
	Chromium		
	Arsenic		
	Selenium		
Persistent Organic Pollutants	Benzo[a]pyrene	1990-2009	1990-2009
	Benzo[b]fluoranthene		
	Benzo[k]fluoranthene		
	Indeno (1,2,3-cd)pyrene		
	PCDD/PCDF		
	Polychlorinated Biphenyls		
	HCH		
	Hexachlorobenzene		

The main difference between the reporting requirements of the NECD, CLRTAP and UNFCCC are highlighted in Table 1-2.

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 emissions inventory reports GHG emissions to the United Nations Framework Convention on Climate Change for compliance with the Kyoto Protocol.

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

Table 1-2 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)[5]	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

[5] Emissions from the LTO cycle include emissions within a 1000 m ceiling of landing.

Table 1-3 Scope of UK Inventory Reporting: Pollutants by Type, Timeseries

Pollutant	Reported under CLRTAP	Inventory Timeseries[1]	Type of Pollutant[2]
Nitrogen Oxides	✓	1970-2009	NAQS, AC, IGHG, O, E
Sulphur Dioxide	✓	1970-2009	NAQS, AC, IGHG
Carbon Monoxide	✓	1970-2009	NAQS, O
Non-Methane Volatile Organic Compounds *	✓	1970-2009	NAQS, O, IGHG
Black Smoke		1970-2009	NAQS
Particulates < 10 µm	✓	1970-2009	NAQS
Particulates < 2.5 µm	✓	1970-2009	-
Particulates < 1 µm		1970-2009	-
Particulates < 0.1 µm		1970-2009	-
Total Suspended Particulates	✓	1970-2009	-
Ammonia	✓	1980-2009	AC, E
Hydrogen Chloride		1970-2009	AC
Hydrogen Fluoride		1970-2009	AC
Lead	✓	1970-2009	NAQS, TP
Cadmium	✓	1970-2009	TP
Mercury **	✓	1970-2009	TP
Copper	✓	1970-2009	TP
Zinc	✓	1970-2009	TP
Nickel **	✓	1970-2009	TP
Chromium **	✓	1970-2009	TP
Arsenic	✓	1970-2009	TP
Selenium	✓	1970-2009	TP
Vanadium		1970-2009	TP
Beryllium		2000-2009	TP
Manganese		2000-2009	TP
Tin		2000-2009	TP
Polycyclic Aromatic Hydrocarbons *	✓	1990-2009	TP
PCDD and PCDF	✓	1990-2009	TP
Polychlorinated Biphenyls *	✓	1990-2009	TP
Lindane (gamma-HCH)	✓[6]	1990-2009	TP
Pentachlorophenol		1990-2009	TP
Hexachlorobenzene	✓	1990-2009	TP
Short-chain chlorinated paraffins		1990-2009	TP
Polychlorinated Naphthalene		NE	TP
Polybrominated diphenyl ethers		SE	TP
Sodium		1990-2009	BC
Potassium		1990-2009	BC
Calcium		1990-2009	BC
Magnesium		1990-2009	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
AC Acid gas
BC Base cation
IGHG Indirect Greenhouse Gas
NAQS National Air Quality Standard/Local Air Quality Management pollutant
TP Heavy metals and POPs are generally referred to as "Toxic Pollutants" (although other pollutants also have toxic properties)
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.

[6] Reported as total HCH

1.1.3 Sources

In principle, the emissions inventory attempts to make 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 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 are not included in the national totals.
- Natural sources and cruise emissions from civil and international aviation are not included in the national totals (although estimates of some sources are made).
- Estimates of “International” emissions such as shipping are made, and reported as memo items (excluded from the UK national totals).
- GHG emissions associated with short-term changes to the carbon cycle are not included; whilst this is not of particular concern here, the principle is extended to other pollutants.

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).

The sources included in the national totals under the NECD and the CLRTAP differ from sources included in the national totals reported under the Kyoto Protocol to the UNFCCC. A list of the sources covered under the Kyoto Protocol can be found in the annual UK Greenhouse Gas Inventory, 1990 to 2009: Annual Report for submission under the Framework Convention on Climate Change (AEA 2011).

1.1.4 Geographical Scope

The UK has associated Overseas Territories (OTs), Crown Dependencies (CDs) and Sovereign Bases (SBs). The exact definition of the UK varies under different protocols within the CLRTAP. Emission estimates for the relevant locations and pollutants are made so that the UK emissions accurately reflect those specified in the individual protocols.

The only CD, OT or SB which is included in emission estimates is Gibraltar. However, Gibraltar is only included in the definition of the UK for some of the protocols within the CLRTAP Convention.

Note that the NECD submission uses the CLRTAP reporting templates (as requested by the European Environment Agency). The UK does not yet make emission estimates from inland waterways. Further information regarding this source will be covered in the Chapter 13.

Under the UNFCCC[7], GHG emissions from all CDs and OTs are included in the national totals. This leads to differences between the NECD pollutants reported under the CLRTAP and the indirect GHG emissions reported for the UK under the UNFCCC.

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

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

All UK emission inventories are compiled and maintained by AEA Group, 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 Climate, Energy, Science & Analysis, Science & Innovation Division of the Department for Energy and Climate Change (DECC) to provide non-GHG emissions inventories and GHG emission inventories respectively.

1.2.1 Defra ALE

The Science and Evidence Team, Atmosphere and Local Environment Programme (ALE) of the Department for Environment, Food and Rural Affairs (Defra) is responsible to meet 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;
- Management of contracts & delivery of emissions inventories;
- Definition of performance criteria for key organisations.

Development of Legal & Contractual Infrastructure

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

1.2.2 AEA Group

As the UK's current inventory agency, 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 hourly.

Inventory Compilation

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

Whilst AEA, on behalf of Defra and DECC, is responsible for the overall management and delivery of the UK emission inventories, other organisations are contracted to compile emission estimates from specific sources, including:

- Agricultural emissions of NH_3 are prepared by a consortium led by North Wyke 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 AEA.

Information Dissemination

Data from the NAEI is made available to national and international bodies in a number of different formats. The NAEI team also hold seminars 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.

The NAEI web pages may be found at: http://www.naei.org.uk

The web pages are arranged to allow easy 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.

- **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://ww2.defra.gov.uk/environment/quality/air/air-quality/

and

http://ww2.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 AEA Group 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 on an hourly basis.

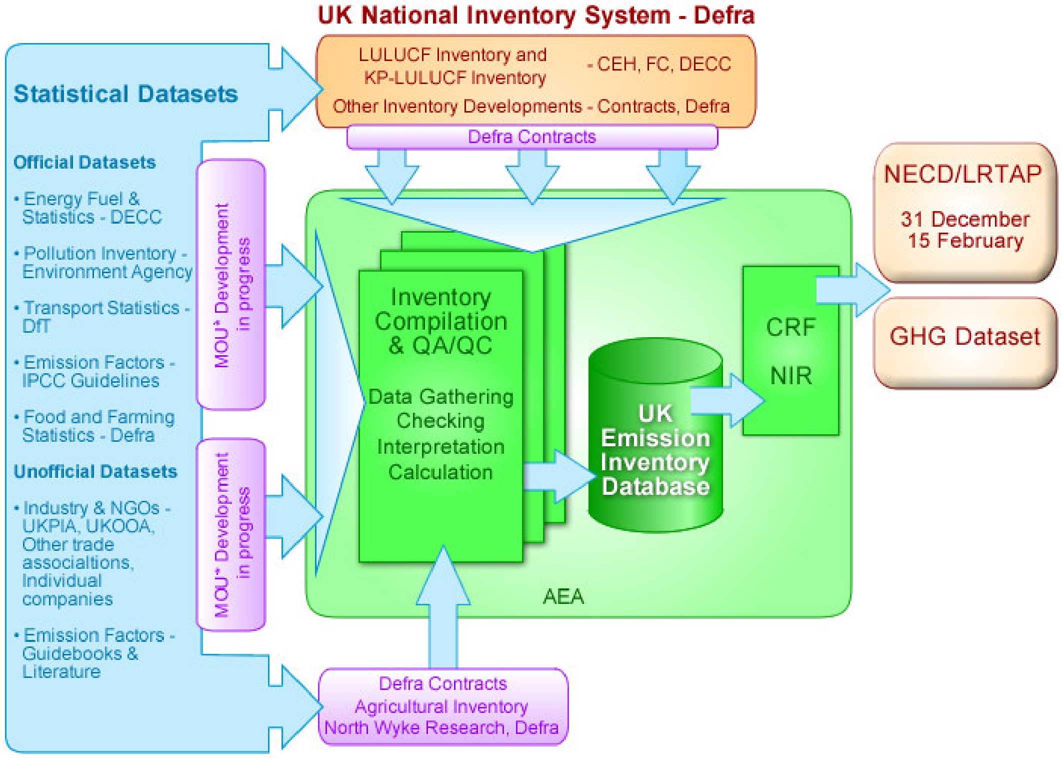
1.3 INVENTORY PREPARATION PROCESS

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.
- AEA 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, including the Department for Energy and Climate Change (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 Department of Environment (DoENI), the Office of National Statistics (ONS), the Centre for Ecology and Hydrology (CEH), North Wyke Research, private companies such as Corus, and business organisations such as UK Petroleum Industry Association (UKPIA), the British Cement Association (BCA) and Oil & Gas UK.

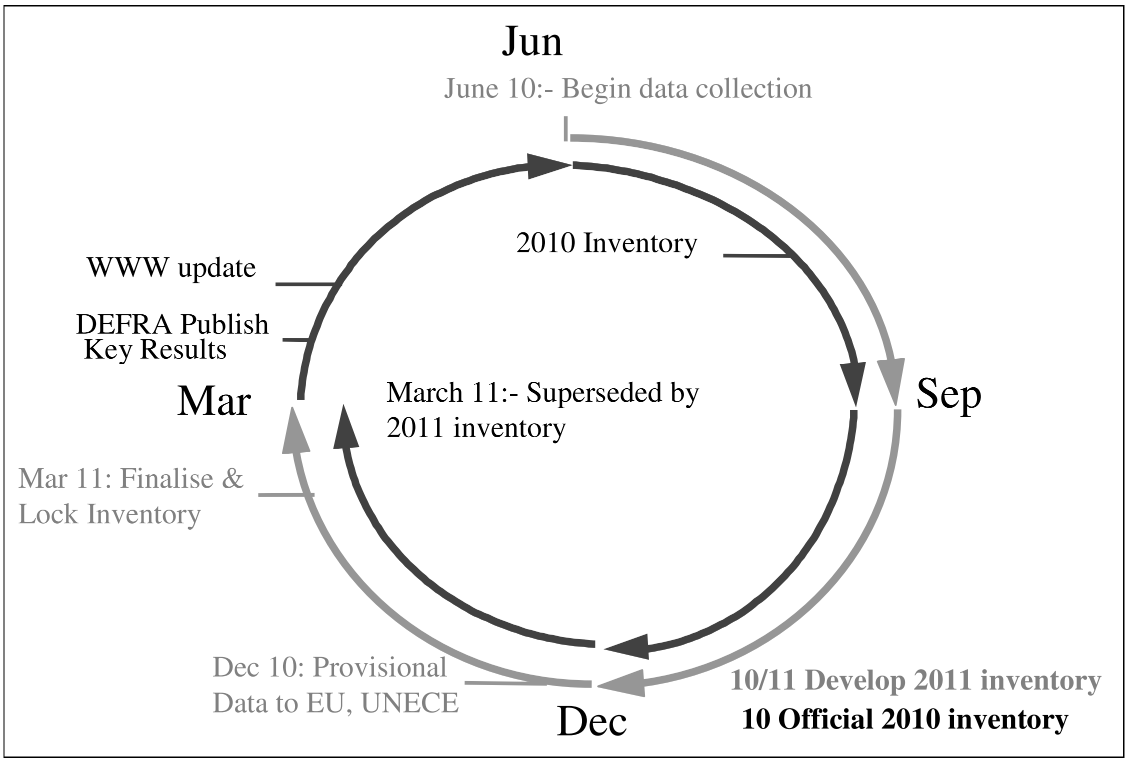
1.3.2 The Annual Cycle of Inventory Compilation

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 UN/ECE, UNFCCC and other international fora.

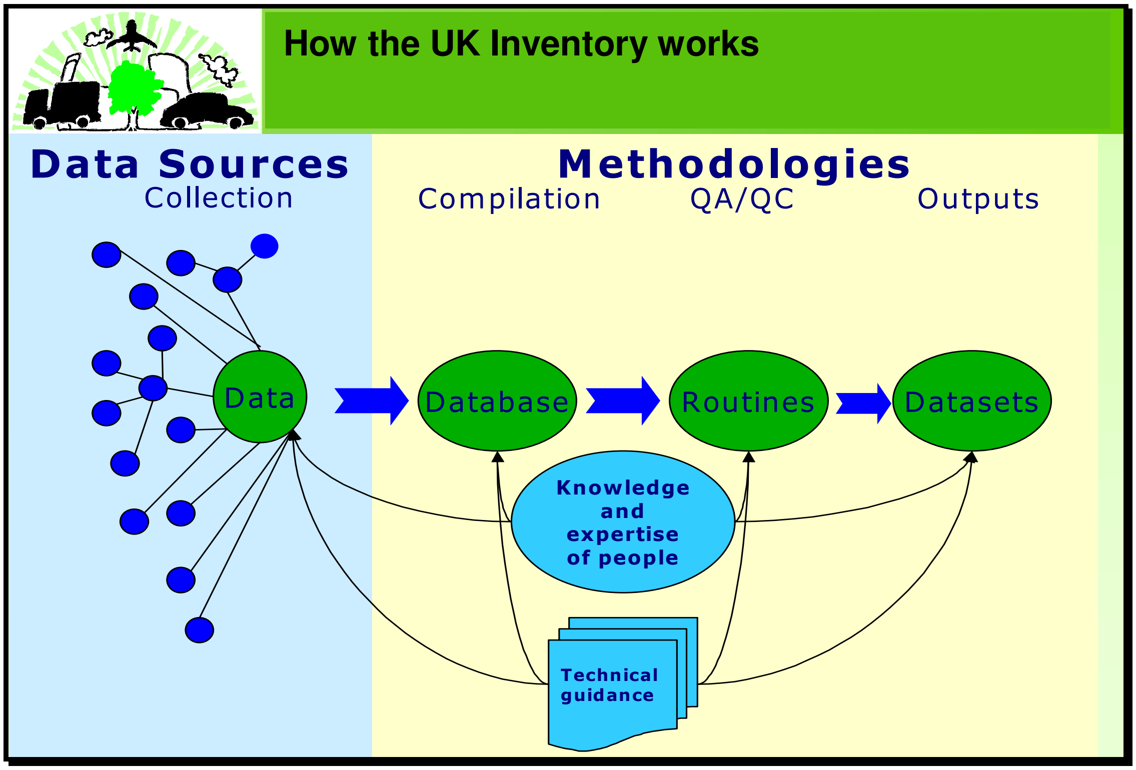
Figure 1-2 The Annual Inventory Cycle in the UK



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 below.

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.

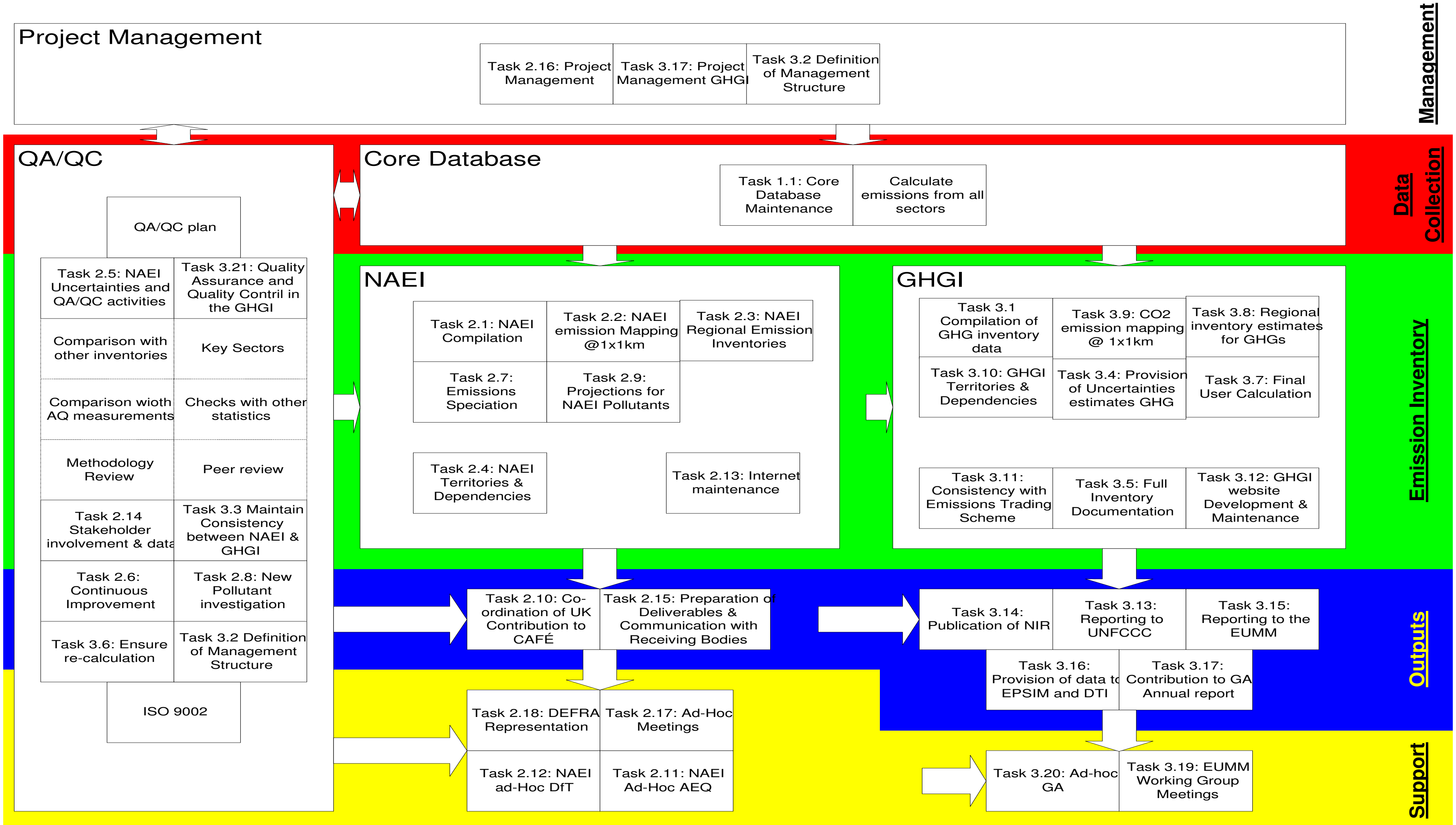
The five-stage summary of the inventory cycle provides a simplistic overview. In practice there are considerably more tasks and the cycle is more complex. For example, some other tasks within the programme would be associated with:

- 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. The range of wider Government support activities are not considered in this report.

Figure 1-4 gives a more detailed indication of how the major tasks in the inventory programme relate to each other.

Figure 1-4 Overview of the main inventory activities and their relationship to the detailed tasks

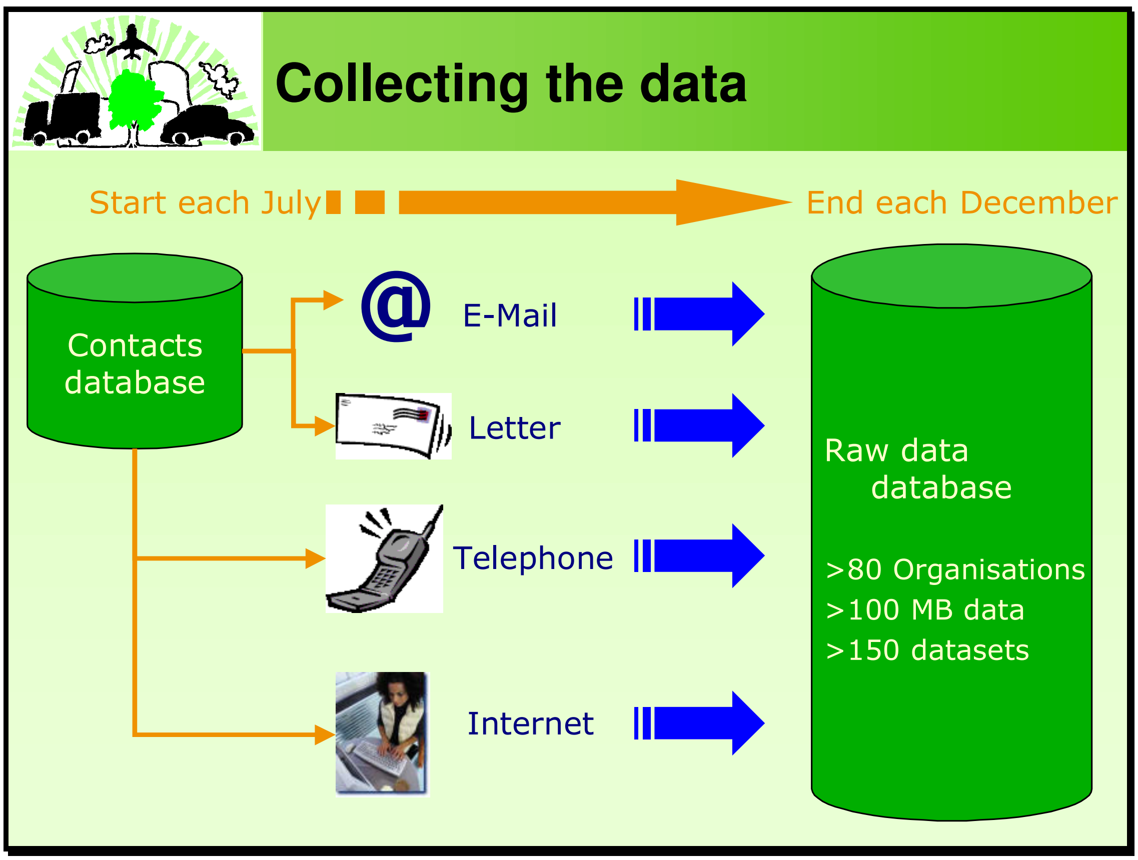


1.3.4 Stage 1: Data Collection

Data Management

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

Figure 1-5 Data collection for core inventory compilation



There 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 in place in the UK to secure the data provision to the emissions inventory (via the GHG inventory), there is currently no obligation for these organisations to provide data pertinent specifically to the air quality pollutant inventories.

However, the major data providers to the emissions inventory are encouraged to undertake the following responsibilities:

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, 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:

http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

DECC include 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 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.

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

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, and fuel suppliers would not necessarily know whether a customer was using gas oil in a mobile or a stationary plant. As a result of 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). 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.

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 AEA by the individual plant operators or from:

1. **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://maps.environment-agency.gov.uk/wiyby/wiybyController?ep=maptopics&lang=_e

2. 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

3. The Northern Ireland Department of Environment – ISR Inventory

The Environment & Heritage Service of the Northern Ireland Department of Environment 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.ehsni.gov.uk/environment/industrialPollution/ipc.shtml

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

The Centre for Ecology and Hydrology (CEH) compiles NH_3 emission estimates for sources in the natural and waste sectors (as well as providing information for mapping NH_3 emissions).

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/CORINAIR 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/CORINAIR, 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 that goes 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 which contains 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 (see section 1.6.6) and submitted.

1.4 METHODS AND DATA SOURCES

Overview information on primary data providers and methodologies has been included in the above sections. Table 1-4 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 1-4 UK Emissions Inventory Compilation Methodologies by NFR

NFR Category	Activity	EFs	Comment
1A1a Public Electricity & Heat Production	UK statistics	Operator reporting under IPPC	
1A1b Petroleum refining	UK statistics	Operator reporting under IPPC	
1A1c Manufacture of Solid Fuels etc.	UK statistics	Operator reporting under IPPC and EEMS	
1A2a Iron & Steel	UK statistics	Majority of EFs reported form Corus/Tata	
1A2b Non-ferrous Metals	-	-	Reported under 1A2f
1A2c Chemicals	-	-	Reported under 1A2f
1A2d Pulp, Paper & Print	-	-	Reported under 1A2f
1A2e Food Processing, Beverages & Tobacco	-	-	Reported under 1A2f
1A2f Other	UK statistics	UK factors & Operator reporting under IPPC	
1A3ai(i) International Aviation (LTO)	UK statistics	UK Literature sources	
1A3aii(i) Civil Aviation (Domestic, LTO)	UK statistics	Literature sources	
1A3b Road Transportation	UK statistics	UK factors	
1A3c Railways	Estimated	UK factors	
1A3d ii National Navigation	UK statistics	UK Literature sources (Entec, 2010)	
1A3e Pipeline compressors	-	-	Reported under 1A1c
1A4a Commercial / Institutional	UK statistics	UK factors	
1A4b i Residential	UK statistics	UK factors	
1A4b ii Household & gardening (mobile)	Estimated	Generic	
1A4c i Agriculture/Forestry/Fishing: Stationary	UK statistics	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	UK factors	

NFR Category	Activity	EFs	Comment
1B1b Solid fuel transformation	UK statistics	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 gas network operators and from DECC	
1 B 3 Other fugitive emissions from geothermal energy			Not Reported (NA)
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	

NFR Category	Activity	EFs	Comment
6A Solid Waste Disposal On Land	UK waste arising 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	Literature sources	
1A3ai (ii) International Aviation (Cruise)	UK Statistics	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 in the annual 'Digest of UK Energy Statistics'. 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://www.naei.co.uk/emissions/index.php

1.5 KEY SOURCE ANALYSIS

Table 1-5 provides an overview of the most important sources for selected pollutants reported under the CLRTAP in the 2011 inventory submission. The top 10 sources or the top sources that add up to at least 95% of the national total in 2009 are defined as being a key source for each pollutant in the table.

For SO_2 and NO_x the single dominant source is 1A1a Public Electricity and Heat Production. Nine of the 12 key sources for NH_3 are from the agriculture sector, with 41% of the emission due from cattle. NMVOC sources are dominated by the use of domestic solvents including fungicides. 40% 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 the emissions it accounts for has increased from 1970-2009 due to the decrease in the emissions from the combustion of coal in the household sector.

For PM_{10} and B[a]P emissions, the dominant source remains the combustion of fuel in the residential sector, although the percentage contribution of that source to overall emissions have decreased significantly since 1970. The sinter production in the iron and steel production sector is the highest source for Pb and Cd emissions in 2009. 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 1-5 Key NFR Sources of Air Quality Pollutants in the UK in 2009 (contributing <95% to the emission total)

SO_2	1A1a (40%)	1A2fi (17%)	1A1b (15%)	1A4bi (9%)	1A3dii (3%)	2C1 (2%)	1B1b (2%)	1A2a (2%)	1A5b (2%)	2A7d (2%)	1A4ai (1%)							
NO_x	1A1a (23%)	1A3biii (17%)	1A3bi (12%)	1A2fi (10%)	1A2fii (7%)	1A3bii (5%)	1A1c (4%)	1A4bi (4%)	1A3c (3%)	1A4cii (3%)	1A3dii (3%)	1A5b (2%)	1A1b (2%)					
NH_3	4B1a (23%)	4B1b (18%)	4D1a (13%)	4D2c (10%)	4B13 (8%)	4B9d (7%)	4B8 (6%)	1A3bi (4%)	4B9a (3%)	6B (2%)	6D (2%)	4B3 (1%)						
NMVOC	3D2 (15%)	3D3 (11%)	2D2 (10%)	1A3bi (7%)	1B2ai (6%)	3A2 (5%)	1A4bi (5%)	3A1 (5%)	1B2b (4%)	1B2av (4%)	1B2c (3%)	3B1 (3%)	1B2aiv (3%)	1A2fii, 2B5a, 3D1, 3C (all 2%)	1A3bii, 1A3biii, 1A3biv, 1A3bv, 1A4bii, 1A4cii, 6A (all 1%)			
CO	1A3bi (40%)	1A4bi (13%)	2C1 (10%)	1A2fii (9%)	1A2fi (4%)	1A1a (3%)	1A4bii (3%)	1A3bii (3%)	1A3biv (3%)	1A3biii (1%)	1A4ci (1%)	2C3 (1%)	1A3aii(i) (1%)	1A4cii (1%)	6Ce (1%)	1A1c (1%)		
PM_{10}	1A4bi (14%)	1A3bvi (8%)	1A2fii (6%)	2A7a (6%)	1A1a (5%)	1A3bi (5%)	4B9b (5%)	2C1 (4%)	1A3bvii (4%)	1A2fi (3%)	1A4ci (3%)	6Ce (3%)	1A3bii (3%)	3A2 (3%)	1A4cii (3%)	1A3biii, 7A, 2A7d, 4G, 4B9d, 2G (all 2%)	1A1b, 1A3dii 4B8, 1B2c, 1A5b, 1A4ai (all 1%)	
Pb	2C1 (41%)	1A2fi (18%)	1A4bi (7%)	2B5a (6%)	1A1a (4%)	1B1b (4%)	2C5e (3%)	2C5b (3%)	2C3 (2%)	1A1b (2%)	1A4ai (2%)	1A3bi (2%)	1A2fii (1%)	6Ca (1%)				
Hg	2C1 (23%)	1A1a (18%)	1A2fi (13%)	6Cd (12%)	2B5a (11%)	6Ca (9%)	6A (5%)	1A4bi (2%)	2C5e (2%)									
Cd	2C1 (29%)	1A2fi (10%)	1A3bi (10%)	1A1a (8%)	1A4bi (8%)	1B1b (6%)	2C3 (4%)	1A3biii (4%)	1A2fii (3%)	1A3bii (2%)	1A2a (2%)	2C5e (2%)	2B5a (2%)	1A3dii (2%)	1A4ai (2%)	1A1b (2%)	1A4cii (1%)	1A3bvi (1%)
DIOX	6Ce (25%)	7A (21%)	2C1 (13%)	1A2fi (8%)	1A4ci (7%)	6Cd (5%)	1A1a (3%)	1A4bi (3%)	2C3 (2%)	2C5b (2%)	1A1b (2%)	1A2fii (1%)	6Cb (1%)	6D (1%)				
B[a]P	1A4bi (72%)	7A (9%)	1B1b (3%)	2C3 (3%)	1A3bi (3%)	2C1 (2%)	6Ce (1%)	1A1b (1%)	1A2fii (1%)									
HCB	4 G (71%)	1 A 1 a (27%)																

1.6 QUALITY ASSURANCE AND QUALITY CONTROL VERIFICATION METHODS

1.6.1 Inventory QA/QC activities

The QA/QC activity summarised in this chapter applies for the whole inventory. For sectors where specific QA/QC procedure is carried out in addition to the information provided below, this is included in the sectoral Chapters 3 to 12. To monitor and improve the quality and robustness of the inventory, uncertainty analysis and QA/QC activities are carried out throughout the entire inventory compilation. These activities include:

- **Assessment of uncertainties** in the inventory so that users have an understanding of the limitations of the estimates and can ensure that they are fit for purpose. Uncertainty analysis is also important in prioritising future inventory improvements.
- **Verification** to understand how well the inventory compares with independent measurements such as ambient monitoring. This provides assurances about how likely modelled datasets are likely to reflect real life.
- **Ensuring Transparency** is maintained in the inventory through maintenance of documentation and referencing procedures. Transparency is an important element in ensuring a robust and high quality inventory that will stand up to the rigorous scrutiny of the UNFCCC in country reviews.
- **Maintenance** of QA/QC practices to EMEP/CORINAIR and IPCC guidelines. Including inventory checking and methodology review.

Maintaining the UK inventories high standards of quality underpins the work undertaken in all the other tasks in this project to ensure that the data delivered is state of-the-art and scientifically robust.

1.6.2 QA/QC Procedures and Development

Throughout the inventory compilation process the following QA/QC tasks take place to ensure that the inventory quality is maintained and improved, that the inventory is transparent and consistent internally and with other government statistics and is compliant with international guidelines on QA/QC and good practice.

While the Inventory is being compiled:

1. **The QA/QC plan** clearly outlines the quality assurance and quality control measures and procedures which are implemented. It defines the requirements and procedures for quality checks throughout the lifecycle of the inventory. The plan also ensures that the inventory is transparent and can provide adequate data on basic assumptions and novel analysis to accompany all data provided to Defra and the Devolved Administrations. The transparency is maintained through the development and maintenance of the AEA contacts database that provide:
    - an internal referencing system for all inventory data and data manipulations to promote internal transparency and inventory clarity;
    - unique referencing system that identifies inventory outputs and allows users to differentiate between different inventory versions;
    - a reference database of inventory data sources and data users.

2. **Internal peer review:** The inventory undergoes continual peer review by senior inventory personnel. A small team of reviewers 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.
3. **ISO 9001** AEA has accreditation to this. AEA uses a project management system that meets required and auditable standards and is subject to independent review.
4. **Stakeholder Involvement and data collection / interpretation:** It is extremely important to involve stakeholders in the data collection process. Often those who use the data for a particular purpose have access to useful information that can be used to improve the inventories. Through a programme of stakeholder engagement during the inventory cycle, the inventory team works to ensure that available data are used appropriately within the inventory compilation, for example to ensure that the scope of activity and/or emissions data from data providers are understood and applied accordingly within national inventory. A key example of this is the regular meetings held with the DECC team of energy statisticians, to ensure that any activity data deviations from published UK energy statistics are reviewed and agreed with the UK Government experts. This constitutes a key part of the pre-submission inventory review process that the inventory agency conducts with Defra and DECC.
5. **Inventory Checking:** At key stages in the inventory compilation the inventory and its associated data and methods are reviewed and checked.
6. **Maintain consistency between NAEI and GHGI:** 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 AQ 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.
7. **Comparison with Other Inventories:** Comparing inventories between countries in Europe and North America to identify differences in methodology etc that cannot be explained by economic and industrial developmental differences ensure that the inventory keeps pace with the state-of-the-art in emission inventory methods.
8. **Inventory Recalculations:** The procedures used in the NAEI and GHGI ensure that estimates are always recalculated as needed. Data produced is based on the same common update to the database and consistent with the latest published statistical datasets. This annual revision of the full time-series ensures that the inventory reflects the latest scientific understanding of emission sources, and that a consistent estimation methodology is used across the time-series.

To check and review the inventory after compilation and to identify where improvements are needed:

9. **Key Sectors:** After identifying those sectors that contribute most to the emissions totals and their trends we then target them for more intensive review to ensure the accuracy of the overall inventories.
10. **Peer Review:** Experts from outside the inventory check the data and are able to identify any problems. This is already part of the IPCC review process, and the CLRTAP review process.
11. **Independent checks with other statistics:** AEA perform basic consistency checks between published UK statistics. Some datasets can be used to check inventories and

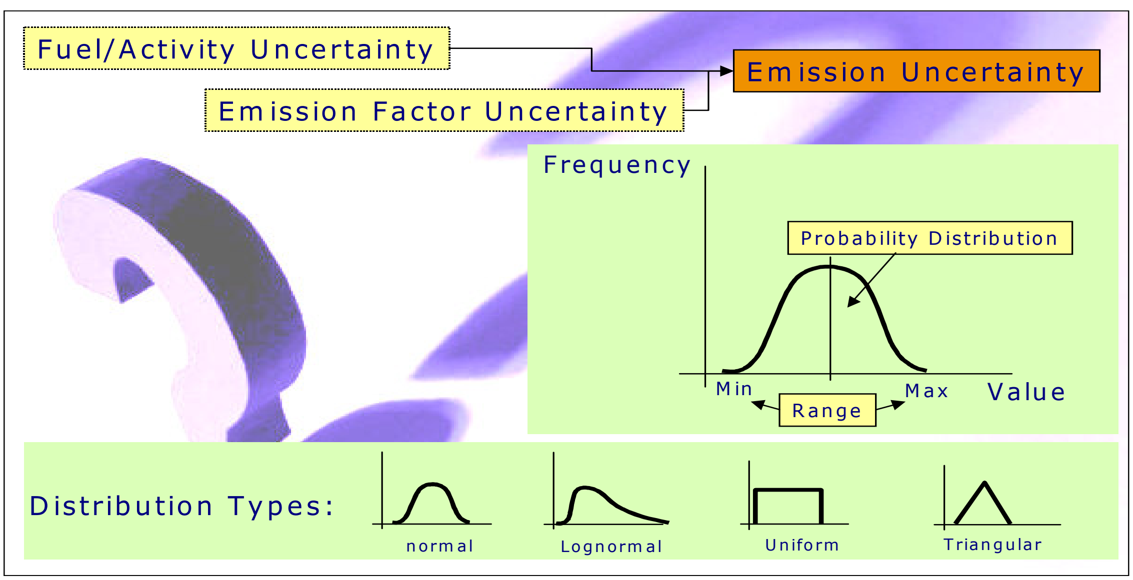
their trends. For example, production-based emission estimates are compared with sales data to check that the trends and values seem reasonable.

12. **Uncertainties:** The UK inventory uncertainty analysis highlights the sources that are significantly contributing to overall uncertainties. The development of sectoral uncertainty estimates requires a good understanding of the methods used to develop the emission factors, and the uncertainties associated with those methods.
13. **Methodology Review:** Each year the methods used (EMEP/CORINAIR, IPCC, National Methods or emission data itself) are reviewed to ensure that the most appropriate method is used. If a method is changed for a particular sector care is taken to apply it, as far as possible, to the entire time series and to ensure that there is no discontinuity in the estimation approach across the time series.
14. **Comparison with AQ measurements:** This work (defined in detail below) identifies where improvements may need to be made to the UK inventory to improve consistency with ambient measurement data.
15. **Continuous Improvement:** Continual review of the data and methodology identifies areas where the inventory can be improved. As statistical data collection changes and more research is performed, new information is considered in the inventory.
16. **New pollutant investigation:** The inventory ensures that it includes all the pollutants of interest.

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 1-6 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 1-6 Illustration of uncertainty assessment techniques



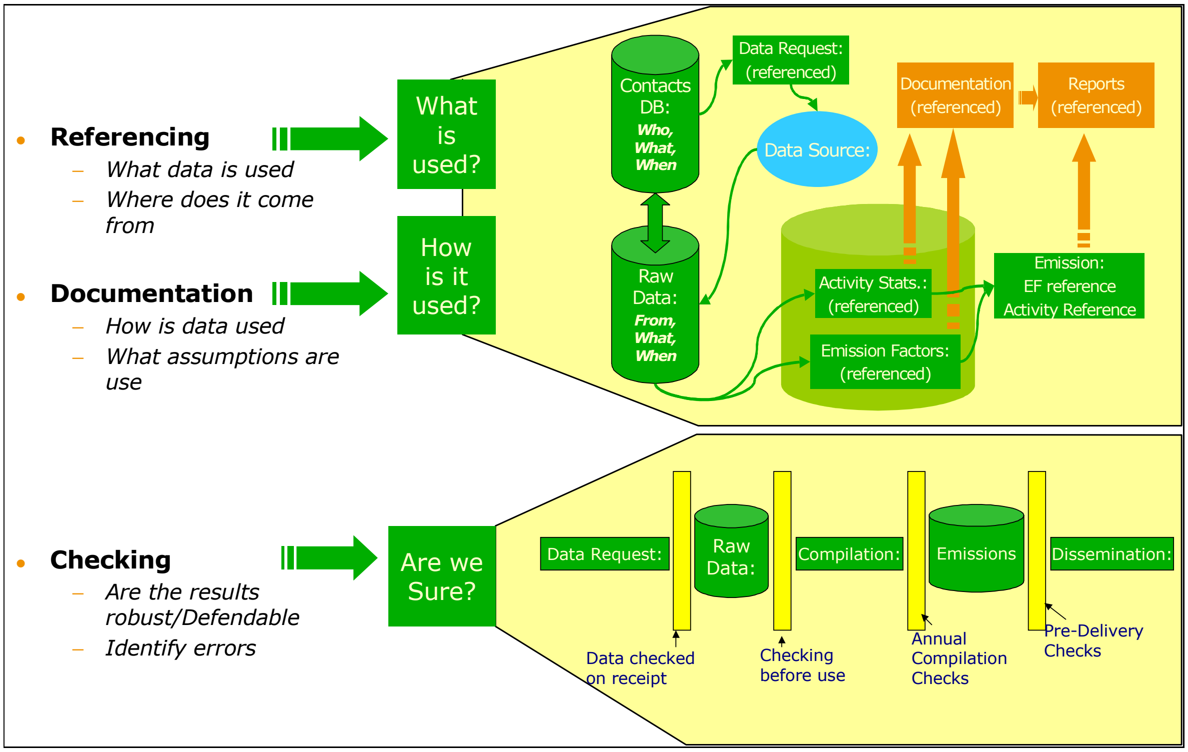
This determines the impact of uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. All analyses are consistent with the IPCC and EMEP/CORINAIR good practice guidance. Uncertainties are assessed for each year's 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 QA/QC development

Figure 1-7 provides an illustration of some of the key QA/QC concepts that are important in inventories, and helps illustrate our approach to controlling and improving quality.

Figure 1-7 Key QA/QC concepts in inventories



The UN/ECE and IPCC have provided detailed information about what is 'good practice' for QA/QC procedures in emission inventories. The QA/QC requirements for pollutants are categorised as Tier 1 and Tier 2. Tier 1 procedures should be applied to the whole inventory at all times. Tier 2 procedures require more effort and it is acceptable that these should be applied to key sources at intervals, though these intervals are unspecified.

The main requirements of Tier 1 are:

- There is an Inventory Agency (currently AEA)
- A QA/QC plan
- A QA/QC Co-ordinator
- Reporting documentation and archiving procedures
- General QC procedures
- Documentation of methodologies and underlying assumptions
- Checks on data transcription
- Checks on calculations
- Database checks
- Review of internal documentation
- Completeness checks

- Compare new estimates with previous estimates.

The current systems used by AEA in preparing the UK emissions inventory essentially comply with the Tier 1 requirements. These include:

1. At the end of each reporting cycle, all the database files, spreadsheets, online manual, electronic source data, paper source data, output files are in effect frozen and archived. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on hard disks that are regularly and automatically backed up. The NAEI and contacts databases are automatically backed up every hour from 07-00 to 20-00. Paper information is archived in a roller racking system and a database of all items in the archive is used.
2. There is an online system of manuals, which defines timetables, procedures for updating the database, document control, checking procedures and procedures for updating the methodology manual.
3. Data received by AEA are logged, numbered and should be traceable back to their source from anywhere in the system.
4. The inventory is held as an Access database of activity data and emission factors. Within the database these data fields are referenced to the data source, or the spreadsheet used to calculate the data. For fuel consumption data, the Table numbers in the Digest of UK Energy Statistics are identified.
5. The database specifically identifies the units of both activity and emission factor data.
6. When revisions are made to the methodologies of the estimates, emissions for all previous years are recalculated as a matter of course.
7. Estimates are made of the uncertainties in the estimates.
8. The final checks on the inventory involve a 'why has this source changed since last year' exercise performed by a designated auditor. Inventory staff are required to explain significant changes in the inventory to satisfy the auditor.

Tier 2 requirements tend to relate to review procedures for particular sources. Tier 2 should be applied to higher tier methodologies and key sources. The areas of emphasis are:

- Appropriateness of emission factors
- Reality checks on emission estimates
- Document QA/QC activities carried out by data providers (e.g. National Statistical Organisations, plant operators)
- Expert Peer Review.

Some of these activities are already carried out, particularly reality checks and the review of appropriateness of emission factors. In practice, there usually is not a great deal of choice of emission factors and methodology and it is usually obvious why a factor should be used.

The emissions inventory programme incorporates a process of external expert peer review, which addresses issues that apply across both GHG and air quality pollutants, including the use of mapped emissions and dispersion models to allow comparisons with measured concentration data.

1.6.5 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 1-8 gives an illustration of the way in which the UK emissions inventory team is organised.

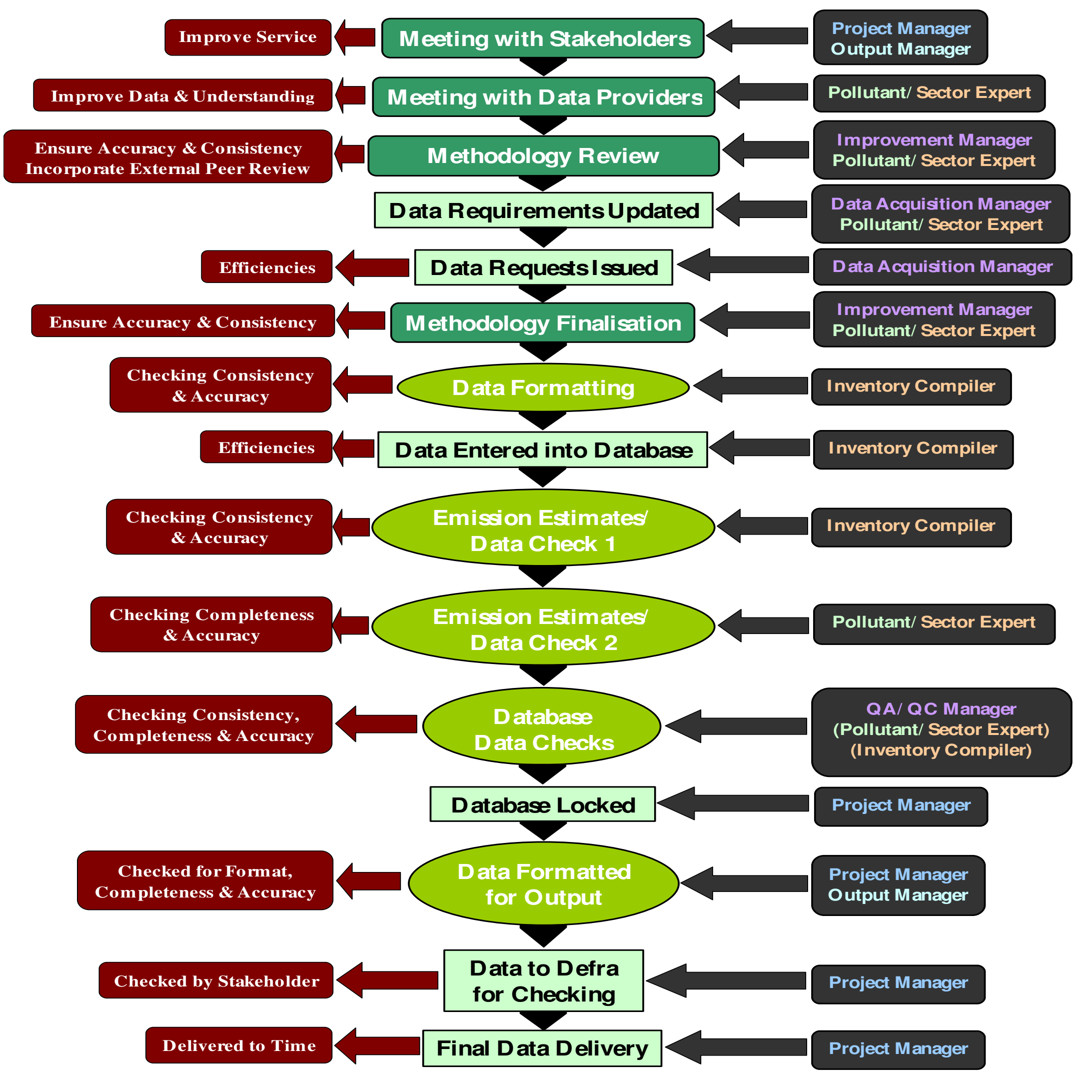
Figure 1-8 Inventory Team Organisation and Responsibilities

This well-defined structure ensures that responsibilities are transparent. The QA/QC related tasks for each of these roles are explained in the following Sections.

1.6.6 Inventory Compilation

Figure 1-9 gives an overview of the data flows in the project. The process is based on the "plan, action, monitor and review" improvement cycle, but has been tailored to encompass the more sophisticated requirements of the project. Whilst elements of the QA/QC process are evident in each step, the tasks which are primarily QA/QC in function are highlighted. Each of the steps is briefly mentioned below with regards to the QA/QC aspects.

Figure 1-9 Data Flows and QA/QC



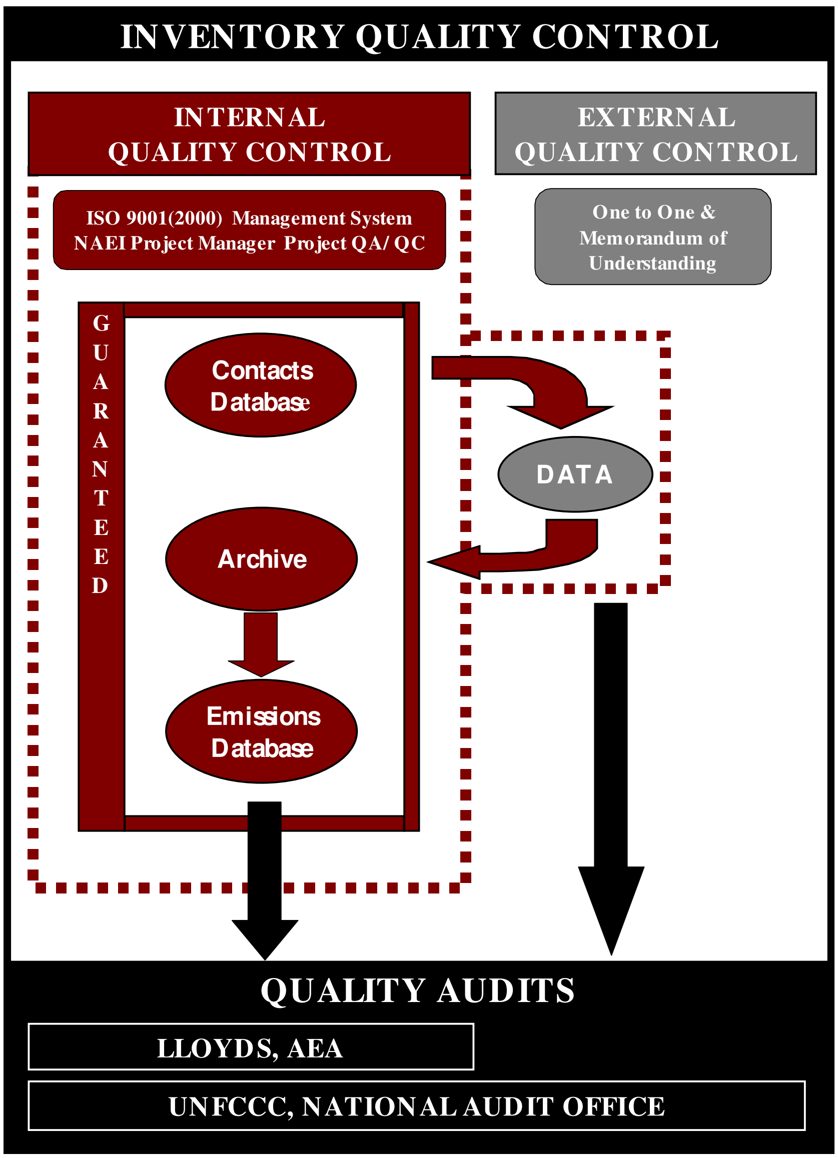
Stages 1 and 2: Input Data Quality

Whilst it is possible to maintain high standards of QA/QC on the processing and systems within the inventory team, the quality of the input data supplied can be variable. The One to

One Programme and the creation of a Memorandum of Understanding for each of the data providers will allow improved understanding of the data, and improved quality control.

Figure 1-10 illustrates how the resulting quality control will thus be extended from inventory team activities to include the input data. The figure also indicates the auditing of the inventory team, processes and data.

Figure 1-10: UK Inventory QA System: Internal and External Quality Control



Stage 3: Spreadsheet Compilation
There are a large number of QA/QC procedures which accompany this stage of the inventory compilation.

Each spreadsheet incorporates a QA sheet which includes key information. This includes information under the following headings:

- **General**
Spreadsheet Reference Number	Spreadsheet Name
NAEI year	Status
Completion Date	Author
Approved by	Approval date
Description of contents	
- **Scope**
Sources	Activities
Pollutants	Years
- **Data Sources**
  A list of the most important reference materials
- **Protocol**
  Indication of the inventory wide colour-coding scheme.
- **Inter-Dependencies**
  Whether (and how) this spreadsheet interacts with other spreadsheets.

There is also other sheet specific information, including a version log, results of QA/QC checks etc.

These spreadsheets vary considerably in their level of complexity. However the completion procedure is the same for all sheets:

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.

First, the QA sheet is interrogated to establish that the status of the sheet is finalised and has been checked. The dates are also checked to establish that they are relatively recent.

The database then automatically uploads all output data from the spreadsheet. The captured data is compared with a listing of the data, which should be received from the relevant spreadsheet. The database then indicates where data was not present in the sheet, or where additional data has been found.

These systems ensure that the data, which is loaded from the spreadsheets into the database, is complete, and has been checked to the QA/QC standards as specified in the programme.

There are then additional checks on the data in the database. These perform different functions:

- **Completeness Checks**- the database is checked for completeness and consistency of entry across the different pollutants. For example, combustion sources are checked for inclusion of all relevant pollutants.
- **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.
- **Time series Checks**- Time series of emissions are checked for step changes. Any unusual features are checked and explained.
- **Sector Checks**- All sources are checked to ensure correct allocation into the SNAP, NFR and CRF categories.
- **Unit Checks**- Units of each emission are taken from the data in the compilation spreadsheets, but these are also checked.

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 submission, a degree of automation has been incorporated into populating the NFR templates. This includes some cross-checks with sectoral data from the database.

The completed templates are cross-matched with data taken directly from the database. This ensures that the national totals agree with previously established data, and that the memo items are correctly reported.

The CLRTAP dataset (in a user-friendly summary format) are passed to the UK Government for clearing. Only after this is the data released, and uploaded to the EIONET.

1.6.7 External Peer Review

There is a team of experts who sit outside of the core inventory team (see Figure 1-8), but who 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.

1.6.8 Continuous Improvements

Continuous improvement of the inventory is delivered through a programme of review of inventory data followed by a programme of targeted research. This is possible through maintaining an on-going “live” list of comments, improvements and problems that the inventory team find at any time of the inventory cycle.

In addition, there is a broader programme of activities, which contribute to the identification of improvement options:

- Attendance at technical national and international workshops, conferences and meetings such as the TFEIP/EIONET.
- Ongoing data collection and inventory compilation.
- Ongoing stakeholder consultation.
- Assessment of results from the annual uncertainty assessments.
- Recommendations from external and internal review.
- Inconsistencies identified in verification work.

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

A briefing note identifying inventory improvement research projects is compiled and prioritised in consultation with the Department. The work outlined in the briefing note is not restricted to that which could feasibly be undertaken as part of the core inventory improvement work. It includes complex, technical research programmes involving in-depth investigation of individual sources (for example through in-situ measurements) that would need different project teams and alternative funding.

AEA have a programme of research that includes the following:

- 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.
- Improvement of the methodology for PM_{10} emissions from processes regulated under LAPC, currently based on use of emission factors developed in the mid 1990s and expressed in terms of emission per process.
- Periodic review of emission factors for small combustion plant, particularly for pollutants such as NO_x, CO, PM_{10} & POPs.
- 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.

EMEP/CORINAIR and the IPCC describe a minimum acceptable level of QA/QC and the UK emissions inventory team aim to exceed these baseline requirements. The QA/QC activities also provide a framework for the identification of cost-effective developments and improvements to the inventories that are undertaken as part of the annual inventory activities.

1.7 UNCERTAINTY EVALUATION

Evaluation of uncertainty is carried out by a Monte-Carlo uncertainty assessment and is detailed 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 UN/ECE Taskforce on Emission Inventories. This work is described in more detail by Passant (Passant NR (2002b)). Uncertainty estimates are shown in Table 1-6. These estimated uncertainties are one of the indicators used to derive where improvements are required in the NAEI.

Table 1-6 Uncertainty of the Emission Inventories for pollutants covered under the NAEI (excluding GHGs)

Pollutant	Estimated Uncertainty %
Carbon monoxide	-20 to +30
Benzene	-30 to + 50
1,3-butadiene	-20 to +40
PM_{10}	-20 to +30
$PM_{2.5}$	-20 to +30
$PM_{1.0}$	-20 to +30
$PM_{0.1}$	-20 to +30
Black smoke	-30 to +50
Sulphur dioxide	+/- 4
Nitrogen oxides	+/- 10
Non-Methane Volatile Organic Compounds	-9 to +10
Ammonia	+/- 20
Hydrogen Chloride	+/- 20
Hydrogen Fluoride[a]	+/- 20
Arsenic	-60 to +200
Cadmium	-20 to +50
Chromium	-30 to +70
Copper	-40 to +80
Lead	-30 to +50
Mercury	-30 to +40
Nickel	-30 to +50
Selenium	-20 to +30
Vanadium	-20 to +30
Zinc	-30 to +60
Beryllium	-40 to +80
Manganese	-30 to +40
Benzo[a]pyrene	-60 to +200
PCDD/PCDF	-50 to +200
Polychlorinated biphenyls	-40 to + 90
Pentachlorophenol	-80 to +200
Hexachlorocyclohexane	-100 to +400
Hexachlorobenzene	-40 to + 90
Short-chain chlorinated paraffins	-90 to +1000
Pentabromodiphenyl ether	-90 to +1000
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 sources dominate the inventory and there is limited potential for error compensation.

1.7.2 Carbon monoxide

Carbon monoxide emissions occur almost exclusively from combustion of fuels, particularly by road transport. Emission estimates for road transport are highly uncertain, due to the relatively small number of emission measurements made and the highly variable results. 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 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 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 widely 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 emission sources with many of similar size and with none dominating (the largest source category contributes just 23% of emissions, and a further 12 sources must be included to cover 95% of the emission). This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector. The other extreme is shown by the inventories for PCP, HCH and HCB where one or two sources dominate and the inventories are highly uncertain.

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. As with NO_x, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

1.7.5 Particulate Matter Estimates

The emission inventory for PM_{10} underwent considerable revision over the last few years of the NAEI and is now to be considered significantly more robust. 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 the size distribution of particle emissions from the different sources.

Emission factors are generally based on a few measurements on an 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 has been 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 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, while it is currently the only one available, 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 as there are additional uncertainties in the size fractions and their applicability 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 and these sources emit very little of the finer particles, road transport dominating instead.

Estimates for total suspended particles (TSP) have been calculated for the first time in the 2011 UK Inventory by applying scaling factors to the PM_{10} emissions. The scaling factors are based on the US EPA factors (US EPA (2007).

1.7.6 Sulphur Dioxide

Sulphur dioxide emissions can be estimated with most confidence as they depend largely on the level of sulphur in fuels. Hence the inventory, being 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 and vanadium are currently judged as least uncertain, followed by the inventories for cadmium, mercury, nickel, lead, manganese and zinc. Those for chromium, arsenic, copper, beryllium and tin are 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 complexity of dealing with POPs as families of congeners (PCDD/PCDF, PCBs). The issue is further exacerbated by a lack of good activity data for some important sources. The inventory for polychlorinated biphenyls is less uncertain than those for other persistent organic pollutants. However the overall uncertainty is still high.

The uncertainty of HCB has continued to improve this year due to the disaggregation of pesticides emissions to air, land and water; and new data to provide more accurate estimates of working concentrations for HCB in pesticides. The uncertainty range for HCB has now been brought into the same range as the poly-chlorinated biphenyls.

1.8 ASSESSMENT OF COMPLETENESS

1.8.1 Not Estimated

Recent comparison of air concentrations with modelling of emission sources has suggested that some fugitive sources of metals may be significant but aren't included in emission inventories. The UK will be investigating whether it is possible to estimate emissions of these sources, although currently our understanding is that no country includes these sources in their emission estimates.

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 2011 CLRTAP submission[8].

1.8.3 Other Notation Keys

"NA" (not applicable), "NE" (Not estimated), "NO" (not occurring) notation keys are used where considered appropriate.

[8] http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envtvpebw

2. Explanation of Key Trends

2.1 UK EMISSION TRENDS FOR KEY SOURCES

This section discusses the key sources of selected pollutants (NO_x, SO_2, NMVOC, NH_3, PM_{10}, CO) and where there have been significant changes in emissions between 1980 and 2009. Further information and analysis on the emission trends of all pollutants reported under the CLRTAP are available on the NAEI website together with the 2009 emission maps for key pollutants.

2.1.1 Power Generation

Power generation is a key source of emissions for CO, NO_x, PM_{10} and SO_2 during 1980 and it remains so during 2009. However, there has been significant reduction in emissions between 1980 and 2009 (see Table 2-1).

Table 2-1 Power Station Emissions: Inventory Significance and Trends, 1980 to 2009

Pollutant	NFR Code	% of total emissions in 2009	% Change from 1980 to 2009
SO_2	1A1a	40%	-95%
NO_x	1A1a	23%	-71%
CO	1A1a	3%	-42%
PM_{10}	1A1a	5%	-92%

Prior to 1989, the decline was mainly due to the increased use of nuclear plant and improvement in efficiency. 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 (see Figure 2-1 and Figure 2-2).

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, which 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 data 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 Large Combustion Plant Directive leading to flue gas desulphurisation being fitted at more sites.

Figure 2-1 Sulphur Dioxide (SO_2) Emissions from Key Source Categories, 1980 to 2009

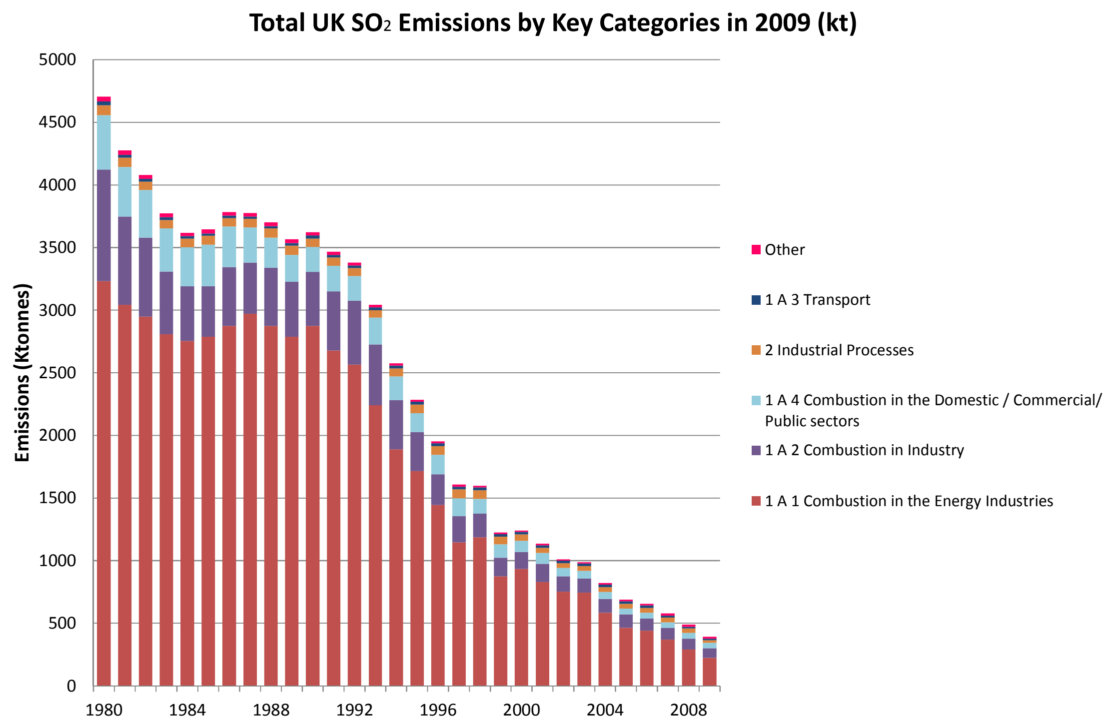


Figure 2-2 PM_{10} Emissions from Key Source Categories, 1980 to 2009

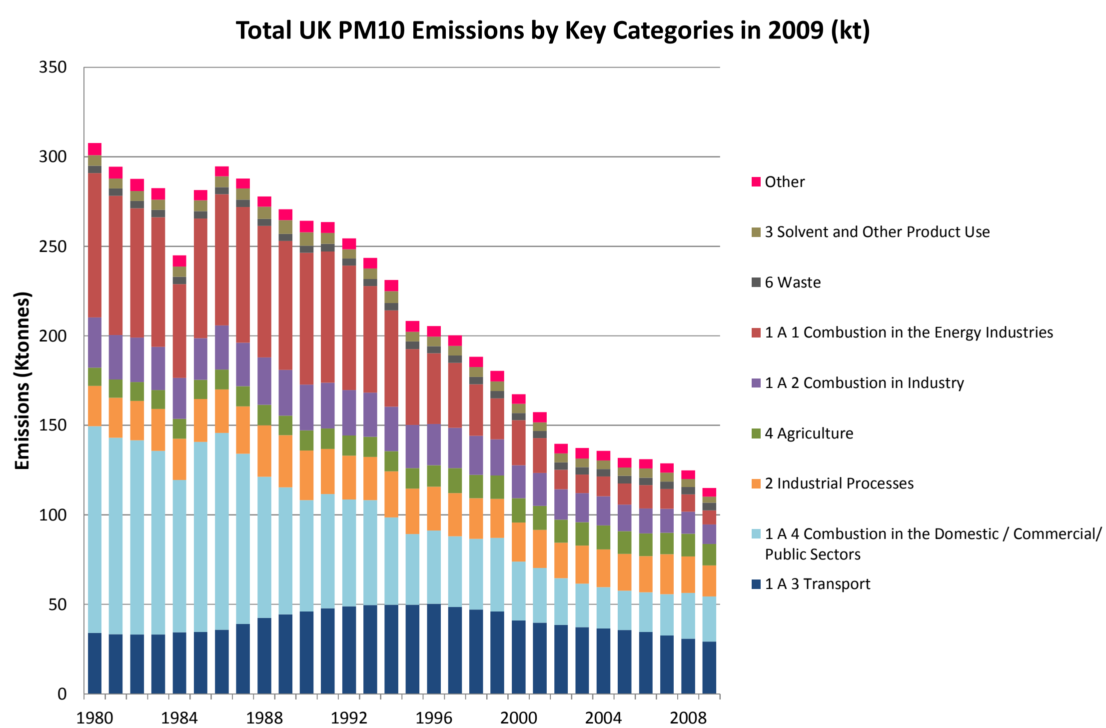
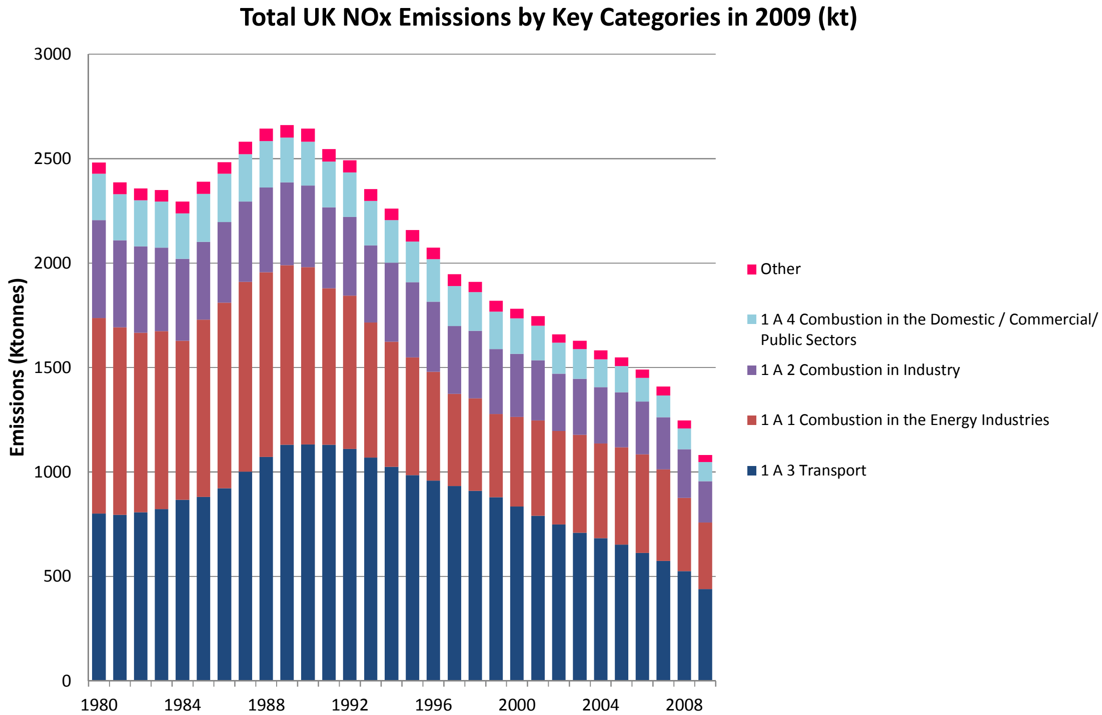


Figure 2-3 NO_x Emissions from Key Source Categories, 1980 to 2009



2.1.2 Domestic and Commercial Sectors

Domestic combustion is a key source of CO, NO_x, NMVOC, PM_{10} and SO_2 emissions during 2009 (see Table 2-2). There have been reductions in emissions of the above pollutants from this sector, mainly because of a decline in the use of solid fuels in favour of gas and electricity. Domestic 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. Between 1980 and 2009, PM_{10} emissions from domestic and commercial and institutional combustion (1A4ai and 1A4bi) have fallen by 83%. Similarly, fuel switching from coal to gas and electricity has reduced emissions from commercial combustion. This trend cannot be seen in the NO_x emissions due to the increased use in gas combustion in this sector where emission reductions have been less steep.

Table 2-2 Residential Emissions: Inventory Significance and Trends, 1980 to 2009

Pollutant	NFR Code	% of total emissions in 2009	% Change from 1980 to 2009
SO_2	1A4bi	9%	-84%
NO_x	1A4bi	4%	-61%
CO	1A4bi	13%	-85%
PM_{10}	1A4bi	14%	-83%
NMVOC	1A4bi	5%	-72%

2.1.3 Industrial Processes

The food and drink industry (2D2) and the chemical industry (2B5a) are two of the key source categories for NMVOC emissions during 2009 (see Table 2-3). Emissions from the food and drink industry comprised 10% of the total NMVOC emission in 2009. 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 this year. The trends with time are primarily driven by production in these sectors. 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 2009 is 86%. The chemical industry is a key source category of Pb, Hg and Cd contributing to 6%, 11% and 2% of the emissions respectively. For other pollutants, the two industries are not key source categories.

Table 2-3 Industrial Process Emissions: Inventory Significance and Trends, 1980 to 2009

Pollutant	NFR Code	% of total emissions in 2009	% Change from 1980 to 2009
NMVOC	2D2	10%	-0.2%
NMVOC	2B5a	2%	-86%
Pb	2B5a	6%	-96%
Hg	2B5a	11%	-92%
Cd	2B5a	2%	-91%

2.1.4 Transport

Transport is a key source of CO, NH_3, NMVOC, NO_x, PM_{10} and SO_2 emissions in the UK (see Table 2-4).

Table 2-4 Road Transport Emissions: Inventory Significance and Trends, 1980 to 2009

Pollutant	NFR Code	% of total emissions in 2009	% Change from 1980 to 2009
SO_2	1A3dii	3%	-57%
NO_x	1A3biii	17%	-35%
NO_x	1A3bi	12%	-69%
NO_x	1A3bii	5%	-12%
NO_x	1A3c	3%	196%
NO_x	1A3dii	3%	-25%
CO	1A3bi	40%	-76%
CO	1A3bii	3%	-88%
CO	1A3biv	3%	-62%
CO	1A3biii	1%	-51%
CO	1A3aii(i)	1%	-51%
PM_{10}	1A3bvi	8%	65%
PM_{10}	1A3bi	5%	50%
PM_{10}	1A3bvii	4%	69%
PM_{10}	1A3bii	3%	59%
PM_{10}	1A3biii	2%	-80%
PM_{10}	1A3dii	1%	-63%
NMVOC	1A3bi	7%	-85%
NMVOC	1A3bv	1%	-96%
NMVOC	1A3bii	1%	-86%
NMVOC	1A3biii	1%	-77%

Pollutant	NFR Code	% of total emissions in 2009	% Change from 1980 to 2009
NMVOC	1A3biv	1%	-77%
NH_3	1A3bi	4%	2413%

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 has 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.

2.1.5 Agriculture

Agricultural sources with emissions from livestock and their wastes (NFR 4B) are the major source of NH_3 emissions, contributing 66% of total emissions in 2009. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. NH_3 emissions 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 is a decline in fertiliser use, which also caused a decrease in emissions. Total NH_3 emissions in 2009 represent a decrease of 36% 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 2.2% 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.

2.1.6 Waste

Emissions of NO_x, CO and SO_2 from the waste category have a negligible effect on overall UK emissions. Emissions of NMVOC from solid waste disposal on land i.e. landfill (6A) contribute approximately 1% of total emissions.

A summary table of all the key sources and their contributions to overall pollutant emissions is provided in Table 2-5 below.

Table 2-5 UK Inventory Key Sources: 2009 Significance and Trends, 1980-2009

Pollutant	Key sources during 2009	NFR Name	% of total emissions in 2009	% Change from 1980 to 2009
SO_2	1A1a	1 A 1 a Public Electricity and Heat Production	40%	-95%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	17%	-92%
	1A1b	1 A 1 b Petroleum refining	15%	-70%
	1A4bi	1 A 4 b i Residential plants	9%	-84%
	1A3dii	1 A 3 d ii National Navigation	3%	-57%
	2C1	2 C 1 Iron and steel production	2%	-7%
	1B1b	1 B 1 b Solid fuel transformation	2%	-74%
	1A2a	1 A 2 a Iron and Steel	2%	-90%
	1A5b	1 A 5 b Other, Mobile (Including military)	2%	11%
	2A7d	2 A 7 d Other Mineral products (Please specify the sources included/excluded in the notes column to the right)	2%	-41%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1%	-97%
	Overall change for all sources			**-92%**
NO_x	1A1a	1 A 1 a Public Electricity and Heat Production	23%	-71%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	17%	-35%
	1A3bi	1 A 3 b i R.T., Passenger cars	12%	-69%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	10%	-68%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	7%	-19%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	5%	-12%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	4%	33%
	1A4bi	1 A 4 b i Residential plants	4%	-61%
	1A3c	1 A 3 c Railways	3%	196%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	3%	-55%
	1A3dii	1 A 3 d ii National Navigation	3%	-25%
	1A5b	1 A 5 b Other, Mobile (Including military)	2%	-35%
	1A1b	1 A 1 b Petroleum refining	2%	-42%
	Overall change for all sources			**-57%**
CO	1A3bi	1 A 3 b i R.T., Passenger cars	40%	-76%
	1A4bi	1 A 4 b i Residential plants	13%	-85%
	2C1	2 C 1 Iron and steel production	10%	-6%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	9%	17%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	4%	-38%
	1A1a	1 A 1 a Public Electricity and Heat Production	3%	-42%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	3%	6%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	3%	-88%

Pollutant	Key sources during 2009	NFR Name	% of total emissions in 2009	% Change from 1980 to 2009
CO continued	1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	3%	-62%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	1%	-51%
	1A4ci	1 A 4 c i Stationary	1%	83%
	2C3	2 C 3 Aluminium production	1%	-1%
	1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	1%	-51%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-16%
	6Ce	6 C e Small scale waste burning	1%	0%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1%	48%
	Overall change for all sources			**-73%**
PM_{10}	1A4bi	1 A 4 b i Residential plants	14%	-83%
	1A3bvi	1 A 3 b vi R.T., Automobile tyre and brake wear	8%	65%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	6%	-29%
	2A7a	2 A 7 a Quarrying and mining of minerals other than coal	6%	-32%
	1A1a	1 A 1 a Public Electricity and Heat Production	5%	-92%
	1A3bi	1 A 3 b i R.T., Passenger cars	5%	50%
	4B9b	4 B 9 b Broilers	5%	72%
	2C1	2 C 1 Iron and steel production	4%	46%
	1A3bvii	1 A 3 b vii R.T., Automobile road abrasion	4%	69%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	3%	-78%
	1A4ci	1 A 4 c i Stationary	3%	62%
	6Ce	6 C e Small scale waste burning	3%	0%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	3%	59%
	3A2	3 A 2 Industrial coating application	3%	-40%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	3%	-60%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	2%	-80%
	7A	7 A Other (included in national total for entire territory)	2%	-6%
	2A7d	2 A 7 d Other Mineral products (Please specify the sources included/excluded in the notes column to the right)	2%	-36%
	4G	4 G OTHER (d)	2%	13%
	4B9d	4 B 9 d Other poultry	2%	2%
	2G	2 G OTHER (Please specify in a covering note)	2%	-14%
	1A1b	1 A 1 b Petroleum refining	1%	-67%
	1A3dii	1 A 3 d ii National Navigation	1%	-63%
	4B8	4 B 8 Swine	1%	-40%
	1B2c	1 B 2 c Venting and flaring	1%	-59%
	1A5b	1 A 5 b Other, Mobile (Including military)	1%	-17%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1%	-83%
	Overall change for all sources			**-64%**
NMVOC	3D2	3 D 2 Domestic solvent use including fungicides	15%	58%
	3D3	3 D 3 Other product use	11%	-34%
	2D2	2 D 2 Food and Drink	10%	0%
	1A3bi	1 A 3 b i R.T., Passenger cars	7%	-85%

Pollutant	Key sources during 2009	NFR Name	% of total emissions in 2009	% Change from 1980 to 2009
NMVOC continued	1B2ai	1 B 2 a i Exploration Production, Transport	6%	-53%
	3A2	3 A 2 Industrial coating application	5%	-64%
	1A4bi	1 A 4 b i Residential plants	5%	-72%
	3A1	3 A 1 Decorative coating application	5%	-27%
	1B2b	1 B 2 b Natural gas	4%	-1%
	1B2av	1 B 2 a v Distribution of oil products	4%	-56%
	1B2c	1 B 2 c Venting and flaring	3%	-45%
	3B1	3 B 1 Degreasing	3%	-72%
	1B2aiv	1 B 2 a iv Refining / Storage	3%	-75%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	2%	3%
	2B5a	2 B 5 a Other chemical industry (Please specify the sources included/excluded in the notes column to the right)	2%	-86%
	3D1	3 D 1 Printing	2%	-57%
	3C	3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	2%	-76%
	1A3bv	1 A 3 b v R.T., Gasoline evaporation	1%	-96%
	6A	6 A SOLID WASTE DISPOSAL ON LAND	1%	-63%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	1%	-86%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	1%	-52%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-43%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	1%	-77%
	1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	1%	-77%
	Overall change for all sources			**-63%**
NH_3	4B1a	4 B 1 a Dairy	23%	-18%
	4B1b	4 B 1 b Non-Dairy	18%	-21%
	4D1a	4 D 1 a Synthetic N-fertilizers	13%	-36%
	4D2c	N-excretion on pasture range and paddock unspecified (Please specify the sources included/excluded in the notes column to the right)	10%	7%
	4B13	4 B 13 Other	8%	4%
	4B9d	4 B 9 d Other poultry	7%	-3%
	4B8	4 B 8 Swine	6%	-51%
	1A3bi	1 A 3 b i R.T., Passenger cars	4%	2413%
	4B9a	4 B 9 a Laying hens	3%	-57%
	6B	6 B WASTE-WATER HANDLING	2%	1%
	6D	6 D OTHER WASTE (f)	2%	318%
	4B3	4 B 3 Sheep	1%	-1%
	Overall change for all sources			**-21%**

3. NFR 1A1: Combustion in the Energy Industries

Table 3-1 Mapping of NFR Source Categories to NAEI Source Categories: Stationary Combustion

NFR Category (1A1)	Pollutant coverage	NAEI Source category	Source of EFs
1 A 1 a Public Electricity and Heat Production	All CLRTAP pollutants *(except HCH)*	Power stations	Operator reporting under IPPC and EEMS, trade association information
1 A 1 b Petroleum refining	All CLRTAP pollutants *(except NH_3, HCB, HCH and PCBs)*	Refineries - combustion	
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	All CLRTAP pollutants *(except HCB and HCH)*	Coke production	
		Collieries - combustion	
		Gas production	
		Gas Production - combustion at gas separation plant	
		Gas Production - gas combustion	
		Nuclear fuel production	
		Oil Production - gas combustion	
		Solid smokeless fuel production	
		Town gas manufacture	
1A3e Pipeline Compressors	All CLRTAP pollutants *(except POPs and PAHs)*	Included under 1A1c - Gas Production	

3.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

The NAEI utilises official UK energy statistics published annually in the Digest of UK Energy Statistics (DECC, 2010), hereafter abbreviated to DUKES. 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. 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 (Nomenclature for Reporting) 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 3-2 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 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 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	
	Waste Oil/ Lubricants	Not identified separately in DUKES.
	Waste Solvents	Not identified separately in DUKES.

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 is available from www.environment-agency.gov.uk, and SPRI data can be viewed at http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx. The ISR is not available online but is supplied directly by the Northern Ireland Environment Agency (NIEA). The reported emissions for each pollutant are available as totals 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.). In some cases, it is therefore necessary to split the reported emissions data by fuel and/or sub-source, and direct consultation with site operators and trade associations is conducted to achieve this more detailed source-specific reporting. 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.

Emissions of some pollutants are estimated using literature emission factors and activity data from DUKES. This is necessary where comprehensive sector emissions are not reported by plant operators, or where the reported data are considered less reliable than use of literature factors.

The following sections give more details of the methodology. Detailed emission factors are available at http://naei.org.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 is 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 is 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'. Overall consistency between NAEI and

DUKES is maintained by reducing the NAEI estimate for fuel oil consumed by the industrial sector.

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). AEA include estimates of petroleum coke burnt by power stations (based on data from industry sources and the EUETS).

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 38 Mtonnes of coal were burnt at 17 power stations during 2009, while approximately 11,100 Mtherms of natural gas were consumed at 41 large power stations and 10 small (<50MWth) regional stations (almost all gas plant are Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at three large facilities, and gas oil or burning oil was used by 4 large and 9 small power stations.

One of the gas-fired power station burns sour gas as well as natural gas, and some coal-fired power stations have trialled use of petroleum coke. In the past, UK power stations have also burnt scrap tyres, orimulsion, and coal slurry, but none currently do 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, yet another burns wood, whilst many coal-fired power stations have increased the use of biofuels such as short-rotation coppice to supplement the use of fossil fuels.

Electricity is also generated at 20 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 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration). The reporting of emissions under 1A4 will be revised for the next version of the inventory since these emissions should also be reported under 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. There is also an EfW plant on the Isle of Man, a very small waste incinerator on the Isle of Scilly, and a much larger waste incinerator on Jersey. The latter is being replaced with an EfW plant which should start operation in 2011. Currently, emissions from the two waste incinerators are also reported under 1A1 and 1A4, rather than 6C but this will be revised for the next version of the inventory.

Landfill gas and sewage gas are also burnt to generate electricity. In 2009, there were at least 390 sites utilising landfill gas and 134 sites utilising 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:

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

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 from power stations burning straw and poultry litter and emissions from the burning of wood and liquid biofuels are estimated using reported emissions data from plant operators. In the case of the single straw-burning plant, all reported emissions are currently allocated to the straw. However, this plant will burn fossil fuel as support fuel and so emissions would be better treated in the same way as for other power stations, with emissions shared between all fuels burnt at the plant. This will be done for the next version of the inventory.

In the case of power stations burning gas oil, burning oil and poultry litter, most of the sites are relatively small plant and emissions of many pollutants are below the reporting thresholds for the PI, SPRI & ISR. This means that the emission factors generated for the inventory can be based on very limited data and may, as a result, be highly variable across the time series. Although this does not lead to significant variation in the total UK emission due to the small-scale of these plants, it is nevertheless an issue that will be reviewed for the next version of the inventory.

Emissions data are available back to 1988 in the case of NO_x and SO_2. 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.

An exception to the use of UK-derived factors is that emissions from landfill gas and sewage gas engines are estimated using literature emission factors from AP-42 (US EPA, 2008). Some such 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 includes 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.

Table 3-3 UK Power Generation Emission Estimation Methodology by Pollutant, 1970-2009

Fuels	Pollutant	Methodology
Coal & fuel oil (including use of Orimulsion and petroleum coke and co-firing of biomass)	NO_x	1990-2009: O 1989: O/M 1970-1988: L
	SO_2	1990-2009: O 1988-1989: O/M 1970-1987: F
	HCl (coal only)	1993-2009: O 1992: O/M 1970-1991: E
	Pb	1997-2009: O 1990-1996: O/M 1970-1989: E
	CO, VOC, other metals, PM_{10}, HF	1997-2009: O 1993-1996: O/M 1970-1992: E
Sour gas	NO_x, SO_2	1992:2009: O 1970-1991: not occurring
	CO	1997:2009: O 1992-1996: L 1970-1991: not occurring
	VOC, PM10	1997:2009: O 1992-1996: O/M 1970-1991: not occurring
Coal slurry	NO_x, SO_2	1994:2009: O 1970-1993: not estimated separately, included with estimates for coal
	CO, VOC, HCl, metals, PM_{10}	1994:2009: O 1994-1996: O/M 1970-1993: not estimated separately, included with estimates for coal
Natural gas	NO_x	1997-2009: O 1992-1996: O/M 1970-1991: E
	SO_2	1997-2009: O 1993-1996: O/M 1970-1992: not estimated
	CO	1997-2009: O 1993-1996: O/M 1970-1992: E
	VOC, Hg, PM_{10}	1997-2009: O 1996: O/M 1970-1995: E
Gas oil	NO_x	1997-2009: O 1994-1996: O/M 1970-1993: L
	SO_2	1997-2009: O 1994-1996: O/M 1970-1993: F
	CO	1997-2009: O 1996: O/M 1970-1995: L
	VOC, metals, PM_{10}	1997-2009: O 1970-1996: L
Poultry litter	All	1997-2009: O 1992-1996: O/M 1970-1991: not occurring

Fuels	Pollutant	Methodology
Straw	All	2000-2009: O 1970-1999: not occurring
Landfill/sewage gas	All	1970-2009: 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, Pb, B[a]P and PCDD/PCDF.

The UK has 12 oil refineries, three of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining nine complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke. The crude oils processed, refining techniques, and 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, the Scottish Pollutant Release Inventory, or Northern Ireland's Inventory of Sources and Releases. 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, 2010). These split the emissions for the nine complex refineries into those from large combustion plant (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:

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

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, 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.

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, SPRI, and ISR is limited and/or highly variable, and therefore emissions are calculated from literature emission factors and activity statistics.

3.6 METHODOLOGY FOR OTHER ENERGY INDUSTRIES (NFR 1A1C)

NFR Sector 1A1c is a key source for NO_x and CO.

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2009, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last six 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 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.

Table 3-4 UK Coke Ovens and SSF Manufacturing Plant in Operation, 1970-2009

Process type	Period	No of plant
Coke ovens	2004-2009	6
	2003	7
	1993-2002	9
	1991-1992	10
	1970-1990	No data
Solid smokeless fuel manufacture	2006-2009	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, the Scottish Pollutant Release Inventory, or Northern Ireland's Inventory of Sources and Releases. Emission estimates for the sector can be based on the emission data reported for individual sites:

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

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 actual emissions data on which to base a split and so all 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, with only CO, NO_x and PM_{10} reported on a regular basis. The reported emissions for these fuels 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.

Use of natural gas by the oil and gas industry is split into offshore oil and gas extraction and onshore use. Emissions from offshore use are reported to the Environmental Emissions Monitoring System maintained by the UK offshore industry. These emissions data are used directly in the NAEI. Emissions from onshore use of natural gas are estimated using literature emission factors because the gas is used in a range of plant both large and small, and a bottom-up approach is not possible.

Other emission sources reported under 1A1c are relatively trivial and are not discussed further.

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.

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	Source of EFs
1 A 2 a Iron and Steel	All CLRTAP pollutants *(except HCB and HCH)*	Blast furnaces	UK factors
		Iron and steel - combustion plant	
1 A 2 b Non-ferrous metals			Included in 1 A 2 f Other Industrial Combustion
1 A 2 c Chemicals			
1 A 2 d Pulp, Paper and Print			
1 A 2 e Food processing, beverages and tobacco			
1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	All CLRTAP pollutants *(except HCH)*	Ammonia production - combustion	UK factors & Operator reporting under IPPC
		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	

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. 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 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.

- Differences in scope of NAEI and NFR categories mainly affect NFR sector 1A2 (Industrial Combustion). The NAEI groups almost all industrial combustion together in a single source "Other industrial combustion" due to a lack of detailed energy statistics across the entire NAEI time series. This NAEI category is mapped to 1A2f, but the source also contains emissions that would be more correctly reported under 1A2b, 1A2c, 1A2d, and 1A2e. In addition, NAEI source categories mapped to 1A2f include two categories which are used for reporting both combustion and process-related emissions, with process-related emissions generally being a significant source. These are 'Cement - non-decarbonising' and 'Lime production - non decarbonising', used to report emissions from cement clinker production and lime kilns respectively.

In these cases, it is not possible to separately report emissions from combustion and processes and so mapping of the NAEI source categories to NFR 1A2 is justified.

A number of emission sources reported under 1A2a would more correctly be reported under 2C1. The allocation and reporting of emissions from these sources will be reviewed in the next inventory cycle. Note also that within the UK there are many thousand small-scale combustion sources, the emissions from which should be reported under 1A2f, but the precise number of industrial combustion processes is not known.

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 1A2A AND 1A2F

NFR Sector 1A2a is a key source for SO_2 and Cd, while 1A2fi is a key source for NO_x, SO_2, CO, PM_{10}, Cd, Pb, Hg and PCDD/PCDF.

Emissions are 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 plant 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 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 British Cement Association (BCA, 2010), and area also available from the EUETS, which also 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. AEA 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 consumed within the sectors listed above.
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 AEA for inclusion in the NAEI. Use of chemical industry wastes is included in the UK Greenhouse Gas Inventory (GHGI) but emissions of non-greenhouse gases have not been included to date. Further development of this area of the inventory may be considered in future.

4.4 METHODOLOGY FOR CEMENT & LIME KILNS

The UK had 13 sites producing cement clinker during 2009, following the closure of 2 sites during the previous year. 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 2009. 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.

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

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

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, 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.

Individual cement works burn a variety of fuels, and emissions of many pollutants will also be emitted from process sources as well. Therefore all emissions are reported using a single, non-fuel specific source category. All lime kilns are thought to use a single fuel, so reported emissions of CO and NO_x are allocated to the fuel burnt at each facility. PM_{10} is also emitted from process sources so this pollutant is reported using a non-fuel specific source category.

4.5 METHODOLOGY FOR BLAST FURNACES

Emissions data for the period 2000-2009 are supplied by the process operator (Corus, 2010). 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. 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, 2010); 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.

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. 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

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

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

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.

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 carbon monoxide, 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 (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, 2007), the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007) and UK emission factor surveys (Walker et al, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2010) 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, and so emissions from this sector are calculated using emission factors derived from all of the reported emissions data and an estimate of coal consumption derived from reported emissions of CO_2 for the plant.

4.7 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

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 lead 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.

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
		Diesel cars (cold start, urban, rural and motorway driving)	
		Road vehicle engines	
1 A 3 b ii Road transport: Light duty vehicles		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	NMVOC	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	Particulate Matter	All Cars, LGVs, HGV rigid and	

NFR Category (1A3)	Pollutant coverage	NAEI Source category	Source of EFs
transport: Automobile road abrasion		articulated, buses and coaches, mopeds and motorcycles (urban, rural and motorway driving)	
1 A 3 c Railways	All CLRTAP pollutants including PCDD/PCDF *(except NH_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 Literature sources
		Shipping - coastal	
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	

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 3-2. 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. Cruise emissions from international and domestic aviation are reported as a memo item to the national inventory, but are not included in national totals. Emissions from the Landing and Take Off (LTO) phase of international and domestic aviation are estimated and included in national totals. The method used to estimate emissions from military aviation can be found towards the end of this section.

A summary of the estimation methodology for UK aviation emissions in the NAEI is given below, and a full description is given in Watterson *et al.* (2004).

Emission estimates are based on the number of aircraft movements broken down by aircraft type at each UK airport. In comparison with earlier inventory estimation methodologies, the current approach is very detailed and reflects differences between airports and the aircraft that use them, which also enables much better local resolution of emission estimates around UK airports, for use within local air quality modelling studies. 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. This work includes the Regional Air Services Co-ordination (RASCO) study (23 regional airports, with a 1999 case calculated from Civil Aviation Authority (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 NO_x 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” (PSDH). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002.

For flight 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. In 2009, these recommendations 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 Auxiliary Power Unit (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. In 2009, these recommendations 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 2011 inventory emissions from flights between the UK and overseas territories have been included within the national inventory totals for the first time, as part of the domestic aviation sector. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item, whilst emissions from flights from overseas territories to the UK were not included at all within previous inventories.

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 International Civil Aviation Organisation (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.

Emission Reporting Categories for Civil Aviation

Table 1-2 shows the emissions included in the emission totals for the domestic and international civil aviation categories currently under the UNFCCC, the EU NECD and the CLRTAP Convention.

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 have been reclassified as domestic aviation.

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

  A summary of aircraft movement data is given in Table 5-2. Fights between the UK and overseas territories are included in domestic.

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

  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DECC (2010). 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 by the Military**

  Total consumption by military aviation is given in ONS (1995) and MoD (2005a) and is 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. Adjustments were made to the data to derive figures on a calendar year basis.

  For the 2008 inventory, figures for 2008/09 were not complete so data for 2007/08 were used. These data have been revised for the 2011 inventory.

Table 5-2 Aircraft Movement Data used in the UK Emission Inventories, 1990-2009

	International LTOs (000s)	**Domestic LTOs (000s)**	**International Aircraft, Gm flown**	**Domestic Aircraft, Gm flown**
1990	408.6	347.2	631.3	111.0
1991	396.0	319.5	620.7	104.5
1992	431.5	337.3	703.2	109.0
1993	442.4	344.3	714.6	112.9
1994	460.7	322.0	789.7	108.6
1995	479.7	336.0	828.7	114.7
1996	506.2	346.9	868.7	119.3
1997	536.7	351.4	946.4	124.1
1998	575.2	364.7	1031.5	131.1
1999	609.0	372.4	1098.8	135.1
2000	645.7	383.5	1168.7	140.2
2001	652.6	398.1	1183.5	149.4
2002	649.0	396.6	1175.9	148.4
2003	668.1	405.8	1227.9	151.4
2004	699.2	436.9	1331.9	161.9
2005	737.8	461.1	1423.6	172.7
2006	760.9	461.4	1488.8	173.6
2007	787.0	453.8	1543.7	170.8
2008	774.7	442.3	1530.3	167.2
2009	711.8	399.9	1414.5	151.9

Notes

Gm   Giga metres, or 10^9 metres

Estimated emissions from aviation are based on data provided by the CAA / International aircraft, Gm flown, calculated from total flight distances for departures from UK airports

Aviation: Emission Factors

The following emission factors were used to estimate emissions from aviation. The emissions of SO_2 and metals depend on the sulphur and metal contents of the aviation fuels. Emission factors for SO_2 and metals have been derived from the contents of 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 5-3 Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2009 (kg/t)

Fuel	**SO_2**
Aviation Turbine Fuel	0.82
Aviation Spirit	0.82

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2010)
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 taken from the ICAO database. The cruise emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

Table 5-4 Air Quality Pollutant Emission Factors for Civil and Military Aviation

	Fuel	Units	NO_x	CO	NMVOC
Civil aviation					
Domestic LTO	AS	kt/Mt	5.17	956.25	13.56
Domestic Cruise	AS	kt/Mt	6.75	3.62	0.24
Domestic LTO	ATF	kt/Mt	10.67	9.30	1.52
Domestic Cruise	ATF	kt/Mt	13.70	2.51	0.55
International LTO	AS	kt/Mt	2.97	1157.78	17.54
International Cruise	AS	kt/Mt	6.90	-	-
International LTO	ATF	kt/Mt	12.92	8.46	1.15
International Cruise	ATF	kt/Mt	14.16	1.15	0.52
Military aviation	ATF	kt/Mt	8.5	8.2	1.10

Notes

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

Emission Estimation Methodology for Civil Aviation Landing and Take-Off Cycles

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 the 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:

1) Taxi-out;
2) Hold;
3) Take-off Roll (start of roll to wheels-off);
4) Initial-climb (wheels-off to 450 m altitude);
5) Climb-out (450 m to 1000 m altitude);
6) Approach (from 1000 m altitude);
7) Landing-roll;
8) Taxi-in;
9) APU use after arrival; and
10) 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.

Emission Estimation Methodology for Civil Aviation Cruise Phase
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.
The EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 1996) provides fuel consumption and emissions of a range of air quality pollutants (including NO_x, HC and CO) for a number of aircraft modes in the cruise phase. 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.

Classification of domestic and international flights
The UK CAA has provided the aircraft movement data used to estimate emissions from civil aviation. The definitions the CAA use to categorise whether a movement is international or domestic are (CAA, *per. comm.*)

- **Domestic** - A flight is domestic if the initial point on the service is a domestic and the final point is a domestic airport; and
- **International** - A flight is international if either the initial point or the final point on the service is an international airport.

Take, for example, a flight (service) that travels the following route: **Glasgow** (within the UK) – **Birmingham** (within the UK) – **Paris** (outside the UK). The airport reporting the aircraft movement in this example is Glasgow, and the final airport on the service is Paris. The CAA categorises this flight as international, as the final point on the service is outside the UK.

Flights to the Channel Islands and the Isle of Man are considered to be within the UK in the CAA aircraft movement data.

Fights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but have been reclassified as domestic aviation in the 2011 inventory.

The CAA definitions above are also used by the CAA to generate national statistics of international and domestic aircraft movements. Therefore, the aircraft movement data used in this updated aviation methodology are consistent with national statistical datasets on aircraft movements.

Emission Estimation Methodology for 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 (1997) and EMEP/CORINAIR (1999) cruise defaults shown in Table 1 of EMEP/CORINAIR (1999). 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, but not fuel uplifted at foreign military airfields or *ad hoc* uplift from civilian airfields.

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

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 ATF fuel consumptions presented in DECC DUKES include the use of both civil and military ATF, and the military ATF use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil ATF consumption has been used in the fuel reconciliation. Emissions from flights from overseas territories to the UK have been excluded from the fuel reconciliation process as the fuel associated with these flights in not included in DUKES. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

Geographical coverage of aviation emission estimates

The national estimates of aviation fuels consumed in the UK are taken from DECC DUKES. The current (and future) methods used to estimate emissions from aviation rely on these data, and so the geographical coverage of the estimates of emissions will be determined by the geographical coverage of DUKES.

UK DECC has confirmed that the coverage of the energy statistics in DUKES is England, Wales, Scotland and Northern Ireland plus any oil supplied from the UK to the Channel Islands and the Isle of Man. This clarification was necessary since this information cannot be gained from UK trade statistics.

DECC have confirmed estimates in DUKES exclude Gibraltar and the other UK overseas territories. The DECC definition accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics (ONS), which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

5.3 RAILWAYS

The UK NAEI reports emissions from both stationary and mobile sources. 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 under 1A4a Commercial/Institutional in the IPCC reporting system. 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. These emissions are based on fuel consumption data from DECC (2010).

The UK NAEI reports emissions from diesel trains in three categories: freight, intercity and regional. Emissions from diesel trains are reported under the IPCC category 1A3c Railways. Emission estimates are based on train kilometres travelled and gas oil consumption by the railway sector.

For the 2011 inventory, emissions have been reported from consumption of coal used to power steam trains using new information on coal consumption allocated to the rail sector in DUKES. Estimates have been made across the time-series from 1990-2009 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.

Gas oil consumption by passenger trains was calculated utilising data provided by the Association of Train Operating Companies (ATOC) and the Office of Rail Regulation (ORR). Fuel consumption was estimated for Intercity and regional rail movements on the basis of reported train kilometres travelled and adjusted to align with the ORR estimates of fuel consumption. As no data from ATOC/ORR were available for 2009, fuel consumption was estimated on the basis of trends in train km from 2008. Fuel consumption for rail freight was also estimated from train km data and adjusted to align with ORR estimates of fuel consumption for the rail freight sector. Again, no data from ATOC/ORR were available for rail freight in 2009, so fuel consumption was estimated on the basis of trends in tonne km from 2008. Alignment with data provided by ORR marked an improvement in the methodology and the change was reflected across the time series.

In 2009, the estimated fuel consumption in regional and Intercity Rail showed a slight increase in comparison to 2008 as a consequence of increased train km travelled. In contrast, fuel oil consumption by Freight Rail in 2009 was estimated to be lower than those recorded in 2008 as a result of a decrease in billion tonne train km travelled.

CO_2, SO_2 and NO_x emissions are calculated using fuel-based emission factors and fuel consumption factors. Emissions of CO, NMVOC, NO_x, PM and CH_4 are based on the train km estimates and emission factors for different train types. The fuel consumption is distributed according to:

- Train km data taken from the National rail trends yearbook (2010) http://www.rail-reg.gov.uk/upload/pdf/nrt-yearbook-2009-10.pdf;

- Assumed mix of locomotives for each category; and,
- Fuel consumption factors for different types of locomotive (LRC (1998), BR (1994) and Hawkins & Coad (2004)).

The emission factors shown in Table 5-5 are aggregate implied factors for 2009 so that all factors are reported on the common basis of fuel consumption.

Compared with the last version of the inventory, changes to implied emission factors are noted for freight rail with respect to NO_x, CO and NMVOC. Similarly, minor changes to the implied emission factors for regional passenger rail with respect to these pollutants, as well as changes for intercity passenger rail with respect to NO_x, CO and NMVOC. These changes to the implied factors are a net result in changes in estimated km travel and fuel consumed by each category following alignment with ORR estimates of fuel consumption.

The emission factor for SO_2 has increased slightly from 1.63 kt/ Mt fuel in 2008 to 1.68 kt/ Mt fuel in 2009 in line with UKPIA's Table of the S-content in fuels in 2009 (UKPIA, 2010).

Table 5-5 Railway Emission Factors for 2009 (kt/Mt fuel)

	NO_x	CO	NMVOC	PM	SO_2
Freight	120.4	13.4	6.70	1.59	1.68
Intercity	40.6	13.1	4.81	0.96	1.68
Regional	32.9	36.5	6.34	0.86	1.68

5.4 ROAD TRANSPORT

ROAD TRANSPORT: 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 of the revised Guidelines on Reporting (ECE/EB.AIR/97) 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 ±7% for both petrol and diesel consumption across the 1990-2009 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.

Improvements in the 2011 inventory
There have been a number of improvements made to the road transport inventory and the key changes are summarised as follows:

- Updated vehicle km activity data by road types in Great Britain. DfT was able to provide a consistent time series of vehicle km data for 1993 to 2009 by road type and vehicle type for the first time. The overall totals for each vehicle type remain the same but the distribution between road types has been updated, in particular over the period 1993-2001 for LGVs, HGVs and motorcycles and from 1993-2001 and 2007 for buses;

- Revisions to the vehicle km activity data for cars, LGVs and rigid HGVs in Northern Ireland (NI) after clarification on the vehicle classifications used in the traffic census report;

- Assumptions on the split between buses and coaches on urban and rural roads have been updated, based on information provided in DfT's Transport Statistics Great Britain (TSGB) on vehicle km done by local and non-local bus services;

- Assumptions on the split in vehicle km for buses by vehicle weight class have been updated using licensing information and correlations between vehicle weight class and number of seats. This is to improve how the emission factors for different bus vehicle weight classes are utilised;

- The treatment of emissions from buses operating in London has been improved by taking into account the specific composition of the fleet operated by TfL separately from other bus services in London;

- The estimation of emissions from HGVs and buses in London in 2008 and 2009 was improved by taking into account the effects of the London Low Emissions Zone on the composition (by Euro class) of the HGV and bus fleet separately from the fleet in other parts of the UK;

- A more detailed breakdown in the activity by 2-stroke and 4-stroke motorcycles has been used following a detailed review of motorcycle sales, population and lifetime by engine size;

- New figures from DfT on average mpg fuel efficiency of different sizes of HGVs in 2008 were used;

- Updated figures from DfT's Bus Services Operators Grant (BSOG) system were used on the average fuel efficiency of local bus services in 2008;

- PM emissions from road abrasion (1A3bvii) are estimated for the first time based on emission factors and methodology provided in the EMEP/CORINAIR emission inventory guidebook;

- The methodology for calculation of evaporative emissions of NMVOCs from petrol vehicles was updated with that recommended in the EMEP/CORINAIR Emission Inventory Guidebook 2007;

- Emission factors for PAHs were updated following a review of available factors in the DfT/TRL compilation and in the 2009 EMEP/CORINAIR emission inventory guidebook combined with expert judgement to obtain a consistent data set of factors crossing all Euro standards.

For CO_2, these changes have only affected the distribution of fuel consumption and hence CO_2 emissions between vehicle types, but the total CO_2 emissions from road transport in all years remains unchanged, because these are based on the total fuel consumption figures reported in DUKES. Estimates of fuel consumption calculated for individual types of vehicles are normalised so that 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.

Fuel-based emissions

Emissions of 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), which is published by DECC, and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies that are included in DUKES (emissions from the Crown Dependencies are calculated elsewhere).

In 2009, 15.76 Mtonnes of petrol and 20.06 Mtonnes of diesel fuel (DERV) were consumed in the UK (a very small proportion of this was used in the Crown Dependencies). For both fuels, this is a decrease in consumption compared with 2008. It was estimated that of this, around 1.7% of petrol was consumed by off-road vehicles and machinery and 0.4% used in the Crown Dependencies, leaving 15.44 Mtonnes of petrol consumed by road vehicles in the UK in 2009. Around 0.05% of road diesel is estimated to be used by off-road vehicles and machinery (the bulk of these use gas oil) and 0.3% used in the Crown Dependencies, leaving 19.99 Mtonnes of diesel consumed by road vehicles in the UK in 2009.

According to figures in DUKES (DECC, 2010), 0.107 Mtonnes of LPG were used for transport in 2009, down from 0.125 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 (2010), 0.25 Mtonnes bioethanol and 0.93 Mtonnes biodiesel were consumed in the UK in 2009. On a volume basis, this represents about 1.5% of all petrol and 4.2% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.152 Mtonnes of mineral-based petrol (about 1.0% of total petrol that would have been consumed) and 0.808 Mtonnes of mineral-based diesel (about 4.0% of total diesel that would have been consumed). The CO_2 emissions arising from consumption of these fuels are not included in the national totals.

Emissions of SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for SO_2 from consumption of petrol and diesel fuels are shown in Table 5-6. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in Table 5-6 for 2009 fuels based on data from UKPIA (2010).

Table 5-6 Fuel-Based Sulphur Dioxide Emission Factors for Road Transport (kg/tonne fuel)

Fuel	**SO_2**[a]
Petrol	0.012
Diesel	0.015

a 2009 emission factor calculated from UKPIA (2010) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2009

Emissions of SO_2 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, and 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/pgr/roads/environment/emissions/ 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://www.dft.gov.uk/pgr/roads/environment/emissions/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 5-7 for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 5-7 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6
	Euro 4	50.8	47.2	53.4
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
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
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
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 fuel efficiency of different sizes of lorries (DfT, 2010a). A time-series of mpg figures from 1989 to 2009 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. New mpg factors for 2008 were used that were not available from DfT for the previous inventory.

Table 5-8 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2009 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2008a and 2010a).

Table 5-8 Average fuel consumption factors for HGVs (in g fuel/km) in the UK fleet based on DfT's road freight statistics

g fuel/km	**Rigid HGVs**			**Artic HGVs**		
	urban	**rural**	**m-way**	**urban**	**rural**	**m-way**
1990	271	220	228	437	337	344
1991	275	224	231	436	335	343
1992	275	224	232	432	333	341
1993	266	216	223	411	316	323
1994	258	210	218	404	311	318
1995	262	215	222	394	304	311
1996	257	212	219	387	299	306
1997	255	211	218	386	299	306
1998	244	203	210	369	287	293
1999	249	208	216	369	287	293
2000	247	208	215	368	287	294
2001	257	217	225	373	292	298
2002	250	212	219	371	290	296
2003	259	220	227	376	293	300
2004	250	212	219	363	283	289
2005	245	209	216	358	279	286
2006	252	214	221	361	281	287
2007	260	221	228	367	286	293
2008	271	230	237	382	297	304
2009	271	229	237	383	297	304

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, 2010b). DfT believe that 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 actually imply an increase in the average fuel consumption factor for local buses, i.e. a reduction in fuel efficiency over the period from 1996 to 2005/2006, which has been levelling off, though factors increased again for the 2008/09 year.

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 more 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 2008/09. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2008/09 figures were used for the 2008 calendar year and superseded estimates for 2008 made last year when these data were not available. As there are no corresponding BSOG data to use for 2009, 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 2008 and 2009. This produced a fuel efficiency scaling factor that could be applied to the factor for 2008.

Table 5-9 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2009 for urban, rural and motorway conditions based on this method.

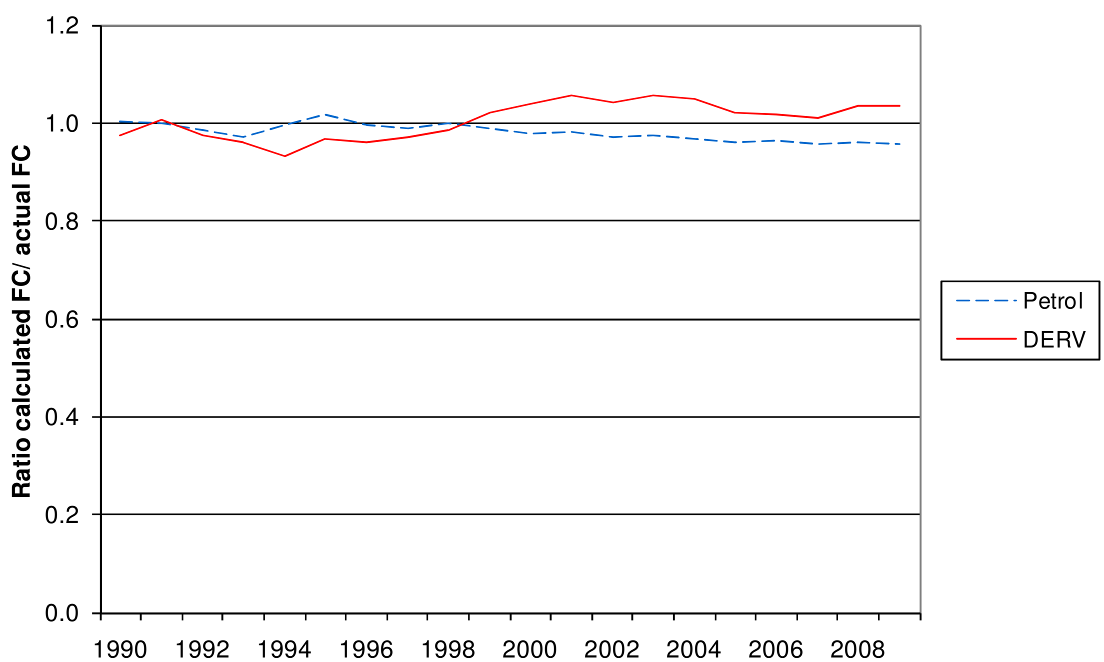
Table 5-9 Average fuel consumption factors for buses and coaches (in g fuel/km) in the UK fleet based on DfT's BSOG data

g fuel/km	Urban	Rural	Motorway
1990	305	190	216
1991	305	190	216
1992	305	190	216
1993	304	190	216
1994	300	188	214
1995	296	185	212
1996	290	182	209
1997	289	182	210
1998	289	183	212
1999	300	191	222
2000	313	200	234
2001	314	201	236
2002	327	210	247
2003	342	220	259
2004	355	228	269
2005	370	237	280
2006	356	228	269
2007	350	224	264
2008	379	242	286
2009	379	242	286

Fuel reconciliation and normalisation
A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data. These "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 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 calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK. 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 unity, but the difference is never higher than 7%. In 2009, the bottom-up method underestimates petrol consumption by 4% and over-estimates diesel consumption by 3%. 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 and hence CO_2 emission 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% to align with fuel sales in 2009. 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 (the difference being 0.67 Mtonnes or 3% in 2009) 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 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 670 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

Total CO_2 emissions from vehicles running on LPG are estimated on the basis of national figures (from DUKES) on the consumption of this fuel by road transport. The CO_2 emissions from LPG consumption cannot be broken down by vehicle type because 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 0.5% of all light duty vehicles run on LPG.

Emissions of CO_2 from LPG consumption are calculated from total consumption figures and carbon factors for LPG fuel.

Emissions from natural gas consumption

Emissions from vehicles running on natural gas are not estimated. The number of such vehicles in the UK is very 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.

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 grammes per kilometre 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.

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 recent review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see http://www.dft.gov.uk/pgr/roads/environment/emissions/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, 2010c). This detailed data was in the past only available for the latest inventory year, however, DfT was able to provide a consistent time series of vkm data by vehicle and road types going back to 1993 for the 2011 inventory, taking into account any revisions to historic data. 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, 2002, 2003, 2006, 2007, 2008, 2009a, 2010a). These provided a consistent time-series of vehicle km data for all years up to 2009. 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, 2010b). Revisions were made to the vehicle km activity data for cars, LGVs and rigid HGVs in Northern Ireland after clarification on the vehicle classifications used in the traffic census report. This has led to an increase in Northern Ireland's car vkm and a reduction in the vkm for LGVs and rigid HGVs compared with the vkm used in the 2008 inventory for 1990-2008.

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 2009, as shown in Table 5-10.

Table 5-10 UK Vehicle Movements (vkm) by road vehicle type, 1990-2009

Billion vkm		**1990**	**1995**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**
Petrol cars	urban	143.3	141.0	140.3	130.0	127.5	125.2	120.8	118.1
	rural	139.0	128.9	127.2	119.0	117.5	113.9	110.0	106.0
	m-way	47.8	45.1	48.4	44.1	43.0	41.5	39.8	38.5
Diesel cars	urban	4.8	14.1	21.5	34.2	37.2	40.3	42.5	45.0
	rural	8.2	23.1	35.5	56.9	62.1	66.4	69.8	72.9
	m-way	4.2	11.7	19.2	29.9	32.4	34.5	36.2	38.0
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.9	1.8	1.6	1.4
	rural	11.4	8.3	5.0	2.3	2.3	2.2	2.0	1.8
	m-way	3.9	3.2	2.0	0.9	1.0	0.9	0.8	0.7
Diesel LGVs	urban	5.7	10.2	15.6	21.7	22.5	23.4	23.6	23.0
	rural	6.1	11.5	18.9	26.2	27.4	29.6	30.0	29.3
	m-way	2.0	4.4	7.4	10.5	11.2	11.7	11.6	11.5
Rigid HGVs	urban	4.5	3.7	3.9	4.1	4.0	3.8	3.7	3.4
	rural	7.1	6.8	7.2	7.5	7.5	7.6	7.3	6.8
	m-way	3.7	3.7	4.2	4.2	4.2	4.2	4.2	4.0
Artic HGVs	urban	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9
	rural	4.3	4.7	5.1	5.3	5.5	5.6	5.6	5.0
	m-way	4.7	6.0	7.4	7.9	8.0	8.3	8.0	7.3
Buses	urban	2.4	2.9	3.0	3.2	3.3	3.4	3.2	3.2
	rural	1.7	1.5	1.7	1.5	1.6	1.7	1.6	1.6
	m-way	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.4
M/cycle	urban	3.3	1.9	2.3	3.0	2.8	3.2	2.7	2.8
	rural	2.0	1.6	2.0	2.2	2.1	2.1	2.1	2.1
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.4
Total		**423.4**	**443.9**	**484.0**	**518.6**	**527.1**	**533.1**	**528.8**	**524.3**

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. Speed data from other DfT publications such as ‘Road Statistics 2006: Traffic, Speeds and Congestion’ (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008b), 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 2009.

Table 5-11 Average Traffic Speeds in Great Britain applied across the time series

		Lights	Heavies	Buses
		kph	kph	kph
URBAN ROADS				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Conurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	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. DfT Vehicle Licensing Statistics (DfT, 2010d) provide the number of vehicles licensed in GB by fuel type. This information is combined with data on the relative mileage done by petrol and diesel cars (DfT, 2008c, pers comm). This indicates that diesel cars do on average 60% more annual mileage than petrol cars. The information originated from the National Travel Survey (DfT, 2007b). It has been assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, the petrol car/diesel car mix on urban roads is assumed to be that 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. This leads to the vehicle km data for petrol and diesel cars on different road types shown in Table 5-10.

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, 2010d). 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, 2008c).

To utilise the DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the new 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.

Only limited information on the sizes of buses and coaches by weight exists and it was assumed, based on analysis of local bus operator information, 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 by vehicle weight class have been updated using 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 motorcycle, the whole time series of vkm for 2-stroke and 4 stroke motorcycles by different engine sizes has been updated, 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.

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 5-12 shows the regulations that have come into force up to 2009 for each vehicle type.

Table 5-12 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) 94/12/EC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4)	 1/7/1992 1/1/1997 1/1/2001 1/1/2006
	Diesel	Pre-Euro 1 91/441/EEC (Euro 1) 94/12/EC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4)	 1/1/1993 1/1/1997 1/1/2001 1/1/2006
LGVs	Petrol	Pre-Euro 1 93/59/EEC (Euro 1) 96/69/EEC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t) 1/1/2006
	Diesel	Pre-Euro 1 93/59/EEC (Euro 1) 96/69/EEC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4)	 1/7/1994 1/7/1997 1/1/2001 (<1.3t) 1/1/2002 (>1.3t) 1/1/2006
HGVs and buses	Diesel (All types)	Pre-1988 88/77/EEC (Pre-Euro I) 91/542/EEC (Euro I) 91/542/EEC (Euro II) 99/96/EC (Euro III) 99/96/EC (Euro IV) 99/96/EC (Euro V)	 1/10/1988 1/10/1993 1/10/1996 1/10/2001 1/10/2006 1/10/2008
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st) 97/24/EC: all sizes (Euro 1) 2002/51/EC (Euro 2) 2002/51/EC (Euro 3)	 1/1/2000 1/7/2004 1/1/2007

The average age profile and the fraction of petrol and diesel cars and LGVs in the fleet each year are based on the composition of the UK vehicle fleet using DfT Vehicle Licensing Statistics. The Transport Statistics Bulletin "Vehicle Licensing Statistics: 2009" (DfT, 2010d) either gives historic trends in the composition of the UK fleet by age directly or provides sufficient information for this to be calculated from new vehicle registrations and average vehicle survival rates. Thus, year-of-first registration data for vehicles licensed in each year from 1990 to 2009 have been taken to reflect the age distribution of the fleet in these years. Statistics are also available on the number of new registrations in each year up to 2009, reflecting the number of new vehicles entering into service in previous years.

The two sets of data combined allow an average survival rate to be determined for each type of vehicle. This defines the turnover in the fleet and therefore the composition of the fleet by Euro standard each year. Particularly detailed information is available on the composition of the HGV stock by age and size. The age composition data are combined with data on the change in annual vehicle mileage with age, to take account of the fact that newer vehicles on average travel a greater number of kilometres in a year than older vehicles. For cars and LGVs, such mileage by age data are from the National Travel Survey (DETR, 1998a); data for HGVs of different weights are taken from the Continuous Survey of Road Goods

Transport (DETR, 1996a). Data from these sources were used to develop a mileage with age profile which is applied to all years.

Separate vehicle licensing statistics for private and light goods vehicles (PLG) in Northern Ireland are available from the Central Statistics and Research Branch of the Department of Regional Development in Northern Ireland (DRDNI, 2010c). These show a higher proportion of diesel cars here than in Great Britain. Unlike other regional licensing statistics, it is more likely that these statistics reflect the actual fuel mix of cars on the road in Northern Ireland and so this information was used in the inventory.

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% in 2000. In 2001, an assumption was made that 15% of all new petrol cars sold in the UK met Euro 4 standards, increasing to 81% in 2004 even though the mandatory date of introduction of this standard was not until 2006 (DfT, 2004). The remaining new petrol car registrations in 2001 - 2005 would meet Euro 3 standards. From 2006, all new cars were required to fully comply with Euro 4 standards.

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, rising 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 VOC 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 emissions from HGVs and buses in 2008 and 2009 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.

The specific features of the fleet of buses operated by 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 75-80% 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 in 2008 and 2009 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 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.

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 Emissions Inventory Guidebooks

Air pollutants and Indirect GHGs: Regulated pollutants NO_x, CO, NMVOCs, PM
Emission factors for NO_x, total hydrocarbons (THC), CO and PM are represented as equations relating emission factor in g/km to average speed (Boulter et al, 2009). The DfT/TRL (Boulter et al, 2009) 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. Table 5-21 to Table 5-24 summarise the NO_x, CO, THC and PM emission factors for all vehicle types under typical urban, rural and motorway road conditions in g/km normalised to 50,000km accumulated mileage and current fuels. These are derived from the tables at http://www.dft.gov.uk/pgr/roads/environment/emissions/ for detailed vehicle size classes and averaged according to the proportion of different vehicle sizes in the UK fleet according to vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for methane 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 5-11. 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.

The inventory takes into account the change in emissions with mileage using the TRL functions and change in mileage with age data and 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 described below.

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 (2010) 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 5-13.

Table 5-13 Scale Factors for Emissions from a Euro II Bus Running on 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 5-14.

Table 5-14 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

Comments on current NO_x emission factors

The current inventory for exhaust emissions of NO_x used emission factors published by DfT/TRL in 2009. The factors are based on TRL's analysis of a database of raw emissions test data from various sources measured over various drive cycles which are supposed to mimic real-world behaviour. However, recent evidence is casting some doubt on the accuracy of these emission factors, especially for more modern diesel vehicles (Euro 3+) and even some of the earlier Euro 1 and 2 petrol cars. The time-series in NO_x emissions in urban areas implied by the emissions inventory shows a clear downward trend in emissions since 2002 that does not seem to be borne out by roadside measurements of ambient NO_x concentrations, which instead show the trend to be fairly flat. There is also some evidence from roadside remote sensing of exhaust plumes from a large number of vehicles that indicates that the NO_x emissions are significantly higher than indicated by the current emission factors. The evidence points to some doubt as to whether the technologies intended to bring emissions from Euro 3+ diesel vehicles to within limits over the regulatory test cycle are actually delivering the expected improvements under real-world conditions.

Work is currently underway by a Defra-led consortium, including the inventory team and other experts, to assess this uncertainty in the NO_x emission factors and the implications to current and future emissions and urban NO_2 concentrations. This work is in progress and when concluded, a report will be prepared for peer-review which may recommend changes to the NO_x emission factors.

Air pollutants and Indirect GHGs: 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.

NH_3 emissions from road transport are calculated in the same ways as emissions of N_2O.
The emission factors for NH_3 for all vehicle types are based on the recommendation of the EMEP Emissions Inventory Guidebook (EMEP/CORINAIR, 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 5-25 summarises the NH_3 emission factors 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 US EPA as compounds of interest using a suggested procedure for reporting test measurement results (US EPA, 1988). Road transport emission factors for these 16 compounds were updated for the current inventory. A thorough review of the DfT/TRL emission factors, available at http://www.dft.gov.uk/pgr/roads/environment/emissions/, was 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 new NAEI emission factors have been derived from the following data sources or combination of sources:

- DfT/TRL emission factors (Boulter et al, 2009);
- NAEI emission factors (Murrells et al, 2010);
- EMEP/EEA emission inventory guidebook 2009, updated June 2010 (EMEP/CORINAIR, 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 5-26.

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/CORINAIR 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 5-15. These should be used in conjunction with the NO_x emissions calculated by the inventory to derive the corresponding emissions of NO_2.

Table 5-15 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**	**2009**
Petrol cars	0.040	0.040	0.040	0.035	0.032
Diesel cars	0.110	0.110	0.113	0.220	0.400
Petrol LGVs	0.040	0.040	0.040	0.037	0.035
Diesel LGVs	0.110	0.110	0.110	0.187	0.357
Rigid HGVs	0.110	0.110	0.110	0.124	0.129
Artic HGVs	0.110	0.110	0.110	0.128	0.132
Buses and coaches	0.110	0.110	0.110	0.124	0.128
Motorcycles	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 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/CORINAIR (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 (EMEP/CORINAIR, 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 CORINAIR 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 CORINAIR Emissions Inventory Guidebook, so this figure was adopted (EMEP/CORINAIR, 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/CORINAIR guidebook (EMEP/CORINAIR, 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 5-16. There are no cold start factors for HGVs and buses. All the cold start emissions are assumed to apply to urban driving.

Table 5-16 Cold Start Emission Factors for NH_3 (in mg/km)

	Petrol cars and LGVs (NH_3 in mg/km)
Pre-Euro 1	2.0
Euro 1	38.3
Euro 2	43.5
Euro 3	4.4
Euro 4	4.4

Evaporative Emissions

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 has been updated in the 2011 inventory following a review on alternative and more up-to-date methodologies (Stewart et al., 2009) and recommendations of a recent review carried by TRL under contract to DfT (Latham and Boulter 2009). It was concluded that the COPERT 4 simple approach is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory (EMEP/CORINAIR 2007). The previous methodology used was largely based on the COPERT II/COPERT III methodology (EEA, 1997) supplemented by factors with a more UK bias.

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 for the first time. 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 as in the previous method, however, it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure rather than continuous mathematical equations relating emission factor to these parameters.

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

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 number of vehicles in the UK equipped with different sized canisters is not available, however the 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+ 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 (2010), 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 EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

An implied emission factor based on the population, composition of the fleet and trips made in 2009 is shown for petrol cars and motorcycles in Table 5-17. The units are in grammes per vehicle per day.

Table 5-17 Fleet-average emission factor for evaporative emissions of NMVOCs in 2009

g/vehicle/day	**2009**
Petrol cars	1.15
Motorcycles	1.70

Adopting the new methodology for petrol cars and motorcycles leads to higher estimate of evaporative emissions in 2008 of around 13.7 ktonnes compared with 10.4 ktonnes previously estimated, or a 32% difference. However, the difference is greater in earlier years indicating that the rate of decline in evaporative emissions is faster than implied by previous estimates. The relative contributions made by the three different processes leading to evaporation of fuel vapour from vehicles are very different to those previously estimated such that the hot soak and running loss mechanisms dominate.

Non-exhaust emissions of PM

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/CORINAIR Guidebook (EMEP/CORINAIR, 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 5-18 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 5-18 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 have been estimated for the first time in the 2011 inventory, based upon the emission factors and methodology provided by the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2009b). 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 5-19. 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 5-19 Emission factors for PM_{10} from road abrasion

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

Emissions of $PM_{2.5}$ and smaller mass ranges are estimated from the fraction of $PM_{2.5}$ in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given elsewhere in this report for different sources. Using information from the DfT/TRL emission factor review and EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007), the fraction of PM_{10} emitted as $PM_{2.5}$ for tyre wear, brake wear and road abrasion is shown in Table 5-20.

Table 5-20 Fraction of PM_{10} emitted as $PM_{2.5}$ for non-exhaust traffic emission sources

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

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

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

Table 5-21 NO_X Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g NO_X (as NO_2-eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.558	1.982	2.600
	Euro 1	0.301	0.319	0.371
	Euro 2	0.143	0.154	0.189
	Euro 3	0.064	0.066	0.079
	Euro 4	0.046	0.043	0.045
Diesel cars	Pre-Euro 1	0.578	0.613	0.805
	Euro 1	0.523	0.550	0.809
	Euro 2	0.617	0.647	0.922
	Euro 3	0.477	0.491	0.660
	Euro 4	0.297	0.328	0.471
Petrol LGVs	Pre-Euro 1	1.496	2.025	2.731
	Euro 1	0.350	0.384	0.462
	Euro 2	0.091	0.089	0.123
	Euro 3	0.050	0.058	0.079
	Euro 4	0.034	0.028	0.025
Diesel LGV	Pre-Euro 1	1.649	1.769	2.353
	Euro 1	1.143	1.339	1.980
	Euro 2	1.247	1.491	2.260
	Euro 3	0.736	0.921	1.478
	Euro 4	0.368	0.461	0.739
Rigid HGVs	Pre-Euro I	8.094	8.229	8.717
	Euro I	5.400	5.540	5.810
	Euro II	5.675	5.738	5.959
	Euro III	4.431	4.390	4.572
	Euro IV	2.729	2.748	2.895
	Euro V	1.608	1.612	1.700
Artic HGVs	Pre-Euro I	14.440	13.426	14.223
	Euro I	10.122	9.430	9.987
	Euro II	10.440	9.714	10.296
	Euro III	8.267	7.654	8.113
	Euro IV	5.101	4.745	5.014
	Euro V	2.989	2.775	2.932
Buses & coaches	Pre-Euro I	11.182	10.106	10.199
	Euro I	7.471	6.658	7.663
	Euro II	7.977	7.047	8.288
	Euro III	6.431	5.366	6.573
	Euro IV	3.935	3.353	4.030
	Euro V	2.361	1.976	2.409
Mopeds, <50cc, 2st	Pre-Euro 1	0.030		
	Euro 1	0.030		
	Euro 2	0.010		
	Euro 3	0.010		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.026	0.039	
	Euro 1	0.041	0.054	
	Euro 2	0.048	0.062	
	Euro 3	0.023	0.036	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.223	0.446	0.569
	Euro 1	0.229	0.443	0.569
	Euro 2	0.127	0.306	0.664
	Euro 3	0.065	0.155	0.337

Table 5-22 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	9.774	6.850	5.531
	Euro 1	2.423	1.637	3.132
	Euro 2	0.534	0.695	1.823
	Euro 3	0.230	0.615	1.583
	Euro 4	0.419	0.705	1.564
Diesel cars	Pre-Euro 1	0.583	0.434	0.361
	Euro 1	0.318	0.223	0.183
	Euro 2	0.193	0.118	0.079
	Euro 3	0.057	0.035	0.024
	Euro 4	0.052	0.030	0.016
Petrol LGVs	Pre-Euro 1	11.689	8.169	6.688
	Euro 1	3.098	3.245	4.807
	Euro 2	0.096	1.154	3.116
	Euro 3	0.406	0.767	2.215
	Euro 4	0.406	0.767	2.215
Diesel LGV	Pre-Euro 1	0.713	0.768	0.953
	Euro 1	0.547	0.456	0.425
	Euro 2	0.592	0.624	0.758
	Euro 3	0.174	0.132	0.120
	Euro 4	0.136	0.103	0.094
Rigid HGVs	Pre-Euro I	2.140	1.957	2.059
	Euro I	1.377	1.296	1.370
	Euro II	1.173	1.122	1.179
	Euro III	1.042	0.963	0.980
	Euro IV	0.567	0.497	0.547
	Euro V	0.078	0.072	0.074
Artic HGVs	Pre-Euro I	2.489	2.258	2.392
	Euro I	2.170	1.981	2.099
	Euro II	1.804	1.692	1.835
	Euro III	1.907	1.738	1.855
	Euro IV	0.340	0.311	0.340
	Euro V	0.134	0.120	0.128
Buses & coaches	Pre-Euro I	2.723	1.893	1.504
	Euro I	1.677	1.106	1.239
	Euro II	1.333	0.867	1.130
	Euro III	1.457	0.922	1.218
	Euro IV	0.127	0.084	0.090
	Euro V	0.129	0.085	0.092
Mopeds, <50cc, 2st	Pre-Euro 1	13.800		
	Euro 1	5.600		
	Euro 2	1.300		
	Euro 3	1.300		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.081	23.667	
	Euro 1	10.608	15.616	
	Euro 2	8.392	12.352	
	Euro 3	4.634	6.818	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.588	22.015	25.843
	Euro 1	10.083	17.564	15.740
	Euro 2	5.270	8.981	9.511
	Euro 3	2.909	4.957	5.252

Table 5-23 THC Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable). NMVOC emission factors are derived by subtracting methane factors from the THC factors

g HC/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.242	0.847	0.644
	Euro 1	0.124	0.091	0.115
	Euro 2	0.045	0.041	0.051
	Euro 3	0.020	0.020	0.027
	Euro 4	0.014	0.010	0.013
Diesel cars	Pre-Euro 1	0.124	0.093	0.076
	Euro 1	0.072	0.048	0.035
	Euro 2	0.054	0.039	0.031
	Euro 3	0.020	0.013	0.010
	Euro 4	0.018	0.015	0.013
Petrol LGVs	Pre-Euro 1	1.444	0.935	0.669
	Euro 1	0.190	0.128	0.151
	Euro 2	0.037	0.038	0.057
	Euro 3	0.028	0.028	0.039
	Euro 4	0.014	0.014	0.019
Diesel LGV	Pre-Euro 1	0.160	0.136	0.124
	Euro 1	0.083	0.057	0.042
	Euro 2	0.082	0.076	0.085
	Euro 3	0.034	0.025	0.024
	Euro 4	0.029	0.022	0.021
Rigid HGVs	Pre-Euro I	0.993	0.836	0.894
	Euro I	0.397	0.355	0.364
	Euro II	0.254	0.225	0.231
	Euro III	0.225	0.200	0.205
	Euro IV	0.011	0.010	0.010
	Euro V	0.011	0.010	0.010
Artic HGVs	Pre-Euro I	0.711	0.609	0.651
	Euro I	0.676	0.589	0.629
	Euro II	0.430	0.372	0.398
	Euro III	0.370	0.322	0.344
	Euro IV	0.018	0.016	0.017
	Euro V	0.019	0.016	0.017
Buses & coaches	Pre-Euro I	1.014	0.676	0.409
	Euro I	0.589	0.413	0.431
	Euro II	0.384	0.271	0.273
	Euro III	0.346	0.245	0.270
	Euro IV	0.018	0.012	0.013
	Euro V	0.018	0.012	0.014
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	7.407	8.113	
	Euro 1	2.341	3.273	
	Euro 2	1.243	1.738	
	Euro 3	0.777	1.084	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.527	1.218	1.726
	Euro 1	0.853	0.753	0.807
	Euro 2	0.381	0.439	0.577
	Euro 3	0.238	0.275	0.362

Table 5-24 PM Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g PM/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	0.004	0.005	0.009
	Euro 1	0.003	0.004	0.006
	Euro 2	0.002	0.003	0.005
	Euro 3	0.002	0.003	0.005
	Euro 4	0.002	0.003	0.005
Diesel cars	Pre-Euro 1	0.179	0.177	0.237
	Euro 1	0.053	0.054	0.092
	Euro 2	0.038	0.047	0.075
	Euro 3	0.034	0.036	0.043
	Euro 4	0.021	0.023	0.029
Petrol LGVs	Pre-Euro 1	0.004	0.005	0.010
	Euro 1	0.002	0.002	0.004
	Euro 2	0.002	0.002	0.004
	Euro 3	0.002	0.002	0.003
	Euro 4	0.002	0.002	0.003
Diesel LGV	Pre-Euro 1	0.269	0.267	0.311
	Euro 1	0.102	0.125	0.211
	Euro 2	0.109	0.124	0.158
	Euro 3	0.048	0.052	0.109
	Euro 4	0.029	0.031	0.065
Rigid HGVs	Pre-Euro I	0.493	0.449	0.474
	Euro I	0.218	0.202	0.207
	Euro II	0.100	0.099	0.118
	Euro III	0.096	0.088	0.090
	Euro IV	0.018	0.016	0.016
	Euro V	0.018	0.016	0.016
Artic HGVs	Pre-Euro I	0.550	0.498	0.528
	Euro I	0.414	0.369	0.392
	Euro II	0.187	0.175	0.242
	Euro III	0.171	0.152	0.162
	Euro IV	0.030	0.026	0.028
	Euro V	0.030	0.026	0.028
Buses & coaches	Pre-Euro I	0.472	0.331	0.331
	Euro I	0.318	0.221	0.237
	Euro II	0.139	0.110	0.127
	Euro III	0.131	0.097	0.112
	Euro IV	0.028	0.019	0.021
	Euro V	0.028	0.019	0.022
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 NH_3 Emission Factors for Road Transport (in mg/km)

mg NH_3 /km		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
Diesel cars	Pre-Euro 1	1	1	1
	Euro 1	1	1	1
	Euro 2	1	1	1
	Euro 3	1	1	1
	Euro 4	1	1	1
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
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
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
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
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
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 5-26 Benzo[a]pyrene Emission Factors for Road Transport (in µg/km)

µg B[a]P/km		All road types
Petrol cars	Pre-Euro 1	0.480
	Euro 1	0.320
	Euro 2	0.201
	Euro 3	0.166
	Euro 4	0.130
	Euro 5	0.130
Diesel cars	Pre - Euro 1	2.850
	Euro 1	0.630
	Euro 2	0.425
	Euro 3	0.284
	Euro 4	0.189
Petrol LGVs	Pre-Euro 1	0.480
	Euro 1	0.320
	Euro 2	0.201
	Euro 3	0.166
	Euro 4	0.130
Diesel LGVs	Pre-Euro 1	4.275
	Euro 1	0.945
	Euro 2	0.638
	Euro 3	0.425
	Euro 4	0.284
Rigid HGVs	Pre - Euro I	1.350
	Euro I	0.675
	Euro II	0.359
	Euro III	0.331
	Euro IV	0.153
Artic HGVs	Pre - Euro I	1.800
	Euro I	0.900
	Euro II	0.479
	Euro III	0.441
	Euro IV	0.204
Buses & coaches	Pre - Euro I	2.628
	Euro I	1.314
	Euro II	0.699
	Euro III	0.644
	Euro IV	0.297
Mopeds, <50cc, 2st	All	1.008
Motorcycles, >50cc, 2st	All	1.008
Motorcycles, >50cc, 4st	All	3.024

5.5 NAVIGATION

The UK NAEI provides emission estimates for coastal shipping, naval shipping and international marine. Coastal shipping is reported within NFR category 1A3dii National Navigation and to date has included emissions from fishing vessels. Emissions from international shipping are reported as a Memo Item for information purposes under NFR category 1A3di International Marine. Emissions from naval shipping are reported under 1A5.

A new method has been used to estimate coastal and international marine emissions for the 2011 inventory. The method is centred around a new procedure developed by Entec under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters using a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The approach represents a Tier 2 method for estimating emissions from water-borne navigation in the EMEP/CORINAIR Guidelines for national inventories and is the first time such an approach has been feasible for the UK inventory. Previous emission estimates for coastal and international marine have been 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 (DECC, 2010). This has 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 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 back-cast movements and fuel consumption to 1990 and forward cast to 2009.

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 new 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 estimation for international marine that retains consistency with total marine fuels data reported in DUKES. Emissions from naval shipping continue to be based on fuel consumption data reported by the MoD.

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 are taken from the Entec study and reported separately under 1A4ciii;

- Entec's estimates for domestic shipping fuel consumption and emissions back-cast to 1990 and forecast to 2009 are used;
- 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 (less fuel used for naval shipping) and the fuel consumption estimate for domestic shipping taken from Entec is assigned to international shipping.

Details in the approach are given in the following sections. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on vessel movements are given in the Entec (2010) report.

Estimation for Domestic Shipping Emissions in 2007

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

The Entec inventory was based on individual vessel movements and characteristics data provided by Lloyd's Marine Intelligence Unit (LMIU) for the year 2007 supplemented by Automatic Identification System (AIS) data transmitted by vessels to shore with information about a ship's position and course. A major part of the Entec study was to consider vessel movements not captured in the LMIU database. These were known to include small vessels and those with multiple callings to the same port each day, such as cross-channel passenger ferries. To assess this, Entec carried out a detailed comparison between the LMIU data and DfT port statistics. The DfT port statistics (DfT, 2008d) 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 covering the North Sea and English Channel came into effect in August 2007 and sulphur limits also applied 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 (2010). 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, but did not cover other greenhouse gases, CH_4 and N_2O. 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 assumptions for each fuel based on current limits and data from IVL, as shown in Table 5-27:

Table 5-27 Assumed sulphur content of fuel for 2007

Fuel	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 the Lloyd’s Register. Factors for NMVOCs are unchanged from those in Entec (2005).

For pollutants not covered in the Entec (2010) study, emission factors used in the last year’s inventory (2008 NAEI) in units g/kg fuel were unchanged.

The detailed Tier 2 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 IPCC category 1A3dii Domestic Water-borne Navigation separate from 1A3di International Water-borne Navigation (International bunkers), according to IPCC Source Categories, as shown in Table 5-28.

Table 5-28 NFR Navigation Source Category and description

NFR Source Category	Description
1 A 3 d i (i) International maritime navigation	*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.*
1 A 3 d ii National navigation (Shipping)	*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(i)) are not included in national totals, but are reported as a Memo item for information.

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.

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.

Estimation of Time Series in Domestic 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 Entec used an alternative approach based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2009 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 ones were assigned to different vessel categories, differentiating between international and domestic movements. Details are given in the Entec (2010) report, and briefly summarised below:

- 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 1990-2009;
- 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 1990-2009;
- 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 fishing vessels category (MMO, 2009).

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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.

It was assumed that 2007 heralded the introduction of MGO and MDO 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 1990-2009 time-series. Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007.

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). Entec (2010) assumed that the sulphur content of marine gas oil fell from 0.2% to 0.1% in 2008/2009.

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

Estimation of International Shipping Emissions from 1990

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 5-29 which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil. 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 of these types of fuel.

Table 5-29 Marine shipping (domestic and international) fuel use: Comparison of Entec study and DUKES data for 2007

Mt fuel	Entec	DUKES
Gas oil	4.34	1.57*
Fuel oil	1.00	2.04

*Excludes military shipping gas oil estimate.

The totals differ markedly. One reason is that 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 of 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 EMEP/CORINAIR 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 EMEP/CORINAIR 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 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, i.e. the difference between the total fuel deliveries statistic in DUKES and the Entec figure for domestic shipping, after further correcting for consumption of fuel by military shipping. Correction for military consumption is necessary because the figures in DUKES include consumption by naval shipping, but these are not included in Entec's estimates for domestic or international movements, and are also reported as a separate source category in the inventory, as described below.

Thus, for fuel consumption across the time series:

International shipping = (DUKES Marine Bunkers + DUKES national navigation –Entec domestic - military)

This implies that the total marine fuel consumption used in the inventory time series is consistent with DUKES, but that a different domestic/international split is used. Table 5-30 shows the consumption of marine fuels by domestic and international shipping, calculated by the inventory approach (GHGI) on the basis of Entec figures for domestic movements compared with figures for national navigation (domestic) and marine bunkers (international) in DUKES for 2007. The DUKES figure excludes gas oil (international) consumption by military vessels. The proportion of fuel consumption (and hence emissions) allocated to domestic shipping is considerably smaller than that implied by the data in DUKES, as can be seen in Table 5-30.

Table 5-30 Comparison of 2007 marine fuel consumption from GHGI (Entec data) and DUKES, split by fuel and domestic/international

Mt fuel		**GHGI**	**DUKES**
Gas oil	Domestic	0.392	0.94
	International	1.177	0.63
	Total	1.569	1.569
	% domestic	25%	60%
Fuel oil	Domestic	0.103	0.569
	International	1.936	1.471
	Total	2.040	2.040
	% domestic	5%	28%

Following this 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 thought the overall movements, fuel consumption and hence emissions are different.

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 and emission factors for domestic and international shipping

Table 5-31 summarises the time-series in fuel consumption for domestic and international shipping derived from this method for fuel oil and gas oil (marine diesel oil plus marine gas oil combined) since 1990. Figures for fishing which are reported as a separate source category in the inventory are also shown.

Table 5-32 shows the implied emission factors for each key pollutant, for both domestic and international vessel movements and fishing in 2009. The units are in g/kg fuel and are implied by the figures in the Entec study.

Table 5-31 UK inventory fuel consumption for domestic and international shipping, 1990-2009

Year	Fuel Consumption (Mt)				
	Gas oil			Fuel oil	
	Domestic (excl. fishing)	Fishing	International	Domestic	International
1990	0.171	0.006	1.704	0.346	1.132
1991	0.169	0.005	1.764	0.342	1.065
1992	0.166	0.006	1.791	0.335	1.095
1993	0.164	0.006	1.708	0.332	1.143
1994	0.174	0.006	1.643	0.352	0.951
1995	0.181	0.006	1.476	0.368	1.196
1996	0.182	0.006	1.700	0.370	1.259
1997	0.178	0.005	1.630	0.361	1.570
1998	0.181	0.005	1.923	0.371	1.417
1999	0.181	0.004	1.580	0.374	0.877
2000	0.169	0.004	1.588	0.347	0.630
2001	0.163	0.004	1.742	0.334	0.541
2002	0.170	0.004	1.332	0.351	0.460
2003	0.166	0.004	1.539	0.342	0.576
2004	0.168	0.005	1.443	0.343	0.935
2005	0.172	0.005	1.361	0.356	1.164
2006	0.163	0.004	1.789	0.337	1.480
2007	0.388	0.004	1.177	0.103	1.936
2008	0.378	0.004	1.056	0.100	2.458
2009	0.359	0.004	1.057	0.094	2.208

Table 5-32 2011 Inventory Implied Emission Factors (units in g/kg fuel)

Fuel	Source	NO_X	SO_2	VOC	PM_{10}	CO
Gas Oil	Domestic (excl. fishing)	64.44	20.36	2.82	1.95	7.40
	Fishing	57.97	2.02	2.04	1.32	7.40
	International	69.33	26.37	2.74	1.85	7.40
Fuel Oil	Domestic	70.57	53.96	3.52	6.56	7.40
	International	77.71	53.92	2.92	6.75	7.40

Emissions from military shipping

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, 2010). 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.

5.6 OFF-ROAD SOURCES

Emissions from military aircraft and naval vessels are reported under 1A5b Other Mobile (including military). Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data.

Emissions from off-road sources are estimated and are reported under the relevant sectors, i.e. Other Industry, Residential, Agriculture and Other Transport.

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 NAEI 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.

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 engine sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \cdot H_j \cdot e_{vj}$$

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 Netcen (now part of AEA Group) 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 2005-2009.

For industrial and construction machinery, a new set of four drivers was used. Each of the individual machinery types was 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 5-33.

Table 5-33 Industrial machinery category, driver source and machinery type for 2004-09 emissions from industrial machinery

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 2010 (ONS, 2010).	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
		bore/drill rigs
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS 2010.	off highway trucks*
		crushing/processing equip
		excavators
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	loaders with pneumatic tyres
		bulldozers
		tracked loaders
		tracked bulldozers
		tractors/loaders
		crawler tractors
		off highway tractors
		dumpers /tenders
General Industry	Based on an average of growth indices for all industrial sectors, taken from data supplied by DECC for use in energy and emissions projections.	generator sets 100-1000KW
		pumps
		air compressors
		gas compressors
		welding equip
		pressure washers
		aerial lifts
		forklifts*
		sweepers/ scrubbers
		other general industrial equip
		other material handling equip

For domestic house and garden machinery, trends in the number of households are used (CLG, 2010), for airport machinery, statistics on the number of terminal passengers at UK airports are used (CAA, 2010), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2010) 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/CORINAIR emission inventory guidebook (EMEP/CORINAIR, 2009).

Aggregated emission factors for the four main off-road machinery categories in 2009 are shown in Table 5-34 by fuel type. The fleet-average (aggregated) emission factors for most machinery types are lower than in the 2008 inventory because of the expiry of old machinery and penetration of new machinery into the fleet as well as the reduction in the sulphur content of fuels.

Table 5-34 Aggregate Emission Factors for Off-Road Source Categories in 2009 (t/kt fuel)

Source	Fuel	CO	NH_3	NO_X	PM_{10}	SO_2	VOC
Agriculture - mobile machinery	Gas oil	16.84	0.03	28.98	2.85	1.68	5.16
Agriculture - mobile machinery	Petrol	716.32	0.01	1.45	0.03	0.01	248.58
Aircraft - support vehicles	Gas oil	12.52	0.03	28.19	2.35	1.68	5.02
House and garden machinery	DERV	4.34	0.03	47.96	1.67	0.01	2.57
House and garden machinery	Petrol	667.85	0.01	3.82	0.03	0.01	61.03
Industrial off-road mobile machinery	Gas oil	16.70	0.03	38.43	3.22	1.68	6.39
Industrial off-road mobile machinery	Petrol	1034.72	0.01	6.24	0.03	0.01	39.33

5.7 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

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

Table 6-1 Mapping of NFR Source Categories to NAEI Source Categories: Domestic / Commercial / Public Sectors

NFR Category (other 1A4)	**Pollutant coverage**	**NAEI Source category**	**Source of EFs**
1 A 4 a i Commercial / institutional: Stationary	All CLRTAP pollutants *(except HCH)*	Miscellaneous industrial/commercial combustion	UK factors
		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	Literature sources
1 A 4 c i Agriculture/Forestry/ Fishing: Stationary	All CLRTAP pollutants *(except HCB and HCH)*	Agriculture - stationary combustion	UK factors
1 A 4 c ii Agriculture/Forestry/ Fishing: Off-road vehicles and other machinery	All CLRTAP pollutants *(except HCB , HCH and PCBs)*	Agricultural engines	Literature sources
		Agriculture - mobile machinery	
1A3e Pipeline Compressors	All CLRTAP pollutants *(except POPs and PAHs)*	Included under 1A1c - Gas Production	

6.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

The NAEI utilises energy statistics published annually in the Digest of UK Energy Statistics (DECC, 2010). The source categories and fuel types used in the NAEI therefore reflect those used in DUKES. In Chapter 3,

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 1A4a (i/ii) and 1A4b (i/ii) NO_x, Pb, Cd, PM_{10}, SO_2, NMVOC, CO, Hg, B[a]P and PCDD/PCDF. Sector 1A4c (i/ii) is a key source only for NO_x, NMVOC, CO, PM_{10}, Cd 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 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.

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. Instead, all 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). AEA 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 industry. AEA 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 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}. Because of the smaller plant, it is not possible to derive bottom-up estimates and 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 [Ktonne])
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 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, 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, 2007), the EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 2009) and UK emission factor surveys (Walker *et al*, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2010) are also used in the generation of emission factors for larger combustion plants in the public and commercial sector source categories.

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 upon emissions data reported in the PI, SPRI and ISR. Section 3.7 discusses QA/QC issues regarding these data.

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	Source of EFs
1 B 1 b Solid fuel transformation	All CLRTAP pollutants *(except Se, HCB and HCH)*	Coke production	Operator reporting under IPPC, literature sources
		Iron and steel - flaring	
		Solid smokeless fuel production	
1 B 2 a i Exploration, production, transport	NO_x, NMVOC, SO_2 and CO	Gas Production - Gas terminal storage	Operator reporting under IPPC and via EEMS
		Gas Production - Offshore Well Testing	
		Gas Production - process emissions	
		Gasification processes	
		Oil Production - Offshore Oil Loading	
		Oil Production - Offshore Well Testing	
		Oil Production - Oil terminal storage	
		Oil Production - Onshore Oil Loading	
		Oil Production - process emissions	
		Petroleum processes	
1 B 2 a iv Refining / Storage	NMVOC and NH_3	Refineries - drainage	Operator reporting under IPPC and data from UKPIA
		Refineries - general	
		Refineries - process	
		Refineries - tankage	
1 B 2 a v Distribution of oil products	NMVOC	Petrol stations - petrol delivery	Literature sources, Institute of Petroleum
		Petrol stations - spillages	

NFR Category (1B1)	Pollutant coverage	Source	Source of EFs
		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 leakage	Gas compositional analysis by network operators
1 B 2 c Venting and flaring	NO_x, NMVOC, SO_2, Particulate Matter and CO	Gas Production - gas flaring	Operator reporting under IPPC and EEMS, and data from UKPIA
		Gas Production - gas venting	
		Oil Production - gas flaring	
		Oil Production - gas venting	
		Refineries - flares	

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 Oil & Gas team in Aberdeen; and
- gas leakage data provided annually by the gas supply network operators in the UK.

Emission estimates are calculated using operator-reported data from refineries and from the oil & gas exploration and production sector, but otherwise the estimates are taken from either literature factors or annual sampling and analysis to determine fuel composition.

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 and other solid smokeless fuel (SSF), and the sector also includes emissions from iron and steel flaring from 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 and these are used directly within the UK inventory estimates. 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/CORINAIR guidebook (EMEP/CORINAIR, 2009), BREF notes, US EPA AP-42 (US EPA, 2007) 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. At the end of 2009, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last six 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 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 1B2 is a key source for NMVOC only.

Around 6% of total UK NMVOC emissions in 2009 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 4.5% of 2009 NMVOC emissions, whilst flaring and venting in oil and gas production installations (1B2c) accounts for around 3% of 2009 NMVOC emissions and just under 1% of PM_{10} 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 AEA.

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. For upstream oil & gas production sites, operators submit annual returns via the Environmental Emissions Monitoring System (EEMS) regulated by DECC Oil & Gas, which includes emission estimates of NMVOC, CO_2, CH_4, CO, NO_X, SO_2 and fluorinated gases reported by emission source and (where appropriate) fuel type. Under 1B2ai, emissions are reported from process emissions (such as acid gas treatment, degassing of associated oil), oil loading at offshore rigs (into ships) and at terminals (from ships to storage vessel), fugitive releases (including tank storage emissions), and emissions from well testing. All upstream oil & gas production sites operate under license to DECC Oil and Gas, 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 timeseries consistency and address any gaps or inconsistencies through consultation with the regulators at DECC and the site operators where necessary.

In addition to these upstream sites, there are some additional sites for petroleum and gas processing (such as compressor sites) 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, 2010), 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 12 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 timeseries to 1990.

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 Mains (UK Transco);
- 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 (UK Transco).

During 2010, consultation with the gas network operators confirmed that the scope of the network leakage model used by each operator did not include estimates of gas leakage downstream from the gas meter, i.e. at the point of use. Therefore, new estimates have been derived for gas leakage at the point of use during this inventory cycle, using data on the numbers of gas appliances in the UK in the commercial and domestic sectors. These new estimates have been included within the gas network leakage data in 1B2b, and represent around 0.5% of the total gas leakage emissions from the transmission and distribution system in the UK in 2009.

An additional method improvement was implemented during 2010 following consultation with the gas network operators, to correct a previous methodological error. The gas compositional data provided by the network operators in 2010 prompted enquiries by the Inventory Agency as the number of gas compositional analyses per network varied greatly in the data submission to the Inventory Agency. Each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition. Through consultation with the network operators the Inventory Agency identified that in some cases a limited (i.e. not fully representative) dataset of gas compositions had previously been provided for some local distribution zones, indicating that the derived UK average composition was incorrect. Supplementary data was therefore obtained from the central database of gas compositional analysis, and the UK average composition re-calculated using this more comprehensive, representative data. The calculation of the reported UK average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs, to provide an average gas composition, which includes an average annual NMVOC figure for natural gas in the UK.

The emissions of NMVOC from this source 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 under DECC Oil and Gas, 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.

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 are described below.

1B2ai, 1B2c

Oil and Gas UK provides emission estimation guidance for all operators to assist in the completion of EEMS and EU-ETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The emission estimates for the offshore industry are based on the Oil and Gas UK EEMS dataset for 1995-2009. Emission estimates from 1990-1994 (i.e. pre-EEMS) are estimated from specific Oil and Gas UK studies of 1991 and 1998, using production data as a basis for interpolation of data between 1990 and 1995. The dataset provided in 2010 by DECC and Oil and Gas UK 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.

The data gaps & inconsistencies evident within the latest (2010) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators and regulators alike. Furthermore there are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. During 2010, the Inventory Agency conducted research to review the emissions data reported by oil and gas terminal operators, refinery operators and several petrochemical manufacturers, using data from EEMS (for the oil and gas sites), IPPC (for all sites) and EUETS (for all sites). The report can be found at:

http://www.airquality.co.uk/archive/reports/cat07/1005251107_DA_Improvement_Report_Industry_Task_May2010_Issue_1.pdf

In many cases, the research enabled the Inventory Agency to clarify the difference in reporting scope between the different mechanisms. However, the research also identified several reporting errors, and has led to several revisions of the source data for oil and gas terminals, and also provided feedback to regulators to help identify where QAQC of emissions data has previously been inconsistent.

1B2aiv, 1B2av

The emission estimates from refineries and from petrol distribution are all derived based on consistent methods across the timeseries 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.

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, and it is this activity that led to the identification of a systematic error in the data processing of gas compositional analysis which is outlined above and was corrected during the current inventory cycle.

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	Industry & Operator reporting under IPPC
2 A 4 Soda Ash Production and use	Particulate Matter and CO	Chemical industry - soda ash	
2 A 6 Road Paving with Asphalt	NMVOC, Particulate Matter, PCDD/ PCDF, benzo[a]pyrene and benzo[k]fluoranthene	Bitumen use	
		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 and 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 - Fletton	
		Brick manufacture - non Fletton	
		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	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Refractories - chromite based	
		Refractories - non chromite based	
		Unglazed ceramics	
2 B 2 Nitric Acid Production	NO_x	Nitric acid production	Operator reporting under IPPC
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 - alkyl lead	
		Chemical industry - ammonia based fertilizer	
		Chemical industry - ammonia use	
		Chemical industry - cadmium pigments and stabilizers	
		Chemical industry - carbon black	
		Chemical industry - carbon tetrachloride	
		Chemical industry - chloralkali process	
		Chemical industry - chromium chemicals	
		Chemical industry - general	
		Chemical industry - halogenated chemicals	
		Chemical industry - magnesia	
		Chemical industry - nitric acid use	
		Chemical industry - pesticide production	
		Chemical industry - phosphate based fertilizers	
		Chemical industry - picloram production	
		Chemical industry - pigment manufacture	
		Chemical industry - reforming	
		Chemical industry - sodium pentachlorophenoxide	
		Chemical industry - sulphuric acid use	
		Chemical industry - tetrachloroethylene	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Chemical industry - titanium dioxide	
		Chemical industry - trichloroethylene	
		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	Industry & Operator reporting under IPPC
		Blast furnaces	
		Cold rolling of steel	
		Electric arc furnaces	
		Hot rolling of steel	
		Integrated steelworks - other processes	
		Integrated steelworks - stockpiles	
		Iron and steel - flaring	
		Sinter production	
2 C 3 Aluminium production	All CLRTAP pollutants *(except NMVOC, NH_3,Se HCH and PCBs)*	Alumina production	
		Primary aluminium production - anode baking	
		Primary aluminium production - general	
		Primary aluminium production - pre-baked anode process	
		Primary aluminium production - vertical stud Soderberg process	
		Secondary aluminium production	
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*	Lead battery manufacture	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
	and Ni) and PCDD/ PCDF	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	
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	
		Tin production	
2 D 1 Pulp and Paper	NH_3	Paper production	UK factors
2 D 2 Food and Drink	NMVOC and NH_3	Bread baking	
		Brewing - fermentation	
		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	
		Other food - margarine and other solid fats	
		Other food - meat fish and poultry	
		Other food - sugar production	
		Spirit manufacture - casking	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Spirit manufacture - distillation	
		Spirit manufacture - fermentation	
		Spirit manufacture - other maturation	
		Spirit manufacture - Scotch whisky maturation	
		Spirit manufacture - spent grain drying	
		Sugar beet processing	
		Wine manufacture	
2 D 3 Wood processing	NMVOC and Particulate Matter	Wood products manufacture	
2 F Halocarbons use	PCDD/ PCDF, HCH, PCBs	Capacitors	International and UK Literature
		Fragmentisers	
		Previously treated wood	
		Transformers	
2 G OTHER	Particulate Matter	Other industry - part B processes	UK factors

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 British Cement 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 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, 2007). 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 2 Fletton brickworks in 2008, although one of these is now closed. 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 uses coal, and so only the latter should have fuel-related SO_2 emissions. 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 and the reported emission for the site is assumed to be due to sulphur from the clay. All of the 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 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.

8.6 METHODOLOGY FOR IRON & STEEL PROCESSES (NFR 2C1)

NFR Sector 2B5a 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. Emissions from these three processes, as well as other minor processes such as slag processing, are reported under 2C1, but excluding emissions from combustion of blast furnace gas, together with coke oven gas and/or natural gas in the hot stoves used to heat blast air, and in other combustion plant at integrated works. Those emissions are instead reported under 1A2a. Following review, we believer it would be more appropriate to report these emissions under 2C1 as well and this change will be made for the next version of the inventory.

Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter.

Blast furnaces are used to reduce the iron oxides in iron ore to iron. 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 2009 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 2009, following the closure of a large producer towards the end of the year, and a larger number of secondary aluminium processes. All of the operational primary aluminium sites, as well as the recently-closed site, use the pre-baked anode process, and anodes were baked at two sites in the UK (one since the 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 1997-2009, 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 1998-2009 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.

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.

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/CORINAIR Guidebook (EMEP/CORINAIR, 2009).

Emission factors for significant sources 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.

2B1

The source emissions data from plant operators is subject to the QA/QC procedures of the Environment Agency's Pollution Inventory.

2B3

During summer 2005, consultation between Defra, AEA, plant operators and the UK Meteorological Office was conducted to discuss factors affecting emissions from the adipic acid plant, including: 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 were intended to clarify the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient N_2O concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

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.

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	Industry & Inventory estimates
		Decorative paint - trade decorative	
3 A 2 Industrial coating application	NMVOC and Particulate Matter	Industrial coatings - agricultural and construction	
		Industrial coatings - aircraft	
		Industrial coatings - automotive	
		Industrial coatings - coil coating	
		Industrial coatings - commercial vehicles	
		Industrial coatings - drum	
		Industrial coatings - marine	
		Industrial coatings - metal and plastic	
		Industrial coatings - metal packaging	
		Industrial coatings - vehicle refinishing	
		Industrial coatings - wood	
3 A 3 Other coating application		Industrial coatings - high performance	
3 B 1 Degreasing	NMVOC	Leather degreasing	UK 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	Industry & Estimated
		Coating manufacture - inks	
		Coating manufacture - other coatings	
		Film coating	

NFR Category (3A)	Pollutant coverage	NAEI Source Category	Source of EFs
		Leather coating	
		Other rubber products	
		Paper coating	
		Textile coating	
		Tyre manufacture	
3 D 1 Printing	NMOVC	Printing - flexible packaging	Industry & Estimated
		Printing - heatset web offset	
		Printing - metal decorating	
		Printing - newspapers	
		Printing - other flexography	
		Printing - other inks	
		Printing - other offset	
		Printing - overprint varnishes	
		Printing - print chemicals	
		Printing - publication gravure	
		Printing - screen printing	
3 D 2 Domestic solvent use including fungicides	NMVOC and NH_3	Aerosols - car care products	
		Aerosols - cosmetics and toiletries	
		Aerosols - household products	
		Agriculture - agrochemicals use	
		Non-aerosol products - automotive products	
		Non-aerosol products - cosmetics and toiletries	
		Non-aerosol products - domestic adhesives	
		Non-aerosol products - household products	
		Non-aerosol products - paint thinner	
		OvTerr Solvent Use (all)- Cayman, Falkland, Montserrat, Bermuda and Gibraltar	
3 D 3 Other product use	NMVOC, PCDD/ PCDF, PAHs and HCH	Creosote use	
		Industrial adhesives - other	
		Industrial adhesives - pressure sensitive tapes	
		Other solvent use	
		Road dressings	
		Seed oil extraction	
		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

In general, emission estimates for NFR sector 3 are based on solvent consumption data supplied by industry or regulators. Published sources of national activity data are not used to any significant extent.

9.3 METHODOLOGY FOR SOLVENT USE (NFR 3)

All NFR source categories within 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) Other rubber products Other solvent use Printing – newspapers Printing - other flexography Printing - other inks Printing - other offset Printing - overprint varnishes Printing - print chemicals Printing - screen printing Surface cleaning - hydrocarbons Surface cleaning - oxygenated solvents Leather degreasing	Solvent consumption data for the sector, assumption that little or no solvent is recovered or destroyed.
Industrial coatings – automotive Printing - heatset web offset Printing - metal decorating Surface cleaning - 111-trichloroethane Surface cleaning – dichloromethane Surface cleaning - tetrachloroethylene	Solvent consumption data for the sector, with adjustments to take account of likely abatement of solvent.

NAEI Source Category	General method
Surface cleaning – trichloroethylene	
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.

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 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	NO_x, NMVOC, NH_3, Particulate Matter, CO, PCDD/ PCDF, PAHs and PCBs	Field burning	UK factors
4 G OTHER	Particulate Matter, HCB	Agricultural pesticide use -	

NFR Category	Pollutant coverage	NAEI Source	Source of EFs
	and HCH	chlorothalonil use	
		Agricultural pesticide use - chlorthal-dimethyl use	
		Agricultural pesticide use - quintozine	
		Agriculture - agrochemicals use	
		Agriculture - stationary combustion	

The following NFR source categories are key sources for major pollutants: 4B1a, 4B1b, 4D1a, 4D2c, 4B13, 4B9d, 4B8, 4B9a, & 4B3. Description of the inventory methodology will focus on these categories.

10.2 ACTIVITY STATISTICS

National statistics on livestock numbers and crop areas are taken from the June Agricultural Survey results, collected by Defra:

http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/junesurvey/index.htm.

Fertiliser use statistics are derived from the British Survey of Fertiliser Practice: https://statistics.defra.gov.uk/esg/bsfp.htm and from DARDNI statistics for Northern Ireland.

Statistics relating to farm management practices (e.g. livestock housing systems, manure storage systems, manure application methods and timings) are derived from a number of sources including Defra Farm Practices Surveys:

http://www.defra.gov.uk/evidence/statistics/foodfarm/enviro/farmpractice/index.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. For ammonia, emission from livestock sources, estimates are derived using the National Ammonia Reduction Strategy Evaluation System (NARSES) model (Webb and Misselbrook, 2004) and for fertilisers following the approach of Misselbrook et al. (2004). A detailed description of the methodology for the estimate of ammonia emissions from UK agriculture for 2007 and the derivation of specific emission factors is given by Misselbrook et al. (2010). The approach in NARSES is essentially to model the flow of total ammoniacal nitrogen (TAN) through each stage of livestock production and livestock waste processing. Emissions of ammonia from each stage are calculated as a proportion of TAN present at that stage. The emission calculations are made to a high level of detail, with in depth consideration of the different emission factors at each stage for over 20 livestock classes.

10.3.1 Major changes between 2008 and 2009

Key areas of revision in the 2011 inventory were[9]:

1. Extending time series back to 1980
Emission factors and activity date were extended back to 1980.

2. 2009 fertiliser use data
Date derived from BSFP for crop year 2009 for England, Wales and Scotland and from DARDNI statistics for Northern Ireland.

Total fertiliser N use increased by a small percentage (1.3%) between 2008 and 2009, the first increase for 5 years. Urea use increased by 28%, which, having a disproportionate effect on total fertiliser emissions, gave an overall increase in emissions of 4.2 kt NH_3.

3. 2009 livestock numbers
Key trends observed since 2008 are:

Cattle – a 0.8% decline in total cattle numbers (across both the dairy and beef herd)
Pigs – a 0.2% increase in pig numbers
Sheep – a 3.3% decline in sheep numbers
Poultry – a 4.2% decline in total poultry numbers, with a 3.2% increase in the laying flock but a 6.5% decrease in broiler numbers

4. Pig and poultry housing
The Pig and Poultry Farm Practices Survey, 2009, (Defra) provided new data for the proportion of pigs and poultry housed under different systems and gave a comparison with the FPS 2006 data. These data were combined with earlier survey data from Sheppard (1998, 2002) and Smith et al. (2000c, 2001a) to produce trends in pig and poultry housing from 1990 – 2009. The main changes over recent years are an increase in sows and weaners reared outdoors, and increase in free-range poultry and an increase in the use of in-house manure drying systems for poultry housing.

FPS2009 (Pig & Poultry) also give a breakdown of free-range laying hens on systems with 'grass and trees' or 'grass only', although we currently have no data on the relative difference in emissions from these systems.

Note that survey data were for England or England and Wales. In the absence of any Scotland or Northern Ireland data, trends from these surveys have been used for the whole UK.

5. Cattle housing
The Farm Practices Survey 2010 (England) provides new data on proportion of dairy and beef cattle housed under different systems. These were used together with data from Smith et al. (2001b) to derive trends in cattle housing 2000 – 2009. The proportion of beef cattle on slurry systems has remained fairly constant, but there is evidence of an increase in the proportion of dairy cows and dairy followers housed on slurry systems.

[9] Misselbrook et al, 2010

Detailed description of the emission factor and activity data sources can be found in the 'Inventory of Ammonia Emissions from UK Agriculture 2009' (Misselbrook at al, 2010).

Ammonia from non-agricultural animals (domestic pets, non-agricultural horses) is also reported under NFR sector 4. This is because they are considered sources which should be included within the national totals, and there is no alternative NFR which is more appropriate. Emission estimates for these sources are provided annually by the Centre for Ecology and Hydrology (CEH) and are based on the use of emission factors (estimated on the basis of the N excretion rates for different animal sizes) and estimates of animal numbers.

Agricultural emissions of PM_{10} are based on estimates for the year 1998 given by IC Consultants, 2000. These estimates are extrapolated to other years on the basis of animal numbers.

Other sources include composting and use of agrochemicals, where emission estimates are based on the use of literature emission factors and national statistics.

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 North Wyke 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 (North Wyke, ADAS and CEH), then sent to AEA and Defra for further checking prior to inclusion in the UK NAEI.

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	Application to land	UK model and assumptions to derive NMVOC factors
		Landfill	
		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	
6 C a Clinical waste incineration (d)	All CLRTAP pollutants *(except NH_3,Se, Indeno (1,2,3-cd) pyrene and HCH)*	Incineration - clinical waste	Operator reporting under IPPC & UK factors
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	
		Foot and mouth pyres	
		Incineration - animal carcases	
6 C e Small scale waste burning	NO_x, NMVOC, Particulate Matter, CO and POPs *(except HCB and HCH)*	Agricultural waste burning	
		Small-scale waste burning	
6 D OTHER WASTE (f)	NH_3, PCDD/ PCDF and PCBs	Accidental fires - vehicles	UK factors
		Composting - NH3	
		RDF manufacture	

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 source categories within sector 6 are key sources for one or more pollutants.

11.2 ACTIVITY STATISTICS

National statistics are not available for many of the sources included in the waste sector and this problem is partly overcome by using reported emissions data and partly by AEA making independent estimates of activity levels.

Waste-derived fuels used for electricity and heat generation are reported in DUKES and these data are used in the inventory.

11.3 METHODS FOR ESTIMATING EMISSIONS

Emissions from incinerators for municipal solid waste (MSW), chemical waste, clinical waste, and sewage sludge are reported in the PI/SPRI/ISR and these emissions data are used in the national inventory.

Emissions of carbon, CO, NO_x, SO_2, and VOC from chemical waste incinerators are estimated based on analysis of data reported to the Pollution Inventory (Environment Agency, 2009). This only covers England and Wales, but there are not thought to be any significant emissions from plant in Scotland and Northern Ireland. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites has been done, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plant but the need for extrapolation of data may contribute to significant variations in the quality of the estimates. New activity data for this source have been provided by the Environment Agency.

Emissions of CH_4, CO, N2O, NOx, SO_2 and VOC from sewage sludge incinerators are estimated from a combination of data reported to the Environment Agency's Pollution Inventory, supplemented with the use of literature-based emission factors for those pollutants where the Pollution Inventory does not give information sufficient to derive estimates. Emissions of NOx are estimated using Pollution Inventory data while emissions of all other direct and indirect greenhouse gases are estimated from literature-based emission factors. The factor for N_2O is the default factor given in the IPCC good practice guidance for UK sewage sludge incineration. Emission factors for other pollutants are taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is estimated, these estimates being based on estimates given in the literature.

Emissions of carbon, CH_4, CO, N2O, NOx, SO_2, and VOC from clinical waste incinerators are estimated using literature-based emission factors. The factor for carbon is the default factor given in the IPCC good practice guidance, while the factor for N_2O is the default for UK MSW incineration given in the same source. Emission factors for other pollutants are largely taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is also estimated, these estimates being based on information given in literature sources.

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.

Emissions of CO, NOx, SO_2 and VOC from crematoria are based on literature-based emission factors, expressed as emissions per corpse, and taken from US EPA (2008). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2009).

All UK plant used to incinerate municipal solid waste (MSW) are now required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under NFR source category 1A1 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration). This has been the case since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery. Emissions from these incinerators are reported under 6C and are generally based on Pollution Inventory data for the period 1993-1997 with use of literature factors generally for the period 1990-1992 to reflect the higher emissions likely from UK MSW incinerators in that period before plant shutdowns and upgrades occured in the 1993-1995 period.

As with other sectors, gaps in reported data are generally filled by extrapolation from data reported in the same year by other processes, or, where available, data for the same process in other years. In the case of chemical waste incineration, this gap filling method, combined with the limited emissions data being reported, have led to problems with highly variable emission factor time series, as has already been noted for some non-ferrous metal processes (see section 8.8). The PI/SPRI/ISR data for sewage sludge and clinical waste incinerators are even more limited and so, for some pollutants it has been judged more reliable to base emission estimates upon AEA estimates of waste incinerated and literature-based emission factors.

Mercury emissions also arise from the disposal of mercury-containing products such as thermometers and emission estimates are based on figures published in WS Atkins, 1997

The emission estimate for ammonia from sewage treatment & disposal is taken from Dragosits & Sutton, 2004. Emissions from landfills are calculated using an emission factor taken from the same report and AEA estimates of the quantity of landfilled waste. Landfill emissions of NMVOC are calculated from methane emission estimates, by assuming a fixed ratio of NMVOC to methane emitted from landfills, which are estimated based on a UK model of landfill inputs, methane elution, capture and oxidation.

Emissions from accidental fires are key sources for PCDD/PCDF and PAH and estimates are made by combining AEA estimates of the mass of materials burnt during accidental fires and literature emission factors. Due to a lack of emission factors for accidental fires themselves, the methodology relies on the use of factors for small-scale combustion e.g. domestic combustion.

11.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

Some emission estimates for 6C rely upon emissions data reported in the PI, SPRI and ISR. Section 3.7 discusses QA/QC issues regarding these data.

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, NH_3, Particulate Matter, CO, Cu and POPs *(except HCB and HCH)*	Accidental fires - dwellings	UK factors
		Accidental fires - other buildings	
		Accidental fires - vehicles	
		Bonfire night	
		Cigarette smoking	
		Fireworks	
		Infant emissions from nappies	

12.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

NFR source category 7 is a key source for PM_{10}, PCDD/PCDF and benzo[a]pyrene and description of methodology will be limited to these sources.

12.2 EMISSIONS FROM BONFIRE NIGHT AND FIREWORKS

Emission estimates for bonfire night are based on AEA 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.

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. Activity data estimates are based on limited official statistics for imported fireworks, plus an assumption that an additional 10% of fireworks are supplied by UK manufacturers.

13. Recalculations and Methodology Changes

Most of the methodology revisions and emission estimate recalculations that have been made for this report are relatively minor in terms of their impact on total emission estimates but they are nonetheless important in terms of an improvement in the quality of the inventory. In addition, several inventory improvements have been implemented in the latest cycle that have led to significant recalculations for UK emission sources. A short description of the most important revisions is given below.

13.1 PERSISTENT ORGANIC POLLUTANTS MULTI-MEDIA INVENTORY

Major improvements have been implemented this year in the UK POPs inventory, as a result of a related Government study to derive multi-media release estimates for several POPs. In May 2009, on behalf of Defra, AEA established complete air, land and water emission inventories for PCDD/PCDF, poly-chlorinated PCBs, dioxin-like PCBs and hexachlorobenzene. This work included a full review of the air emissions quoted within the NAEI.

As part of the review data within the NAEI was updated, and the methodology for accidental fires modified to move emissions away from a population based method. The new methodology linked the estimates to fire statistics and allowed for a more practical approach to be adopted which should illustrate the impact of fire safety measures such as smoke detectors on the emissions time-series.

The research also identified a number of gaps within emission sources and included these ‘new’ sources within the NAEI framework:

- PCDD/PCDF
  - Tobacco consumption
  - Leaks from dielectric fluids
- PCBs
  - Accidental fires- buildings and vehicles (generated from uncontrolled combustion of plastics)
- HCB
  - Shipping- both coastal and international (based on use of waste oils in commercial fleets)
  - Cement manufacture (based on guidance from the UNECE guidebook)

As of December 2009 a continued programme of improvement for POPs inventories commenced on behalf of Defra. This was driven in part by the addition of nine new POPs to the UNEP Stockholm Convention on Persistent Organic Pollutants.

The research included a sampling and analysis cycle of pesticide products to help derive more representative data on working concentrations of HCB within the pesticide chlorothalonil.

This has led to the application of a new UK emission factor of 8 ppm in 2009, to revise the previous emission estimates that were based on the FAO legal limit of 40 ppm.

The emission estimates associated with HCB in pesticides have evolved considerably over the last two inventory compilation cycles due to new research. In the 1990-2008 inventory the emissions of HCB from pesticides were re-distributed based on new assumptions to partition releases from use of crop-sprayers between air, land and water. Previously emission estimates assumed 100% of product was lost to air. In the revised method 70% of emissions were assumed to be emitted to air (28.8% land and 1.2% water). Furthermore the UK emission factors were also amended in light of new data, reducing the assumed working concentration of HCB in chlorothalonil from 300 PPM to 40 PPM to bring it into line with the FAO legal limit. This reflected a more accurate representation of UK estimates, although working concentrations were expected to be lower still.

The sampling and analysis programme that has led to revisions in the current inventory cycle has supported that hypothesis, with working concentrations measured at levels as low as 0.16 PPM. The average UK working concentration for HCB in chlorothalonil has been revised to 8ppm for 2009 with a linear decrease in concentrations assumed since 2006, the point at which the 40 ppm limit was adopted. Table 13- 1 illustrates the changes seen within emission estimates for HCB over the last two compilation cycles.

Table 13-1 Comparison of emissions of HCB emissions due to agricultural pesticides use between the 2009 and 2011 inventory

	Units	2004	2005	2006	2007	2008	2009
4G (2011 inventory)	**Kg**	42.5	39.2	35.4	31.42	26.9	23.3
4G (2010 inventory)	**Kg**	61.7	61.7	60.3	59.5	59.5	
4G (2009 inventory)	**Kg**	821.8	811.6	787.5	786.3		

The POPs work programme has also included a sampling and analysis project, measuring POPs (PCBs, PCDD/PCDF and HCB) within sewage sludge. This is expected to have the greatest impact for estimates of POPs releases to land via sludge disposal to landfill, land reclamation and agricultural land spreading. However, PCB emissions to air from the use of sewage sludge in agriculture are also an important source for PCB emissions. The research is still being finalised, and the findings will be considered within the next inventory cycle.

Other parts of the work package have included a full national survey of waste burning habits to help update the AEA estimates made for activity data in small scale waste burning. The work has also looked to review the emissions to land from incinerators and non-ferrous metal plants based on the generation of ash and dust from those sectors.

13.2 FURTHER DISAGGREGATION OF NAEI SOURCES

In the 2011 inventory a few NAEI source categories were added or existing source categories were further disaggregated.

Table 13-2 Disaggregation of NAEI source categories and new source categories

NFR code	Source Name	Activity Name	2008 NAEI source
1A3bvii	Road transport	Road abrasion	New source
1A3bii	Road transport - all vehicles biofuels use	Bioethanol	New source
1A3bii	Road transport - all vehicles biofuels use	Biodiesel	New source
1A3c	Rail - coal	Coal	New source
1B2ai	Gas Production - process emissions	Non-fuel combustion	Oil and gas: process emissions
1B2ai	Gas Production - Gas terminal storage	Non-fuel combustion	Oil and gas: terminal storage
1B2ai	Gas Production - Offshore Well Testing	Exploration drilling :no of wells	Oil and gas: well testing
1B2b	Gas leakage	Natural Gas (leakage at point of use)	New source
1B2c	Gas Production - gas flaring	Non-fuel combustion	Oil and gas: gas flaring
1B2c	Gas Production - gas venting	Non-fuel combustion	Oil and gas: gas venting
Memo	Aircraft between UK and CDs - TOL	Aviation spirit/ Aviation turbine fuel	Aircraft - TOL
1A3aii(i)	Aircraft between UK and Gibraltar - TOL		Aircraft - TOL
Memo	Aircraft between UK and other OTs (excl Gib.) - TOL		Aircraft - TOL
Memo	Aircraft between UK and CDs - Cruise		Aircraft - Cruise
1A3aii(ii)	Aircraft between UK and Gibraltar - Cruise		Aircraft - Cruise
Memo	Aircraft between UK and other OTs (excl Gib.) - Cruise		Aircraft - Cruise

13.3 ROAD TRANSPORT

There have been a number of improvements made to the road transport inventory mainly in terms of the application of more detailed activity data and methodologies. Changes in activity data have caused changes in the inventories for all pollutants and in most cases for all years back to 1990.

Some of the changes affected all pollutants while others were specific to certain pollutants. The key changes are summarised below.

Changes affecting all pollutants

- Updated vehicle km activity data by road types in Great Britain. DfT was able to provide a consistent time series of vehicle km data for 1993 to 2009 by road type and vehicle type for the first time. The overall totals for each vehicle type remain the same as previous years' estimates but the distribution between road types has been updated, in particular over the period 1993-2001 for LGVs, HGVs and motorcycles and from 1993-2001 and 2007 for buses.

- Revisions to the vehicle km activity data for cars, LGVs and rigid HGVs in Northern Ireland (NI) after clarification on the vehicle classifications used in the traffic census report. This was mainly responsible for the reduction in emissions from rigid HGVs observed across the time series.

- Assumptions on the split between buses and coaches on urban and rural roads have been updated, based on information provided in DfT's Transport Statistics Great Britain (TSGB) on vehicle km done by local and non-local bus services.

- Assumptions on the split in vehicle km for buses by vehicle weight class have been updated using licensing information and correlations between vehicle weight class and number of seats. This is to improve how the emission factors for different bus vehicle weight classes are utilised. This, and the change noted above, is responsible for most of the changes observed in the bus emissions across the time series.

- The treatment of emissions from buses operating in London has been improved by taking into account the specific composition of the fleet operated by TfL separately from other bus services in London.

- The estimation of emissions from HGVs and buses in London in 2008 and 2009 was improved by taking into account the effects of the London Low Emissions Zone on the composition (by Euro class) of the HGV and bus fleet separately from the fleet in other parts of the UK. This and the change noted above generally led to small reductions in UK bus and HGV emissions.

- A more detailed breakdown in the activity by 2-stroke and 4-stroke motorcycles has been used following a detailed review of motorcycle sales, population and lifetime by engine size. This was responsible for most of the changes observed in the motorcycle emissions.

Changes affecting specific pollutants

In addition to the changes highlighted above, the following changes have affected specific pollutants:

- NMVOC emissions
  The methodology for calculation of evaporative emissions of NMVOCs from petrol vehicles was updated with that recommended in the EMEP/CORINAIR Emission Inventory Guidebook 2007 in conjunction with UK specific fuel volatility and temperature data. This led to an increase in emissions in all years, but the changes were greater in years before 2000. The trend in evaporative emissions is converging towards previous estimates in more recent years indicating that the new methodology

is showing a steeper decline in emissions than previously estimated.

- PM emissions
  A new source, PM emissions from road abrasion (1A3bvii), is estimated for the first time. This additional non-exhaust emission source is based on emission factors and methodology provided in the EMEP/CORINAIR emission inventory guidebook. This leads to an overall increase in emissions from road transport across the time-series for PM_{10} and $PM_{2.5}$.

- PAH emissions
  Emission factors for PAHs were updated following a review of available factors in the DfT/TRL compilation and in the 2009 EMEP/CORINAIR emission inventory guidebook combined with expert judgement to obtain a consistent data set of factors crossing all Euro standards. Each individual PAH species was assessed independently and as a result the changes in emissions for each PAH species occur in different directions and to different extents.

More details on these methodology changes and recalculations are given in AEA (2011).

13.4 RAIL

Changes to the emissions inventory for rail stem from improvements in the activity data available for passenger and freight trains by using new information from train operators (ATOC) and the Office of Rail Regulation on the consumption of gas oil by diesel trains. The most significant change has been made to fuel consumption by rail freight. Fuel consumption has been reduced to bring into line with figures from ORR based on figures they obtained from rail freight operators. Previously, fuel consumption for freight trains had to be estimated using tonne km data from DfT. For passenger rail, a small revision has been made to fuel consumption data for Intercity trains to bring in line with revised figures from ATOC/ORR.

These changes are from the first phase of a larger programme of improvements for the rail sector which will continue next year through dialogue with DfT who are currently undertaking improvements to the UK national rail model that is expected to yield more accurate activity data on the split between rail movements by region and stock type.

Another minor change was made by including emissions from the consumption of coal used to power steam trains (heritage trains) using new information on coal consumption allocated to the rail sector in DUKES which was confirmed to be that used for powering steam engines.

13.5 SHIPPING

Large changes to the inventory time-series of shipping emissions are due to a new, more detailed Tier 2 methodology being adopted. The new method developed by Entec calculates fuel consumption and emissions from shipping activities around UK waters using a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys in 2007 (Entec, 2010). Previous emission estimates for coastal and international marine have been based on total consumption of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES, 2010). There have been considerable uncertainties with this data source into the split between domestic and international bunker fuel consumption. This has led to very erratic time series trends in fuel consumption and emissions which bears little resemblance to other activity statistics associated with shipping such as port movement data. The new method was used to estimate fuel consumption and emissions from domestic shipping in 2007 and DfT ports data were used as proxy drivers for fuel consumption in other years.

Fuel consumption for international shipping using UK bunker fuels was estimated by difference with total marine fuel consumption data to maintain consistency with national fuel statistics. Overall, this leads to a reduction in domestic shipping emissions and an increase in international shipping emissions. Entec's work also involved changes to shipping emission factors, by taking account of different factors for different parts of a shipping cycle, and different shipping engines and fuel types used in the fleet.

13.6 OFF-ROAD

Minor revisions to the emissions of all pollutants have been made for off-road transport and machinery sources (e.g. agricultural, industrial and construction machinery). As no national activity statistics are available for these sources each year, it is necessary to use proxy activity drivers to estimate trends in fuel consumption. A preferred, more detailed set of activity drivers were used for industry and construction machinery appropriate for each individual machinery type to estimate levels of activity and fuel consumption for all years relative to a 2004 base year. The new drivers come from sources at ONS, DECC and British Geological Survey.

13.7 AVIATION

In 2006, the Department for Transport (DfT) published its report "Project for the Sustainable Development of Heathrow" (PSDH). This laid out recommendations for the improvement of emission inventories at Heathrow 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. In 2009, these recommendations 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. In 2009, these recommendations 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, in 2009, were used as a basis for the UK inventory.

In 2010 flights between the UK and overseas territories were 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.

Military Aviation
The estimates of aviation fuels consumed in the commodity balance table in the DECC publication DUKES are the national statistics on fuel consumption, and EMEP/CORINAIR 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. This has been an improvement in the methodology included for the first time in the 2008 inventory. The ATF (Aviation Turbine Fuel) consumptions presented in DECC DUKES include the use of both civil and military ATF, and the military ATF use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil ATF consumption has been used in the fuel reconciliation. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

13.8 FUGITIVE EMISSIONS FROM OIL & GAS INDUSTRIES

A number of recalculations have been made due to revisions to source data in the oil and gas sector due to the 2010 research and revisions from operator data through EEMS, the correction of the gas leakage methodology, and the addition of the gas leakage at point of use estimates.

Recalculations to 2008 NMVOC emission estimates in the current inventory cycle, for the 1B2 sources are as follows:

- Emissions from oil loading (1B2ai) have been reduced by 2.5 kt NMVOC, due to decreased estimates for one offshore rig (Foinavon) and one terminal (Hound Point).
- Emissions from flaring (1B2c) have been reduced by 0.5 kt NMVOC, with increased estimates at three offshore rigs (Marathon Brae) all exceeded by a reduction in emission estimates from one terminal (Hound Point). In this same NFR sector, however, the venting emissions have increased by 0.5 kt due to a reported increase at one offshore rig (Elgin PUQ).
- Emissions from fugitive sources (1B2ai) have decreased by 0.7 kt with revised 2008 operator data from 7 terminals and 5 production installations.
- Emissions from gas leakage (1B2b) have increased by 2.6 kt, mainly due to the correction in the gas compositional analysis dataset, but also partly due to the addition of the new source of gas leakage at the point of use (i.e. within domestic and commercial properties, downstream from the gas meter).

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.

- **Fugitive emissions from oil and gas industries**

The data from the EEMS reporting system will be reviewed with the regulatory body during 2011, to address any site-specific reporting inconsistencies. The gas leakage estimates from the transmission and distribution networks will be reviewed with the network operators, and the compositional analysis data will be kept under close review in order to ensure that a representative dataset is used within future inventory compilation.

- **Road Transport**

Many significant improvements have been made to the inventory for road transport over the past few years and any further improvements will depend on wider inventory improvement priorities to be agreed with Defra.

The key areas to be considered for improvement are as follows:

➔ Changes in NO_x (and possibly PM) emission factors for all road vehicles following conclusions from the current review of ambient roadside measurements of NO_x, roadside remote sensing data and alternative emission factor sources. The inventory team is involved in this review as part of a wider consortium of emissions and air quality modelling experts and decisions will be made on whether to change the current emission factors used in the inventory in light of current evidence.

➔ In connection with the above, the potential for using alternative fleet composition data based on Automatic Number Plate Recognition data from a representative sample of sites will be considered. This may allow more area-type and road-type specific data on the vehicle mix by age, vehicle/engine size and fuel type to be used instead of national licensing statistics which only indicate details of the national fleet composition as registered rather than where used.

The aim of both these priority areas will be to provide a time-series in emissions which is more consistent with trends in ambient concentrations of NO_x and NO_2. Such an activity represents an important form of inventory verification.

- **Rail**

Developments for the rail sector will involve assessing the rail activity and stock data from DfT's Rail Emissions Model (REM) to achieve a better split in emissions between stock types, routes and regions taking into account changes in emission factors for new rail engines consistent with current EU emission regulations. Progress on this depends on the progress made by DfT in developing and providing necessary information from the REM.

- **Inland waterways**

At present, emissions from this source are not treated explicitly in the inventory. There are no national statistics on the amount of activity or fuel used by inland waterways and recreational craft, and current fuel balance procedures in the inventory effectively mean the emissions are being misallocated and possibly mis-represented in other source categories.

Work is already in progress exploring alternative sources on the population and usage of different craft used on inland waterways by reviewing port and harbour statistics held by DfT and contacting harbour authorities and river agencies and other organisations with an interest in this sector. The focus of this work is on Greenhouse Gas emissions from this source, but the work will consider the implications to air pollutant emissions as well.

- **Aviation**

Periodically AEA produce inventories for the major British airports. Data from these inventories get incorporated into the NAEI. AEA has recently produced an inventory for Heathrow for 2009. These data are likely to be incorporated into the 2010 NAEI.

The NAEI currently includes no flights between overseas territories and non-UK airports nor within overseas territories. Data for these flights will to be incorporated into the 2010 NAEI and reported as international aviation, recorded as a memo item, for flights between overseas territories and non-UK airports or as domestic for flights within overseas territories.

In addition to this, the NAEI currently includes no fugitive particulate emissions from aircraft brake and tyre wear. This is an improvement that is required to be addressed in future inventories.

- **Industrial Process Emissions**

Ongoing consultation with trade associations will continue to provide insights into factors affecting emissions of NMVOC, PM_{10}, CO, SO_2 & NO_x from industrial processes reported in the PI, SPRI and ISR; in some cases, fluctuations in reported emissions require specific enquiry to ensure data quality.

14. Projections

Projected emissions for the four National Emission Ceiling Directive (NECD) pollutants are compiled by the NAEI team in AEA to enable comparisons with international commitments to be assessed. A summary of the latest forecasts was submitted in December 2010 under the NECD reporting requirements. The 2010 NECD projections report is available under http://uk-air.defra.gov.uk/reports/cat07/1012161052_2010_NECD_Submission_Report.pdf

Emission projections are also submitted under the CLRTAP every 5 years, with the latest dataset being provided in February 2011.

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 target emissions are provided in Table 14-1 below together with the UK's actual emissions in 2010 (the latest year available). These targets are to be achieved in 2010 and subsequent years. The data shows that the NH_3, SO_2, NO_x and NMVOC ceilings have already been met in 2008.

Table 14-1: The UK's emissions in 2008 (as reported to the NECD) and the 2010 ceilings.

Pollutant	**Emissions in 2008 (ktonnes)**	**Gothenburg Protocol target in 2010 (ktonnes)**	**NECD Emissions ceiling target in 2010 (ktonnes)**	**Reduction required between 2008 and 2010 Emissions ceiling target**
NO_x	1,403	1,181	1,167	17%
SO_2	512	625	585	N/A
NMVOCs	942	1,200	1,200	N/A
NH_3	282	297	297	N/A

14.2 METHODOLOGY

The NAEI projection methodology broadly follows the methodology outlined in the EMEP / CORINAIR Emission Inventory Guidebook 2009.

In order to establish consistency between historic and projected emissions, emission inventories and emission projections should be based on the same structure. Therefore a similar method to that used to calculate historic emissions has been used to estimate future emissions. Historical emissions are calculated by combining an emission factor (for example, kilograms of a pollutant per million tonnes of fuel consumed) with an activity statistic (for example, million tonnes of fuel consumed).

For example:

$E_{2008} = A_{2008} * EF_{2008}$

where E = emission, A = activity and EF = emission factor, all for the year 2008.

For projected emissions:

$E_{2010} = A_{2010} * EF_{2010}$

Where E = emission, A = activity and EF = emission factor, all for the year 2010.

The UK projections submitted under the NECD (31st Dec 2010) and CLRTAP (15th Feb 2011) are based on the 2009 UK inventory. The latest set of projections is not based on the 2010 inventory because the 2010 inventory is not finalised till the end of January 2011. Hence the finalised 2009 UK inventory is used as the base year. The 2008 data in the projections template are thus taken from the 2009 UK inventory submitted to the CLRTAP in February 2010.

14.2.1 ACTIVITY DATA FORECASTS

To produce a projection, each source in the NAEI is linked to an activity driver. Examples of drivers may include forecasts of fuel use, vehicle kilometres, animal numbers or broader indicators such as forecasts of population, or economic indicators such as Gross Domestic Product (GDP) or Gross Value Added (GVA). The latest activity drivers are derived from a number of sources including the Department of Energy & Climate Change (DECC) latest energy forecasts from UEP38. The UEP38 energy forecast is based on the UK Low Carbon Transition Plan and can be found under:

http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/lc_trans_plan/lc_trans_plan.aspx.

The energy projections take account of the projected impacts of government policies that are deemed “firm and funded” at the time the projections are produced. The projections include those policies outlined in the UK Low Carbon Transition Plan. They do not include policies that are still under consideration.

Other sources that are used to derive activity drivers include (but are not limited to) information from the Department for Transport (DfT) for the road transport and aviation sectors and information from trade associations.

14.2.2 FUTURE EMISSION FACTORS

In addition to changes in activity influencing emissions, improvements in abatement measures will reduce emissions. The implementation of more stringent abatement measures, often the result of established legal requirements, must be considered when estimating future emissions. Therefore the emission factors where relevant have been varied to account for this. The projections do not include the impact of additional policies and measures that are currently subject to review and have not yet been implemented into UK law.

Table 14-2: Low Carbon Transition Plan (additional policy) included in the UEP38 scenario projections.

Sector	**Policies in Low Carbon Transition Plan**
Main Policy	- 2009 UK Low Carbon Transition Plan
Residential	- Domestic Energy Efficiency package - Zero Carbon Homes - CERT uplift - Better Billing and Metering - Product Policy - Community Energy Saving Programme - Renewable Heat Incentive
Business/Public Sector	- Carbon Reduction Commitment - Energy Performance of Buildings Directive - Product Policy - Smart Meters for SMEs - Loans for SMEs - Loans to public sector - Renewable Heat Incentive (business, public and industry)
Industry	- CCS demonstration plant (Energy Industry) - Renewable Energy Strategy
Transport	- EU new car average fuel efficiency standards - Low carbon emission buses - SAFED training for bus drivers

In addition to legislation, emissions may be changed through closure of older, generally more polluting plant and/or commissioning of newer, generally less polluting plant. Such changes can affect the overall activity level within a sector as well as emission factors but for technical reasons it is preferable to deal with these in the projections as influencing emission factors only. Changes in the immediate future can also be taken into account, although a judgement needs to be made about the likelihood of the change actually occurring. In the current economic situation, a number of site closures have been announced or proposed and, where appropriate, the impacts of these closures have been considered in these projections.

14.2.3 GENERAL ASSUMPTIONS: THE "WITH MEASURES" PROJECTIONS SCENARIO

The projections method presented here assumes in general that:

- All operators comply with new legislation;
- New abatement is applied to sources in order to meet the limits imposed by new regulations or in response to the impacts of trading mechanisms, but further emission reductions by voluntary actions over and above those levels are not achieved, unless this occurs anyway through actions in response to non-environmental factors e.g. replacing older, more polluting plant with newer technology on economic grounds.

Cases where the projections do include reductions that might be considered as 'voluntary' include:

- Projections from coating processes include the impact of product reformulation which in some cases may exceed the requirements of legislation;
- Power station emission projections are based on site or plant design-specific fuel projection data (from UEP38) and anticipated plant modifications (from consultation with operators) that in some cases may go over and above the minimum legislative requirements;
- Similarly for other heavy industry sectors, such as cement and iron & steel, the projections are based on site-specific emissions data and known plant closures & modifications.

These exceptions aside, it is considered that the "with measures" projections scenario that is presented in this report, drawing on the "central, central, central"[10] analysis of UEP38 and only modelling the impacts of "firm and funded" policies, is a conservative estimate of future emissions. Further reductions may be achieved due to voluntary measures or unexpected / additional impacts of EU and UK policy measures.

14.3 QA / QC

The projections dataset is based on a live database system into which quality assurance and quality control procedures have been built over several years. The projections database links to the main NAEI database. The main NAEI database consists essentially of a table of activity data and a table of emission factors for the NAEI source categories, which are multiplied together to produce emission estimates. The projections database consists of activity drivers for each source / fuel combination and a table of future emission factors.

The NAEI is subject to BS EN ISO 9001: 2000 and is audited by Lloyds and AEA internal QA auditors to test elements including authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking and project management.

In summary, the existing QA/QC system incorporates the following checking activities:

- Spreadsheet calculations are checked using internal consistency calculations and data sources are referenced within spreadsheets;
- Data entry into the database is peer-checked;
- Consistency checks are made to compare future projected emissions against historic estimates. A designated auditor identifies sources where large increases or decreases in emissions are expected and inventory staff are required to explain these changes to satisfy the auditor; and
- A final check is made by comparing the emissions generated in the latest dataset against previous projection versions. A designated checker identifies sources where there have been significant changes and inventory compilers are required to explain these changes.

14.4 PROGRESS TOWARDS NECD TARGETS

The emission projections show that the UK is likely to meet the NECD targets in 2010 for all four pollutants (see Table 14-3).

[10] Central fuel and carbon prices, central economic growth forecasts and central policy impacts

Table 14-3. Predicted emissions for those sectors covered under the NECD using DECC's UEP38 energy projections (Ktonnes).

Projected Year	**2010**	**NECD 2010**
NO_x	1,132	1,167
SO_2	372	585
NMVOC	774	1,200
NH_3	291	297

The 2010 Emission Projections report describes in detail the changes between the 2009 NECD projections and the 2010 NECD projections for each of the four pollutants.

The main changes include:

- Revision to the shipping inventory based on the bottom-up shipping study by Entec (2010) based on vessel movements for domestic shipping yields changes in fuel consumption.

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Appendix 1

Table A 1-1 Updates to emission factors and activity data from external data sources

NAEI Source	Change made to	Data Source	Comments
Accidental fires	Activity Data	CLG and ODPM fire statistics	Replaced rolled 2007 data with 2008 data
Agriculture-PM	Activity Data	Defra	Revision to Defra Statistics
Chemical waste incineration	Emission Factor Activity Data	PI	The emission factors are based on site calculations and reported emissions in the PI. Both emission factors and activity data have been updated for all years (1990-2008) due to site changes.
CO Factors	Emission Factor	DUKES	Updated GCVs from DUKES for propane, butane and SSF
Coal	Activity data	DUKES	Updated DUKES data
Coating	Emission Factor Activity Data	ONS	Index of production changed across the time series and impacted on implied emission factor and activity data
Coke & SSF	Activity Data	DUKES	Updated DUKES data for 2006 and 2008
Construction	Activity Data	Construction Statistics Annual	Update of method, using newer version of dataset
Consumer	Activity Data	CTPA	Revisions to household data and CTPA data
PCDD/PCDF	Activity Data	Fire Statistics (DCLG)	Updated fire statistics
Electric arc furnaces	Emission Factor	PI and EIPPCB	Correction of ratios used to calculate emissions of pollutants from non-reporting sites
Feedstock	Emission Factor Activity Data	Plant Operators at Kemira	Some Kemira emissions data were not provided in the required format for 2008 and 2009. Last year this was rolled, this year it has been interpolated using production values.

NAEI Source	Change made to	Data Source	Comments
Food	Emission Factor Activity Data	PI, ONS, Defra's Expenditure & Food Survey	Updated emission factor and activity data for sugar production from sugar beet in 2008; also revision to animal feeds data for 2008.
Foundry	Emission Factor Activity Data	PRODCOM, BGS	Updates to PRODCOM data and to BGS data
Fuel oil	Activity Data	DUKES, OT	Revised figures reported in DUKES and data reported by OT and CD
Gas	Activity Data	DUKES, OT	Revisions to data for Guernsey and Isle of Man but no change at UK total level; also revisions to DUKES activity data.
Gas main (Gas leakage)	Emission Factor Activity Data	UKD, Scotia Gas, Wales & West, Northern Gas Networks and Phoenix.	Revision in the approach to the estimation usage by distribution network based on the usage from LA and not an estimate using the counts of readings as undertaken in previous years. Emission factor revisions due to the changes to approach to calculating the average composition of the leaking gas being based composition and usage.
Non-ferrous metals - PM & metals	Emission Factor	PI, ONS	Updated index of production
NH3 Factors	Emission Factor	CEH	Updated emission factors
Off road	Activity Data	ONS Construction Statistics, DECC DUKES, BGS Aggregate Quarrying data, sectoral growth projections from DECC, CAA	Industrial off road machinery has been broken down into more detailed sub categories, and relevant drivers for construction, quarrying or general industry have been used to estimate equipment usage. Projections data have been replaced with actual historic data, where available (aircraft support, agriculture).
Other oil	Activity Data	CD	Change to Crown Dependencies estimates for burning oil
Other processes and solvent using sectors	Activity Data	ONS	Index of production base year changed from 2005 and 2006. All time series changed by small amount.
Other PI-related sources of VOC	Emission Factor Activity Data	PI, DUKES	Inclusion of plants which were not included in analysis last year, and revisions to DUKES data.
PAH	Emission Factor	PI	The 2006 - 2008 benzo[a]pyrene factors for coal tar distillation are based on calculations; however this year's PI has reported values for those years.

NAEI Source	Change made to	Data Source	Comments
PCB	Activity Data	Defra, Ofwat	Statistics for 1991-2005 are made available from Defra and 2008 statistics from Ofwat.
Peat	Activity Data	CEH	New data sourced for peat use in Northern Ireland
Pesticides	Emission Factor Activity Data	CSL	Last year's emission factor for HCB emission from Chlorothalonil was revised to capture the best 'working concentration' estimates. This is based on the Bailey paper which quotes 40 ppm. In 2010 as part of the POPs further review and update a sampling and analysis regime was conducted to look at pesticides. 30 samples were taken (23 from chlorothalonil products) at point of usage and analysed for both chlorothalonil and HCB. Based on market share this gives a new weighted average of 8 PPM. Have assumed that the 1998 (and before) factors are correct and extrapolated between 1998 - 2009. Assuming that 1008 will be 40 PPM and 2009 will be 8 PPM. 2008 data were not available in time for the 2010 compilation. Have rectified for this compilation.
Petrocoke	Emission Factor	DUKES	Revision to GCV value for petcoke
Petrol	Activity Data	DUKES	Revision to DUKES data for unleaded petrol in 2008 and new source added this year for loading petrol into sea going vessels.
Primary aluminium-PAH	Emission Factor	Industry data	Amended an estimate for B[K]F to match the operator's submission.
Quarrying	Activity Data	DUKES	Changes to input data
Rail	Activity Data	ORR	Adjustment of activity data for all years in order to align estimates with DfT/ORR data.
Road transport	Emission Factor Activity Data	DfT, EMEP/CORINAIR Guidebook	Revised PAH emission factors which mostly sourced from EMEP/CORINAIR Guidebook 2009; adopted new methodology for calculating evaporative emissions based on COPERT 4 simple approach; new source added this year for road abrasion. Revised vehicle-km data from DfT for all vehicle types; revised HGV fuel consumption factors on mpg fuel efficiency for different sizes of HGVs for 2008 from DfT. Updated buses and coaches fuel consumption factor for 2008 (now based on BSOG 2008/9 FY)
Secondary aluminium	Emission Factor Activity Data	BSG	Update to production values from BGS, removal of closed site and update to PI dates (2007 and 2008).

NAEI Source	Change made to	Data Source	Comments
Sulphur - coal	Emission Factor	PI	Betwys colliery data was rolled from 2000. Plant closed in 2003, so assumed 0 for this colliery from 2004 onwards Coking coal from UK coal was incorrect in source spreadsheet. .
Shipping	Emission Factor Activity Data	Entec	New factors for detailed vessel types and shipping movements from Entec (2010) study. Bottom-up study by Entec (2010) based on vessel movements for domestic shipping yields changes in fuel consumption. New methodology for reconciling with DUKES total shipping fuels to estimate international shipping fuel consumption.

See the Glossary for notes on Abbreviations & Acronym

Appendix 2

Table A2-1 Emission Factors for the Combustion of Liquid Fuels for 2009[1] (kg/t)

Fuel	**Source**	**Units**	**NO_x**	**CO**	**NMVOC**	**SO_2**
ATF	Aircraft Military	kg/t	8.5[ad]	8.2[ad]	1.1[ad]	0.87[z]
Burning Oil	Domestic	kg/t	3.23[l]	1.85[l]	0.047[f]	0.52[z]
Burning Oil	Other Industry	kg/t	3.33[l]	0.19[l]	0.028[e]	0.52[z]
Burning Oil	Public Service, Railways (Stationary)	kg/t	2.05[l]	0.16[l]	0.047[f]	0.52[z]
Burning Oil	Miscellaneous	kg/t	2.70[l]	0.16[l]	0.047[f]	0.52[z]
Gas Oil	Cement	kg/t	C	C	C	C
Gas Oil	Domestic	kg/t	3.19[l]	1.82[l]	0.047[f]	1.68[z]
Gas Oil	Fishing, Coastal Shipping, Naval, International Marine	kg/t	57.97, 64.44, 69.33, 69.33[av]	7.4[ap]	2.04, 2.82, 2.74, 2.74[av]	2.02, 20.36, 26.37, 26.37[av]
Gas Oil	Iron&Steel	kg/t	6.78[l]	2.00[l]	0.028[f]	1.68[z]
Gas Oil	Refineries	kg/t	4.56[k]	0.24[i]	0.028[f]	1.68[z]
Gas Oil	Other Industry	kg/t	14.76[l]	3.29[l]	0.028[f]	1.68[z]
Gas Oil	Public Service	kg/t	2.44[l]	0.38[l]	0.047[f]	1.68[z]
Gas Oil	Miscellaneous	kg/t	0.29[l]	0.04[l]	0.047[f]	1.68[z]
Fuel Oil	Agriculture	kg/t	7.69[l]	0.31[l]	0.139[f]	16.98[z]
Fuel Oil	Cement	kg/t	C	C	C	C
Fuel Oil	Public Service	kg/t	7.48[l]	0.83[l]	0.139[f]	16.98[z]
Fuel Oil	Miscellaneous	kg/t	0.74[l]	0.03[l]	0.139[f]	16.98[z]
Fuel Oil	Coastal Shipping, International Marine	kg/t	70.57, 77.71[av]	7.4[ap]	5.517, 2.924[av]	53.96, 53.92[av]
Fuel Oil	Domestic	kg/t	0[ap]	0[ap]	0.139[f]	16.98[z]
Fuel Oil	Iron&Steel	kg/t	7.19	0.89[l]	0.034[f]	16.98[z]
Fuel Oil	Railways (Stationary)	kg/t	7.48[l]	0.83[l]	0.139[f]	16.98[z]
Fuel Oil	Other Industry	kg/t	10.84[l]	1.60[l]	0.034[f]	16.98[z]

Fuel	Source	Units	NO_x	CO	NMVOC	SO_2
Fuel Oil	Refineries (Combustion)	kg/t	3.52[ag]	0.75[ag]	0.034[f]	29.74[ag]
Lubricants	Other Industry	kg/t	4.56[k]	0.25[f]	0.133[f]	11.41[x]
Petrol	Refineries	kg/t	4.62[k]	0.24[e]	0.028[e]	0.01[z]
Naphtha	Refineries (Combustion)	kg/t	4.62[k]	0.24 [i]	0.028 [f]	0.2 [ax]
Waste oils	Cement (Combustion)	kg/t	C	C	C	C
Waste solvent	Cement (Combustion	kg/t	C	C	C	C
Petroleum Coke	Domestic	kg/t	3.95[az]	158 [az]	4.9 [az]	142.4 [az]
Petroleum Coke	Refineries	kg/t	6.15ag	2.30[ag]	0.054[ai]	28.44[ag]
Petroleum Coke	Cement Production –Combustion	kg/t	C	C	C	C
Petroleum Coke	Other Industry	kg/t	C	C	C	C
LPG	Domestic	g/GJ Gross	62.19[f]	8.90[f]	3.779[f]	0
LPG	I&Sak, Other Industry, Refineries,	g/GJ Gross	62.19[f]	15.11[f]	3.779[f]	0
LPG	Gas Production – combustion at gas separation plant	g/GJ Gross	127.37[aw]	65.54[aw]	4.272[aw]	0.73[aw]
OPG	Gas production	g/GJ Gross	70.00[k]	2.37[i]	3.779[f]	0
OPG	Refineries (Combustion)	g/GJ Gross	86.78[ag]	13.68[z]	3.779[f]	0
OPG	Other Industry	g/GJ Gross	70.00[k]	2.37[i]	3.779[f]	0
OPG	Gas production – combustion at gas separation plant	g/GJ Gross	127.37[aw]	65.54[aw]	4.272[aw]	0.73[aw]

Table A2-2 Emission Factors for the Combustion of Solid fuels for 2009[1] (kg/t)

Fuel	Source	Units	NO_x	CO	NMVOC	SO_2
Coal	Agriculture	Kg/tonne	4.75[l]	8.25[l]	0.05[o]	17.0[aa]
Coal	Collieries	Kg/tonne	4.75[l]	8.25[l]	0.05[o]	23.0[aa]
Coal	Domestic	Kg/tonne	2.34[l]	159.96[l]	14.00[o]	23.2[aa]
Coal	Iron and Steel (Combustion)	Kg/tonne	1.23	0.53	0.05[o]	17.0[aa]
Coal	Lime Production (Combustion)	Kg/tonne	28.26[v]	3.83[v]	0.05[o]	17.0[aa]
Coal	Miscellaneous	Kg/tonne	4.74[l]	8.09[l]	0.05[o]	17.0[aa]
Coal	Public Service	Kg/tonne	4.72[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Other Industry	Kg/tonne	4.28[l]	1.94[l]	0.05[o]	17.0[aa]
Coal	Railways	Kg/tonne	4.72[l]	7.00[l]	0.05[o]	17.0[aa]
Coal	Autogenerators	Kg/tonne	5.54[l]	1.63[l]	0.03[o]	17.0[aa]
Coal	Cement production (combustion)	Kg/tonne	C	C	C	C
Anthracite	Domestic	Kg/tonne	3.47[k]	208.2[k]	1.7[o]	15.4[aa]
Coke	Agriculture	Kg/tonne	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	SSF Production	Kg/tonne	IE	IE	0.05[p]	19[ab]
Coke	Domestic	Kg/tonne	3.04[l]	118.6[l]	4.9[o]	15.4[aa]
Coke	I&Sak (Sinter Plant)	Kg/tonne	13.69[ae]	352.7[ae]	0.44[ae]	18.8[ae]
Coke	I&Sak (Combustion)	Kg/tonne	0.87[l]	226[l]	0.05[p]	19[ab]
Coke	Other Industry	Kg/tonne	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	Railways	Kg/tonne	4.52[l]	18.29[l]	0.05[p]	19[ab]
Coke	Miscellaneous; Public Service	Kg/tonne	4.52[l]	18.29[l]	0.05[p]	19[ab]
Peat	Domestic	Kg/tonne	0.70[g]	69.5[g]	23.63[g]	NE
SSF	Miscellaneous;	Kg/tonne	4.58[k]	48.9[k]	0.05[o]	19[ab]

Fuel	Source	Units	NO_x	CO	NMVOC	SO_2
	Public Service					
SSF	Domestic	Kg/tonne	3.05[k]	130.4[k]	4.9[p]	16[ab]
SSF	Other Industry	Kg/tonne	4.58[g]	48.9[g]	0.05[g]	19 [ab]
Blast Furnace Gas	Coke Production	g/GJ Gross	79.0[k]	39.5[k]	5.60[k]	0
Blast Furnace Gas	I&Sak (Combustion), I&Sak (Flaring)	g/GJ Gross	79.0[k]	39.5[k]	5.60[k]	0
Blast Furnace Gas	Blast Furnaces	g/GJ Gross	37.0[v]	39.5[k]	5.60[k]	0
Coke Oven Gas	Other Sources	g/GJ Gross	80.5[k]	40.0[k]	4.35[k]	270.4[v]
Coke Oven Gas	I&Sak Blast Furnaces	g/GJ Gross	37.0[v]	40.0[k]	4.35[k]	270.4[v]
Coke Oven Gas	Coke Production	g/GJ Gross	365.8[v]	40.0[k]	4.35[k]	270.4[v]

Table A2-3 Emission Factors for the Combustion of Gaseous Fuels 2009[1] (g/GJ gross)

Fuel	Source	NO_x	CO	NMVOC	SO_2
Natural Gas	Agriculture	39.2[l]	2.13[l]	2.22[f]	0
Natural Gas	Miscellaneous	52.9[l]	58.2[l]	2.22[f]	0
Natural Gas	Public Service	56.0[l]	13.48[l]	2.22[f]	0
Natural Gas	Coke Production, SSF Prodn[al],	175.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Refineries	70.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Blast Furnaces	37.0[v]	2.37[l]	2.22[f]	0
Natural Gas	Domestic	22.5[l]	30.8[l]	2.22[f]	0
Natural Gas	Gas Prodn[al],	89.5[l4]	17.4[l]	2.22[f]	0
Natural Gas	Oil Prodn[al]	184.4[aw]	65.1[aw]	1.43[aw]	3.28[aw]
Natural Gas	I&S[ak]	176.7[l]	172.9[l]	2.22[f]	0
Natural Gas	Railways	89.4[l]	33.8[l]	2.22[f]	0
Natural Gas	Other Industry	139.9[l]	74.4[l]	2.22[f]	0
Natural Gas	Nuclear Fuel Prodn[al], Collieries	139.9[l]	74.4[l]	2.22[f]	0
Natural Gas	Autogenerators	61.9[l]	20.6[l]	2.22[f]	0
Natural Gas	Ammonia (Combustion)	157.2[d]	NE	2.22[f]	0
Colliery Methane	Other Industry, collieries	70.0[k]	2.37[i]	2.22[f]	0
Colliery Methane	Coke Production, Gas Production	70.0[k]	2.37[i]	2.22[f]	0

Table A2-4 Emission Factors for the Combustion of other fuels and biomass 2009[1]

Fuel	Source	Units	NO_x	CO	NMVOC	SO_2
MSW	Miscellaneous	Kg/tonne	0.76[v]	0.09[v]	0.0046[v]	0.074[v]
Scrap tyres	Cement (combustion)	Kg/tonne	C	C	C	C
Waste	Cement (combustion)	Kg/tonne	C	C	C	C
Straw	Agriculture	Kg/tonne	1.5[k]	75[g]	9[k]	
Wood	Domestic	Kg/tonne	0.7[k]	69.5[k]	23.6[o]	0.11[aa]
Wood	Other industry	Kg/tonne	2.06	68.5	0.82	0.13
Sewage Gas	Public Services	g/GJ Gross	66.78[f]	7.1[f]	2.42[f]	0
Landfill Gas	Miscellaneous	g/GJ Gross	38.96[f]	122.4[f]	3.62[f]	0

Footnotes to Table A2-1 to Table A2-4:

a Carbon Factor Review (2004), Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW, and selected recent updates to the factors presented in this report.
b CORINAIR (1992)
b+ Derived from CORINAIR(1992) assuming 30% of total VOC is methane
c Methane facto r estimated as 12% of total hydrocarbon emission factor taken from EMEP/CORINAIR(1996) based on speciation in IPCC (1997c)
d Based on operator data: Terra Nitrogen (2009), Invista (2009), BP Chemicals (2009)
e As for gas oil
f USEPA (2005)
g IPCC (1997c)
h EMEP (1990)
i Walker *et al* (1985)
j As for fuel oil.
k EMEP/CORINAIR (2003)
l AEA estimate based on disaggregation of UK fuel use by sector and device type with application of literature-based emission factors or data reported in the Pollution Inventory for each disaggregated sector/device combination (2009)
m USEPA (1997)

n	British Coal (1989)
o	Brain *et al,* (1994)
p	As for coal
q	EMEP/CORINAIR (2003)
r	AEA Energy & Environment estimate based on carbon balance
s	As for natural gas
t	EMEP/CORINAIR (1996)
u	IPCC (2000)
v	Emission factor derived from emissions reported in the Pollution Inventory (Environment Agency, 2008)
w	Fynes *et al* (1994)
x	Passant (2005)
y	UKPIA (1989)
z	Emission factor derived from data supplied by UKPIA (2006, 2007, 2008, 2009)
aa	Emission factor for 2005 based on data provided by UK Coal (2005), Scottish Coal (2006), Celtic Energy (2006), Tower (2006), Betwys (2000)
ab	Munday (1990)
ac	Estimated from THC data in CRI (Environment Agency, 1997) assuming 3.% methane split given in EMEP/CORINAIR (1996)
ad	EMEP/CORINAIR (1999)
ae	AEA Energy & Environment estimate based on data from Environment Agency (2005) and Corus (2005)
af	UKPIA (2004)
ag	AEA Energy & Environment estimate based on data from Environment Agency (2005), UKPIA, DUKES, and other sources
ah	Royal Commission on Environmental Pollution (1993)
ai	DTI (1994)
aj	Emission factor as mass carbon per unit fuel consumption
ak	I&S = Iron and Steel
al	Prodn = Production
am	As for SSF
an	As for burning oil
ao	AEA Energy & Environment estimate based on carbon factors review
ap	EMEP/CORINAIR
aq	AEA Energy & Environment estimate
ar	Directly from annual fuel sulphur concentration data
as	Based on sulphur content of pet coke used in Drax trials (Drax Power Ltd, 2008)
at	Based on factors presented in EU-ETS returns
au	Data supplied directly by the British Cement Association (BCA)

av UK Ship Emissions Inventory (Entec, 2010)
aw EEMS 2008 and 2009, DECC Oil and Gas.
ax UKPIA, pers. Comm., 2000
ay Loader *et al* (2008)
az As for domestic wood
NE Not estimated
NA Not available
IE Included elsewhere
[1] These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may are available electronically [on the CD accompanying this report]. Note that all carbon emission factors used for Natural Gas include the CO_2 already present in the gas prior to combustion.