UK Informative Inventory Report (1980 to 2010)

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March 2012

Executive Summary

This is the 7th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) team. The report is compiled to accompany the UK's 2012 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 in Nomenclature for Reporting (NFR) format, for:

- Nitrogen oxides (NO_x), carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOCs), particulate matter (PM) and heavy metals (1980 to 2009); and
- Persistent organic pollutants (1990 to 2009).

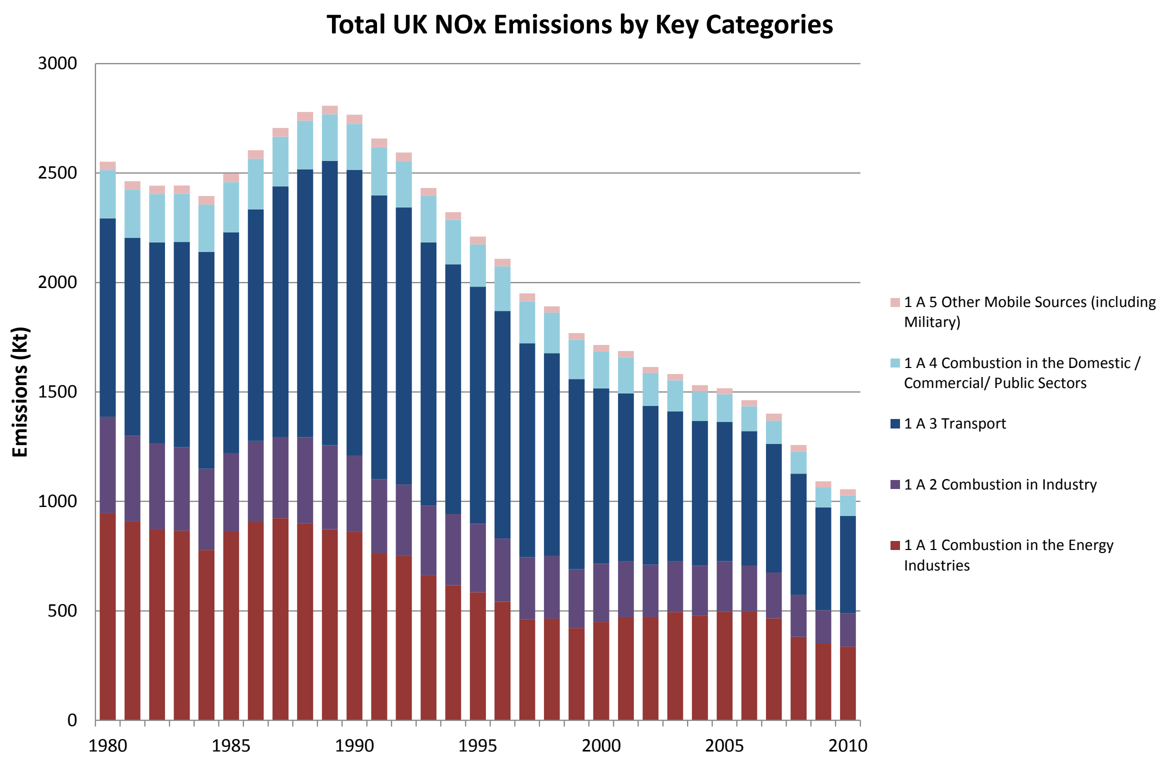
As part of the commitments to the CLRTAP, countries are also required to submit emission projections for nitrogen oxides, sulphur dioxide, non-methane volatile organic compounds and ammonia (under the Gothenburg Protocol).

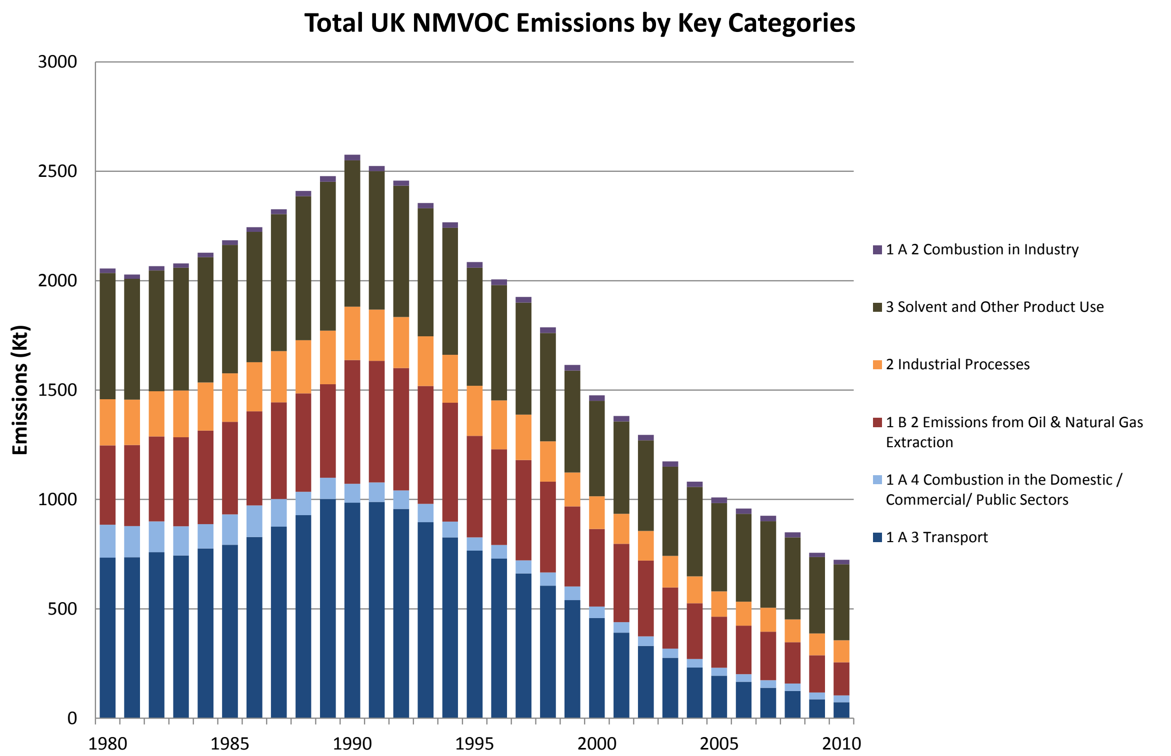
In 2012 Member States also have to report gridded data and Large Point Source (LPS) data for 2005 and 2010. The 2010 gridded and LPS data are not yet available. Thus we will submit 2009 data and resubmit the 2010 data in 2013.

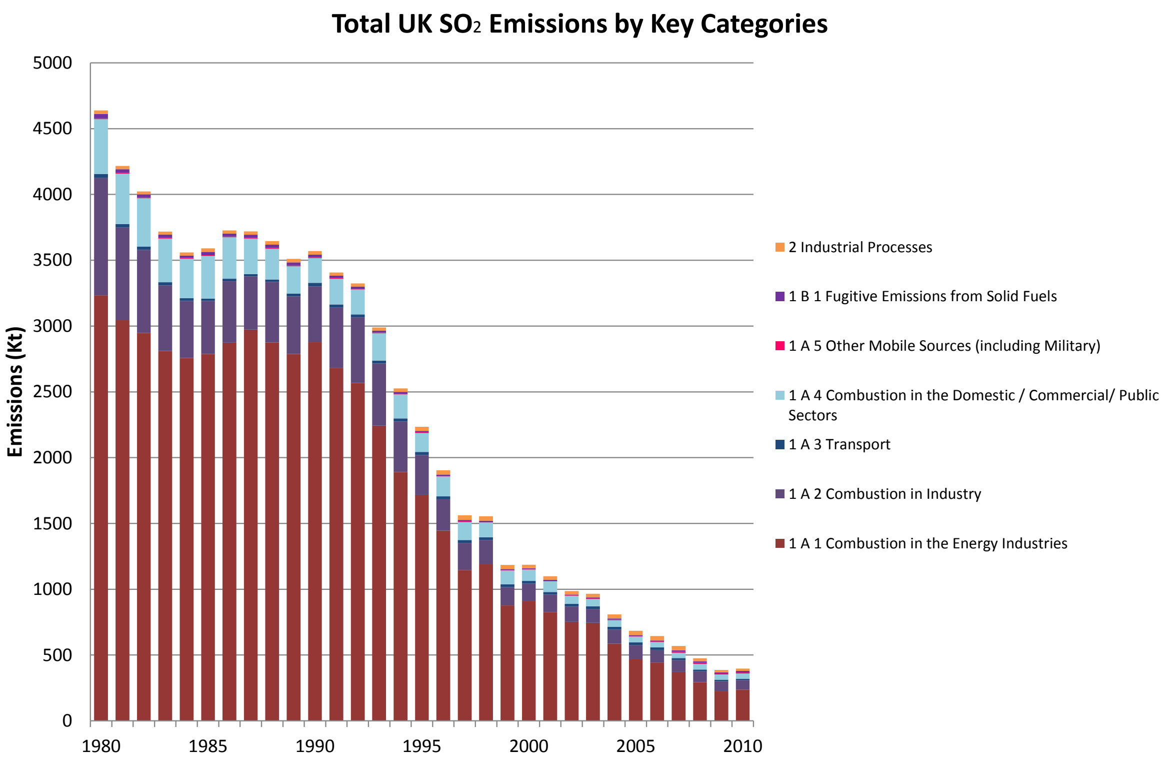
Selected pollutants under the CLRTAP are also covered under the Directive 2001/81/EC of the European Parliament and the Council on National Emissions Ceilings (NECD) which sets upper limits for each Member State for the total emissions in 2010. Under the NECD the UK submits the emissions for the previous five years and 2010 projections for nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane volatile organic compounds (NMVOC) and ammonia (NH_3). In this, the 2012 report, emissions for 2010 are based on actual emissions rather than projections.

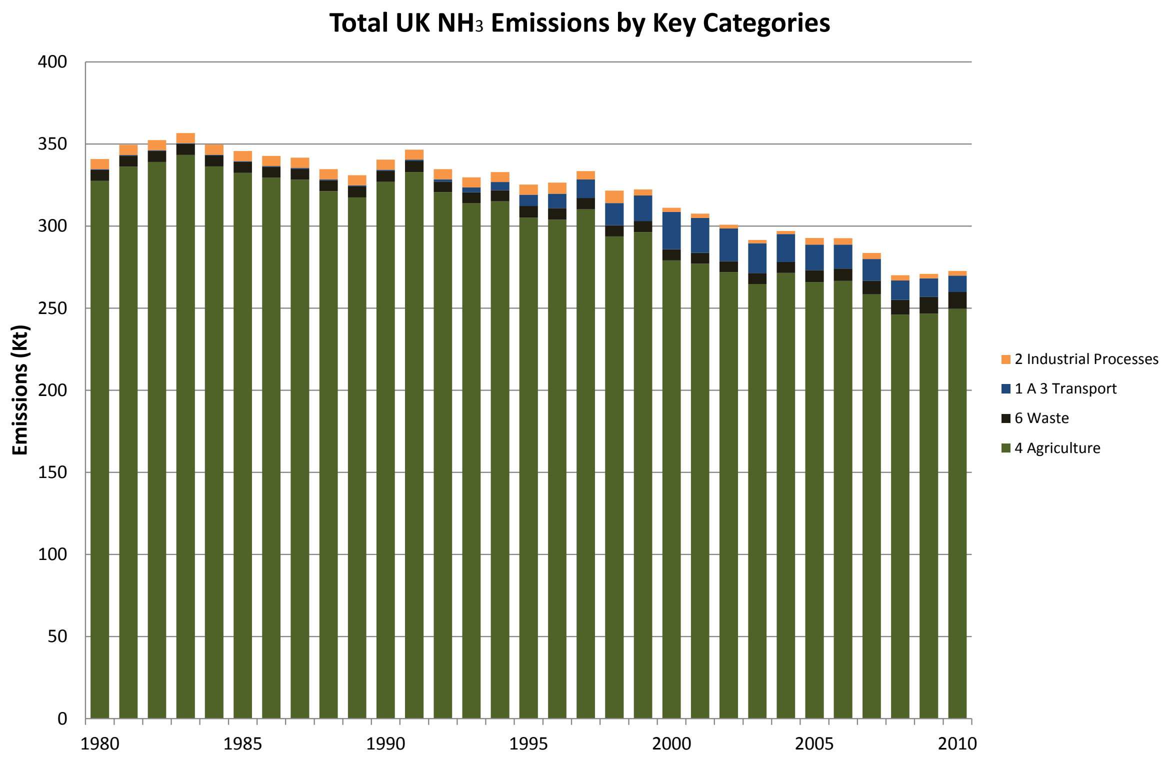
[1] See http://www.ceip.at/reporting-instructions/reporting-programme/ for reporting requirements set up by TFEIP/UNECE Guidelines for estimating and reporting emissions data under LRTAP.

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), 1980-2010.






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


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

Reductions in the 1980 emissions of headline pollutants by 2010 are summarised in the table below.

Table ES-1 Air Quality Pollutant Emission Reductions between 1980 and 2010

Pollutant	% Change from 1980 to 2010
NO_x	-58%
SO_2	-91%
NH_3	-22%
NMVOC	-65%
CO	-75%
PM_{10}	-65%

The emissions inventory makes 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 journeys are not included in the national totals.
- Estimates of "International" emissions such as from shipping are made, and reported as memo items (excluded from the UK national totals).
- 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 2010 data submitted under the NECD in December 2011 are provisional data only. The inventory team has made some further improvements to the data since the 2011 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 2010;
- 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 activity data for aviation were reviewed and final emissions recalculated post the NECD 2011 submission.

- 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://naei.defra.gov.uk/data_warehouse.php. The complete 2012 UK CLRTAP submission templates are available from the European Environment Information and Observation Network (EIONET) under http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envtzp7xq/index_html.

Any revisions to inventory compilation methodologies for key pollutants and key sectors between the 2011 and 2012 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 the respective NFR chapter. 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 2009) have been addressed in the 2010 inventory.

Planned improvements for future national inventory compilation cycles are discussed in section 13.7.

In addition, Table ES-2 gives an overview of differences in the 2012 (current) submission compared to the 2011 CLRTAP submission. The emissions data do differ from those in the previous submission, notably for NOx where estimated emissions across the time series are now higher than in the 2011 submission. This is due largely to changes in the methodology used to estimate emissions, rather than, for example, changes in energy or other raw data. In particular, we have revised upwards estimates for NOx from landfill gas engines, road transport, and shipping, whilst reducing our estimates for NOx from industrial combustion of natural gas.

Other pollutants that changed by more than 10% compared to the 2011 submission are PCB, PCDD/PCDF and benzene.

Emissions PCB and PCDD/PCDF are now significantly lower due to a number of assumptions that have been reviewed for all inventory years for this compilation. These changes relate to expert judgements, made regarding waste burning habits by the general public:

- For disposal of wastes on domestic grates, an assumption about the proportion of households using open fires has been reduced across all years.
- For garden bonfires we have reduced the estimate of the number of bonfires per household per year, but with an assumption that more waste is burnt per event.

The changes in benzene emissions are due to a revision of the emission factors for wood combustion. The previous emission factors were based on rather outdated speciation profiles developed by the US EPA. The improved values, now based on an AEA report on biomass emission factors, are significantly lower, especially for benzene for domestic wood.

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:

- **Power Stations**
- **Industrial Process Emissions.**

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

Pollutant	**2011 Submission**	**2012 Submission**		**Unit**	**Comment/Explanation (changes between the 2011 and 2012 CLRTAP Submissions)**
	2009	**2009**	**2010**		
NO_x	1086	1143	1106	kt	Road Transport improvements in the 2010 Inventory led to an increase in emissions. New NOx emission factors were implemented for all vehicles (except motorcycles) and the emissions degradation methodology for LDVs, based on COPERT 4 (version 8.1). New data suggests that the vehicle fleet on roads are generally newer than what we previously assumed. The revision and reallocation of gas oil and road diesel (DERV) led to:1) A revised estimate of the amount of DERV used to power small off-road machinery; 2) An estimate of the amount of gas oil, DERV and petrol used to power vessels on inland waterways; 3) An overall, revised figure of DERV and petrol used by non-road transport emission sources; 4) A re-evaluation of gas oil used across different marine sectors, leading to a re-assignment of gas oil previously assigned to international shipping to domestic UK marine activities; 5) A revised allocation of gas oil consumption across all inventory sectors, including that used for stationary combustion in industry and the public sector.
CO	2277	2317	2125	kt	Activity data reported from Refineries burning Fuel Oil were updated.
NMVOC	826	822	789	kt	Emissions revised upward in the 2010 Inventory due to change to emission factor for landfills resulting from new assumptions about the VOC content of landfill gas.
SO_2	397	397	406	kt	Revision and reallocation of gas oil and road diesel (DERV). The improvement work led to:1) A revised estimate of the amount of DERV used to power small off-road machinery; 2) An estimate of the amount of gas oil, DERV and petrol used to power vessels on inland waterways; 3) An overall, revised figure of DERV and petrol used by non-road transport emission sources; 4) A re-evaluation of gas oil used across different marine sectors, leading to a re-assignment of gas oil previously assigned to international shipping to domestic UK marine activities; 5) A revised allocation of gas oil consumption across all inventory sectors, including that used for stationary combustion in industry and the public sector.
NH_3	288	283	284	kt	The June survey methodology from 2010, feeding into the 2010 Inventory, covers only commercial holdings, with the exception of cattle where all animals are covered by the cattle tracing scheme. Previous June survey, feeding into the 2009 Inventory, covered all agricultural holdings and therefore some livestock, with the exception of cattle, will not be counted under the new methodology.
TSP	209	201	204	kt	Road Transport improvements in the 2010 Inventory lead to decreases in emissions. New data suggests that the vehicle fleet on roads are generally newer than what we previously assumed
PM_{10}	119	114	114	kt	Road Transport improvements in the 2010 Inventory lead to decreases in emissions. New data

Pollutant	2011 Submission	2012 Submission		Unit	Comment/Explanation (changes between the 2011 and 2012 CLRTAP Submissions)
	2009	2009	2010		
					suggests that the vehicle fleet on roads are generally newer than what we previously assumed
$PM_{2.5}$	70	67	67	kt	Road Transport improvements in the 2010 Inventory lead to decreases in emissions. New data suggests that the vehicle fleet on roads are generally newer than what we previously assumed
Pb	60	63	59	tonnes	No significant changes.
Cd	2	2	2	tonnes	No significant changes.
Hg	7	7	6	tonnes	No significant changes.
As	13	13	13	tonnes	No significant changes.
Cr	26	27	26	tonnes	No significant changes. Small change between the 2009 and 2010 Inventory in line with changes in DUKES activity data and Pollution Inventory data.
Cu	52	50	51	tonnes	No significant changes. Small change between the 2009 and 2010 Inventory in line with changes in DUKES activity data and Corus data.
Ni	83	81	79	tonnes	No significant changes. Small change between the 2009 and 2010 Inventory in line with changes in DUKES activity data and Pollution Inventory data.
Se	31	31	32	tonnes	No significant changes.
Zn	339	342	355	tonnes	No significant changes. Small change between the 2009 and 2010 Inventory in line with changes in DUKES activity data and Corus Pollution Inventory data.
HCH	8760	8760	7709	kg	No significant changes.
PCB	906	817	800	kg	A number of assumptions have been reviewed in the waste burning mastersheet for all inventory years in the 2010 Inventory. These changes are based on expert judgement, made in relation to a national survey of waste burning habits. • For domestic grates the proportion of households using open fires has been reduced. • For bonfires there is a reduction in the estimate of the number of bonfires per year, but with an assumption that more waste is burnt per event.
PCDD/PCDF	193	163	186	grams TEQ	A number of assumptions have been reviewed in the waste burning mastersheet for all inventory years in the 2010 Inventory. These changes are based on expert judgement, made in relation to a national survey of waste burning habits. • For domestic grates the proportion of households using open fires has been reduced. • For bonfires there is a reduction in the estimate of the number of bonfires per year, but with an assumption that more waste is burnt per event.
Benzo[a]pyrene	3	3	3	tonnes	No significant changes.
Benzo[b]fluoranthene	3	3	3	tonnes	No significant changes.
Benzo[k]fluorant	1	1	1	tonnes	No significant changes.

Pollutant	2011 Submission	2012 Submission		Unit	Comment/Explanation (changes between the 2011 and 2012 CLRTAP Submissions)
	2009	2009	2010		
hene					
Indeno(1,2,3-cd)pyrene	1	1	1	tonnes	No significant changes.
HCB	33	32	32	kg	No significant changes.
PCP	NR	NR	NR	kg	Not reported.
SCCP	NR	NR	NR	kg	Not reported.

NR: Not Reported

(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 ERG 1103.

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 and DECC: http://naei.defra.gov.uk/ .

(II) GLOSSARY

Emission Units

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

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

Acronyms and Definitions

ABI	Annual Business Inquiry
AEA	Lead 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	After1999 called EMEP/EEA
EMEP/EEA	European Monitoring and Evaluation Program Emission Inventory Guidebook
EPRTR	European Pollutant Release and Transfer Register
EUETS	European Union Emissions Trading Scheme
FGD	Flue gas desulphurisation
GCV	Gross Calorific Value
GHG	Greenhouse gases
GHGI	Greenhouse gas inventory
GWh	Giga Watt Hour (unit of energy)
GWP	Global Warming Potential

HGV	Heavy Goods Vehicles
ICAO	International Civil Aviation Organisation
IEF	Implied Emission Factor
IPPC	Integrated Pollution Prevention and Control
ISR	Inventory of Statutory Releases (DoENI)
ISSB	Iron and Steel Statistics Bureau
Kt	Kilo tonne
KtC	Kilo tonne of Carbon
KtC-e	Kilo tonne of Carbon-equivalent (taking account of GWP)
LA-IPPC	Local Authority Integrated Pollution Prevention and Control
LAPC	Local air pollution control
LGV	Larger Goods Vehicles
LPG	Liquefied petroleum gas
LTO	Landing & Take Off
MoD	Ministry of Defence
MPP	Major Power Producers (i.e. most power station operators)
MSW	Municipal Solid Waste
Mt	Megatonne
Mtherms	Megatherms
NFR	Nomenclature for Reporting
NAEI	National Atmospheric Emissions Inventory
NECD	National Emission Ceiling Directive
NIEA	Northern Ireland Environment Agency
NMVOC	Non-Methane Volatile Organic Compounds
OCGT	Open Cycle Gas Turbine
ONS	Office for National Statistics
ORR	Office of Rail Regulation
OT	Overseas Territories
PAHs	Polycyclic Aromatic Hydrocarbons
PAMs	Policies and Measures
PI	Pollution Inventory (of the Environment Agency of England & Wales)
POC	Port of call
POPs	Persistent Organic Pollutants
ppm	Parts per million
PRODCOM	PRODuction COMmunautaire
PSDH	Project for the Sustainable Development of Heathrow
QA/QC	Quality assurance and quality control
RASCO	Regional Air Services Co-ordination
RESTATs	Renewable Energy Statistics (published by DECC)
RTFO	Renewable Transport Fuels Obligation
RVP	Reid Vapour Pressure
SCCP	Short Chain Chlorinated Paraffins
SEPA	Scottish Environmental Protection Agency
SPRI	Scottish Pollutant Release Inventory
SWA	Scotch Whisky Association
THC	Total Hydrocarbons
TSP	Total Suspended Particulate
TRL	Transport Research Laboratory
TFEIP	Task Force on Emission Inventories and Projections
UEP	Updated Energy Projection (UK energy forecasts produced by DECC)
UKCCP	UK Climate Change Programme
UKD	UK Gas Distributors
UKMY	UK Minerals Yearbook
UKPIA	UK Petroleum Industries Association
UN/ECE	United Nations Economic Commission for Europe
US EPA	United States Environment Protection Agency
USLP	Ultra-low Sulphur Petrol
WML	Waste Management Licensing
WID	Waste Incineration Directive

Abbreviations for Chemical Compounds

Chemical Name	Abbreviation
Nitrogen Oxides	NO_x
Sulphur Dioxide	SO_2
Carbon Monoxide	CO
Non-Methane Volatile Organic Compounds	NMVOC
Black Smoke	BS
Particulates < 10 µm	PM_{10}
Particulates < 2.5 µm	$PM_{2.5}$
Particulates < 1 µm	PM_1
Particulates < 0.1 µm	$PM_{0.1}$
Total Suspended Particulates	TSP
Ammonia	NH_3
Hydrogen Chloride	HCl
Hydrogen Fluoride	HF
Lead	Pb
Cadmium	Cd
Mercury	Hg
Copper	Cu
Zinc	Zn
Nickel	Ni
Chromium	Cr
Arsenic	As
Selenium	Se
Vanadium	V
Beryllium	Be
Manganese	Mn
Tin	Sn
Polycyclic Aromatic Hydrocarbons	PAH
- Benzo[a]pyrene	B[a]P
- Benzo[b]fluoranthene	
- Benzo[k]fluoranthene	
- Indeno (1,2,3-cd)pyrene	
Polychlorinateddibenzo-p-dioxins/ Polychlorinated dibenzofurans	PCDD/PCDF
Polychlorinated Biphenyls	PCB
Lindane (gamma-HCH)	HCH
Pentachlorophenol	PCP
Hexachlorobenzene	HCB
Short-chain chlorinated paraffins	SCCP
Polychlorinated Naphthalene	PCN
Polybrominated diphenyl ethers	PBDE
Sodium	Na
Potassium	K
Calcium	Ca
Magnesium	Mg

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 1-4.

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 2012 UK submission
Main Pollutants	Nitrogen Oxides	1980-2010	1980-2010
	Sulphur Dioxide		
	Carbon Monoxide		
	Non-Methane Volatile Organic Compounds		
	Ammonia		
Particulate Matter	Particulates < 10 µm	2000-2010	1980-2010
	Particulates < 2.5 µm		
	Total Suspended Particulates		
Priority Heavy Metals	Lead	1990-2010	1980-2010
	Cadmium		
	Mercury		
Other Heavy Metals	Copper	1990-2010	1980-2010
	Zinc		
	Nickel		
	Chromium		
	Arsenic		
	Selenium		
Persistent Organic Pollutants	Benzo[a]pyrene	1990-2010	1990-2010
	Benzo[b]fluoranthene		
	Benzo[k]fluoranthene		
	Indeno (1,2,3-cd)pyrene		
	PCDD/PCDF		
	Polychlorinated Biphenyls		
	HCH		
	Hexachlorobenzene		

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

Every five years, starting in 2007 (2005 emissions), Member States also have to report gridded emissions and emissions from large point sources. 2012 is a five yearly reporting year. The required information is listed in Table 1-2.

Table 1-2 Summary of five yearly reporting requirements for estimating and reporting emissions under the CLRTAP[5]

Group	Pollutant	Required reporting years	Reported years in 2012 UK submission
Gridded data in the EMEP 50x50 km2 grid	SO_2, NO_x, NH_3, NMVOC, CO, PM, Pb, Cd, Hg, PAHs, HCH, HCB, PCBs, PCDD/PCDF	2005, 2010	2005, 2009
Emissions from large-point sources (LPS)	SO_2, NO_x, NH_3, NMVOC, CO, PM, Pb, Cd, Hg, PAHs, HCH, HCB, PCBs, PCDD/PCDF	2005, 2010	2005, 2009
Historical activity data[6]		1990-2010	1990-2010
Projected activity data and projected emissions[7]	SO_2, NO_x, NH_3, NMVOC, PM	2010, 2015, 2020, 2025, 2030	2010, 2015, 2020, 2025, 2030

As requested by the Centre on Emission Inventories and Projections[8] the gridded emissions do not include emissions from large-point sources and are reported separately.
Emissions from large-point sources and gridded data for 2010 are not yet available due to the timeline of the UK compilation cycle. The 2010 Emissions from large-point sources and gridded data will be available in the summer 2012 and will be submitted as part of the 2013 CLRTAP submission.

Under the NECD the UK submits the provisional emissions for the pollutants for the previous five years and under the CLRTAP, the final emissions of pollutants covering 1980 to the most recent reported year (see Table 1-1).

In addition, the UK national Atmospheric Emissions Inventory team reports GHG emissions to the United Nations Framework Convention on Climate Change for compliance with the Kyoto Protocol on behalf of DECC. The main difference between the reporting requirements of the NECD, CLRTAP and UNFCCC are highlighted in Table 1-3.

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

Table 1-3 Scope of UK Emissions Inventory Reporting under the CLRTAP, NECD and UNFCCC

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

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

Table 1-4 Scope of UK Inventory Reporting: Pollutants by Type, Timeseries

Pollutant	Reported under CLRTAP	Inventory Timeseries[1]	Type of Pollutant[2]
Nitrogen Oxides	✓	1970-2010	NAQS, AC, IGHG, O, E
Sulphur Dioxide	✓	1970-2010	NAQS, AC, IGHG
Carbon Monoxide	✓	1970-2010	NAQS, O
Non-Methane Volatile Organic Compounds *	✓	1970-2010	NAQS, O, IGHG
Black Smoke		1970-2010	NAQS
Particulates < 10 µm	✓	1970-2010	NAQS
Particulates < 2.5 µm	✓	1970-2010	-
Particulates < 1 µm		1970-2010	-
Particulates < 0.1 µm		1970-2010	-
Total Suspended Particulates	✓	1970-2010	-
Ammonia	✓	1980-2010	AC, E
Hydrogen Chloride		1970-2010	AC
Hydrogen Fluoride		1970-2010	AC
Lead	✓	1970-2010	NAQS, TP
Cadmium	✓	1970-2010	TP
Mercury **	✓	1970-2010	TP
Copper	✓	1970-2010	TP
Zinc	✓	1970-2010	TP
Nickel **	✓	1970-2010	TP
Chromium **	✓	1970-2010	TP
Arsenic	✓	1970-2010	TP
Selenium	✓	1970-2010	TP
Vanadium		1970-2010	TP
Beryllium		2000-2010	TP
Manganese		2000-2010	TP
Tin		2000-2010	TP
Polycyclic Aromatic Hydrocarbons *	✓	1990-2010	TP
PCDD and PCDF	✓	1990-2010	TP
Polychlorinated Biphenyls *	✓	1990-2010	TP
Lindane (gamma-HCH)	✓[10]	1990-2010	TP
Pentachlorophenol		1990-2010	TP
Hexachlorobenzene	✓	1990-2010	TP
Short-chain chlorinated paraffins		1990-2010	TP
Polychlorinated Naphthalene		NE	TP
Polybrominated diphenyl ethers		SE	TP
Sodium		1990-2010	BC
Potassium		1990-2010	BC
Calcium		1990-2010	BC
Magnesium		1990-2010	BC

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

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

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

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

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

[10] Reported as total HCH

1.1.3 Sources

In principle, the emissions inventory makes estimates of all known emissions to air in as high a level of disaggregation as is possible. However, by following international guidelines on emissions reporting, there are a number of known sources, which are deliberately not included in the inventory:

- Natural sources are not included in the national totals (although estimates of some sources are made)
- The inventory 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).

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

1.1.4 Geographical Scope

The 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).

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

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

All UK emission inventories are compiled and maintained by the National Atmospheric Emissions Inventory team at AEA, under contract to the Science and Evidence Team, Atmosphere and Local Environment Programme (ALE) of the Department for Environment, Food and Rural Affairs (Defra) and the Science & Innovation Division of the Department for Energy and Climate Change (DECC) to provide non-GHG emissions inventories and GHG emission inventories respectively.

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

1.2.1 Defra ALE

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

As the UK's current inventory agency, AEA's National Atmospheric Emissions Inventory team is responsible for compiling the emission inventories, including the following roles and responsibilities:

Planning

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

Preparation

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

Management

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

Inventory Compilation

- Data acquisition, 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.
- Aether, under subcontract to AEA, provides the DA and rail emission Inventories, provide expert advice on projections and lead on TFEIP activities.
- SKM Enviros, under subcontract to AEA, provide expert advice on Industrial processes and solvents.
- AMEC, under subcontract to AEA, provide expert advice on projections.

Information Dissemination

Data from the NAEI is made available to national and international bodies in a number of different formats. The NAEI team also 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://naei.defra.gov.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 whenever the files are being changed.

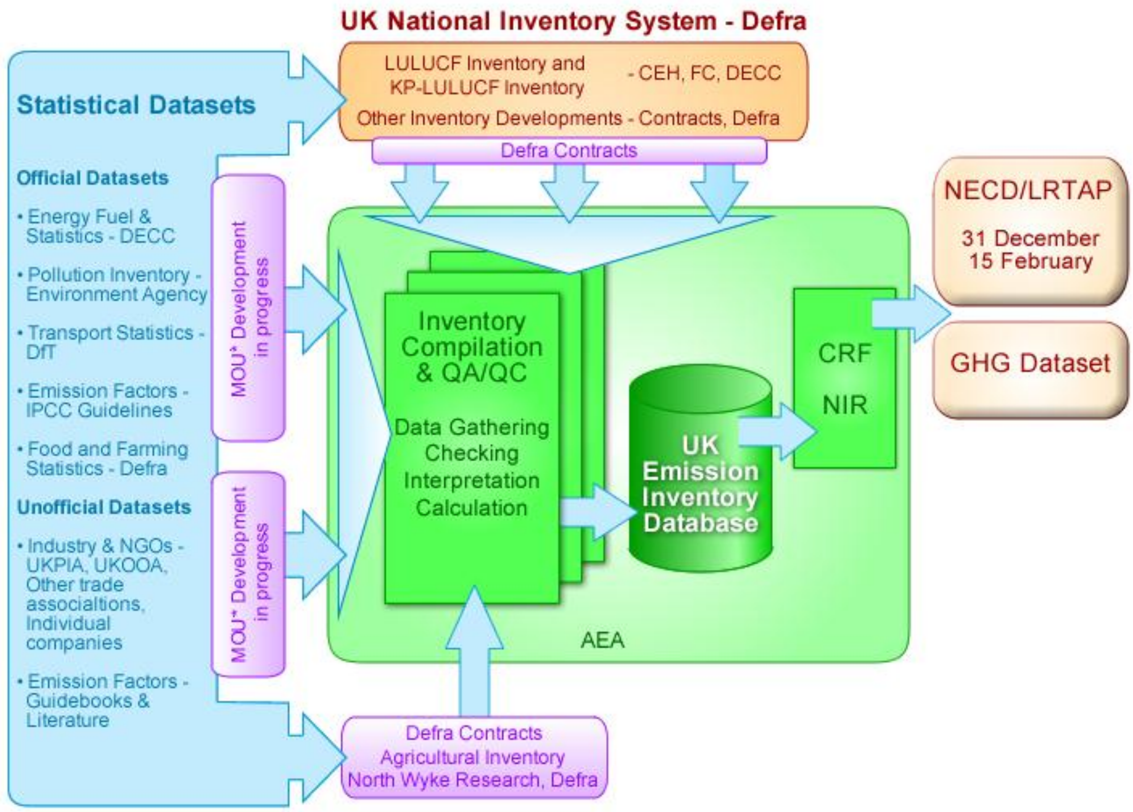
1.3 INVENTORY PREPARATION PROCESS

1.3.1 Introduction

Figure 1-1 shows the main elements of the UK emissions inventory system, including provision of data to international organisations.

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

Figure 1-1 Main elements for the preparation of the UK Emissions Inventory



Key Data Providers are also included on this figure, and include other government departments, 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.

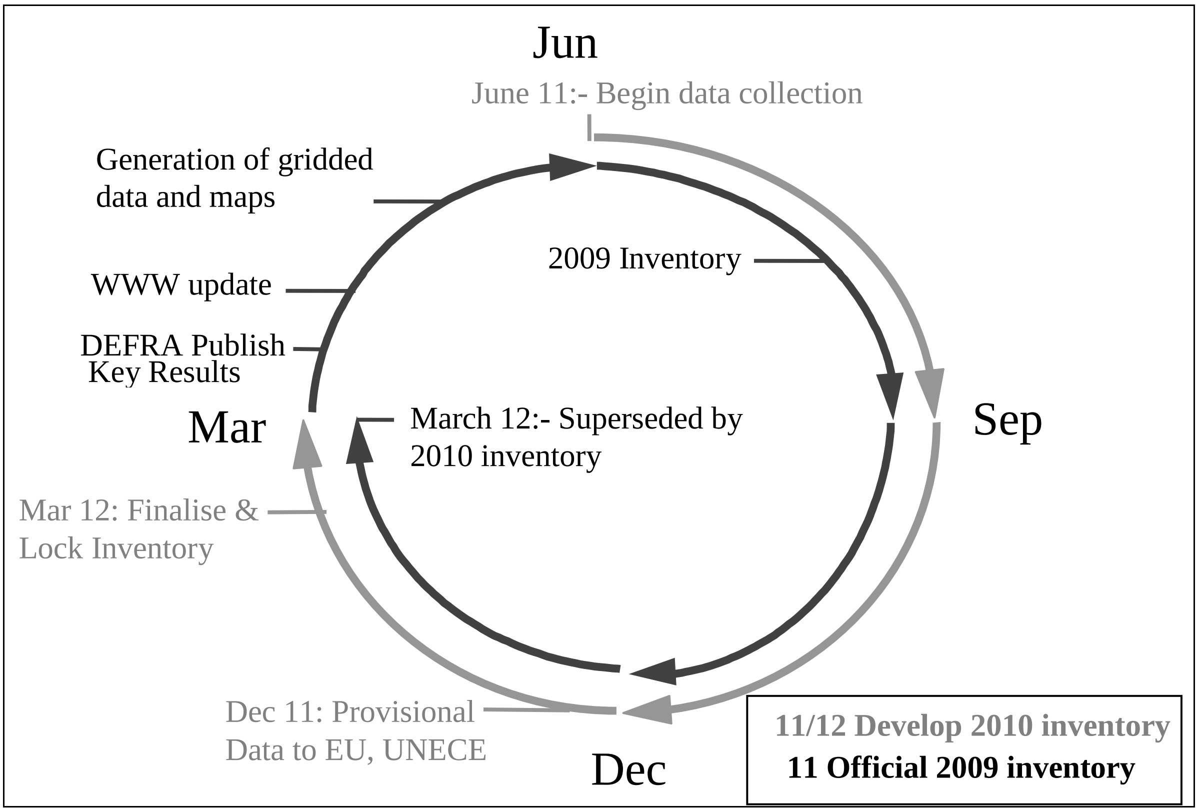
1.3.2 The Annual Cycle of Inventory Compilation

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 UNECE, and other international fora.

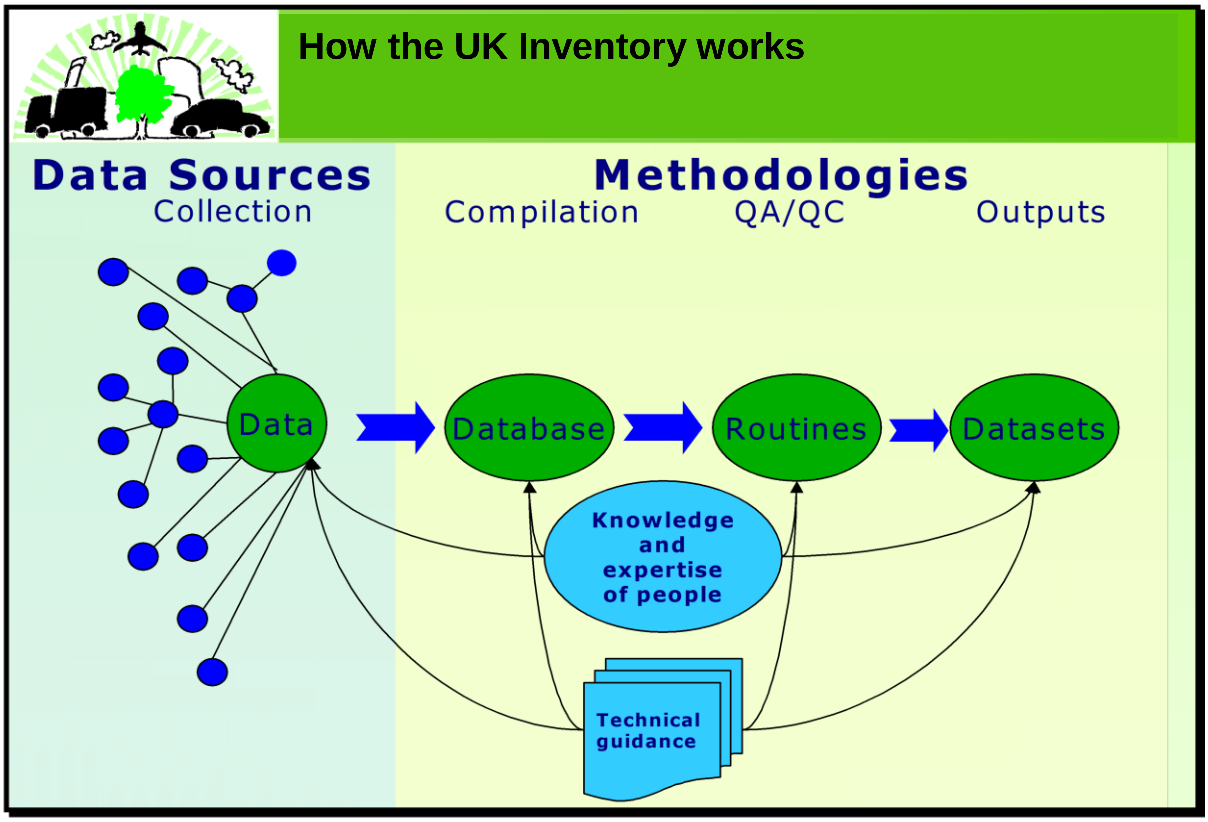
Figure 1-2 The Annual Inventory Cycle in the UK



1.3.3 Data Flows and Infrastructure Organisation

The compilation of the UK inventory requires a systematic approach to the collation of quite disparate statistical and source emission measurement information, and the subsequent calculation of comprehensive, coherent and comparable air emissions data to a range of users as illustrated in Figure 1-3.

Figure 1-3: Summary of UK Inventory data flows.



The compilation method can be summarised as follows:

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

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

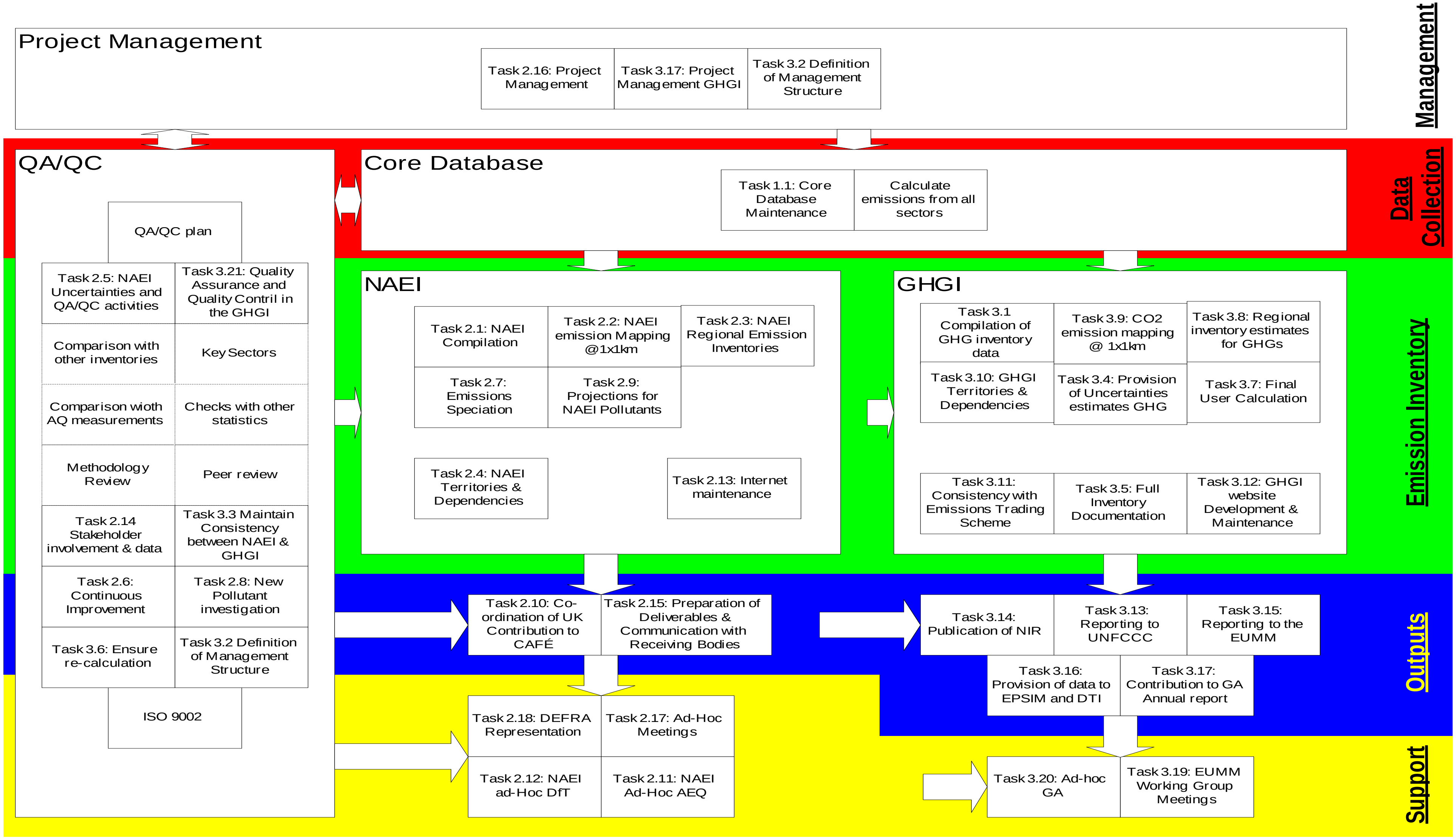
The five-stage summary of the inventory cycle provides a simplistic overview. In practice there are considerably more tasks and the cycle is more complex. For example, some other tasks within the programme would be associated with:

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

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

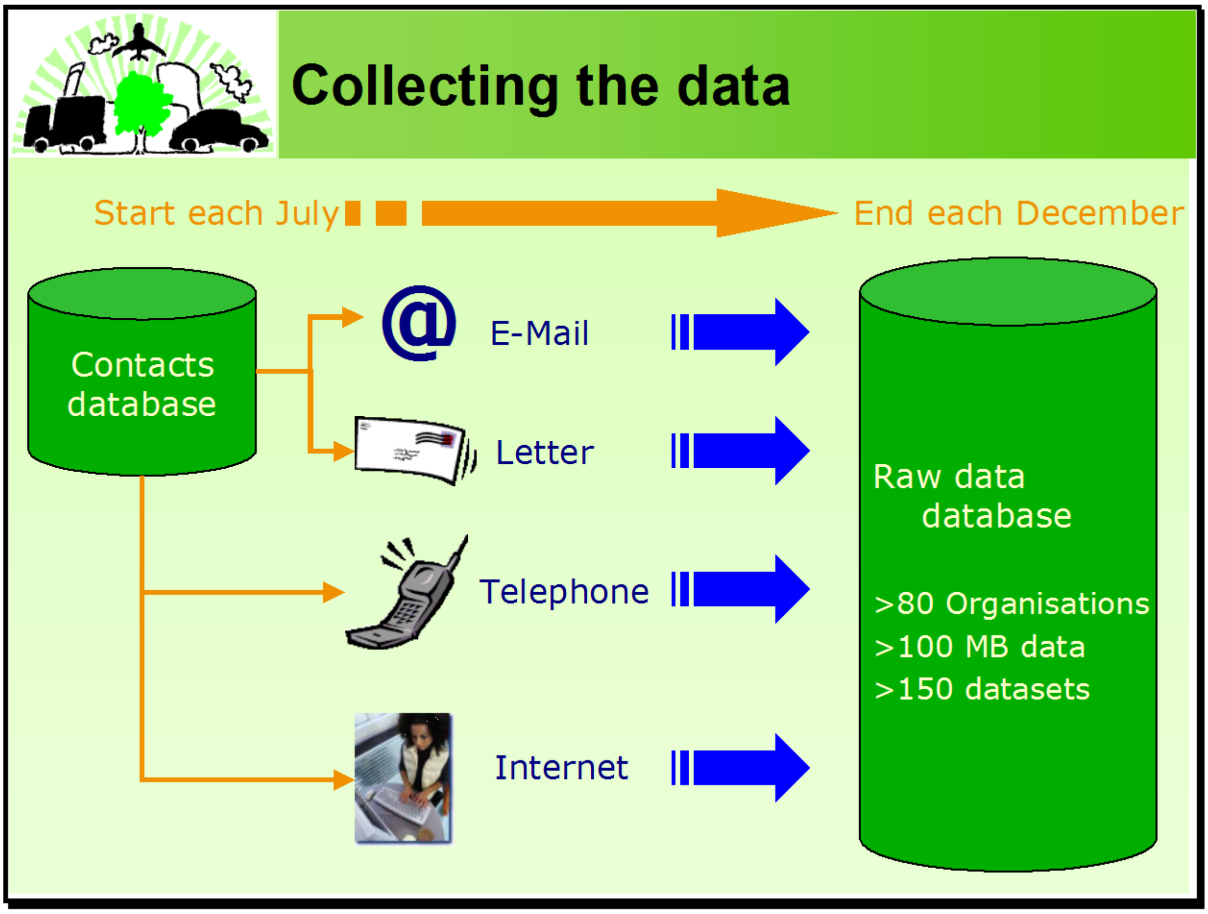


1.3.4 Stage 1: Data Collection

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://www.environment-agency.gov.uk/business/topics/pollution/32254.aspx

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).

Aether compiles the DA, OT, CD and SB inventories and the rail inventory.

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

The UK emission inventories are compiled according to international Good Practice Guidance (EMEP/CORINAIR [now EMEP/EEA] and IPCC). Each year the inventory is updated to include the latest data available. Improvements to the methodology are made and are backdated to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new guidance from EMEP/EEA, relevant work by IPCC, new research, or specific research programmes sponsored by Defra or DECC.

1.3.5 Stage 2: Raw Data Processing

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

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

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

1.3.6 Stage 3: Spreadsheet Compilation

All data 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 1-5 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 1-5 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	UK statistics	UK factors & Operator reporting under IPPC	
1A2c Chemicals	UK statistics	UK factors & Operator reporting under IPPC	
1A2d Pulp, Paper & Print	UK statistics	UK factors & Operator reporting under IPPC	
1A2e Food Processing, Beverages & Tobacco	UK statistics	UK factors & Operator reporting under IPPC	
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	
1A3di (ii) International inland waterways	UK statistics		Not estimated (NE)
1A3d ii National Navigation			
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	
1B1b Solid fuel transformation	UK statistics	Operator reporting under IPPC, literature sources	
1B1c Other	-	-	Reported under

NFR Category	Activity	EFs	Comment
			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	
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	

NFR Category	Activity	EFs	Comment
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://naei.defra.gov.uk/data_warehouse.php

1.5 KEY SOURCE ANALYSIS

Table 1-6 provides an overview of the most important sources for selected pollutants reported under the CLRTAP in the 2010 inventory submission. The sources that add up to at least 95% of the national total in 2010 are defined as being a key source a each pollutant.

For SO_2 and NO_x the single dominant source is 1A1a Public Electricity and Heat Production. Nine of the 13 key sources for NH_3 are from the agriculture sector, with 42% of the emission due from cattle. NMVOC sources are dominated by the use of domestic solvents including fungicides. 37% of CO emissions arise from passenger cars in the road transport sector, which has been a dominant source throughout the time series. However the share of emissions from this sector increased between 1970 and 2010 due to the decrease of emissions in other sectors such as 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 2010. 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 1-6 Key NFR Sources of Air Quality Pollutants in the UK in 2010 (contributing <95% to the emission total)

SO_2	1A1a 42.7%	1A1b 13.7%	1A2fi 11.7%	1A4bi 8.9%	1B1b 3.1%	1A3dii 3.0%	1A2a 2.3%	2C1 2.1%	1A1c 2.1%	1A2c 1.7%	2A7d 1.7%	1A5b 1.6%	1A4ai 1.1%	1A2d 0.6%	2C3 0.6%	1A2fii 0.5%	1A2e 0.4%	
NO_x	1A1a 22.5%	1A3bi 14.8%	1A3biii 13.3%	1A2fii 7.0%	1A1c 5.9%	1A2fi 5.6%	1A3bii 5.4%	1A4bi 4.1%	1A3dii 3.4%	1A3c 3.3%	1A4cii 2.6%	1A5b 2.5%	1A1b 2.0%	1A4ai 1.9%	1A2c 1.3%			
NH_3	4B1a 23.8%	4B1b 17.8%	4D1a 13.5%	4D2c 8.8%	4B9d 7.1%	4B13 6.6%	4B8 5.7%	1A3bi 3.5%	4B9a 3.0%	6B 2.0%	6D 1.6%	4B6 1.4%	2B5a 1.0%					
NMVOC	3D2 16.5%	3D3 11.3%	2D2 10.5%	1A3bi 6.0%	1B2ai 5.0%	3A2 4.7%	3A1 4.5%	1B2b 4.5%	6A 3.7%	1B2av 3.7%	1B2c 3.3%	3B1 3.0%	1A4bi 2.7%	1B2aiv 2.6%	1A2fii 2.5%	2B5a, 3D1, 3C 2.3%	1A3bv, 1A3dii, 1A3bii, 1A4cii, 1A4bii, 1A3biv, 3B2 1%	
CO	1A3bi 36.9%	1A4bi 15.0%	1A2fii 10.3%	2C1 7.2%	1A2fi 4.4%	1A1a 3.4%	1A4bii 3.3%	1A3bii 2.4%	1A3biv 2.4%	1A4ci 1.7%	1A3dii 1.5%	1A3biii 1.1%	2C3 1.0%	1A4cii, 1A3aii(i), 1A1c, 2B5a 0.9%	1A3c 0.7%	7A 0.6%		
PM_{10}	1A4bi 15.7%	1A3bvi 8.0%	1A1a 5.8%	1A2fii 5.7%	4B9b 5.4%	2A7a 5.1%	1A3bi 4.7%	1A4ci 4.4%	1A3bvii 4.2%	2C1 3.8%	3A2 3.1%	1A3bii 3.1%	1A2fi 2.7%	1A4cii 2.3%	7A 2.3%	2A7d 2.3%	1A3biii 2.1%	4G, 4B9d, 1A3dii, 6Ce, 2G, 4B8, 1A1b, 1B2c, 1A5b, 2D3, 1A4ai, 1A3c, 1A2c <2%
Pb	2C1 38.0%	1A2fi 19.2%	1A4bi 7.4%	2B5a 6.2%	1A1a 5.4%	1B1b 3.7%	2C5e 3.5%	2C5b 2.2%	1A1b 2.1%	2C3 2.0%	1A3bi 1.5%	1A4ai 1.5%	1A2fii 0.9%	6Ca 0.9%	1A2c 0.8%	1A3biii 0.7%		
Hg	1A1a	6Cd	2B5a	1A2fi	2C1	6A	6Ca	1A1b	1A4bi	2C5b	1A2c	2C5e	6Cb	1A4ai				

	23.4 %	13.3%	12.9%	10.1 %	6.2%	5.7%	5.5%	5.1%	3.1%	3.0%	2.6%	2.5%	1.5%	1.2%				
Cd	2C1	1A2fi	1A3bi	1A4bi	1B1b	1A1a	1A3biii	2C5e	2C3	1A3bii	1A2fii	1A3dii	1A4ai	1A2a, 1A4cii, 1A1b, 1A3bvi, 2C5b, 1A2c, 6Ca, 1A5b				
	26.1 %	16.4%	9.0%	7.9%	6.3%	4.4%	3.6%	3.5%	2.6%	2.0%	1.9%	1.5%	1.5%	1.4%				
DIOX	2C1	7A	6Ce	1A2fi	1A4ci	6Cd	1A4bi	2C3	1A1b	1A1a	6Cb	1A2fii	1A3bi	6D	1A4cii			
	22.6 %	21.8%	13.9%	10.2 %	8.2%	5.6%	3.2%	2.2%	2.1%	1.5%	1.4%	0.9%	0.9%	0.7%	0.6%			
B[a]P	1A4bi	7A	1B1b	1A3bi	2C1	1A1b	6Ce	1A2fii	1A3bii									
	75.1 %	8.4%	3.3%	2.4%	2.1%	1.3%	1.0%	0.9%	0.9%									
HCB	4G	1A1a																
	69.9 %	29.2%																

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/EEA 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. **BS EN ISO 9001:2008** 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

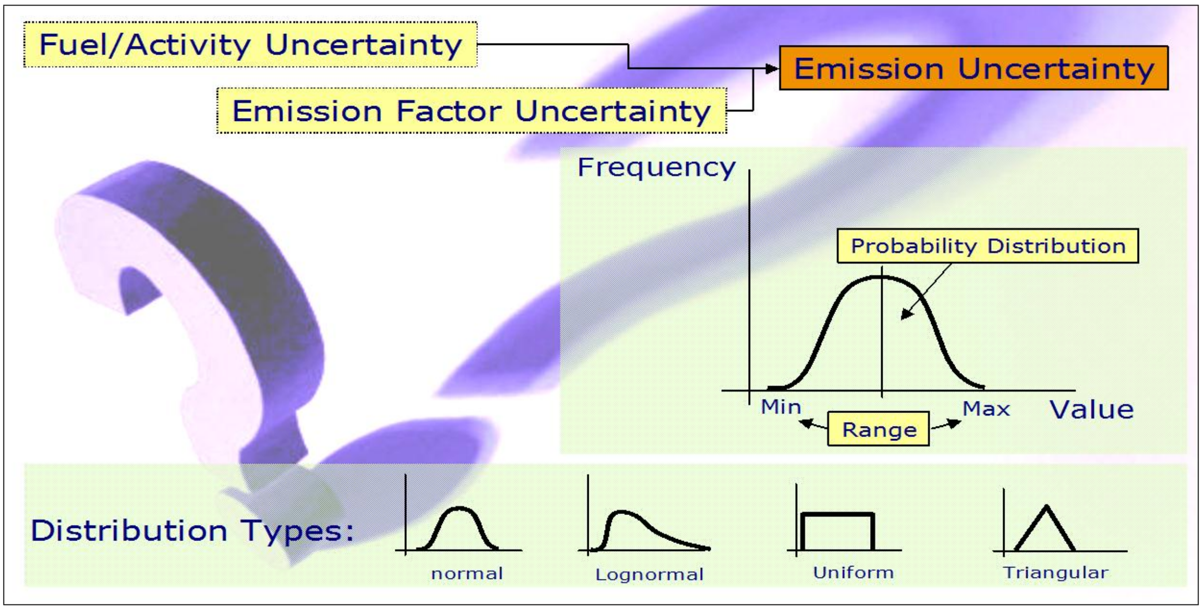
their trends. For example, production-based emission estimates are compared with sales data to check that the trends and values seem reasonable.

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/EEA, 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

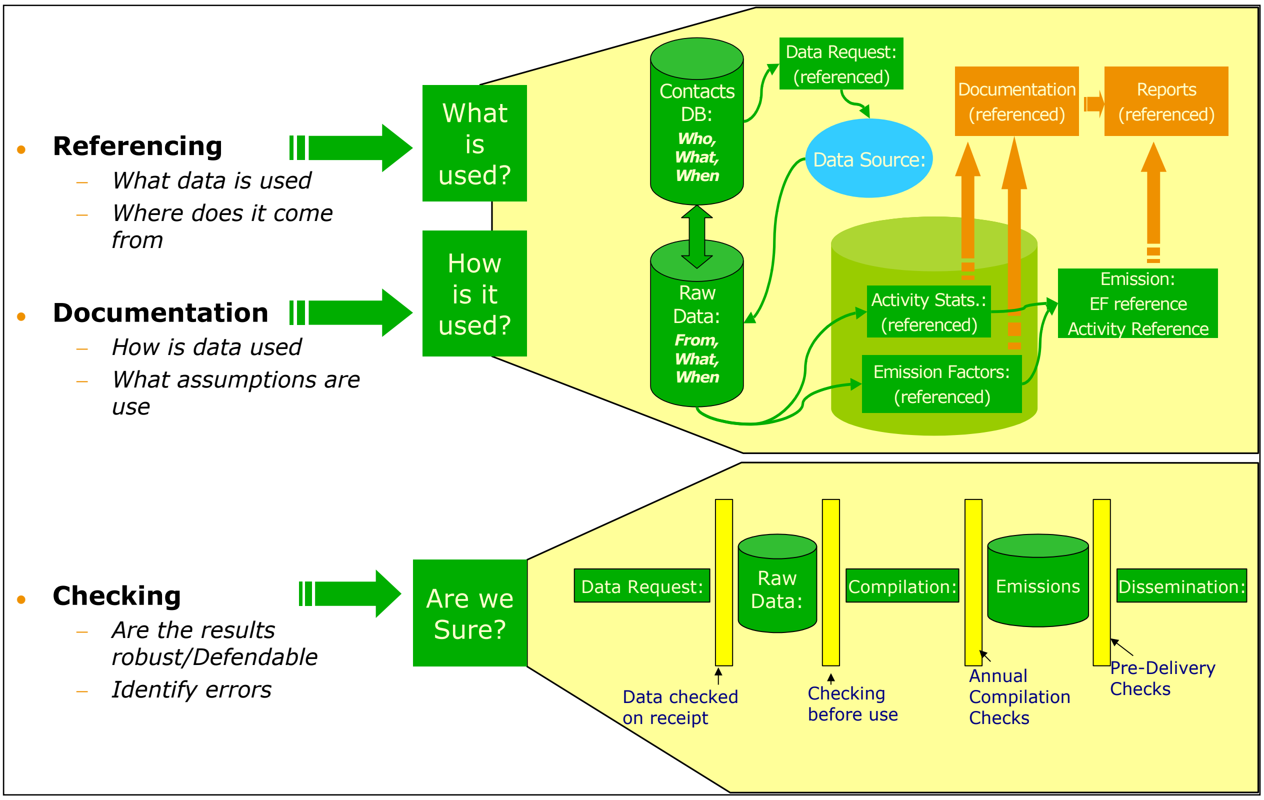


This determines the impact of uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. All analyses are consistent with the IPCC and EMEP/EEA good practice guidance. Uncertainties are assessed for each year's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

1.6.4 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 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.

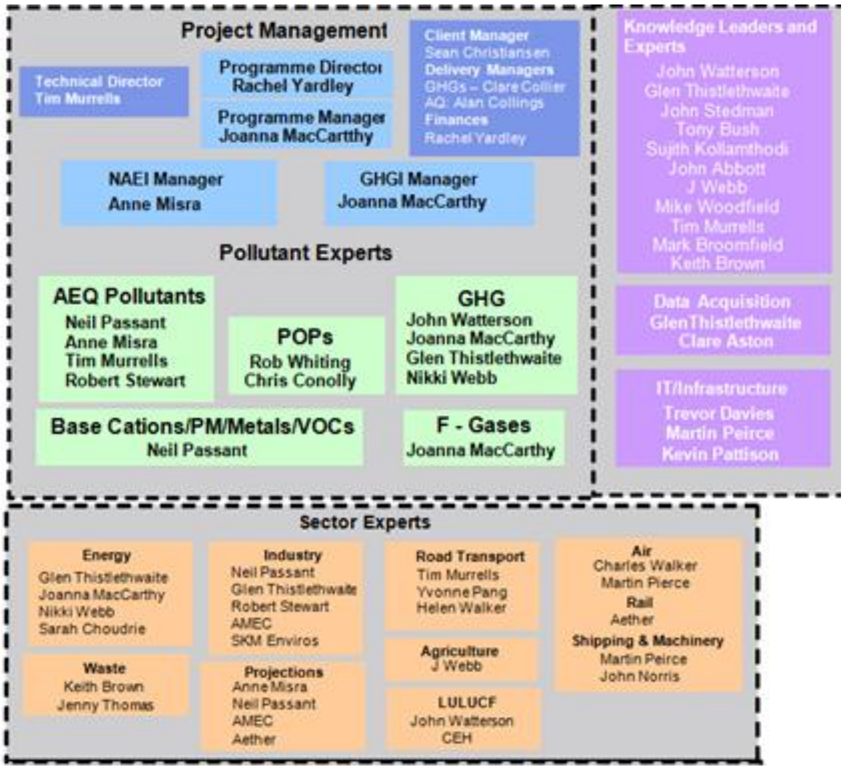
Some of these activities are already carried out, particularly reality checks and the review of appropriateness of emission factors. In practice, there usually is not a great deal of choice of emission factors and methodology and it is usually obvious why a factor should be used.

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

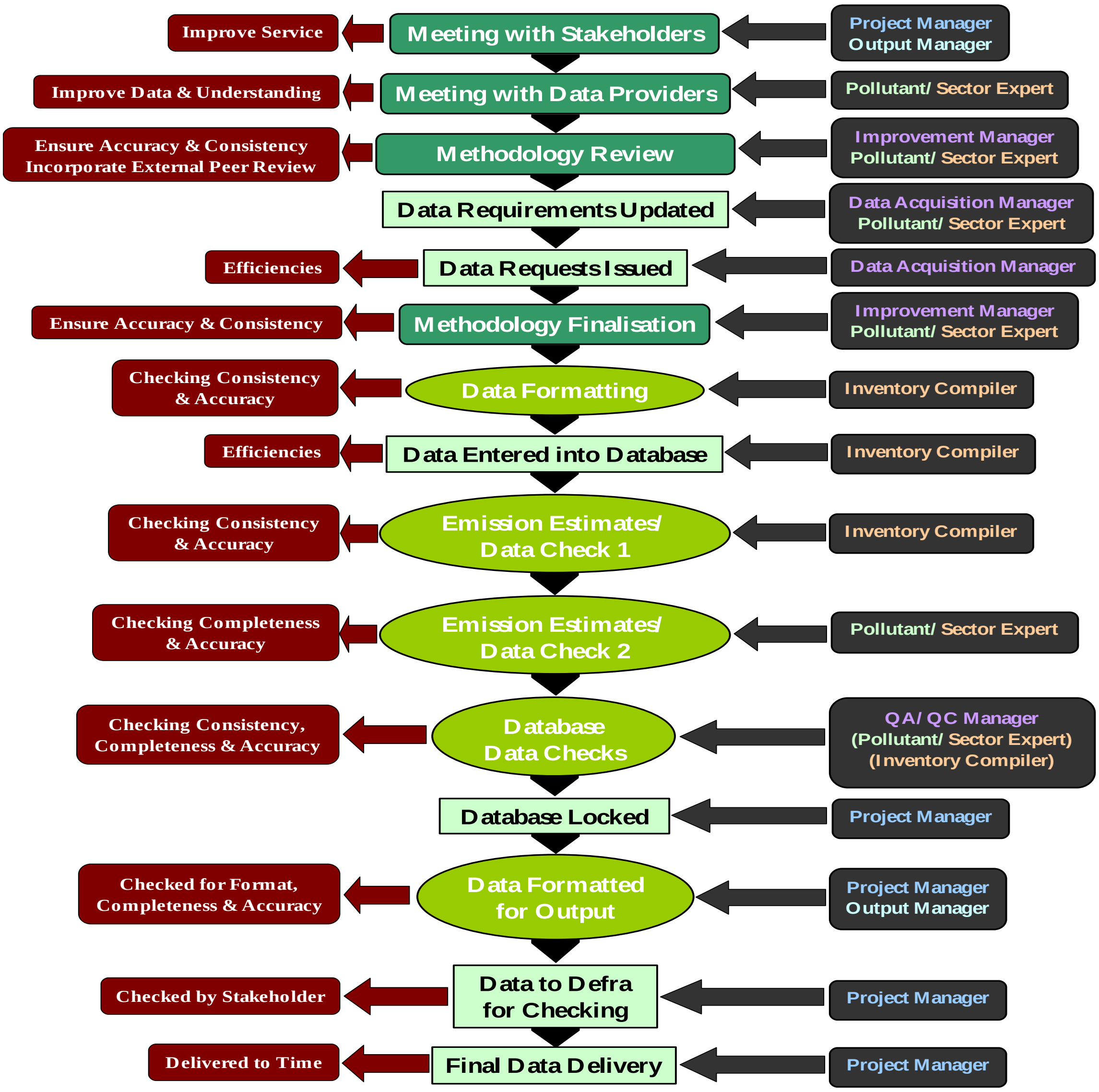


This well-defined structure ensures that responsibilities are transparent. The QA/QC related tasks for each of these roles are explained in the following Sections.

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

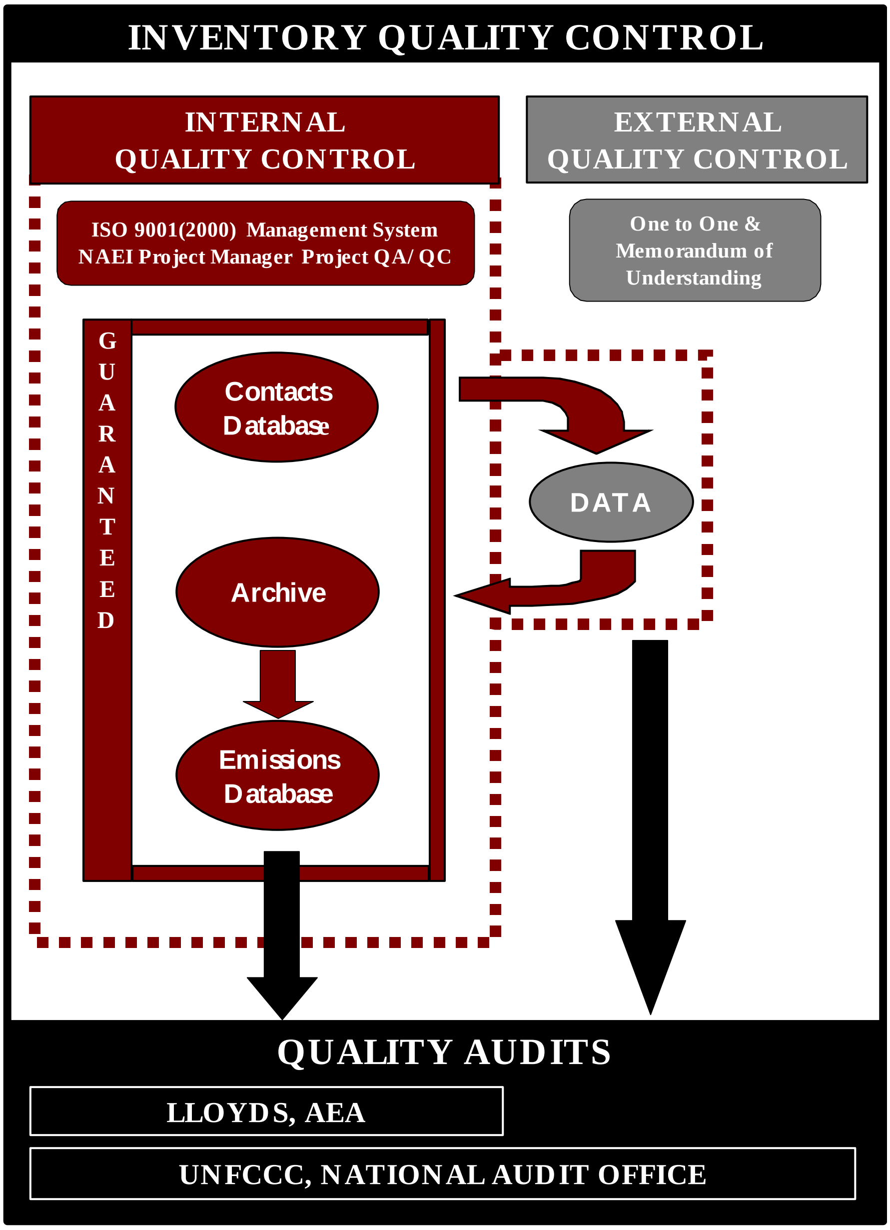


Stages 1 and 2: Input Data Quality

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: Auditing of the inventory team, processes and data



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/EEA and the IPCC describe a minimum acceptable level of QA/QC and the UK emissions inventory team aim to exceed these baseline requirements. AEA is currently accredited to BS EN ISO 9001:2008. Lloyds Register Quality Assurance carried out a three yearly recertification audit of AEA in September and October 2011. AEA successfully passed the recertification, with no major non compliances, and a new certificate was issued. AEA is currently certificated both for the Quality Assurance ISO 9001:2008, including TiCKIT, and Environmental Management System ISO 14001 standard. 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 as indicated in section 1.6.3.

Quantitative estimates of the uncertainties in emission inventories are based on calculations made using a direct simulation technique, which corresponds to the methodology proposed in draft guidance produced by the UNECE Taskforce on Emission Inventories. This work is described in more detail by Passant (Passant NR (2002b)). Uncertainty estimates are shown in Table 1-7. These estimated uncertainties are one of the indicators used to derive where improvements are required in the NAEI.

Table 1-7 Uncertainty of the Emission Inventories for pollutants covered under the NAEI (excluding GHGs)

Pollutant	Estimated Uncertainty %
Carbon monoxide	+/- 20
Benzene	+/- 20
1,3-butadiene	-20 to +30
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	+/- 10
Ammonia	+/- 20
Hydrogen Chloride Hydrogen Fluoride[a]	-30 to +40 -30 to +50
Arsenic	-70 to +200
Cadmium	+/- 20
Chromium	-40 to +100
Copper	-50 to +120
Lead	-20 to +30
Mercury	+/- 30
Nickel	-30 to +50
Selenium	+/- 30
Vanadium	-20 to +30
Zinc	-40 to +60
Beryllium	-40 to +70
Manganese	-40 to +70
Benzo[a]pyrene	-70 to +150
PCDD/PCDF	-40 to +80
Polychlorinated biphenyls	-50 to + 70
Pentachlorophenol	-80 to +130
Hexachlorocyclohexane	-100 to +400
Hexachlorobenzene	-70 to + 110
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 uncertain sources dominate the inventory.

1.7.2 Carbon monoxide

Carbon monoxide emissions occur almost exclusively from combustion of fuels, particularly by road transport. Emission estimates for road transport are highly uncertain, due to the relatively small number of emission factor measurements available and the highly variable nature of these values.

Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. The emission factors used in the inventory have been derived from relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in emission data for major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_x, CO_2 and SO_2 which are also emitted mainly from major combustion processes.

1.7.3 Nitrogen oxides

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

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

1.7.4 Non-Methane Volatile Organic Compounds

The NMVOC inventory is more uncertain than those for SO_2 and NO_x. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. Given the broad range of independent sources of NMVOCs, as with NO_x, there is a reduced uncertainty in the national total, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

1.7.5 Particulate Matter Estimates

The emission inventory for PM_{10} has undergone considerable revision over the last few years of the NAEI and is now considered significantly improved. Nonetheless, the uncertainties in the emission estimates must still be considered high. These uncertainties stem from uncertainties in the emission factors themselves, the activity data with which they are combined to quantify the emissions and that in the size distribution of particle emissions from the different sources.

Emission factors characteristically are based upon a few measurements made on one emitting source, which is assumed to be representative of the behaviour of all similar sources. Emission estimates for PM_{10} are based whenever possible on measurements of PM_{10} emissions from the source, but sometimes measurements have only been made on the mass of total particulate matter and it is therefore necessary to convert this to PM_{10} - based either on the size distribution of the sample collected or, more usually, on size distributions given in the literature. Many sources of particulate matter are diffuse or fugitive in nature e.g. emissions from coke ovens, metal processing, or quarries. These emissions are difficult to measure and in some cases it is likely that no entirely satisfactory measurements have ever been made.

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction. All parts of the inventory would need to be improved before the overall uncertainty in PM could be reduced to the levels seen in the inventories for CO_2, SO_2, NO_x or NMVOC.

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

Estimates for total suspended particles (TSP) are calculated by applying scaling factors to the PM_{10} emissions data. The scaling factors are based on the US EPA factors (US EPA (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, which is based upon comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture, industry and domestic sectors, contains accurate emission estimates for the most important sources.

1.7.7 Heavy Metals

Among the metal inventories, those for selenium 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 the most uncertain. This ranking of the inventories reflects the relative contributions made by sources that can be estimated with more certainty, such as emissions from fuel combustion and chemicals manufacture, compared with the contributions made by sources for which estimates are very uncertain, such as burning of impregnated wood

1.7.8 Persistent Organic Pollutants

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

1.8 ASSESSMENT OF COMPLETENESS

1.8.1 Not Estimated

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

1.8.2 Included Elsewhere

Sources that are unspecified within the NFR disaggregation for a specific sector are reported in categories such as 2 C 5 e - Other metal production. The list of sources included in these aggregated categories is reported in the additional information table within the 2012 CLRTAP submission[12].

1.8.3 Other Notation Keys

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

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

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 2010. Further information and analysis on the emission trends of all pollutants reported under the CLRTAP are available on the NAEI website (http://naei.defra.gov.uk/) together with the emission maps for key pollutants.

2.1.1 Power Generation

Power generation was a key source of emissions for CO, NO_x, PM_{10} and SO_2 in 1980 and it remains so during 2010. However, there has been significant reduction in the magnitude of emissions from this source between 1980 and 2010 (see Table 2-1).

Table 2-1 Power Station Emissions: Inventory Significance and Trends, 1980 to 2010

Pollutant	NFR Code	% of total emissions in 2010	% Change from 1980 to 2010
SO_2	1A1a	43%	-94%
NO_x	1A1a	23%	-71%
CO	1A1a	3%	-40%
PM_{10}	1A1a	6%	-91%

Prior to 1989, the decline was mainly due to the increased use of nuclear plant and improvement in efficiency of fossil powered plant. In 1984 the miners' strike led to a significant decrease in the use of coal for combustion in electricity generation, industry and the domestic sector. As a result there is a noticeable dip in emissions from coal-fired combustion sources in 1984 (see Figure 2-1, Figure 2-2, Figure 2-3).

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

Figure 2-1 Sulphur Dioxide (SO_2) Emissions from Key Source Categories, 1980 to 2010

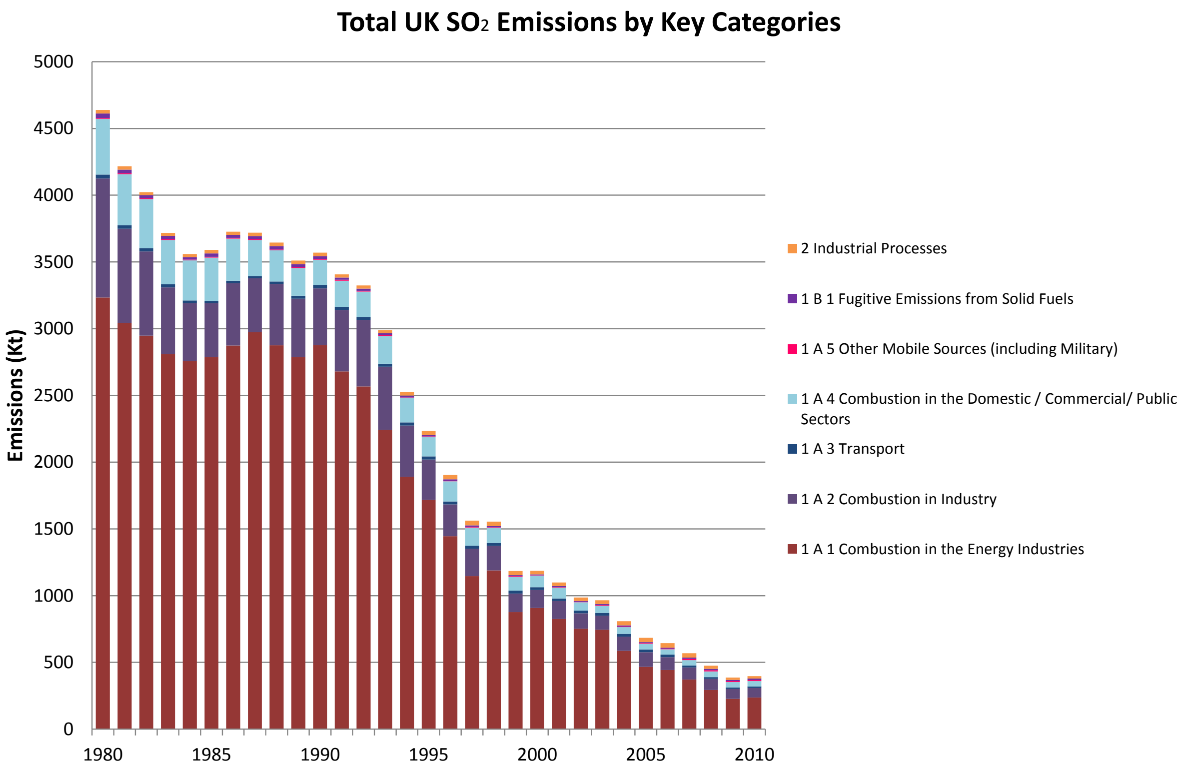


Figure 2-2 PM_{10} Emissions from Key Source Categories, 1980 to 2010

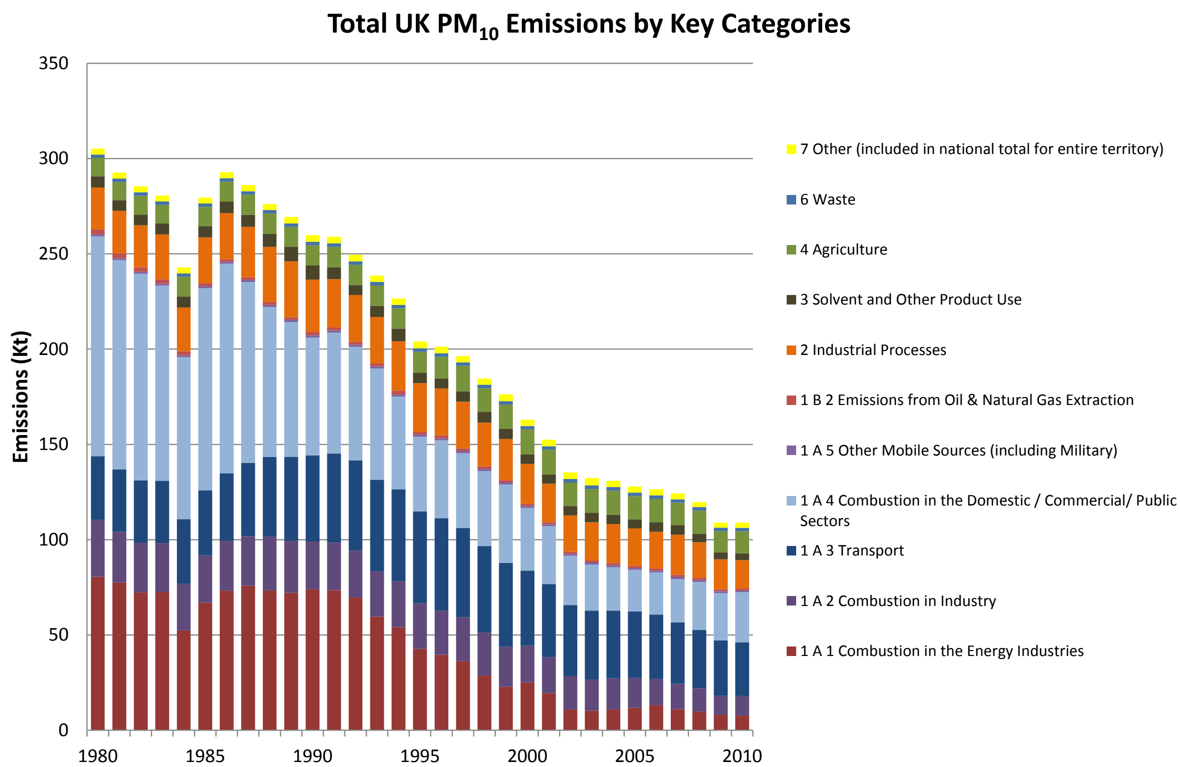
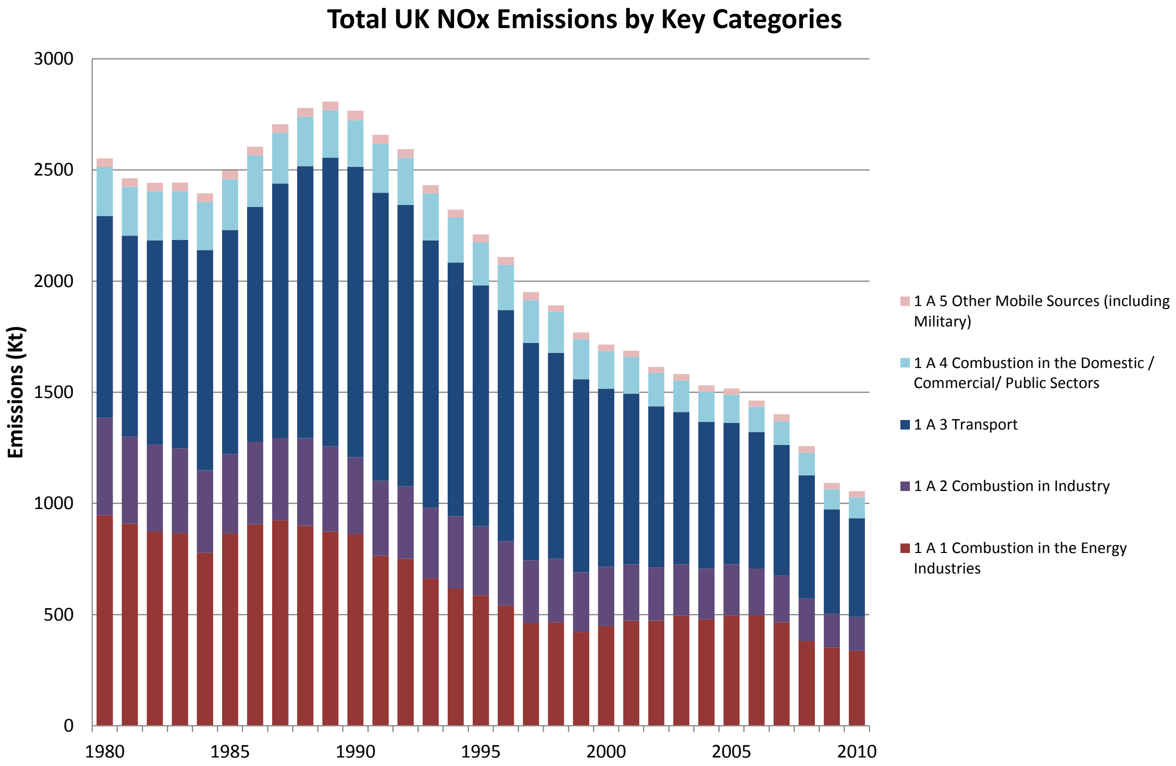


Figure 2-3 NO_x Emissions from Key Source Categories, 1980 to 2010



2.1.2 Residential and Commercial Sectors

Residential combustion is a key source of CO, NO_x, NMVOC, PM_{10} and SO_2 emissions during 2010 (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. Residental 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 2010, PM_{10} emissions from domestic and commercial and institutional combustion (1A4ai and 1A4bi) have fallen by 82%. 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 2010

Pollutant	NFR Code	% of total emissions in 2010	% Change from 1980 to 2010
SO_2	1A4bi	9%	-84%
NO_x	1A4bi	4%	-56%
CO	1A4bi	15%	-84%
PM_{10}	1A4bi	16%	-82%
NMVOC	1A4bi	3%	-83%

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 2010 (see Table 2-3). Emissions from the food and drink industry comprised 10% of the total NMVOC emission in 2010. 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 2010. The emission 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 2010 is 86%. The chemical industry is a key source category of Pb, Hg and Cd, contributing to 6%, 13% and 1% 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 2010

Pollutant	**NFR Code**	**% of total emissions in 2009**	**% Change from 1980 to 2009**
NMVOC	2D2	10%	+1.4%
NMVOC	2B5a	2%	-86%
Pb	2B5a	6%	-96%
Hg	2B5a	13%	-92%
Cd	2B5a	1%	-96%

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 Transport Emissions: Inventory Significance and Trends, 1980 to 2010

Pollutant	**NFR Code**	**% of total emissions in 2010**	**% Change from 1980 to 2010**
SO_2	1A3dii	3%	-60%
NOx	1A3bi	15%	-69%
NOx	1A3biii	13%	-41%
NOx	1A3bii	5%	-16%
NOx	1A3dii	3%	-16%
NOx	1A3c	3%	192%
CO	1A3bi	37%	-80%
CO	1A3bii	2%	-91%
CO	1A3biv	2%	-68%
CO	1A3dii	2%	176%
CO	1A3biii	1%	-65%
CO	1A3aii(i)	1%	-58%
CO	1A3c	1%	13%
PM_{10}	1A3bvi	8%	63%
PM_{10}	1A3bi	5%	33%
PM_{10}	1A3bvii	4%	67%
PM_{10}	1A3bii	3%	39%
PM_{10}	1A3biii	2%	-82%
PM_{10}	1A3dii	2%	-49%
PM_{10}	1A3c	1%	6%
NMVOC	1A3bi	6%	-88%

Pollutant	NFR Code	% of total emissions in 2010	% Change from 1980 to 2010
NMVOC	1A3bv	1%	-97%
NMVOC	1A3dii	1%	105%
NMVOC	1A3bii	1%	-88%
NMVOC	1A3biv	1%	-81%
NH_3	1A3dii	4%	2191%

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

The further tightening up of emission standards on petrol cars and all types of new diesel vehicles over the last decade has also contributed to the reduction in NO_x emissions. Fuel switching from petrol cars to diesel cars has reduced CO and NMVOC emissions.

Diesel engine vehicles emit a greater mass of particulate matter per vehicle kilometre than petrol engine vehicle. Since around 1992, however, emissions from diesel vehicles on a per vehicle kilometre travelled basis have been decreasing due to the penetration of new vehicles meeting tighter PM emission regulations ("Euro standards" for diesel vehicles were first introduced in 1992) and this has more than offset the increase in diesel vehicle activity so that overall PM_{10} emissions from road transport have been falling.

Further detailed information on Transport is covered in Chapter 5.

2.1.5 Agriculture

Agricultural sources with emissions from livestock and their wastes (NFR 4B) are the major source of NH_3 emissions, contributing 65% of total emissions in 2010. 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 2010 represent a decrease of 22% on the 1980 emissions.

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

2.1.6 Waste

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

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

Pollutant	**Key sources during 2010**	**% of total emissions in 2010**	**% Change from 1980 to 2010**
SO_2	1 A 1 a Public Electricity and Heat Production	43%	-94%
	1 A 1 b Petroleum refining	14%	-72%
	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Autogenerators, Other industrial combustion)	12%	-94%
	1 A 4 b i Residential plants	9%	-84%
	1 B 1 b Solid fuel transformation	3%	-63%
	1 A 3 d ii National Navigation	3%	-60%
	1 A 2 a Iron and Steel	2%	-88%
	2 C 1 Iron and steel production	2%	-17%
	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	2%	-64%
	1 A 2 c Chemicals	2%	168%
	2 A 7 d Other Mineral products (Brick manufacture - Fletton)	2%	-36%
	1 A 5 b Other, Mobile (Including military)	2%	3%
	1 A 4 a i Commercial / institutional: Stationary	1%	-98%
	1 A 2 d Pulp, Paper and Print	1%	326%
	2 C 3 Aluminum production	1%	-52%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Industrial off-road mobile machinery)	1%	-86%
	1 A 2 e Food Processing, Beverages and Tobacco	0%	-31%
	Overall change for all sources		**-91%**
NOx	1 A 1 a Public Electricity and Heat Production	23%	-71%
	1 A 3 b i R.T., Passenger cars	15%	-69%
	1 A 3 b iii R.T., Heavy duty vehicles	13%	-41%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Industrial off-road mobile machinery)	7%	-31%
	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	6%	46%

Pollutant	Key sources during 2010	% of total emissions in 2010	% Change from 1980 to 2010
NOx	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Cement - non-decarbonising, Autogenerators)	6%	-81%
	1 A 3 b ii R.T., Light duty vehicles	5%	-16%
	1 A 4 b i Residential plants	4%	-56%
	1 A 3 d ii National Navigation	3%	-16%
	1 A 3 c Railways	3%	192%
	1 A 4 c ii Off-road Vehicles and Other Machinery	3%	-61%
	1 A 5 b Other, Mobile (Including military)	3%	-26%
	1 A 1 b Petroleum refining	2%	-46%
	1 A 4 a i Commercial / institutional: Stationary	2%	-54%
	1 A 2 c Chemicals	1%	169%
	Overall change for all sources		**-58%**
CO	1 A 3 b i R.T., Passenger cars	37%	-80%
	1 A 4 b i Residential plants	15%	-84%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Industrial off-road mobile machinery)	10%	27%
	2 C 1 Iron and steel production	7%	-39%
	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Cement - non-decarbonising, Autogenerators)	4%	-38%
	1 A 1 a Public Electricity and Heat Production	3%	-40%
	1 A 4 b ii Household and gardening (mobile)	3%	6%
	1 A 3 b ii R.T., Light duty vehicles	2%	-91%
	1 A 3 b iv R.T., Mopeds & Motorcycles	2%	-68%
	1 A 4 c i Stationary (Agriculture - stationary combustion)	2%	134%
	1 A 3 d ii National Navigation	2%	176%
	1 A 3 b iii R.T., Heavy duty vehicles	1%	-65%
	2 C 3 Aluminum production	1%	-28%
	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-17%
	1 A 3 a ii Civil Aviation (Domestic, LTO)	1%	-58%
	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	1%	45%
	2 B 5 a Other chemical industry (Chemical industry - titanium dioxide, Chemical industry - general)	1%	-69%
	1 A 3 c Railways	1%	13%
	7 A Other (included in national total for entire territory)	1%	-7%
	Overall change for all sources		**-75%**
PM_{10}	1 A 4 b i Residential plants	16%	-82%

Pollutant	Key sources during 2010	% of total emissions in 2010	% Change from 1980 to 2010
PM_{10}	1 A 3 b vi R.T., Automobile tyre and brake wear	8%	63%
	1 A 1 a Public Electricity and Heat Production	6%	-91%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Industrial off-road mobile machinery)	6%	-39%
	4 B 9 b Broilers	5%	76%
	2 A 7 a Quarrying and mining of minerals other than coal	5%	-39%
	1 A 3 b i R.T., Passenger cars	5%	33%
	1 A 4 c i Stationary	4%	105%
	1 A 3 b vii R.T., Automobile road abrasion	4%	67%
	2 C 1 Iron and steel production	4%	4%
	3 A 2 Industrial coating application	3%	-41%
	1 A 3 b ii R.T., Light duty vehicles	3%	39%
	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Other industrial combustion)	3%	-84%
	1 A 4 c ii Off-road Vehicles and Other Machinery	2%	-67%
	7 A Other (included in national total for entire territory)	2%	-15%
	2 A 7 d Other Mineral products (Brick manufacture - non Fletton, Glass - container)	2%	-36%
	1 A 3 b iii R.T., Heavy duty vehicles	2%	-82%
	4 G OTHER (d)	2%	8%
	4 B 9 d Other poultry	2%	6%
	1 A 3 d ii National Navigation	2%	-49%
	6 C e Small scale waste burning	2%	0%
	2 G OTHER (Other industry - part B processes)	1%	-39%
	4 B 8 Swine	1%	-43%
	1 A 1 b Petroleum refining	1%	-77%
	1 B 2 c Venting and flaring	1%	-59%
	1 A 5 b Other, Mobile (Including military)	1%	-10%
	2 D 3 Wood processing	1%	-60%
	1 A 4 a i Commercial / institutional: Stationary	1%	-85%
	1 A 3 c Railways	1%	6%
	1 A 2 c Chemicals	1%	1136%
	Overall change for all sources		**-65%**
NMVOC	3 D 2 Domestic solvent use including fungicides	16%	60%
	3 D 3 Other product use	11%	-37%

Pollutant	Key sources during 2010	% of total emissions in 2010	% Change from 1980 to 2010
NMVOC	2 D 2 Food and Drink	10%	1%
	1 A 3 b i R.T., Passenger cars	6%	-88%
	1 B 2 a i Exploration Production, Transport	5%	-61%
	3 A 2 Industrial coating application	5%	-66%
	3 A 1 Decorative coating application	5%	-32%
	1 B 2 b Natural gas	4%	-5%
	6 A SOLID WASTE DISPOSAL ON LAND	4%	-58%
	1 B 2 a v Distribution of oil products	4%	-63%
	1 B 2 c Venting and flaring	3%	-44%
	3 B 1 Degreasing	3%	-74%
	1 A 4 b i Residential plants	3%	-83%
	1 B 2 a iv Refining / Storage	3%	-79%
	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Industrial off-road mobile machinery)	3%	-5%
	2 B 5 a Other chemical industry (Chemical industry)	2%	-86%
	3 D 1 Printing	2%	-59%
	3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	2%	-76%
	1 A 3 b v R.T., Gasoline evaporation	1%	-97%
	1 A 3 d ii National Navigation	1%	105%
	1 A 3 b ii R.T., Light duty vehicles	1%	-88%
	1 A 4 c ii Off-road Vehicles and Other Machinery	1%	-49%
	1 A 4 b ii Household and gardening (mobile)	1%	-61%
	1 A 3 b iv R.T., Mopeds & Motorcycles	1%	-81%
	3 B 2 Dry cleaning	1%	-71%
	Overall change for all sources		**-65%**
NH_3	4 B 1 a Dairy	24%	-16%
	4 B 1 b Non-Dairy	18%	-22%
	4 D 1 a Synthetic N-fertilizers	14%	-32%
	4 D 2 c N-excretion on pasture range and paddock unspecified	9%	-10%
	4 B 9 d Other poultry	7%	-5%
	4 B 13 Other	7%	-14%
	4 B 8 Swine	6%	-55%
	1 A 3 b i R.T., Passenger cars	4%	2191%
	4 B 9 a Laying hens	3%	-55%
	6 B WASTE-WATER HANDLING	2%	1%
	6 D OTHER WASTE (f)	2%	318%
	4 B 6 Horses	1%	

Pollutant	Key sources during 2010	% of total emissions in 2010	% Change from 1980 to 2010
NH_3	2 B 5 a Other chemical industry (Chemical industry - ammonia use, Chemical industry - ammonia based fertilizer)	1%	-54%
	Overall change for all sources		**-22%**

3. NFR 1A1: Combustion in the Energy Industries

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

<table>
<tr><th>NFR Category (1A1)</th><th>Pollutant coverage</th><th>NAEI Source category</th><th>Source of EFs</th></tr>
<tr><td>1 A 1 a Public Electricity and Heat Production</td><td>All CLRTAP pollutants (except HCH)</td><td>Power stations
Miscellaneous industrial/commercial combustion[13]</td><td rowspan="12">Operator reporting under IPPC and EEMS, trade association information</td></tr>
<tr><td>1 A 1 b Petroleum refining</td><td>All CLRTAP pollutants (except NH_3, HCB, HCH and PCBs)</td><td>Refineries - combustion</td></tr>
<tr><td rowspan="9">1 A 1 c Manufacture of Solid Fuels and Other Energy Industries</td><td rowspan="9">All CLRTAP pollutants (except HCB and HCH)</td><td>Coke production</td></tr>
<tr><td>Collieries - combustion</td></tr>
<tr><td>Gas production</td></tr>
<tr><td>Gas Production - combustion at gas separation plant</td></tr>
<tr><td>Gas Production - gas combustion</td></tr>
<tr><td>Nuclear fuel production</td></tr>
<tr><td>Oil Production - gas combustion</td></tr>
<tr><td>Solid smokeless fuel production</td></tr>
<tr><td>Town gas manufacture</td></tr>
<tr><td>1A3e Pipeline Compressors</td><td>All CLRTAP pollutants (except POPs and PAHs)</td><td>Included under 1A1c - Gas Production</td></tr>
</table>

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).

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[13] reported to 1A1a in those cases where this NAEI source category is used for combustion of MSW & landfill gas to produce heat.

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

Table 3-2 Fuel types used in the NAEI

Fuel type	Fuel name	Comments
Crude-oil based fuels	Aviation Spirit Aviation Turbine Fuel (ATF) Burning Oil Fuel Oil Gas Oil/ DERV Liquefied Petroleum Gas (LPG) Naphtha Orimulsion® Other Petroleum Gas (OPG) Petrol Petroleum Coke Refinery Miscellaneous Vaporising oil	 Includes fuel that is correctly termed jet gasoline. Also known as kerosene DUKES uses the terms “propane” and “butane” An emulsion of bitumen in water DUKES uses the terms “ethane” and “other petroleum gases” Covers ‘green’ coke used as a fuel and catalyst coke. Not used as a fuel since 1978
Coal-based fuels	Anthracite Coal Slurry Coke Solid Smokeless Fuel (SSF) Coke Oven Gas Blast Furnace Gas	 Coal-water slurry. Not included separately in DUKES. Includes coke breeze Includes basic oxygen furnace gas
Gas	Natural Gas Sour Gas Colliery Methane Town Gas	 Unrefined gas used by offshore installations and one power station. Not included separately in DUKES. Not used as a fuel since 1988
Biomass	Wood Straw Poultry Litter Landfill Gas Sewage Gas Liquid bio-fuels	 Includes meat & bone meal. Liquid bio-fuels used at power stations
Wastes	Municipal Solid Waste Scrap Tyres Waste Oil/ Lubricants Waste Solvents	 Not identified separately in DUKES. 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. In general, this is done by estimating the split, although direct consultation with site operators and trade associations is conducted to achieve more accurate source-specific reporting in critically important cases, for example where reporting of emissions must be spread over more than one NFR category (such as the steelworks example mentioned above).

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

Emissions of some pollutants are estimated using literature emission factors and activity data from DUKES. This is particularly true of pollutants such as NMVOC, benzene,1,3-butadiene, metals and POPs, where the level of emissions reporting is much lower than is the case for NO_x, for example. Many operators do not have to provide emissions data for these pollutants because these emissions are below minimum thresholds for reporting. This means that far fewer reported data are available from which to estimate emission factors, so any factors that are derived would be less representative and probably less reliable. But the sectors and pollutants affected in this way are typically minor contributors to UK emission totals (which is why most sites emit below the reporting thresholds in the first place).

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

3.3 FUEL CONSUMPTION DATA

As stated previously, fuel consumption data are taken from DUKES, but with some areas of the inventory where the NAEI energy data deviates from the detailed statistics given in DUKES. This is done for two reasons:

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

The most important of these deviations are as follows:

1) DUKES data for the quantity of fuel oil consumed by power stations are much lower than the quantity reported by process operators to the NAEI team and, more recently, quantities reported under the EU Emissions Trading Scheme (EUETS). Partly, this is due to the use of recovered waste oils as 'fuel oil', but the DUKES figures are still considered too low. The operators' data are used in the NAEI and split into consumption of 'waste oil' and 'fuel oil'. This split is determined by the independent estimates that we make for use of waste oils as a power station fuel (see below). Overall consistency between NAEI and DUKES for fuel oil is maintained by reducing the NAEI estimate for fuel oil consumed by the industrial sector compared with the figure in DUKES.

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

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

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 40 Mt of coal were burnt at 17 power stations during 2010, while approximately 11,700 Mtherms of natural gas were consumed at 42 large power stations and 11 small (<50MWth) regional stations (almost all gas plant are Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 4 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 small quantities of sour gas as well as natural gas, although much larger quantities were burnt in the 1990s. Some coal-fired power stations have trialled use of petroleum coke in the past, and it is now used as a partial substitute for coal at a few sites. In the past, UK power stations have also burnt scrap tyres, orimulsion, and coal slurry, but none currently does so.

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

Electricity is also generated at 21 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. The use of MSW to generate heat was previously wrongly reported under 1A4 while MSW used to generate electricity was reported under 1A1, but this has been revised for this version of the inventory with both types of emissions now 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, and emissions from those sites is reported under NFR 6C. There is also an EfW plant on the Isle of Man, a very small waste incinerator on the Isle of Scilly, and a much larger waste incinerator on Jersey. The latter is being replaced with an EfW plant which should have started operation in early 2011. Currently, emissions from the waste incinerators on the Scilly Isles and Jersey are also reported under 1A1, rather than 6C but this will be reviewed 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 data for NMVOC and metals are quite limited and emission factors generated using these data can show large year-on-year variations, particularly for power stations burning oil, gas oil and poultry litter. These are relatively small plant and emissions of NMVOC and metals are often below the reporting thresholds for the PI, SPRI & ISR. Due to the small-scale of all of these sites, variation in emission factors for the sector does not lead to significant year-on-year variation in the total UK emission. However, the power stations methodology is reviewed each year, and revision of the methods for these more uncertain emission factors could be considered. The general approach described above is used for power stations burning coal, oils, natural gas and biomass as their primary fuel, with one exception in the case of the single straw-burning plant, all reported emissions are currently allocated to the straw.

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

Emissions data are available back to 1988 in the case of NO_x and SO_2 from major fossil-fuel powered stations. For NO_x, emission factors from Stewart & Walker (1997) are used for the years prior to 1989, while in the case of SO_2, factors for 1970-1987 are based on information provided by coal suppliers. The emission factors for NO_x & SO_2 back to 1990 and for other pollutants back to 1997 are reviewed each year so that any changes in reported emissions, activity data, or underlying assumptions, are taken into account in recalculations. The emission factors for the remaining years in the time series (1970-1989 for NO_x and SO_2, 1970-1996 for most other pollutants) are not reviewed each year. They are based on a combination of the use of emissions data published by operators or supplied by regulators; use of UK-based literature emission factors; use of UK-specific fuel composition data; and use of emission factors derived from later UK emissions data. However, the methodologies lack transparency compared with those used to generate later emission factors and so the early factors are more uncertain. They are due for review, and improvement to methodological transparency is a priority.

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

An exception to the use of UK-derived factors is that emissions from landfill gas and sewage gas engines are estimated using literature emission factors from AP-42 (US EPA, 2008). Some sites have reported emissions in the PI, SPRI & ISR in recent years but these data are not currently used as the scope of installation emission estimates because they include other emission sources (i.e. not only the power generating activities) and also the level of operator reporting does not currently provide complete sector coverage.

The NOx emission factor for engines, burning landfill gas and sewage gas, has been revised upward for this version of the inventory after an internal review by AMEC. The new factor is based on engines being typically 3MW and complying with regulatory emission limit values appropriate for this size of plant. We have also introduced SO_2 emission factors for landfill gas engines based on monitoring results for seven landfill gas engines (reported in Gregory, 2002).

Table 3-3 UK Power Generation Emission Estimation Methodology by Pollutant, 1970-2010

Fuels	Pollutant	Methodology
Coal & fuel oil (including use of Orimulsion and petroleum coke and co-firing of biomass)	NO_x	1990-2010: O 1989: O/M 1970-1988: L
	SO_2	1990-2010: O 1988-1989: O/M 1970-1987: F
	HCl (coal only)	1993-2010: O 1992: O/M 1970-1991: E
	Pb	1997-2010: O 1990-1996: O/M 1970-1989: E
	CO, VOC, other metals, PM_{10}, HF	1997-2010: O 1993-1996: O/M 1970-1992: E
Sour gas	NO_x, SO_2	1992:2010: O 1970-1991: not occurring
	CO	1997:2010: O 1992-1996: L 1970-1991: not occurring
	VOC, PM10	1997:2010: O 1992-1996: O/M 1970-1991: not occurring
Coal slurry	NO_x, SO_2	1994:2010: O

Fuels	Pollutant	Methodology
		1970-1993: not estimated separately, included with estimates for coal
	CO, VOC, HCl, metals, PM_{10}	1994:2010: O 1994-1996: O/M 1970-1993: not estimated separately, included with estimates for coal
Natural gas	NO_x	1997-2010: O 1992-1996: O/M 1970-1991: E
	SO_2	1997-2010: O 1993-1996: O/M 1970-1992: not estimated
	CO	1997-2010: O 1993-1996: O/M 1970-1992: E
	VOC, Hg, PM_{10}	1997-2010: O 1996: O/M 1970-1995: E
Gas oil	NO_x	1997-2010: O 1994-1996: O/M 1970-1993: L
	SO_2	1997-2010: O 1994-1996: O/M 1970-1993: F
	CO	1997-2010: O 1996: O/M 1970-1995: L
	VOC, metals, PM_{10}	1997-2010: O 1970-1996: L
Poultry litter	All	1997-2010: O 1992-1996: O/M 1970-1991: not occurring
Straw	All	2000-2010: O 1970-1999: not occurring
Landfill/sewage gas	All	1970-2010: 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 currently has 11 oil refineries, three of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining eight complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke. The crude oils processed, the refining techniques, and the product mix will differ from one refinery to another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

All of these sites are required to report emissions to either the Pollution Inventory or the Scottish Pollutant Release Inventory. Additional data for CO, NO_x, SO_2, and PM_{10} are supplied annually by process operators via the United Kingdom Petroleum Industry Association (UKPIA, 2011). These data split the emissions[14] for the complex refineries into those from large combustion plants (burning fuel oil and OPG) and those from processes (predominantly catalyst regeneration involving the burning of petroleum coke). Emission estimates for the sector can be based on the emission data reported for individual sites:

Emission =	Σ Reported Site Emissions

The UKPIA data used in the NAEI extend back to 1999, and data for English and Welsh sites are available in the Pollution Inventory for the years 1998-2010. Data for Scotland's refineries has been reported in the SPRI for the years 2002 and 2004-2010. Emissions data for NO_x and SO_2 from the large combustion plant present on refinery sites is available back to 1990. Thus, emission factors are generally based on reported data back to 1990 for NO_x and SO_2, and back to 1998 for other pollutants, while emission factors for earlier years are generated by extrapolation from 1990 data for NO_x and $SO_{2,}$ and 1998 data for other pollutants.

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

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

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

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

3.6 METHODOLOGY FOR OTHER ENERGY INDUSTRIES (NFR 1A1C)

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

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2010, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last ten years, due to closure of associated steelworks or closure of other coke consumers. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes regulated under IPPC are included in the inventory since only these give rise to significant emissions. Currently, there are two such sites. Town gas was manufactured from coal, but has not been consumed in the UK since 1988, after the closure of the last coal gas plants in the UK in 1987.

Table 3-4 UK Coke Ovens and SSF Manufacturing Plant in Operation, 1970-2010

Process type	Period	No of plant
Coke ovens	2004-2010	6
	2003	7
	1993-2002	9
	1991-1992	10
	1970-1990	No data
Solid smokeless fuel manufacture	2006-2010	2
	2000-2005	3
	1997-1999	4
	1996	5
	1991-1995	6
	1970-1990	No data

All of these sites are required to report emissions in either the Pollution Inventory or the Scottish Pollutant Release Inventory. Emission estimates for the sector can be based on the emission data reported for individual sites:

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

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 detailed source- and fuel-specific emissions data on which to base a split and so all of the reported site emissions are allocated to a non-fuel specific source category covering both types of emissions. These emissions are reported under NFR Sector 1B1b.

Processes manufacturing SSF are relatively small compared with coke ovens, and so reporting of emissions is very limited in the Pollution Inventory due to reporting thresholds, with only CO, NO_x and PM_{10} reported on a regular basis. The reported emissions for these pollutants are allocated to a non-fuel specific source category. Emissions of other pollutants are estimated using literature emission factors. These emissions are reported under NFR Sector 1B1b.

Use of natural gas and other fuels by the oil and gas industry is split in the NAEI into a number of categories:

- ‘Gas production – gas consumption’ – consumption of natural gas and gas oil by the upstream gas industry. This sector covers offshore gas exploration and production facilities (including mobile drill rigs), and terminals handling gas from offshore production facilities.
- ‘Oil production – gas consumption’ – consumption of natural gas and gas oil by the upstream oil industry. This sector covers offshore oil exploration and production facilities (including mobile drill rigs), and terminals handling oil from offshore production facilities.
- ‘Gas production – combustion at gas separation plant’ – consumption of LPG and OPG by the upstream oil and gas industry, probably mainly at oil and gas terminals
- ‘Gas production’ – combustion of natural gas and other fuels by the downstream gas industry, primarily at compressor stations.

The use of these four source categories will be reviewed before the next version of the inventory, and they will be renamed and/or restructured as necessary to ensure clarity within the inventory.

Other emission sources reported under 1A1c include fuels used at collieries and fuels used at sites processing nuclear fuels, but emissions 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
1 A 2 a Iron and Steel	All CLRTAP pollutants (except HCB and HCH)	Blast furnaces
		Iron and steel - combustion plant
1 A 2 b Non-ferrous metals	All CLRTAP pollutants (except HCH)	Autogenerators (coal only)
		Autogenerators – exported to grid (coal only)
		Non-ferrous metal (combustion)
1 A 2 c Chemicals	All CLRTAP pollutants (except HCH)	Ammonia production - combustion
		Chemicals (combustion)
1 A 2 d Pulp, Paper and Print	All CLRTAP pollutants (except HCH)	Pulp, paper & print (combustion)
1 A 2 e Food processing, beverages and tobacco	All CLRTAP pollutants (except HCH)	Food & drink, tobacco (combustion)
1 A 2 f i Stationary combustion in manufacturing industries and construction: Other	All CLRTAP pollutants (except HCH)	Autogenerators (gas only)
		Autogenerators – exported to grid (gas only)
		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. The NAEI source categories are the level at which emission estimates are derived, but reporting would not normally be at this detailed level, the NFR system being used instead for submission under the CLRTAP. All of the subsectors of 1A2 consist of a mixture of large and small plant, but the precise number of industrial combustion processes is not known.

In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR source category. However there are a few instances where the scope of NAEI and NFR categories is different because the NAEI source category is used for reporting both combustion and process-related emissions. These are 'Cement - non-decarbonising' and 'Lime production - non decarbonising', used to report emissions from cement clinker production and lime kilns respectively, and reported under 1A2f. In these cases, estimates are based on emissions data are reported by operators which do not differentiate between combustion and process-related emissions (see Section 4.4) and so mapping of the NAEI source categories to NFR 1A2 is justified.

Following a UNFCCC recommendation, this year for the first time emissions for combustion in manufacturing industries and construction have been fully disaggregated to categories 1A2a to 1A2f in the case of the most significant fuels. Previously, the inventory methodology only split out 1A2a, while all remaining sectors of industry were reported under 1A2f. The revised methodology has been applied for coal, fuel oil, gas oil and natural gas. Data on the sectoral split of consumption for other fuels were insufficient to allow a similar disaggregation at this stage. Details of the methods used to disaggregate the fuel data are given in Section 4.3.

A number of emission sources reported under 1A2a might be more correctly reported under 2C1. The allocation and reporting of emissions from these sources will be reviewed in the next inventory cycle.

Almost all of the NFR source categories listed in Table 4-1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

4.2 GENERAL APPROACH FOR 1A2

NFR Sector 1A2a is a key source for SO_2 and Cd, 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 ammonia production plant because gas consumption data are available as a result of the need to estimate non-energy use of natural gas by the chemical industry. Emission estimates are based on reported data for NO_x but literature emission factors for other pollutants.

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

4.3 FUEL CONSUMPTION DATA

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

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

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

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

This year, for the first time, emissions for manufacturing industries and construction have been fully disaggregated to categories 1A2a to 1A2f for coal, fuel oil, gas oil and natural gas. Full details of the changes made to activity data in order to implement these improvements are given below.

4.3.1 Coal

DUKES contains data on the use of coal by subsector for the whole of the period 1990-2010, although there are some changes to the format of data over this time series. More of concern though was data for the period 1997-2000 which indicated large step changes in the use of coal by some sectors, including a short-fall in coal allocated to the mineral industry between 1997 and 1999, compared with the independent estimates for cement and lime production previously used within the inventory. These independent estimates suggest a much more gradual change in coal consumption over this period.

We have reviewed data including the fuel use estimates provided by the industry; clinker production data, site closures and new sites construction, site capacity, the choices of fuel available to the cement industry and IPC permit documents indicating the choice of fuels in the early to mid-1990s. Following this, we have concluded that most of this evidence is consistent with a gradually changing industry as opposed to the step changes seen in the time series compiled from the DUKES data between 1997 and 2000. Therefore, the existing estimates for coal used by the cement sector have been retained and the time series for the rest of the industry sector has been built around these. Although the lime sector has not been reviewed in detail, it is known that there were no closures over that period and there is no evidence to support any major changes in that industry either, so again existing estimates for the lime sector have been retained. It has also been considered that other users within the mineral products sector will also burn coal e.g. a number of brickworks. The DUKES data for 1996 and 2000 suggest that these other processes used substantial amounts of coal in those years.

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

4.3.2 Natural Gas

Fuel consumption data for 1A2a to 1A2e are taken directly from DUKES. 1A2f makes up the rest of the industry sector and the fuel consumption total is consistent with that in DUKES. One small modification is to add the non-energy use estimate from DUKES into the industry total, and then take out the NAEI independent estimate for non-energy use, provided to the NAEI by plant operators. 1A2f also contains our independent estimates of consumption by the cement and lime industries.

4.3.3 Fuel Oil

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

4.3.4 Gas Oil

Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. DUKES provides a breakdown of gas oil consumption in different industry and other sectors but is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory. Previously, we have made independent estimates of the consumption of gas oil in off-road transport and machinery, in trains, and in various other sectors and then used the difference between the consumption in those sectors, and the total consumption given in DUKES as our estimate for consumption of gas oil in stationary plant. This approach though is problematic in that the year-on-year variations in our estimates for other sectors, and the variations in the DUKES total lead to big variations in our estimates of stationary plant consumption from one year to the next, in a way that does not seem realistic. In the most extreme cases, our independent estimates for the transport and other sectors exceed the DUKES total for all gas oil, thus meaning that it is impossible to allocate any gas oil to stationary plant using this method.

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

The new estimates for consumption in stationary plant are based on data for the period 2005 to 2010. For these years, EUETS data suggests that most of gas oil consumed in stationary plant is used as a backup or secondary fuel, with natural gas being the primary fuel on the site. We have therefore assumed that consumption of gas oil is related to consumption of gas, and that we can therefore use the ratio of gas oil or gas in the EUETS data, to estimate the use of gas oil in non ETS plant, based on the consumption of gas in non-ETS stationary plant. The latter can be estimated with some confidence as the difference between total demand given in DUKES for each sector, and the total consumption given in EUETS (since there is no need to consider gas use in mobile equipment unlike the case of gas oil.) In this way, we have estimated consumption of gas oil in stationary plant for the agricultural, commercial, industrial and public sectors and these estimates form the minimum values allowed for these sectors. If our estimates for off-road vehicles and machinery and other sources are too small to account for all of the remaining gas oil, then we allow a higher volume of gas oil for stationary plant in order to maintain consistency with the UK demand figures in DUKES. If on the other hand, our estimates for off-road vehicles and machinery and other sources are bigger than the remaining gas oil, it is these estimates that are reduced in order to maintain consistency with the DUKES totals.

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

4.4 METHODOLOGY FOR CEMENT & LIME KILNS

The UK had 13 sites producing cement clinker during 2010, 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 2010. Two of these produce lime for use on-site in the Solvay process and four produce lime for use on-site in sugar manufacturing. Lime kilns are fired with natural gas, coke, anthracite or coal as the main fuel.

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

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

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.

Each cement works will burn a variety of fuels, and many pollutants will be emitted from the use of each fuel, and from process sources as well. We consider that it would be impractical to allocate emissions to each of these numerous sources therefore all emissions are reported using a single, non-fuel specific source category. All lime kilns burn either a single fuel such as natural gas or, in a few cases, are likely to burn a large variety of fuels like cement kilns, so reported emissions of CO and NO_x are allocated to a single source-category for each facility, based on the main fuel burnt at each site. PM_{10} is also emitted from process sources as well as fuel combustion, so this pollutant is reported using a non-fuel specific source category.

4.5 METHODOLOGY FOR BLAST FURNACES

Emissions data for the period 2000-2010 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, and emission factors calculated using gas consumption data given in DUKES. We assume the same emission factor for each type of gas. For other pollutants, reported emissions are allocated to a non-fuel specific source category which is reported under NFR category 2C1.

For the period 1998-1999, emissions data are available from the Pollution Inventory (EA, 2011); however they do not distinguish between emissions from the various sources on each steelmaking site (combustion plant, blast furnaces, sinter plant etc.). Therefore, the detailed emission breakdown for 2000, supplied by the process operator, has been used to generate source-specific emissions data for 1998 and 1999, which are then allocated to fuels as normal.

Emission factors calculated from the 1998 emissions data are also used for the earlier part of the time-series, despite the Pollution Inventory containing some emissions data for some years. The 1998 factors are used in preference because of the limited number of pollutants which are reported, and because some of the emissions that are reported prior to 1998 are very much lower than the emissions reported in subsequent years. It is possible that they may be underestimates.

4.6 METHODOLOGY FOR OTHER INDUSTRIAL COMBUSTION OF COAL, COKE AND OIL

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

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

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. The limited nature of the reported data will be a reflection of the minimum reporting thresholds, which mean that most large combustion plant will not need to report emissions of, for example, metals or hydrogen chloride.

In most cases where literature emission factors are used, a single factor is applied for a given source category and pollutant. However, in the case of CO, NO_x and PM_{10} emissions, a more detailed approach is taken in order to derive estimates that are more representative of the wide range of combustion appliances in existence (e.g. different designs, thermal capacities, varying levels of abatement).. The more detailed approach breaks down the source/fuel combinations by a) thermal input of combustion devices; b) type of combustion process (e.g. boilers, furnaces, turbines etc), and appliance-specific emission factors are then applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (US EPA, 2009), the EMEP/EEA Guidebook (EMEP/ EEA, 2007) and UK emission factor surveys (Walker et al, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2011) are also used in the generation of emission factors for larger combustion plants in the autogeneration, iron and steel combustion plant, and other industrial combustion source categories.

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

4.7 METHODOLOGY FOR INDUSTRIAL GAS COMBUSTION

Emissions from industrial gas combustion were previously estimated in the same manner as emissions from industrial combustion of coal, coke and oils (see Section 4.6). However, an alternative approach which was used initially to predict future emission factors for the sector suggested that the original approach overestimated emissions. The emission factor calculated for 2010 using the alternative approach is now used for all years in the NAEI. This is a temporary measure and we aim to extend the approach back as far as practicable in future versions of the NAEI.

The new method differs from the old in that rather than dividing fuel use into consumption by different technologies, it is now split according to environmental regulation. For example, gas burnt by plant covered by the Large Combustion Plant Directive (LCPD) is separated from gas burnt by plant regulated under Local Air Pollution Control (LAPC) etc. Emissions are then estimated by reference to the emission standards that are imposed on those plant as a result of their regulation. We assume that all plant achieve these standards but do not go beyond them i.e. plants which have emission limit values achieve the maximum allowable concentration in stack gases rather than reducing this concentration below it. The method might therefore tend to overestimate emissions.

4.8 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

1A2

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

Some emission estimates for 1A2 rely upon emissions data reported in the PI, SPRI and ISR. Section 3.7 discusses QA/QC issues regarding these data.

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)	

NFR Category (1A3)	Pollutant coverage	NAEI Source category	Source of EFs
1 A 3 b vii Road transport: Automobile road abrasion	Particulate Matter	All Cars, LGVs, HGV rigid and articulated, buses and coaches, mopeds and motorcycles (urban, rural and motorway driving)	
1 A 3 c Railways	All CLRTAP pollutants including PCDD/PCDF *(exceptNH$_3$,PAHs, HCB, HCH and PCBs)*	Rail - coal	UK factors
		Railways - freight	
		Railways - intercity	
		Railways - regional	
1 A 3 d ii National navigation (Shipping)	All CLRTAP pollutants *(except NH$_3$, HCH and PCBs)*	Marine engines	UK 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. Emissions from international aviation are recorded as a memo item, and are not included in national totals. Emissions from both the Landing and Take-Off (LTO) phase and the Cruise phase are estimated. The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

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

The current method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport, and so complies with the EMEP/IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. In comparison with earlier methods used to estimate emissions from aviation, the current approach is much more detailed and reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also now included.

This method utilises data from a range of airport emission inventories compiled in the last few years by AEA. This work includes the RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NOx and fuel use from the Heathrow inventory have been used to verify the results of this study.

In 2006, the Department for Transport (DfT) published its report “Project for the Sustainable Development of Heathrow” (PSHD). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002. For departures, the PSDH made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights. In 2007, these recommendations for Heathrow were incorporated into the UK inventory and in the 2008 inventory they were incorporated into the UK inventory for all airports, along with further recommendations relating to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

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

Since publication of the PSDH report, inventories at Gatwick and Stansted have been updated. These inventories incorporated many of the recommendations of the PSDH and have been used as a basis for the 2008 inventory. For the 2009 inventory flights between the UK and overseas territories have been included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.

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

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

In the current UK inventory there is a noticeable reduction in emissions from 2005 to 2006 despite a modest increase in aircraft movements and kilometres flown. This is attributable to the propagation of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in emissions, which is attributable to both a modest decrease in aircraft movements and kilometres flown and the propagation of more modern aircraft into the fleet. In 2008, and 2009 and 2010 there are reductions in both emissions and aircraft movements, in line with the economic downturn.

Emission Reporting Categories for Civil Aviation

Table 5-2 below shows the emissions included in the emission totals for the domestic and international civil aviation categories currently under the UNFCCC, the EU NECD and the LRTAP Convention. Note the reporting requirements to the LRTAP Convention have altered recently – the table contains the most recent reporting requirements.

Table 5-2 Components of Emissions Included in Reported Emissions from Civil Aviation

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

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

Aircraft Movement Data (Activity Data)

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

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

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

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

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

A summary of aircraft movement data is given in Table 5-3. Fights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Turbine Fuel and Aviation Spirit**
  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DUKES (DECC 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 and Aviation Spirit by the Military**
  Historically, total consumption by military aviation has been given in ONS (1995) and MOD (2005a) and was assumed to be aviation turbine fuel. A revised, but consistent time series of military aviation fuel was provided by the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2009 and 2010) covering each financial year from 2003/04 to 2009/10. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). The new data also included estimates of aviation spirit and fuel classed as "Casual Uplift". The latter is drawn from commercial airfields world-wide and assumed not to be included in DUKES.

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

Table 5-3 Aircraft Movement Data

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

Notes

Gm Giga metres, or 10^9 metres

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

Emission factors used

The following emission factors were used to estimate emissions from aviation. The emissions of CO_2, SO_2 and metals depend on the carbon, sulphur and metal contents of the aviation fuels'. Emissions factors for CO_2, SO_2 and metals have been derived from the contents of carbon, sulphur and metals in aviation fuels. These contents are reviewed, and revised as necessary, each year. Full details of the emission factors used are given in Watterson *et al*. (2004).

Table 5-4 Carbon Dioxide and Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2010 (kg/t)

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

Notes

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

Table 5-5 Average Non-CO2 Emission Factors for Civil and Military Aviation in kt/Mt, 2010

	Fuel	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Civil aviation						
Domestic LTO	AS	1.54	0.10	3.83	1072.52	12.55
Domestic Cruise	AS	-	0.10	7.40	2.49	0.20
Domestic LTO	ATF	0.18	0.10	12.62	8.58	1.65
Domestic Cruise	ATF	-	0.10	14.24	2.43	0.49
International LTO	AS	1.91	0.10	1.93	1260.27	15.54
International Cruise	AS	-	0.10	6.81	0.79	0.01
International LTO	ATF	0.13	0.10	13.90	8.93	1.21
International Cruise	ATF	-	0.10	14.11	1.17	0.52
Military aviation	ATF	-	0.10	7.40	2.49	0.20

Notes

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

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

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

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

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

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

Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

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

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

Estimating emissions of the indirect and non-greenhouse gases

The EMEP/EEA Emission Inventory Guidebook (EMEP/ CORINAIR, 1996) provides fuel consumption and emissions of non-GHGs (NO_x, HC and CO) for a number of aircraft modes in the cruise. The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP/ EEA 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.

Estimating emissions of the direct greenhouse gases

Estimates of CO_2 were derived from estimates of fuel consumed in the cruise (see equation above) and the carbon contents of the aviation fuels.

Methane emissions are believed to be negligible at cruise altitudes, and the emission factors listed in EMEP/EEA guidance are zero (EMEP/CORINAIR, 1996); we have also assumed them to be zero. This was the assumption in the previous aviation calculation method also.

Estimates of N_2O have been derived from an emission factor recommended by the IPCC (IPCC, 1997) and the estimates of fuel consumed in the cruise (see equation above).

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, *pers. 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 since the 2009 inventory. Flights between overseas territories (obtained from the DfT data) have been classed as domestic aviation. Other flights originating from the overseas territories have been classed as international.

By following the IPCC Good Practice Guidance (IPCC, 2000), it is necessary to know whether passengers or freight are put down before deciding whether the whole journey is considered as an international flight or consisting of a (or several) domestic flight(s) and an international flight. We feel the consequence of the difference between CAA and IPCC definitions will have a small impact on total emissions.

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.

Overview of method to estimate emission from military aviation

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

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

Fuel reconciliation

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

Geographical coverage of aviation emission estimates

According to the IPCC Guidelines, "inventories should include greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction." IPCC, (1997a); (IPPC Reference Manual, Overview, Page 5).

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 in chapter 6. These emissions are based on fuel consumption data from DECC (2011). Emission factors are reported in Table 5 6. 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.

Emissions are reported from the consumption of coal used to power steam trains and from gas oil. Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2010 and are believed to be due to consumption by heritage trains. For the air pollutants, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions from coal-fired steam trains.

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

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). Data from these two sources are consistent for years after 2007. As no data from ATOC/ORR were available for 2010, fuel consumption for this year was estimated on the basis of the trend in train kilometres from 2009 to 2010. In this year’s inventory gas oil consumption data for years before 2005 were re-scaled using train km data to bring consistency with the more recent trends in the ATOC/ORR fuel consumption data. Revisions were also made to the split between Intercity and regional trains to bring consistency with total passenger train km from the ORR published in the National Rail Trends Yearbook (NRTY).

Gas oil consumption by freight trains was also calculated utilising data provided by ORR for 2005-2009. These data were consistent with figures from ATOC. As no data from ATOC/ORR were available for 2010, fuel consumption for this year was estimated on the basis of the trend in train tonne kilometres from 2009 to 2010. For years prior to 2005, fuel consumption was scaled using net tonne kilometre trends data taken from ORR's NRTY.

In 2010, the estimated fuel consumption in both passenger and freight rail showed a slight increase in comparison to 2009 as a consequence of increased train kilometres travelled.

Sulphur dioxide emissions are calculated using fuel-based emission factors and the total fuel consumed as provided in the National Rail Trends Yearbook. Emissions of CO, NMVOC, NO_x and PM are based on the train kilometre estimates and emission factors for different train types. The fuel consumption is distributed according to:

- Train kilometre data taken from the National Rail Trends Yearbook (2011) http://www.rail-reg.gov.uk/server/show/nav.2026;
- 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 5-6 are aggregate implied factors for diesel trains in 2010, so that all factors are reported on the common basis of fuel consumption.

No revisions have been made to any of the emission factors, which are provided in terms of g/km. However, compared with the last version of the inventory, the implied emission factors on a per fuel consumed basis differ slightly for pollutants other than SO_2. This is because emissions are estimated using train kilometre data, but then divided by the fuel consumed to derive an implied emission factor in terms of kt/Mt fuel. Therefore, if the fuel consumed changes this will impact on the implied emission factor in terms of kt/Mt fuel. In this case, the fuel consumption estimates have been modified slightly from previous years due to more accurate data becoming available and this therefore has a knock on effect on the implied emission factors per fuel consumed.

The emission factor for SO_2 has decreased from 1.68 kt/ Mt fuel in 2009 to 1.44 kt/ Mt fuel in 2010 in line with UKPIA's Table of the Sulphur content (UKPIA, 2011) showing a reduction in the sulphur content of gas oil.

Table 5-6 Railway Emission Factors for 2010 (kt/Mt fuel)

	NO_x	**CO**	**NMVOC**	**PM**	**SO_2**
Freight	114.3	12.7	6.4	1.50	1.44
Intercity	40.6	13.5	4.1	0.97	1.44
Regional	33.1	36.8	6.4	0.87	1.44

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 and 16 of the revised Guidelines on Reporting (ECE/EB.AIR/2008/4) is that it does allow the UK to report emissions on the basis of fuel used or kilometres driven only.

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

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

The UK does estimate fuel consumption estimated from kilometres driven and g/km factors and compares these each year with national fuel sales figures. This point is discussed in the road transport methodology section of this report. The agreement is good, to within ±8% for both petrol and diesel consumption across the 1990-2010 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 2010 inventory

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

- Revised emission factors for NO_x for all vehicle types (except motorcycles) and emission degradation methodology for light duty vehicles based on latest version of COPERT 4 (v8.1)
- Use of Automatic Number Plate Recognition (ANPR) data and Regional Vehicle Licensing Statistics (DVLA) to define the petrol and diesel car mix by road type and by Devolved Administrations. The ANPR and DVLA data were also used to define fleet composition (in terms of age mix/ Euro standard) for cars, LGVs and HGVs.
- Revised 2009 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development.
- Removed previous assumptions made on the early uptake of Euro 4 petrol cars as these appear to have been overly optimistic. Their date of introduction is now based on the mandatory date set in the European emissions directive.
- Assumptions on the split in vehicle km for HGVs by vehicle weight class have been updated using information provided by DfT's Road Freight Statistics. This is to improve how the emission factors for different HGV vehicle weight classes are utilised.
- Updated the composition of bus fleet as operated by Transport for London (TfL)
- Revised assumptions on how the London Low Emission Zone (LEZ) scheme affects emissions from HGVs. It was previously assumed that the LEZ for HGVs would affect all pollutants from 2008 onwards through increased uptake of newer vehicles; however, it is now assumed that only Particulate Matter (PM) emissions would be affected as vehicles are achieving the LEZ requirement via retrofit of particulate traps. Other pollutant emissions are assumed not to be affected by the scheme
- Revised figures from DfT on average mpg fuel efficiency of different sizes of HGVs between 2006 and 2009.
- Time series revision of DfT's Bus Services Operators Grant (BSOG) data on the average fuel efficiency of local bus services, to take account of the fuel consumption for journeys to and from the start and end of a bus route.
- Revised trip length for calculating cold start NH_3 emissions from petrol cars.
- Re-allocation of more petrol and DERV to off-road and inland waterways sectors across all years following a major review on the allocation of these fuels across a range of sectors described elsewhere in this report Annex. For 2009, an extra 89 kt petrol was re-allocated from road transport to off-road and inland waterways (0.5% of all petrol) and an extra 336 kt DERV was re-allocated from road transport to off-road and inland waterways (1.7% of all DERV).

For pollutants calculated from fuel consumption, these changes have affected the distribution of fuel consumption and hence emissions between vehicle types, but have no effect on the total road transport emissions. Total fuel-related emissions from road transport in all years are slightly different (1% less) compared to the 2009 inventory, due to the re-allocation of more petrol and DERV to off-road and inland waterways sectors. It should be noted that estimates of fuel consumption calculated for individual types of vehicles are normalised so the total adds up to the DUKES figures for petrol and diesel consumption (corrected for off-road consumption). For other pollutants where emissions are not directly related to fuel consumption, the changes in methods, activity data and emission factors alter the total emissions for road transport reported in each year.

Fuel-based emissions

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

In 2010, 14.99 Mt of petrol and 20.87 Mt of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2009. It was estimated that of this, around 2.5% of petrol was consumed by inlands waterways and off-road vehicles and machinery and 0.4% used in the Crown Dependencies, leaving 14.55 Mt of petrol consumed by road vehicles in the UK in 2010. Around 1.8% of road diesel is estimated to be used by inland waterways and off-road vehicles and machinery (the bulk of these use gas oil), and 0.2% used in the Crown Dependencies, leaving 20.46 Mt of diesel consumed by road vehicles in the UK in 2010.

According to figures in DUKES (DECC, 2011), 0.106 Mt of LPG were used for transport in 2010, a small reduction from 0.107 Mt 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 (2011), 0.50 Mt bioethanol and 0.93 Mt biodiesel were consumed in the UK in 2010. On a volume basis, this represents about 3.1% of all petrol and 4.1% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.300 Mt of mineral-based petrol (about 2.0% of total petrol that would have been consumed) and 0.808 Mt of mineral-based diesel (about 3.9% of total diesel that would have been consumed).

Emissions of SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for CO_2 and SO_2 from consumption of petrol and diesel fuels are shown in Table 5-7. Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in Table 5-7 for 2010 fuels based on data from UKPIA (2011).

Table 5-7 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	**C**[a]	**SO_2**[b]
Petrol	855	0.012
Diesel	863	0.015

a Emission factor in kg carbon/tonne, based on UKPIA (2005)

b 2010 emission factor calculated from UKPIA (2011) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2010

Emissions of SO_2 and fuel-based pollutants such as the metals can be broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants.

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

Fuel consumption factors for petrol and diesel vehicles

Equations relating fuel consumption to average speed are based on the relationships for detailed categories of vehicles compiled by TRL on behalf of DfT. The factors themselves are available at http://www.dft.gov.uk/publications/road-vehicle-emission-factors-2009/ together with appropriate documentation from TRL on how the emission factors were derived (see for example the report by Boulter et al. (2009) at http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-3.pdf. The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, LGVs and motorcycles, the speed-related fuel consumption factors in g fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types as described below. The fleet-average fuel consumption factors calculated for these vehicle types grouped into their respective Euro emission standards are shown in Table 5-8 for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 5-8 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km		**Urban**	**Rural**	**Motorway**
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6
	Euro 4	50.8	47.2	53.4
	Euro 5	44.7	41.2	47.4
Diesel cars	Pre-Euro 1	60.3	55.0	61.2
	Euro 1	58.5	53.2	59.4
	Euro 2	54.9	49.6	55.8
	Euro 3	50.2	44.9	51.1
	Euro 4	47.7	42.4	48.7
	Euro 5	42.0	36.7	42.9
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8
	Euro 2	60.9	56.3	62.1
	Euro 3	57.1	52.5	58.3
	Euro 4	52.3	47.7	53.6

g fuel /km		Urban	Rural	Motorway
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 (mpg) fuel efficiency of different sizes of lorries (DfT, 2011a). A time-series of mpg figures from 1989 to 2010 is provided by the road freight statistics and these can be converted to g fuel per kilometre fuel consumption factors. The figures will reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorway roads. The shape of the DfT/TRL speed-related functions based on test cycle measurements of more limited samples of vehicles are then used to define the variation, relative to the averaged value, in fuel consumption factor with speed and hence road type. The mpg factors for 2006 to 2009 have been revised by DfT and are used in the latest inventory.

Table 5-9 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2010 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a). The factors in this table are slightly different from the factors in the corresponding table last year partly due to the revisions in the mpg factors, but also because of revised assumptions on the distribution of vehicle km by different weight classes of HGVs which affects the factors in all years.

Table 5-9 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
1990	272.4	217.7	231.5	438.8	337.1	343.6
1991	276.6	221.0	235.1	437.2	335.9	342.4
1992	277.0	221.4	235.4	433.9	333.3	339.8

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
1993	266.9	213.5	227.0	412.1	316.7	322.8
1994	259.0	207.8	221.1	405.1	311.6	317.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
1996	258.2	209.0	222.8	388.1	299.3	305.1
1997	256.3	208.4	222.3	387.2	299.2	304.9
1998	245.1	200.5	214.1	370.8	287.2	292.7
1999	249.8	205.4	219.6	370.3	287.3	292.8
2000	247.8	204.8	219.2	370.2	287.7	293.2
2001	259.8	214.2	228.8	375.4	292.0	297.6
2002	252.9	208.4	222.3	373.2	290.0	295.6
2003	262.7	216.1	230.0	378.3	293.7	299.4
2004	253.8	208.5	221.7	365.0	283.1	288.6
2005	250.6	204.9	217.3	360.9	279.7	285.1
2006	261.7	213.0	225.4	363.4	281.4	286.9
2007	269.9	218.4	230.5	365.9	283.1	288.6
2008	279.4	225.9	238.3	379.7	293.5	299.3
2009	281.6	227.9	240.6	381.1	294.3	300.1
2010	285.1	229.8	242.3	384.9	296.9	302.7

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, 2011b). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. In the 2010 inventory, DfT has revised the whole time series of BSOG data to take account of fuel consumption on local bus services that were carried out on dead mileage, i.e. mileage to and from the start and end of a bus route. This had been omitted previously and the revised BSOG data now represent lower fuel consumption factors compared to the factors used in the last year's inventory. In terms of trend, the BSOG data continue to imply an increase in the average fuel consumption factor for local buses, i.e. a reduction in fuel efficiency over the period from 1998/9 to 2009/20010.

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

The BSOG data are provided on a financial year basis, the most recent being for 2009/10. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2009/10 figures were used for the 2009 calendar year and superceded estimates for 2009 made last year when these data were not available. As there are no corresponding BSOG data to use for 2010, 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 2009 and 2010. This produced a fuel efficiency scaling factor that could be applied to the factor for 2009.

Table 5-10 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2010 for urban, rural and motorway conditions based on this method. The revised BSOG factors lead to a reduction in the factors compared with those shown in the corresponding table last year.

Table 5-10 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data

g fuel/km	**Urban**	**Rural**	**Motorway**
1990	268.9	167.8	190.9
1991	268.9	167.8	190.9
1992	268.9	167.8	190.9
1993	268.2	167.5	190.5
1994	265.0	165.7	189.0
1995	260.8	163.3	187.0
1996	255.9	160.7	184.8
1997	255.3	160.9	185.8
1998	255.1	161.5	187.4
1999	264.5	168.2	195.9
2000	277.0	176.7	206.4
2001	278.3	177.9	208.4
2002	290.0	186.1	219.0
2003	303.9	195.0	229.8
2004	309.5	198.6	234.1
2005	324.4	208.1	245.6
2006	319.2	204.7	241.6
2007	327.6	209.7	247.7
2008	340.7	217.8	257.3
2009	340.1	217.0	256.6
2010	340.2	216.7	256.5

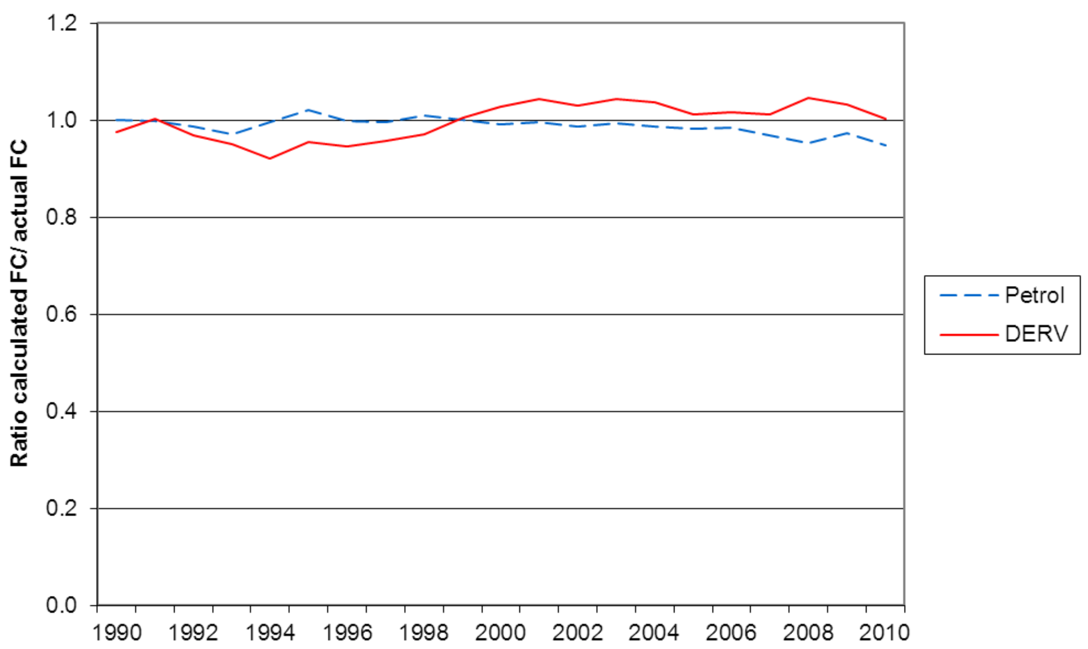
Fuel reconciliation and normalisation

A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data. The "bottom-up" calculated estimates of petrol and diesel consumption are then compared with DECC figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by, inland waterways, off-road machinery and consumption in the Crown Dependencies. Consumption of petrol and diesel by off-road machinery were revised this year following a major review on the allocation of these fuels across a range of sectors described in Appendix 1. This review highlighted the greater consumption of road fuels for small and intermittently used machinery and vessels than had been previously assumed.

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

Figure 5-1 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. The ratio fluctuates just above and below the 1 line, but the difference is never higher than 8%. In 2010, the bottom-up method underestimates petrol consumption by 5.2% and over-estimates diesel consumption by 0.2%. 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 5.2% to align with fuel sales in 2010. Cars consume the vast majority of this fuel, so the DUKES figures provide a relatively accurate description of the trends in fuel consumption and CO_2 emissions by petrol cars. A small residual is consumed by petrol LGVs and motorcycles, so their estimates are susceptible to fairly high levels of uncertainty introduced by the normalisation process.

For diesel, a number of different vehicle classes (cars, LGVs, HGVs and buses) all consume similar amounts of fuel. Either the fuel consumption for all diesel vehicles can be scaled to align with DUKES, as carried out for petrol normalisation, or consumption for specific vehicle types can be adjusted to bring the total in line with DUKES. Because all vehicle types make a similar contribution to diesel consumption, adjusting the calculated figures for all vehicle types by scaling can lead to distorted trends in the figures for specific vehicle types over a time-series. After discussions with officials at DfT, it was decided to retain the consumption for cars, LGVs and buses at the values calculated by the bottom-up approach and use HGVs to “carry the burden” of bringing the total diesel consumption in line with DUKES (DfT, 2009a). There were two main reasons for this. First, because HGVs are the largest overall consumer of diesel, this approach of correcting for the difference between calculated diesel consumption and fuel sales figures from DUKES has a smaller effect on HGVs than other vehicle classes. A second reason is that a rationale can be given for HGVs leading to the overestimation of diesel consumption compared with sales since 1998 on the basis of “fuel tourism” effects. This is where vehicles consume fuel on UK roads that was purchased abroad. In this case, the fuel would not appear in the UK sales figures, but would be represented in consumption figures calculated from traffic movement data. Given the recent price differential between diesel sold in the UK and the rest of Europe and the amount of cross-border haulage operations, HGVs are believed to make a larger contribution to potential fuel tourism effects than any other class of vehicle. Furthermore, DfT were able to provide some data to back up this hypothesis. This included DfT estimates of the amount of fuel purchased abroad by UK vehicles and the kilometres travelled in the UK by foreign vehicles (DfT, 2009a). The 2009 figures suggested the total amount of fuel purchased abroad (and therefore not contributing to UK fuel sales in DUKES) by HGVs operating in the UK could be around 550 kt compared with a gap of around 652 kt in the estimate of total diesel consumption and the figures based on fuel sales in DUKES. This is at least consistent with a theory indicating HGV fuel tourism contributing to the gap and partial justification for adjusting the bottom-up estimated diesel consumption for HGVs to bring the total diesel consumption in line with DUKES. However, it is important to recognise that other factors including modelling uncertainty will also be playing a factor.

Emissions from LPG consumption

Few vehicles in the UK run on LPG. There are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest less than 0.5% of all light duty vehicles run on LPG.

Emissions from natural gas consumption

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

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_{10} and $PM_{2.5}$.

Hot exhaust emissions

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

For a particular vehicle, the drive cycle over a journey is the key factor that determines the amount of pollutant emitted over a given distance. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). A similar conclusion was reached in the recent review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-2.pdf).
Emission factors for average speeds on the road network are then combined with the national road traffic data.

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

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

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

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

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

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2011c). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2010 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, 2011a). These provided a consistent time-series of vehicle km data for all years up to 2010. Data for 2009 has been revised slightly in particularly for the buses and coaches activity on rural and motorway, with an overall 15% reduction in total buses and coaches vkm compared with the 2009 data used in the 2009 inventory. Additional information is provided by DRDNI about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by DRDNI of licensing data (DRDNI, 2011b).
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 2010 as shown in Table 5-11.

Table 5-11 UK vehicle km by road vehicles

Billion vkm		**1990**	**1995**	**2000**	**2005**	**2008**	**2009**	**2010**
Petrol cars	urban	142.2	137.9	135.6	122.6	110.2	108.7	102.6
	rural	141.0	133.9	134.0	127.5	115.4	113.7	109.2
	m-way	49.2	48.3	52.9	48.8	42.7	43.3	41.6
Diesel cars	urban	5.8	17.2	26.2	41.7	53.1	54.5	56.1
	rural	6.2	18.1	28.7	48.4	64.4	65.3	67.2
	m-way	2.8	8.5	14.6	25.2	33.3	33.3	33.6
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.6	1.4	1.3
	rural	11.4	8.3	5.0	2.3	2.0	1.8	1.6
	m-way	3.9	3.2	2.0	0.9	0.8	0.7	0.6
Diesel LGVs	urban	5.7	10.2	15.6	21.7	23.6	23.0	23.4
	rural	6.1	11.5	18.9	26.2	30.0	29.3	29.8
	m-way	2.0	4.4	7.4	10.5	11.6	11.5	11.4
Rigid HGVs	urban	4.5	3.7	3.9	4.1	3.7	3.4	3.3
	rural	7.1	6.8	7.2	7.5	7.3	6.7	6.6
	m-way	3.7	3.7	4.2	4.2	4.2	4.0	4.1
Artic HGVs	urban	1.1	1.1	1.1	1.0	0.9	0.9	0.8
	rural	4.3	4.7	5.1	5.3	5.6	5.0	5.0
	m-way	4.7	6.0	7.4	7.9	8.0	7.3	7.5
Buses	urban	2.4	2.9	3.0	3.2	3.2	3.2	3.2
	rural	1.7	1.5	1.7	1.5	1.6	1.6	1.6
	m-way	0.6	0.5	0.5	0.5	0.5	0.4	0.5
M/cycle	urban	3.3	1.9	2.3	3.0	2.7	2.8	2.6
	rural	2.0	1.6	2.0	2.2	2.1	2.1	1.8
	m-way	0.3	0.3	0.4	0.4	0.5	0.4	0.4
Total		**423.4**	**443.9**	**484.0**	**518.6**	**528.8**	**524.3**	**515.9**

Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008a) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned. Table 5-11 shows the speeds used in the previous and 2010 inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2010.

Table 5-12 Average Traffic Speeds in Great Britain

		Lights kph	Heavies kph	Buses kph
URBAN ROADS				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Connurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	20
	Motorways	97	82	82
Urban	Major principal roads	36	36	32
	Major trunk roads	53	52	32
	Minor roads	35	34	29
	Motorways	97	82	82
RURAL ROADS				
Rural single carriageway	Major roads	77	72	71
	Minor roads	61	62	62
Rural dual carriageway		111	90	93
Rural motorway		113	90	95

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

Vehicle kilometre data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. Prior to the 2010 inventory, the petrol car/diesel car mix on different road types was defined by the DfT Vehicle Licensing Statistics and data on the relative mileage done by petrol and diesel cars (DfT, 2008b, pers comm). The latter information, as originated from the National Travel Survey (DfT, 2007b), indicated that diesel cars do on average 60% more annual mileage than petrol cars. It was assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, it was previously assumed that the petrol car/diesel car mix on urban roads was to be indicated by the population mix according to vehicle licensing data (i.e. that there is no preferential use of diesel or petrol cars on urban roads) and the mix on rural and motorways adjusted to give an overall mileage pattern over all roads in the UK that leads to an average 60% higher annual mileage by diesel cars compared with petrol cars.

One of the main improvements made in the 2010 inventory is the application of Automatic Number Plate Recognition (ANPR) data provided by DfT (2011d, pers comm) for defining the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday

(8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for 2007, 2008, 2009 and 2010. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

Following a series of analysis and discussions with officials from DECC, Defra and DfT, it was concluded that the ANPR data should be best used to define the fleet composition on different road types for the whole of Great Britain (GB) while combining DA-country specific vehicle licensing data (hereafter referred as DVLA data) to define regional variation (DfT, 2010a). The ANPR data is used in two aspects for the 2010 inventory to define:

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

As the ANPR data are only available between 2007 and 2010, it was necessary to estimate the road-type variations in the fleet for years before the ANPR became available (2007) otherwise a step-change would be introduced in the emission time-series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel vehicles as indicated by the DfT Vehicle Licensing Statistics. The result was then further adjusted by the DVLA data to define the variation of the petrol/diesel mix by the DA regions. The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. The net result was an increase in diesel car km on urban roads, but less on motorways than had been previously assumed. For Northern Ireland, the ANPR data for 2010 show that there was no major difference in the proportion of diesel cars observed on different road types and that the proportion was similar to that implied by the licensing data; as a result, it is assumed that there is no preferential use of diesel cars, and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI. This leads to the vehicle km data for petrol and diesel cars on different road types in the UK shown in Table 5-11.

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems. Table 5-13 shows the regulations that have come into force up to 2010 for each vehicle type. The year 2010 saw the introduction of Euro 5 standards for cars and small vans. The date into service is taken to be roughly the mid-point of the Directive's implementation dates for Type-Approval and New Registrations.

Table 5-13 Vehicles types and regulation classes

Vehicle Type	**Fuel**	**Regulation**	**Approx. date into service in UK**
Cars	Petrol	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/7/1992
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
		98/69/EC (Euro 4) EC 715/2007 (Euro 5)	1/1/2006 1/7/2010
	Diesel	Pre-Euro 1 91/441/EEC (Euro 1) 94/12/EC (Euro 2) 98/69/EC (Euro 3) 98/69/EC (Euro 4) EC 715/2007 (Euro 5)	 1/1/1993 1/1/1997 1/1/2001 1/1/2006 1/7/2010
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

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The new ANPR data provided direct evidence on the age mix of vehicles on the road and how this varied on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2010 and it was important to consider how the trends observed in these limited years of ANPR data availability could be rolled back to earlier years. This was done by developing a pollutant and vehicle specific factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with the GB average between 2007-2010 and its impact on emissions. This factor is extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types or DA countries have no effect on emissions. This factor is then combined with a DA-specific “driver” derived from trends in licensing data to account for the relative differences in the fleet in each DA country compared with the GB average. An overall year-, vehicle-, road-, DA- and pollutant-specific factor is then applied to GB average emission factors calculated in the fleet model.

It should be noted that the application of the ANPR and DVLA data is dependent on the vehicle, pollutant and region combination. For instance, when calculating fuel consumption and CO_2 emissions, data on the average mpg fuel efficiency of different sizes of lorries from the Road Freight Statistics and the BSOG data for buses take precedence over the ANPR data, and they are continued to be used to define the fuel consumption/ CO_2 emissions for HGVs and buses respectively, without any adjustment to account for variations in the age of the HGV or bus fleets. For other pollutants where the mpg data from Road Freight Statistics are not used in the calculations of HGV emissions, the ANPR data are utilised. The ANPR or DVLA data have not been analysed or applied to the calculation of other pollutant emissions from buses/coaches, as there are likely to be variations in local bus fleets according to local authority measures to address air quality concerns that will not be reflected by licensing information alone, while coaches spend less time in the areas where they are registered. Similarly, neither the ANPR nor DVLA data have been analysed for motorcycles due to lack of data and their relative small contribution to the overall UK fleet.

The DfT/TRL emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The vehicle licensing statistics have shown that there has been a growing trend in the sales of bigger and smaller engine-sized cars in recent years, in particular for diesel cars at the expense of medium-sized cars. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, 2011e). In addition, the relative mileage done by different size of vehicles was factored into the ratios, this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2008b).

To utilise the DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover three different weight classes of LGVs, eight different size classes of rigid HGVs, five different weight classes of artic HGVs, five different weight classes of buses and coaches and seven different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types was obtained from vehicle licensing statistics and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles.

Assumptions on the split in vehicle km for HGVs by vehicle weight class have been updated. Previously the assumptions do not vary with time. However, DfT Road Freight Statistics (DfT, 2011a) show that there has been a gradual reduction in traffic activity for the rigid HGVs below 7.5 tonnes, while there has been an increase in traffic activity for rigid HGVs over 25 tonnes over the period 2000 to 2010. For artic HGVs, the dominant group continues to be those over 33 tonnes, and traffic activity from the below 33 tonnes category have been decreasing over time. These trends have now been reflected in the 2010 inventory.

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

Assumptions on the split in vehicle km for buses by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t.

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

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

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

Voluntary measures and retrofits to reduce emissions

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

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

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, and this would rise to 14,000 vehicles by the end of 2005 (DETR, 2000). This was accounted for in the inventory for its effects on PM, NO_x, CO and 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 PM emissions from HGVs and buses from 2008 is taken into account by using a different Euro standard mix for HGVs within the LEZ area. To be compliant, vehicles must meet Euro III standards or above from 2008, but this is only in respect of PM emissions. With respect to other pollutant emissions, the London fleet of HGVs and buses (except TfL's buses) are assumed to be the same as the national fleet.

The specific features of the fleet of buses operated by Transport for London (TfL) in London were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used. Based on information from DfT, it is assumed that approximately 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 the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level sulphur content was not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2004, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

Hot Emission Factors

The emission factors for different pollutants were mostly taken from the database of vehicle emission factors released by DfT/TRL in 2009 (Boulter et al., 2009) or from EMEP/EEA Emissions Inventory Guidebooks.

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

Emission factors for NO_x have been revised as recent evidence has shown that there is lack of consistency between the trends in the road transport NO_x emissions inventory and trends in ambient roadside concentrations of NO_x (Carslaw et al., 2011). Moreover, the previous emission factors for some vehicle classes do not seem to reflect real-world NO_x emissions, especially for more modern diesel vehicles (Euro 3+).

NO_x emission factors from the COPERT 4 v8.1 model (published in May 2011) are adopted in the 2010 inventory. The COPERT 4 v8.1 factors are based on new sources of information on vehicle emissions emerged since the TRL/DfT emission factors were developed. The development of COPERT 4 model is coordinated by the European Environment Agency and is used widely by other Member States to calculate emissions from road transport. The latest version of the COPERT model is available for download from http://www.emisia.com/copert/. The COPERT NO_x emission factors are represented as equations relating emission factor in g/km to average speed. These baseline emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors to take account of degradation in emissions with accumulated mileage. Detailed methodology of emission degradation is provided in the 2009 EMEP/EEA Emissions Inventory Guidebook (EEA, 2009). In addition, there are separate emission functions available for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NO_x control. According to European Automobile Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available (it is not expect that the UK situation will vary from this European average).

The TRL/DfT (Boulter et al., 2009) emission factors for $PM_{10}/_{2.5}$, total hydrocarbons (THC) and CO are continued to be used in the 2010 inventory, and are also represented as equations relating emission factor in g/km to average speed. The TRL/DfT emission factors are provided for an extensive range of vehicle types, sizes and Euro standards and are based on emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. Scaling factors are also provided to take into account the effects of fuel quality since some of the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT NO_x emission factors.

Table 5-22, Table 5-23, Table 5-24 and Table 5-25 summarise the baseline COPERT NOx emission factors (before any degradation corrections to the petrol LDVs factors and normalised to current fuels) and the TRL/DfT's CO, THC and PM emission factors (normalised to 50,000km accumulated mileage and current fuels) for all vehicle types under typical urban, rural and motorway road conditions in g/km. The factors have been averaged according to the proportion of different vehicle sizes in the UK fleet based on vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for CH_4 from the corresponding THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in Table 5-12. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

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

The inventory uses the TRL fuel scaling factors to take into account the prevailing fuel quality in different years. Various other assumptions and adjustments were applied to the emission factors, as follows.

The emission factors used for NMVOCs, NO_x, CO and PM are already adjusted to take account of improvements in fuel quality for conventional petrol and diesel, mainly due to reductions in the fuel sulphur content of refinery fuels. An additional correction was also made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels were based on the figures from HMRC (2011) and it was assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Account was taken of some heavy duty vehicles in the fleet being fitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO and NMVOC emissions beyond that required by Directives. Emissions from buses were scaled down according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in Table 5-14.

Table 5-14 Scale Factors for Emissions from a Euro II Bus 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 5-15

Table 5-15 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

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

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.

Ammonia 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/EEA Emissions Inventory Guidebook (EEA, 2007) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*".

For NH_3 emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content. The factors for diesel vehicles and motorcycles make no distinction between different Euro standards and road types and bulk emission factors are provided. Table 5-26 summarises the NH_3 emission factor for all vehicle types and road conditions in mg/km; the factors for petrol cars and LGVs are shown for zero accumulated mileage, but the inventory takes account of the increase in emissions with mileage.

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

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

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

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

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

Pollutant speciation

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

Nitrogen oxides are emitted in the form of nitric oxide (NO) and nitrogen dioxide (NO_2). The fraction emitted directly as NO_2 (f-NO_2) is of particular interest for air quality modelling and the inventory is required to provide estimates of the fraction emitted as NO_2 for different vehicle categories. Evidence has shown that diesel vehicles are particularly prone to high f-NO_2 values and especially those vehicles fitted with certain types of catalyst systems for controlling other pollutant emissions such as oxidation catalysts and diesel particulate filters for controlling CO, HC and PM. Thus, diesel vehicles meeting more recent Euro standards tend to have higher f-NO_2 values.

Values of f-NO_2 are given in the DfT/TRL emission factors review and the EMEP/EEA Emissions Inventory Guidebook (2007) for different vehicle types and Euro standards. Based on these and the turnover in the fleet, the fleet-averaged values of f-NO_2 for each main vehicle class are given in Table xxx. These should be used in conjunction with the NO_x emissions calculated by the inventory to derive the corresponding emissions of NO_2.

Table 5-16: Fleet-average values of f-NO_2 for road vehicles representing the mass fraction of NOx emitted as NO2.

f-NO_2	**1990**	**1995**	**2000**	**2005**	**2010**
Petrol cars	0.040	0.040	0.040	0.035	0.032
Diesel cars	0.110	0.110	0.113	0.221	0.425
Petrol LGVs	0.040	0.040	0.040	0.037	0.034
Diesel LGVs	0.110	0.110	0.110	0.202	0.432
Rigid HGVs	0.110	0.110	0.110	0.128	0.128
Artic HGVs	0.110	0.110	0.110	0.132	0.125
Buses and coaches	0.110	0.110	0.110	0.124	0.127
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/EEA Emissions Inventory Guidebook (2007), the fraction of PM_{10} emitted as $PM_{2.5}$ is assumed to be 0.95 for all vehicle exhaust emissions.

NMVOCs are emitted in many different chemical forms. Because of their different chemical reactivity in the atmosphere, the formation of ozone and secondary organic aerosols depends on the mix of VOCs emitted and the chemical speciation of emissions differs for different sources. The NMVOC speciation in the inventory is discussed elsewhere, but the speciation of NMVOCs emitted from vehicle exhausts is taken from EMEP/EEA Emissions Inventory Guidebook (2007).

Cold-Start Emissions

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

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

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

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

Cold start emissions are calculated from the formula:

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

where

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

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

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

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

where

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

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

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

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

Cold start emissions of NH_3 were estimated using a method provided by the COPERT 4 methodology for the EMEP/EEA Emissions Inventory Guidebook (EEA, 2007). The method is simpler in the sense that it uses a mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up., i.e. under “cold urban” conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle’s accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for NH_3 emissions from light duty vehicles are shown in Table 5-17. There are no cold start factors for HGVs and buses.

Table 5-17 Cold Start Emission Factors for NH_3 (in mg/km)

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

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

Evaporative Emission

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

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

i) Diurnal Loss

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

ii) Hot Soak Loss

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

iii) Running Loss

These are evaporative losses that occur while the vehicle is in motion.

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

COPERT 4 provides a method and emission factors for estimating evaporative emissions for more detailed vehicle categories and technologies than the previous method and also has the benefit of including factors for motorcycles 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, and it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure.

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

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

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

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

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

The COPERT 4 methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (2011), the COPERT 4 emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

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

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

An implied emission factor based on the population, composition of the fleet and trips made in 2010 is shown for petrol cars and motorcycles in Table 5-18. The units are in g per vehicle per day.

Table 5-18 Fleet-average emission factor for evaporative emissions of NMVOCs in 2010

g/vehicle.day	**2010**
Petrol cars	0.94
Motorcycles	1.63

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 /EEA Emissions Inventory Guidebook (EMEP/EEA, 2007) derived from a review of measurements by the UNECE Task Force on Emissions Inventories (http://vergina.eng.auth.gr/mech0/lat/PM10/). Emission factors are provided in g/km for different vehicle types with speed correction factors which imply higher emission factors at lower speeds. For heavy duty vehicles, a load correction factor is provided and tyre wear emissions depend on the number of axles. Further details are given in the AQEG (2005) report on PM.

Table 5-19 shows the PM_{10} emission factors (in mg/km) for tyre and brake wear for each main vehicle and road type based on the average speed data used in the inventory. There are no controls on emissions from tyre and brake wear, so the emission factors are independent of vehicle technology or Euro standard and are held constant each year. Emissions are calculated by combining emission factors with vehicle km data and are reported under NFR code 1A3bvi.

Table 5-19: Emission factors for PM_{10} from tyre and brake wear

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

	Rural	2.92	2.76
	Motorway	2.49	0.68

PM emissions from road abrasion are estimated based upon the emission factors and methodology provided by the EMEP/EEA Emissions Inventory Guidebook (EMEP/EEA, 2009). The emission factors are given in g/km for each main vehicle type and are constant for all years, with no road type dependence. The factors for PM_{10} (in mg/km) are shown in Table 5-20. The factors are combined with vehicle-km data to calculate the national emissions of PM from this source. Emissions from road abrasion are reported under 1A3bvii.

Table 5-20: Emission factors for PM_{10} from road abrasion

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

Emissions of $PM_{2.5}$ and smaller mass ranges are estimated from the fraction of $PM_{2.5}$ in the PM_{10} range. Mass fractions of PM_{10} for different PM sizes are given elsewhere in this report for different sources. Using information from the DfT/TRL emission factor review and EMEP/EEA Emissions Inventory Guidebook (EMEP/EEA, 2007), the fraction of PM_{10} emitted as $PM_{2.5}$ for tyre wear, brake wear and road abrasion is shown in Table 5-21.

Table 5-21: Fraction of PM_{10} emitted as $PM_{2.5}$ for non-exhaust traffic emission sources

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

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

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

Table 5-22: NO_x Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs15

g NOx (as NO_2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2.11	2.66	3.58
	Euro 1	0.26	0.31	0.59
	Euro 2	0.14	0.16	0.19
	Euro 3	0.07	0.06	0.06
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Diesel cars	Pre-Euro 1	0.57	0.53	0.74
	Euro 1	0.57	0.58	0.74
	Euro 2	0.60	0.56	0.79
	Euro 3	0.69	0.67	0.86
	Euro 4	0.48	0.44	0.72
	Euro 5	0.35	0.31	0.52
Petrol LGVs	Pre-Euro 1	2.82	3.34	3.97
	Euro 1	0.41	0.42	0.61
	Euro 2	0.14	0.14	0.21
	Euro 3	0.09	0.09	0.13
	Euro 4	0.04	0.04	0.06
Diesel LGV	Pre-Euro 1	1.29	0.81	2.08
	Euro 1	1.05	1.01	1.50
	Euro 2	1.05	1.01	1.50
	Euro 3	0.88	0.85	1.26
	Euro 4	0.72	0.68	1.02
Rigid HGVs	Pre-Euro I	8.65	7.89	7.91
	Euro I	5.92	5.45	5.51
	Euro II	6.40	5.77	5.76
	Euro III	5.01	4.45	4.42
	Euro IV	3.47	3.19	2.86
	Euro V	2.77	1.34	0.81
Artic HGVs	Pre-Euro I	13.95	11.17	10.07
	Euro I	9.79	7.87	7.13
	Euro II	10.42	8.36	7.59
	Euro III	8.35	6.72	6.14
	Euro IV	5.74	4.81	3.59
	Euro V	3.83	1.94	1.27
Buses & coaches	Pre-Euro I	10.84	9.31	8.64

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

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

Table 5-23: CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13
	Euro 2	0.53	0.69	1.82
	Euro 3	0.23	0.62	1.58
	Euro 4	0.42	0.71	1.56
	Euro 5	0.34	0.58	1.29
Diesel cars	Pre-Euro 1	0.58	0.43	0.36
	Euro 1	0.32	0.22	0.18
	Euro 2	0.19	0.12	0.08
	Euro 3	0.06	0.04	0.02
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Petrol LGVs	Pre-Euro 1	11.69	8.17	6.69
	Euro 1	3.10	3.25	4.81
	Euro 2	0.10	1.15	3.12
	Euro 3	0.41	0.77	2.22
	Euro 4	0.41	0.77	2.22
Diesel LGV	Pre-Euro 1	0.71	0.77	0.95
	Euro 1	0.55	0.46	0.43
	Euro 2	0.59	0.62	0.76
	Euro 3	0.17	0.13	0.12
	Euro 4	0.14	0.10	0.09
Rigid HGVs	Pre-Euro I	2.14	1.96	2.06
	Euro I	1.38	1.30	1.37
	Euro II	1.17	1.12	1.18
	Euro III	1.04	0.96	0.98
	Euro IV	0.57	0.50	0.55
	Euro V	0.08	0.07	0.07
Artic HGVs	Pre-Euro I	2.49	2.26	2.39
	Euro I	2.17	1.98	2.10
	Euro II	1.80	1.69	1.83
	Euro III	1.91	1.74	1.86
	Euro IV	0.34	0.31	0.34
	Euro V	0.13	0.12	0.13
Buses & coaches	Pre-Euro I	2.72	1.89	1.50
	Euro I	1.68	1.11	1.24
	Euro II	1.33	0.87	1.13
	Euro III	1.46	0.92	1.22
	Euro IV	0.13	0.08	0.09
	Euro V	0.13	0.09	0.09
Mopeds, <50cc, 2st	Pre-Euro 1	13.80		
	Euro 1	5.60		
	Euro 2	1.30		
	Euro 3	1.30		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.08	23.67	
	Euro 1	10.61	15.62	
	Euro 2	8.39	12.35	
	Euro 3	4.63	6.82	

g CO/km		Urban	Rural	Motorway
Motorcycles, >50cc, 4st	Pre-Euro 1	16.59	22.01	25.84
	Euro 1	10.08	17.56	15.74
	Euro 2	5.27	8.98	9.51
	Euro 3	2.91	4.96	5.25

Table 5-24: 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
	Euro 5	0.013	0.009	0.012
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
	Euro 5	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

g HC/km		Urban	Rural	Motorway
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 5-25: 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
	Euro 5	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
	Euro 5	0.001	0.001	0.001
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

g PM/km		Urban	Rural	Motorway
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 5-26: NH_3 Emission Factors for Road Transport (in mg/km)

mg/km	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2	2	2
	Euro 1	70	131	73
	Euro 2	138	148	83
	Euro 3	2	29	65
	Euro 4	2	29	65
	Euro 5	2	29	65
Diesel cars	Pre-Euro 1	1	1	1
	Euro 1	1	1	1
	Euro 2	1	1	1
	Euro 3	1	1	1
	Euro 4	1	1	1
	Euro 5	1	1	1
Petrol LGVs	Pre-Euro 1	2	2	2
	Euro 1	70	131	73
	Euro 2	138	148	83

mg/km	Standard	Urban	Rural	Motorway
	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 5-27: Benzo(a)pyrene Emission Factors for Road Transport (in g/km)

g B(a)P/km	**Standard**	**All road types**
Petrol cars	Pre-Euro 1	4.80E-07
	Euro 1	3.20E-07

g B(a)P/km	Standard	All road types
	Euro 2	2.01E-07
	Euro 3	1.66E-07
	Euro 4	1.30E-07
	Euro 5	1.30E-07
Diesel cars	Pre - Euro 1	2.85E-06
	Euro 1	6.30E-07
	Euro 2	4.25E-07
	Euro 3	2.84E-07
	Euro 4	1.89E-07
	Euro 5	1.34E-07
Petrol LGVs	Pre-Euro 1	4.80E-07
	Euro 1	3.20E-07
	Euro 2	2.01E-07
	Euro 3	1.66E-07
	Euro 4	1.30E-07
Diesel LGVs	Pre-Euro 1	4.28E-06
	Euro 1	9.45E-07
	Euro 2	6.38E-07
	Euro 3	4.25E-07
	Euro 4	2.84E-07
Rigid HGVs	Pre - Euro I	1.35E-06
	Euro I	6.75E-07
	Euro II	3.59E-07
	Euro III	3.31E-07
	Euro IV	1.53E-07
Artic HGVs	Pre - Euro I	1.80E-06
	Euro I	9.00E-07
	Euro II	4.79E-07
	Euro III	4.41E-07
	Euro IV	2.04E-07
Buses & coaches	Pre - Euro I	2.63E-06
	Euro I	1.31E-06
	Euro II	6.99E-07
	Euro III	6.44E-07
	Euro IV	2.97E-07

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

5.5 NAVIGATION

The UK inventory provides emission estimates for coastal shipping, naval shipping, international marine and fishing.

A new method was used to estimate coastal and international marine emissions for the 2009 inventory, and has been used for the 2010 inventory. The method is centred around a procedure developed by Entec (now AMEC) under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters 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 CLRTAP Guidelines for national inventories and was the first time such an approach had been feasible for the UK inventory. Previous emission estimates for coastal and international marine were based on total deliveries of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES, 2011). This led to very erratic time series trends in fuel consumption and emissions which bear little resemblance to other activity statistics associated with shipping such as port movement data. The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are believed to be an accurate representation of the amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption.

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

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

the first time in this year's inventory. To maintain the overall marine fuel balance, the fuel allocated to international shipping has been revised.
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
- Estimates for domestic shipping fuel consumption and emissions backcast to 1990 and forecast to 2010 are used
- Fuel consumption and emissions are calculated separately for naval shipping from data provided by the MoD
- Fuel consumption and emissions are calculated separately for inland waterways from estimates of vessel population and activities
- A reconciliation with fuels data in DUKES is made whereby the difference between the sum of the currently reported fuel deliveries for marine bunkers and national navigation in DUKES and the sum of the fuel consumption estimate for domestic shipping taken from Entec, and the fuel consumption estimates for naval shipping and the UK's inland waterways is assigned to international shipping.

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

Estimation for Domestic 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, 2008c) are derived from primary LMIU data in combination with estimates from MDS-Transmodal for frequent sailings missing from the LMIU database. The DfT port data are reported as annual totals by port and ship type in Maritime Statistics and refer to movement of all sea-going vessels >100 Gross Tonnage (GT) involved in the movement of goods or passengers. In this comparison, special consideration was given to movements involving small vessels <500 tonnes, fishing vessels and movements from and to the same port. Missing from both data sources are movements by tugs, dredgers, research vessels and other vessels employed within the limit of the port or estuary as well as small pleasure craft.

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

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

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

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

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

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

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

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

Entec calculated fuel consumption and emissions from g/kWh emission factors appropriate for the engine type and fuel type for operations “at sea” cruising, “at berth” when stationary in port and for “manoeuvring” while entering and leaving port. The 2007 emission factors and formulae used for calculating emissions are given in the Entec report. As well as the time spent cruising, in berth and manoeuvring, the formulae used the installed engine power and average load factor for the main ship engine and auxiliary engines.

The emission factors used by Entec come from amendments to an earlier set of emission factors compiled by Entec during a study for the European Commission (Entec, 2002, 2005). These largely originate from Lloyds Register Engineering Services and a study by IVL.

The Entec study considered only fuel consumption and CO_2 emissions and emissions of NO_x, SO_2, PM and NMVOCs. For NO_x, the factors took into account limits on emissions from engines installed on ships constructed or converted after 1 January 2000, as required to meet the NO_x Technical Code of the MARPOL agreement. As the age of the engine is identified in the LMIU dataset, an average factor for engines in 2007 could be determined. Emission factors for SO_2 depend on the sulphur content of the fuel. Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table 5-28: Assumed sulphur content of fuel for 2007

	Sulphur content of fuel (2007)
Marine gas oil	0.2%
Marine diesel oil	1.5%
Residual fuel oil	2.7%

Emission factors for PM taken from the Entec (2005) study for the European Commission were adjusted where necessary by Entec to take account of changes in sulphur content of fuel using relationships between PM emissions and fuel sulphur content taken from Lloyd’s Register. Factors for NMVOCs are unchanged from those in Entec C (2005).

For pollutants not covered in the Entec (2010) study, including CH_4 and N_2O, emission factors in units g/kg fuel were taken from the EMEP/EEA guidebook.

The detailed Tier 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 NFR category 1A3dii Domestic Water-borne Navigation separate from 1A3di International Water-borne Navigation (International bunkers), according to NFR Source Categories:

Table 5-29: NFR Navigation Source Category and description

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

Emissions from domestic navigation (1A3dii) are included in the national totals, emissions from international navigation (1A3dii) 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. The Entec study did not cover small tugs and service craft used in estuaries, private leisure craft and vessels used in UK rivers, lakes and canals. These were captured in the estimates for inland waterways described below.

Estimating the 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 an alternative approach was used based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2010 from the 2007 base year emissions. The variables that were considered were:

- Trends in vessel movements over time affected by changes in the number of vessels and their size.
- Trends in fuel type in use over time reflecting the era before the introduction of SECAs which would have permitted higher sulphur content fuel to be used
- Changes in emission factors.

The key consideration was the trend in vessel movements over time. For this, DfT's annual published Maritime Statistics were used as proxies for activity rate changes which were taken to be indicators of fuel consumed. A range of time-series trends back to 1990 from the DfT statistics are available and appropriate data were assigned to different vessel categories, differentiating between international and domestic movements. Details are given in the Entec (2010) report, but in brief:

- All ports traffic data based on tonnes cargo for domestic and international movements was assigned as an indicator for the bulk carrier, general cargo and tanker vessel categories. Trends were available from 1990-2010.
- 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 1990-2010
- 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, 2010).

The Entec (2010) report shows the trends in each of the relevant statistics relative to the 2007 base year level. Figure 13.1 in that report shows that before 2007, all statistics were showing a growth in the level of activity from 1990 with the exception of three. These were trends in ports traffic (tonnes cargo) for domestic movements, international sea passenger numbers and fish landings which showed declining activity. However, in the period between 2007 and 2009, almost all statistics showed a decreasing level of activity. Between 2009 and 2010, some of these statistics showed an increase, while others showed a decreasing trend, but overall led to a decreasing trend in fuel consumption.

It was assumed that 2007 heralded the introduction of marine gas oil and marine diesel oil consumption by vessels that had previously used residual fuel oil in the SECA around UK coasts. Thus in years between 1990-2006, all vessels except fishing and those in the ‘other’ category were assumed to be using fuel oil for their main engine. It was also assumed that passenger vessels outside the SECA started to use MDO in 2007 in order to comply with the SCMF Directive having previously been using fuel oil. However, other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2010 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. This assumption was maintained for 2010.

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

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 5-30 which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil. Note that DUKES makes no separation between marine diesel oil and marine gas oil, so the figures here and in the inventory for gas oil refer to the combined amounts for both these types of fuel.

Table 5-30: Total consumption of marine fuels for domestic and international shipping calculated by the Entec method compared with figures for national navigation and marine bunkers in DUKES for 2007. The DUKES figure for gas oil has consumption by military vessels excluded

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

The totals differ markedly. One reason for that is the Entec “international” category includes fuel consumed by vessels arriving at UK ports that purchased their fuel overseas and so would not be included in the DUKES marine bunkers supply. However, in reporting emissions from international shipping movements as a Memo item, the UK is only responsible for emissions from fuel supplied by the UK’s bunker fuels market. Another issue is the international bunker fuels market itself and how the figures in DUKES for marine bunkers relate to actual consumption by international shipping movements starting in the UK. International fuel bunkering may be affected by variations in international marine fuel prices such that it is conceivable that fuel tankering occurs to a greater or lesser extent each year. This may explain why the trend in total marine fuel consumption implied by DUKES since 1990 is more erratic than trends in shipping movements implied by port statistics.

All these factors can lead to potential differences in the total domestic plus international fuel consumption calculated from a method based on vessel movements from fuel statistics in DUKES. Moreover, DECC acknowledged that there is uncertainty with refineries who submit data to DUKES as to where the fuel ultimately gets used, i.e. whether for domestic shipping activities or for international marine fuel bunkers. So not only could the total fuel consumed be different, but these uncertainties could allocate the incorrect amounts of the DUKES marine fuels to domestic (national navigation) and international (marine bunkers) consumption. The key point is that for emission reporting under CLRTAP guidelines, the UK is only responsible for emissions from the fuel it supplies, whatever it is used for, but an accurate estimate is required of the amount of fuel used for domestic shipping consumption because emissions arising from this are accounted for in the UK inventory totals. Therefore, to retain overall consistency with national energy statistics and the requirements of inventory reporting under CLRTAP Guidelines it was decided at a meeting with stakeholders (Defra, DECC, DfT and Entec) in July 2010 to adopt an approach for the inventory whereby the figures for domestic 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.

A further adaptation of the approach was made in this year's inventory to account for consumption of gas oil by inland waterways which in last year's inventory would have been captured in the residual assigned to international shipping. Discussions with the DUKES team during a study on the allocation of gas oil across sectors (Murrells et al., 2011) revealed that it is likely that gas oil supplied by marinas and filling points along rivers is included in the DUKES figures for national navigation.

Thus for fuel consumption across the time series:

International shipping fuel consumption = (total DUKES fuel consumption – Entec domestic shipping fuel consumption – naval fuel consumption – inland waterways fuel consumption)

This implies that the total marine fuel consumption by all marine activities covered in the inventory is considered a "closed" system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic shipping, fishing, naval and inland waterways) is consistent with the total amount of gas oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES as can be seen in Table 5-31.

However, the significance of including inland waterways in this year's inventory is that less fuel is reported to international shipping as an inventory Memo item compared with the 2009 inventory, and more is included in the UK national totals. This table differs from the corresponding table in last year's inventory report by including inland waterway fuel consumption in the inventory figure for domestic gas oil consumption, reducing the residual assigned to international consumption. Nevertheless, even with this change the proportion of fuel assigned to domestic consumption is still considerably lower than the figure implied by DUKES.

Table 5-31: Consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic movements and inventory estimates of inland waterway activities compared with figures for national navigation (domestic) and marine bunkers (international) in DUKES for 2007. The DUKES figure for gas oil (international) has consumption by military vessels excluded.

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.496	0.942
	International	1.073	0.627

Mt fuel		NAEI	DUKES
	Total	1.569	1.569
	% domestic	32%	60%
Fuel oil	Domestic	0.103	0.569
	International	1.936	1.471
	Total	2.040	2.040
	% domestic	5%	28%

Following this revised approach, emissions for international shipping (1A3di) were calculated by multiplying the residual fuel consumption calculated above with an implied emission factor for international vessel movements. The implied emission factors were derived from the Entec study by dividing the Entec emission estimates for international vessel movement by their associated fuel consumption for each fuel type. This effectively means the inventory does capture the types of vessels, engines, speeds and activities used for international movements in Entec's inventory even though the overall movements, fuel consumption and hence emissions are different.

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 5-32 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. Fuel consumption by inland waterways are not included in this table.

Table 5-32: Fuel consumption for domestic coastal and international shipping derived from inventory method

Year	Fuel Consumption (Mt)				
	Gas oil			Fuel oil	
	Domestic (excl. fishing)	Fishing	International	Domestic	International
1990	0.171	0.006	1.614	0.346	1.132
1991	0.169	0.005	1.674	0.342	1.065

Year	Fuel Consumption (Mt)				
	Gas oil			Fuel oil	
	Domestic (excl. fishing)	Fishing	International	Domestic	International
1992	0.166	0.006	1.700	0.335	1.095
1993	0.164	0.006	1.616	0.332	1.143
1994	0.174	0.006	1.545	0.352	0.951
1995	0.181	0.006	1.378	0.368	1.196
1996	0.182	0.006	1.602	0.370	1.259
1997	0.178	0.005	1.531	0.361	1.570
1998	0.181	0.005	1.824	0.371	1.417
1999	0.181	0.004	1.481	0.374	0.877
2000	0.169	0.004	1.489	0.347	0.630
2001	0.163	0.004	1.645	0.334	0.541
2002	0.170	0.004	1.233	0.351	0.460
2003	0.166	0.004	1.440	0.342	0.576
2004	0.168	0.005	1.343	0.343	0.935
2005	0.172	0.005	1.258	0.356	1.164
2006	0.163	0.004	1.686	0.337	1.480
2007	0.388	0.004	1.073	0.103	1.936
2008	0.378	0.004	0.929	0.100	2.458
2009	0.359	0.004	0.925	0.094	2.208
2010	0.341	0.004	0.862	0.088	1.855

Table 5-33 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2010. The units are in g/kg fuel and are implied by the figures in the Entec study.

Table 5-33: 2010 Inventory Implied Emission Factors for Shipping

Fuel	Source	NO_X	SO_2	VOC	PM_{10}	CO
		g/kg	g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.44	20.36	2.82	1.95	7.40
	Fishing	57.97	2.02	2.04	1.32	7.40
	International	69.33	20.50	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, 2011). Data are provided on a financial year basis so adjustments were made to derive figures on a calendar year basis.

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

Emissions from Inland Waterways

For the first time, emissions from inland waterways have been included in the 2010 inventory. Although this is a new source in the inventory, it does not represent an overall increase in emissions, but it does re-allocate some emissions that were assigned to international shipping to a maritime sector that is included in national totals.

Emissions from vessels used on inland waterways were previously not reported in the UK inventory because there are no national fuel consumption statistics on the amount of fuel used by this sector in DUKES. However as all fuel consumed by all sources in the UK was captured by the inventory; emissions from inland waterways were effectively captured, but were misallocated to other sectors using the same types of fuels.

The CLRTAP Guidelines indicate that emissions from inland waterways are a sub-set of the NFR category 1A3d Waterborne Navigation which also covers shipping. In the UK, all emissions from inland waterways are included in domestic totals whereas in some other countries, vessels on inland waterways could be classed as international since they pass between countries.

The Guidelines specify that category 1A3d should include not only fuel used for marine shipping, but also for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts.

The methodology applied to derive emissions from the inland waterways sector for the 2010 inventory uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP/EEA, 2007, 2009a). The inland waterways class is divided into four categories and sub-categories:

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    - recreational craft operating on inland waterways;
    - recreational craft operating on coastal waterways;
    - workboats;
- Personal watercraft i.e. jet ski; and
- Inland goods carrying vessels.

Details of the approach used are given in the report by Walker et al (2011). A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

The methodology used to estimate the total amount of each fuel consumed by the inland waterways sector follows that described in the EMEP/EEA Emissions inventory guidebook

(EMEP, 2009b) where emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi$$

where:
E = mass of emissions of pollutant i or fuel consumed during inventory period,
N = source population (units),
HRS = annual hours of use,
HP = average rated horsepower,
LF = typical load factor,
EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker et al., 2011). Some smaller vessels also run on petrol engines. As a result, around 90 kt of DERV and 90 kt of petrol previously assigned to the road transport sector for 2009 in last year's inventory are now allocated to inland waterways.

Walker at al. (2011) and Murrells et al. (2011) draw attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap.

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time series 1990 – 2010:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on "Recreation and culture"; http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html;
- Commercial passenger/tourist craft – Visit England, Visitor Attractions Trends in England 2010, Annual Report Visitor numbers. Table 9.1 Trends in the number of visits to UK attractions 1989-2010, Total England Attractions; http://www.visitengland.org/Images/Final%20report_tcm30-27368.pdf
- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table 1.3 - Foreign and domestic traffic, by port: 1965 - 2009, United Kingdom and Great Britain Total (supplementary spreadsheet); http://www2.dft.gov.uk/pgr/statistics/datatablespublications/maritime/compendium/maritimestatistics2009.html; and

- Freight – DfT Waterborne Freight in the United Kingdom, Table 1.1: Waterborne transport within the United Kingdom, 1990 – 2009; Goods lifted - UK inland waters traffic - Non-seagoing traffic - Internal http://www2.dft.gov.uk/pgr/statistics/datatablespublications/maritime/waterborne/waterbornefreight2009.html

One of these four proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate.

Table 5-34 shows the trend in fuel consumption by inland waterways from 1990-2010 developed for the inventory this year. Table 5-35 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2010. More detail regarding the vessels and their fuel type can be found in the report by Walker et al., 2011.

Table 5-34: Fuel consumption for inland waterways derived from inventory method

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1990	86.2	3.82	0.59	27.6	22.0	11.2
1991	86.5	3.44	0.62	28.8	22.6	11.7
1992	86.9	3.76	0.68	31.5	24.1	12.8
1993	88.4	4.07	0.74	34.3	25.5	13.9
1994	92.8	4.52	0.80	37.0	27.0	15.0
1995	94.3	4.20	0.85	39.8	28.5	16.1
1996	94.9	3.63	0.91	42.5	29.9	17.2
1997	95.2	3.06	0.97	45.3	31.1	18.3
1998	95.8	2.74	1.03	48.0	32.2	19.4
1999	95.5	2.74	1.09	50.7	33.6	20.5
2000	96.1	2.74	1.15	53.5	34.8	21.6
2001	94.5	2.71	1.21	56.2	35.9	22.8
2002	96.0	2.52	1.30	60.4	38.7	24.4
2003	96.4	2.02	1.39	64.6	41.0	26.1
2004	98.8	1.65	1.48	68.8	43.2	27.8
2005	100.2	2.16	1.57	72.9	45.2	29.5
2006	101.1	2.26	1.66	77.1	47.6	31.2
2007	101.7	2.14	1.75	81.3	49.9	32.9
2008	100.3	2.35	1.84	85.5	52.2	34.6
2009	94.6	2.08	1.93	89.6	54.8	36.3
2010	97.0	2.35	1.93	89.6	55.1	36.3

Table 5-35: 2010 Inventory Emission Factors for Inland Waterway Vessels

Fuel	NO_X g/kg	SO_2 g/kg	VOC g/kg	PM_{10} g/kg	CO g/kg
DERV	42.5	0.0148	4.72	4.12	10.9
Gas Oil	42.5	1.442	4.72	4.12	10.9
Petrol	9.0	0.012	50.0	0.036	300.0

5.6 OTHER SECTORS (1A4)

The mapping of NAEI categories to 1A4 Other Sectors is shown in Section A3.2. For most sources, the estimation procedure follows that of the base combustion module using DECC reported fuel use data and emission factors from section 1. The NAEI category public service is mapped onto 1A4a Commercial and Institutional. This contains emissions from stationary combustion at military installations, which should be reported under 1A5a Stationary. Also included are stationary combustion emissions from the railway sector, including generating plant dedicated to railways. Also included in 1A4 are emissions from the ‘miscellaneous’ sector, which includes emissions from the commercial sector and some service industries.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. The estimation of emissions from off-road sources is discussed in Section 5.7 below. Emissions from fishing vessels are now included within the coastal shipping sector, due to the withdrawal of more detailed fuel use datasets that have historically been provided by DECC but are now determined to be of questionable accuracy.

5.7 OTHER (1A5)

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. The methodology of these estimates is discussed in chapter 1.

5.7.1 Estimation of Other Off-Road Sources

Emissions are estimated for 77 different types of portable or mobile equipment powered by diesel or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers; aircraft support equipment. In the inventory they are grouped into four main categories:

- domestic house & garden
- agricultural power units (includes forestry)
- industrial off-road (includes construction and quarrying)
- aircraft support machinery.

The mapping of these categories to the appropriate NFR code is shown in Table 6-1. Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery.

The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). Emissions are calculated using the following equation for each machinery class:

$$E_j = N_j \,.\, H_j \,.\, P_j \,.\, L_j \,.\, W_j.(1 + Y_j \,.\, a_j /2).\, e_j$$

where

E_j	=	Emission of pollutant from class j	(kg/y)
N_j	=	Population of class j.	
H_j	=	Annual usage of class j	(hours/year)
P_j	=	Average power rating of class j	(kW)
L_j	=	Load factor of class j	(-)
Y_j	=	Lifetime of class j	(years)
W_j	=	Engine design factor of class j	(-)
a_j	=	Age factor of class j	(y^{-1})
e_j	=	Emission factor of class j	(kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \,.\, H_j \,.\, e_{vj}$$

where

E_{vj}	=	Evaporative emission from class j	kg
evj	=	Evaporative emission factor for class j	kg/h

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by AEA on behalf of the Department for Transport (Netcen, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from DECC on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. Therefore, other activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2010.

For industrial and construction machinery, a set of four drivers is used. Each of the individual machinery types is mapped to one of these four drivers depending on the typical industry sector in which the machinery type is usually used. The four categories and drivers used are described in Table 5-36.

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

A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP/CORINAIR (1996) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004b). For equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in terms of how they apply to different machinery types. Each of the 77 different machinery types was mapped to the relevant regulation in terms of implementation date and limit value.

The methodology follows the Tier 3 methodology described in the latest EMEP/EEA emission inventory guidebook (EMEP/EEA, 2009).

Table 5-36: Activity drivers used for off-road machinery in the industry and construction sector.

Category	Driver source	Machinery types
Construction	ONS construction statistics. The value of all new work (i.e. excluding repair and maintenance work) at constant (2005) prices and seasonally adjusted. Taken from the Construction Statistics Annual 2011. http://www.ons.gov.uk/ons/rel/construction/construction-statistics/no--12--2011-edition/construction-statistics-annual-report-2011.pdf	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS 2011.	bore/drill rigs
		off highway trucks*
		crushing/processing equip
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	excavators
		loaders with pneumatic tyres
		bulldozers
		tracked loaders

Category	Driver source	Machinery types
		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

Aggregated emission factors for the four main off-road machinery categories in 2010 are shown in Table 5-37 by fuel type. The fleet-average (aggregated) emission factors for most machinery types are lower than in the 2009 inventory because of the expiry of old machinery and penetration of new machinery into the fleet. Factors for SO_2 are changed due to changes in the sulphur content of fuels. For industrial off-road machinery, some machinery types with diesel engines previously assumed to be using gas oil are now assumed to be using DERV, following a study into the use of gas oil in the UK (Appendix 1). This study leads to a re-allocation of 0.25 Mt DERV previously assigned to road transport in 2009 to industrial off-road machinery, mainly small machinery types used on an irregular basis, such as small portable generators and small cement and mortar mixers.

Table 5-37: Aggregate Emission Factors for Off-Road Source Categories in 2010 (t/kt fuel)

Source	Fuel	CO	NH_3	NO_x	PM_{10}	SO_2[1]	NMVOC
Domestic House&Garden	DERV	4.34	0.03	47.96	1.67	0.01	2.57
Domestic House&Garden	Petrol	667.85	0.01	3.62	0.03	0.01	49.52
Agricultural Power Units	Gas oil	16.57	0.03	24.73	2.34	1.44	4.55
Agricultural Power Units	Petrol	716.32	0.01	1.45	0.03	0.01	248.58
Industrial Off-road	DERV	18.83	0.03	41.99	3.60	1.44	7.07
Industrial Off-road	Gas oil	18.83	0.03	41.99	3.60	1.44	7.07
Industrial Off-road	Petrol	1034.72	0.01	6.24	0.03	0.01	39.33
Aircraft Support	Gas oil	12.52	0.03	26.62	2.23	1.44	4.93

1 Based on sulphur content of fuels in 2009 from UKPIA (2011).

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

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

NFR Category (other 1A4)	Pollutant coverage	NAEI Source category	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	
1A 4 c iii Agriculture/Forestry/ Fishing: National fishing	All CLRTAP pollutants *(except NH_3, PCDD/ PCDF, HCB, HCH, PCBs and)*	Fishing vessels	Entec
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.

Table 3-2 lists the fuels used in the inventory.

Table 6-1 relates the detailed NAEI source categories to the equivalent NFR source categories for stationary combustion. In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR (Nomenclature for Reporting) source category; however there are some instances where the scope of NAEI and NFR categories are different to a significant degree. Instances of this are discussed below. The NAEI source categories are the level at which emission estimates are derived, but reporting would not normally be at this detailed level, the NFR system being used instead for submission under the CLRTAP.

Almost all of the NFR source categories listed in Table 6-1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

6.2 GENERAL APPROACH FOR 1A4

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

The NAEI source categories reported under 1A4 consist mainly of large numbers of very small plant with only a few large plant in the commercial and public sectors, and an exclusively bottom-up approach utilizing reported emissions is not possible.

6.3 FUEL CONSUMPTION DATA

As stated previously, fuel consumption data are taken from DUKES. However, there are some areas of the inventory where the NAEI energy data deviates from the detailed statistics given in DUKES. This is done for two reasons:

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

The most important of these deviations in 1A4 are as follows:

- DUKES does not include any energy uses of petroleum coke by this sector, and only includes very recent data for some sectors covered by 1A1 and 1A2. Instead, the remaining consumption of petroleum coke is allocated to 'non-energy uses' in the commodity balance tables for petroleum products. AEA therefore include estimates of petroleum coke burnt by the domestic sector based on data provided by industry.
- Gas oil is used in large quantities as a fuel for off-road vehicles and mobile machinery. These devices are not treated as a separate category in DUKES and the fuel they use is included in the DUKES data for agriculture, industry, public administration, railways, and the commercial sector. AEA generate independent estimates of gas oil use for off-road vehicles and mobile machinery, derived from estimates of the numbers of each type of vehicle/machinery in use, and the fuel consumption characteristics. Overall consistency with UK consumption of gas oil, as given in DUKES, is maintained by reducing NAEI estimates for gas oil consumed by the sectors listed above.

6.4 METHOD FOR COMMERCIAL, DOMESTIC AND PUBLIC SECTOR COMBUSTION SOURCES

Individual combustion plants range in scale from domestic appliances such as central heating boilers and open fires, up to a few ‘large combustion plant’ with thermal inputs exceeding 50 MW_{th} used in the commercial or public sectors. Even in the latter two sectors, most combustion plant will be small, and cecause of this, it is not possible to derive bottom-up estimates. Emissions can best be estimated using an appropriate emission factor applied to national fuel consumption statistics taken from DUKES i.e. emissions are calculated according to the equation:

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

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’ in the commercial and public sectors and the methodology allows for these reported data to be used in the case of NO_x only. Data are also available for SO_2 but it is considered that the use of emission factors based on fuel composition data are more appropriate than use of plant-specific emissions data for SO_2. Reported data for other pollutants are extremely limited and are not used directly in the UK inventory for these sources.

For most pollutants, a single factor is applied for a given source category but, in the case of carbon monoxide, NO_x and PM_{10} emissions for the commercial, agricultural and public sectors, a more detailed approach is taken. This is done in order to derive estimates that are more representative of the wide range of combustion appliances (e.g. different designs, thermal capacities) with different combustion performance, abatement and emission profiles that are evident within these source categories. The more detailed approach breaks down the source/fuel combinations by a) thermal input of combustion devices; b) type of combustion process (e.g. boilers, furnaces, turbines etc), and appliance-specific emission factors are then applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (US EPA, 2009), the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA, 2009) and UK emission factor surveys (Walker *et al*, 1985). Emissions data for NO_x reported in the Pollution Inventory (EA, 2011) are also used in the generation of emission factors for larger combustion plants in the public and commercial sector source categories.

Emissions from domestic combustion are estimated using literature emission factors, generally a single factor across the entire time series. Suitable factors are not always available for some minor fuels, and so emission factors for a similar fuel are used instead e.g. a factor reported in the literature for coke might be used for other manufactured smokeless fuels.

A constant emission factor is used across the time series for most domestic sector fuels, implying that combustion technology and, therefore, emission rates have not changed. This is an over-simplification since a range of developing technologies is available for all fuels, but it also reflects the absence of any data on the proportion of fuels consumed in different types of appliance. The NAEI does include a modelled approach to estimate changes in emission rates for domestic gas combustion. This method is necessarily still very simplistic, assuming that all gas is burnt in boilers, and that emission rates for new plant are constant over the following three periods:

1970-1989	70 g NO_x/GJ
1990-2004	24 g NO_x/GJ
2005-2010	19 g NO_x/GJ

It is further assumed that all boilers have a 15 year lifetime and that an equal number are replaced each year, so that while all boilers in 1989 emit 70 g NO_x/GJ, 1 in 15 of these boilers are replaced in 1990 with new boilers that emit 24 g NO_x/GJ and that by 2004 all boilers emit 24 g NO_x/GJ. The three emission factors chosen are, respectively i) the EMEP/EEA Guidebook default factor for domestic gas combustion; ii) a factor taken from the Ecodesign Directive preparatory studies on central heating boilers (Lot 1) and water heaters (Lot 2) and derived from the GEMIS database for gas boilers; and iii) the Class 5 standard for new boilers introduced in EN 483. A similar approach might be worthwhile for other fuels to reflect changes in the use of fuels over time, and improvements in technology, but as for gas, the method would necessarily need to be simplistic and rely on assumed values for the proportions of different types of appliance.

6.5 SOURCE SPECIFIC QA/QC AND VERIFICATION

The QA/QC procedure for this sector is covered by the general QA/QC of the NAEI in section 1.6.

Some emission estimates for 1A4 rely partially upon emissions data reported in the PI, SPRI and ISR. Section 3.7 discusses QA/QC issues regarding these data.

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/EEA guidebook (EMEP/EEA, 2009), BREF notes, US EPA AP-42 (US EPA, 2009) and industry-specific studies.

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

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. 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.

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

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, 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, 2011), 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 EUETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The emission estimates for the offshore industry are based on the Oil and Gas UK EEMS dataset for 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 QA/QC 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	
		Hot-dip galvanising	
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	

NFR Category	Pollutant coverage	NAEI Source Category	Source of EFs
		Spirit manufacture - casking	
		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.

The 2010 compilation will include a new source for dioxins and furans under NFR 2C5d for hot-dip zinc galvanising. As with the other non-ferrous metals in this sector activity data was not readily available from the ONS, and emissions have been based on AEA estimates against industry data and literature emission factors taken from a study of dioxin and furan emissions from air pollution control equipment (Jones K. and Lee R. (2003)).

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, 2009). 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 2C1 is a key source for SO_2, CO, PM_{10}, Pb, Hg, Cd and PCDD/PCDF.

UK iron and steel production may be divided into integrated steelworks, electric arc steelworks, downstream processes such as continuous casting and rolling of steel, and iron & steel foundries.

UK integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces.

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

Blast furnaces are used to reduce the iron oxides in iron ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron.

Gas leaving the top of the blast furnace has a high heat value because of the residual CO content, and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. Subsequent cooling of the slag with water can cause emissions of SO_2.

Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is lost and the carbon content of this gas is reported under CRF category 2C1.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, some losses occur and these losses are reported with blast furnace gas losses under CRF category 2C1.

Electric arc furnaces produce steel from ferrous scrap, using electricity to provide the high temperatures necessary to melt the scrap. Emissions of NO_x occur due to oxidation of nitrogen in air at the high temperatures within the furnace. Emissions of NMVOC and CO occur due to the presence of organic contaminants in the scrap, which are evaporated and partially oxidised.

Emission estimates for all of these processes are generally based on a bottom-up approach using i) data covering the period 2000 to 2010 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 2010, 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 1997-2010, 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 1998-2010 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/EEA Guidebook (EMEP/EEA, 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, PAHs	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 6 Horses	NH_3	Agriculture livestock - horses	
4 B 8 Swine	NH_3 and Particulate Matter	Agriculture livestock - pigs	
		Agriculture livestock - pigs wastes	
4 B 9 a Laying hens		Agriculture livestock - laying hens	
		Agriculture livestock - laying hens wastes	
4 B 9 b Broilers	Particulate Matter	Agriculture livestock - broilers	
		Agriculture livestock - broilers wastes	
4 B 9 d Other poultry	NH_3 and Particulate Matter	Agriculture livestock - other poultry	
		Agriculture livestock - other poultry wastes	
4 B 13 Other	NH_3	Domestic pets	
		Non-agriculture livestock - horses wastes	
4 D 1 a Synthetic N-fertilizers	NH_3	Agricultural soils	Literature sources
		House and garden machinery	
4D2c N-excretion on pasture range and paddock unspecified		N-excretion on pasture range and paddock unspecified	
4 F Field Burning Of Agricultural Wastes	NH_3 (NOx, NMVOC, Particulate Matter, PCDD/ PCDF, PAHs, PCBs for 1990-1992 only)	Field burning	UK factors

NFR Category	Pollutant coverage	NAEI Source	Source of EFs
4 G OTHER	Particulate Matter, HCB	Agricultural pesticide use - 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 weights are obtained from census statistics provided by each devolved administration (England, Scotland, Wales and Northern Ireland). The UK total is derived as the sum of the DA values. Proportion of animals in each housing type - cattle from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (1998), pigs from Sheppard (1998, 2002). Proportion of pigs outdoors from Sheppard (1998, 2002). Poultry housing and % manure dropped outdoors provided by A Elson (ADAS).

Manure output values per animal are from Smith and Frost (2000) and Smith et al., (2000). N excretion values are derived from Cottrill, B.R. and Smith,K.A. (2007) 'Nitrogen output of livestock excreta', Final report, Defra Project WT0715NVZ, June 2007. Manure TAN[16] contents from expert opinion. Proportion of waste produced as slurry or FYM from ADAS Surveys of Animal Manure Practices in the Dairy, Beef, Pig and Poultry Industries (Smith et al., 2000c, 2001a, 2001b).

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

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

Statistics relating to the sale and use of pesticides within the UK, are published by FERA (Food and Environmental Research Agency):

http://www.fera.defra.gov.uk/scienceResearch/science/lus/pesticideUsage.cfm

[16] total ammoniacal nitrogen

10.3 METHODS FOR ESTIMATING EMISSIONS

Agricultural sources are the most significant emission sources in the UK ammonia inventory. The methodology is described in detail in (Misselbrook et al. 2010). A summary of the methodology is given below for completeness.

The estimate of NH_3 emission from UK agriculture for 2010 was made using the spread sheet version of the National Ammonia Reduction Strategy Evaluation System (NARSES) model (file: NH3inv2010_NARSES_draft2_200911.xls). NARSES models the flows of total nitrogen and total ammoniacal N (TAN) through the livestock production and manure management system, with NH3 losses given at each stage as a proportion of the TAN present within that stage (Webb and Misselbrook, 2004). NARSES was first used to provide the 2004 inventory estimate for UK agriculture, replacing the previously used UK Agricultural Emissions Inventory model (UKAEI). NARSES brings improvements over the UKAEI model in that emission sources are linked, such that changes in an upstream source will be reflected downstream, it has an internal accounting check that not more than 100% of TAN excreted can be emitted, it can incorporate trends in N excretion by certain livestock classes (e.g. dairy cattle, pigs, poultry) and it is much better suited to scenario testing. The NARSES model was therefore used to provide the NH3 emissions estimate for UK agriculture for 2010. Emissions from fertiliser use within agriculture are estimated using a simple process-based model as described by Misselbrook et al. (2004), which has been incorporated into the NARSES spreadsheet model (Misselbrook et al. 2010).

10.3.1 Major changes between the 2009 Inventory and the 2010 Inventory

Key areas of revision in the 2010 inventory were[17]:

1. 2010 fertiliser use data
Data were derived from BSFP for crop year 2010 for England, Wales and Scotland and from DARD statistics for Northern Ireland.

The steady decline in fertiliser N use in UK agriculture since 1990 appears to be levelling out, with a low point reached in 2008 and increases in use in both years since then. Total fertiliser N use increased by 8% between 2009 and 2010, and there was a further increase in the proportion applied as urea (up from 21% in 2009 to 22% in 2010). The combined effects of greater fertiliser N use and a higher proportion as urea gave an overall increase in emissions of 2.2 kt NH_3.

2. 2010 livestock numbers

Headline changes from 2009 are:

- Cattle – a 0.8% increase in total cattle numbers (0.6% total dairy cattle and 1.0% total beef cattle)
- Pigs – a 5.4% decline in pig numbers
- Sheep – a 3.0% decline in sheep numbers
- Poultry – a 2.9% increase in total poultry numbers, with a 7.5% increase in the laying flock and a 2.5% increase in broiler numbers

[17] Misselbrook et al, 2011

It should be noted that the June survey methodology from 2010 covers only commercial holdings (> 10 cows, 50 pigs, 20 sheep, 20 goats or 1,000 poultry), with the exception of cattle where all animals are covered by the cattle tracing scheme. Previous June surveys covered all agricultural holdings and therefore some livestock, with the exception of cattle, will not be counted under the new methodology.

<u>3. Dairy cow N excretion</u>
Dairy cow N excretion values were previously derived from project WT0715NVZ[18] with interpretation by B Cotteril and K Smith (ADAS). This project gave projected values for 2006 onwards, based on projected milk yields. These data have now been revised according to reported average annual milk yields for each year (derived from Agriculture in the UK publications, Defra), using the empirical relationship between N excretion and milk yield as reported in WT0715NVZ.

<u>4. Cattle sub-categories</u>
The previously used sub-categories within the beef and dairy cattle sectors have been revised and rationalised, reflecting changes in the reporting of livestock statistics by the Devolved Administrations and harmonising with the categories used in the revised greenhouse gas inventory model. Cattle sub-categories now comprise: dairy cows and heifers, dairy heifers in calf, dairy replacements >1yr, dairy calves, beef cows and heifers, beef heifers in calf, all other beef >1yr (also will include dairy bulls), beef calves.

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.

[18] For the full list of projected see *Misselbrook (2011). Inventory of ammonia emissions from UK agriculture 2010. Inventory submission report, September 2011. DEFRA Contract AC0112.*

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 - NH_3	
		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 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 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 CO, NO_x, 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 pollutants are estimated from literature-based emission factors, taken from the EMEP/EEA Emission Inventory Guidebook. The quantity of waste burnt annually is estimated, these estimates being based on estimates given in the literature.

Emissions of CO, NOx, SO_2, and VOC from clinical waste incinerators are estimated using literature-based emission factors, largely taken from the EMEP/EEA Emission Inventory Guidebook (2009). 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 (2009). 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 (Energy Production), 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 occurred 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 CO, 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

In 2009 a major improvement programme commenced to further update the areas of highest uncertainty within the newly created POPs ‘multi-media inventory’ (air, land and water vectors) produced by AEA on behalf of Defra. This project included a broad array of tasks looking at dioxins and furans, PCBs, dioxin-like PCBs and HCB; as well as the development of a new multi-vector inventory for pentachlorobenzene (covered under the UNEP Stockholm Convention). The majority of these tasks were completed and the results used to update the 2009 compilation cycle for the NAEI reported last year.

The results from the remaining tasks have been used to further update air emissions quoted within the current NAEI inventory cycle.

Backyard burning of waste
As part of the improvement programme a national survey was carried out with the general public in 2010 to assess people’s attitudes towards backyard burning and the prevalence of the activity. This also included questions to assess the nature and volumes of waste being burned in uncontrolled open sites. The results showed a good general aware of the issues surrounding the combustion of waste plastics on open fires. The results did also show some regional variation in waste burning attitudes, and potentially an issue with disposal of tradesman’s waste via domestic open burning.

The activity used to calculate the emissions associated with open burning of waste are based on AEA estimates, for the number of viable burning sites (such as properties with a back garden), the frequency of burning events and the quantity and nature of the waste burned, which has been based on a similar study conducted by the England and Wales Environment Agency in 2003. The results of the current study suggest that previous quoted emissions overestimate the frequency and number of burning sites available in the UK. The results have therefore been used to update the activity estimates for this source accordingly:

- Open burning in fire places
    - The original estimates assume that 75% of households have a fireplace and use this as a method to get rid of a proportion of their household waste. This value is now revised to 30% of households in the UK based on results of 2010 study.
    - Waste composition unchanged.

- Bonfires
  - The original estimates quote that approximately 7% of households have a viable bonfire site, with 13 events per annum. The number of sites would be appropriate with results of 2010 study, but frequency of events would appear to be an overestimate. Frequency of events has been revised to 2.5 events per annum (to allow for regional variations)
  - Quantity of material burnt at each event was quoted as 6.75kg; the results of the 2010 survey suggest fewer events but potentially more waste burnt on each occasion. Quantity of material burnt at each event has been revised to 12.5 kg.

- Commercial and Industrial opening burning
  - The survey results have highlighted an issue with burning of 'business waste' by tradesman as a means of disposal. This would likely best reflect the construction industry proportion of the estimates.
  - Estimates for activity under this source have been maintained in the 2010 compilation cycle.

The revision of activity statistics for open burning has been applied across all years of the inventory, which matches the previous method. The quantity of material burned in the 2009 compilation cycle is quoted as 299 Kt for the UK in total per year. For this year's inventory cycle the quantity of waste burned is quoted as 144 Kt for the UK in total per year. The amendments applied during the current cycle will reduce the uncertainty in the estimates, although due to the disparate nature of the activity and highly variably nature of combustion mechanics and fuels, the estimates will seem have high uncertainty attached to them.

Sewage sludge spreading

The improvement programme carried out for POPs inventories including a sampling and analysis regime for PCB concentrations within sewage sludge. The key route of disposal for sewage sludge in the UK is via agriculture, with an increasing importance since the ban on dumping at sea was implemented. The emission of PCBs through volatisation to air and uptake by soil and biota was therefore a key area for review. Previous estimates for PCB emissions to air in the NAEI were based on a sampling and analysis programme carried out in 2000. The improvement programme was intended to repeat this study to update on current trends.

Samples were taken from a set of water treatment works with variety of core waste streams (urban, industrial and rural) and also during different seasons of the year, prior to clean-up and analysis by high resolution gas chromatography mass spectroscopy. The results of the study show a clear decline in the PCB concentrations seen in sewage sludge for 2010 compared to 2000; with 2010 concentrations approximately 10% of the 2000 value. The results have therefore been used to modify the emission factor applied to UK data. The emission factor applied to sewage sludge emissions (to air) will have a linear regression using 440 µg/kg in 2000 (previous study) down to 42 µg/kg in 2010 (current study). The activity statistics for sewage sludge have continued to use the same method of calculation as used in previous compilation cycles.

Non-ferrous metals

The improvement programme included a review of the non-ferrous metal sector; including a stakeholder exercise to review the generation of solid wastes and disposal routes under the requirement of the land vector in the Stockholm Convention. However it also reviewed the existing sources quoted within the NAEI and activity statistics which cover emissions to air. The results of this review identified a new source previously not included in the NAEI and amendment of activity data for two further sources.

A study by Jones K. and Lee R. (2003) reviewed the issue of dioxin and furans contamination of air pollution control (APC) residues (based on bag filters) from hot-dip zinc galvanising. The same study also discusses emissions to air and industry data to derive emission factors for emissions to air. This is quoted as 0.12 µg/tonne of product and has been applied to all years. Activity data for hot-dip galvanising is based on AEA estimates against available industry data.

Additionally the activity data for secondary aluminium and gray iron foundries has been updated to work more closely with the available data from the British Geographic Survey; previous estimates had used a static activity value for 2003 onwards. The new methodology applies AEA estimates and interpretation of the BGS data to more closely align the activity for these two sources against the BGS statistics.

13.2 FURTHER DISAGGREGATION OF NAEI SOURCES

In the 2010 inventory source categories were further disaggregated.

Table 13-1 Disaggregation of NAEI source categories

NFR code	Source Name	Activity Name	2009 NAEI source
1 A 2 b	Stationary Combustion in manufacturing industries and construction: Non-ferrous metals	All	1 A 2 f
1 A 2 c	Stationary combustion in manufacturing industries and construction: Chemicals	All	1 A 2 f
1 A 2 d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	All	1 A 2 f
1 A 2 e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	All	1 A 2 f

13.3 ROAD TRANSPORT

There have been a number of improvements made to the road transport inventory. 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.

Revised emission factors for NOx for all vehicle types (except motorcycles) and emission degradation methodology for light duty vehicles based on latest version of COPERT 4 (v8.1)
Use of Automatic Number Plate Recognition (ANPR) data and Regional Vehicle Licensing Statistics (DVLA) to define the petrol and diesel car mix by road type and by Devolved Administrations. The ANPR and DVLA data were also used to define fleet composition (in terms of age mix/ Euro standard) for cars, LGVs and HGVs.

Revised 2009 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development.

Removed previous assumptions made on the early uptake of Euro 4 petrol cars as these appear to have been overly optimistic. Their date of introduction is now based on the mandatory date set in the European emissions directive.
Assumptions on the split in vehicle km for HGVs by vehicle weight class have been updated using information provided by DfT's Road Freight Statistics. This is to improve how the emission factors for different HGV vehicle weight classes are utilised.

Updated the composition of bus fleet as operated by Transport for London (TfL)

Revised assumptions on how the London Low Emission Zone (LEZ) scheme affects emissions from HGVs. It was previously assumed that the LEZ for HGVs would affect all pollutants from 2008 onwards through increased uptake of newer vehicles; however, it is now assumed that only Particulate Matter (PM) emissions would be affected as vehicles are achieving the LEZ requirement via retrofit of particulate traps. Other pollutant emissions are assumed not to be affected by the scheme

Revised trip length for calculating cold start NH_3 emissions from petrol cars

Re-allocation of more petrol and DERV to off-road and inland waterways sectors across all years following a major review on the allocation of these fuels across a range of sectors described elsewhere in this report Annex. For 2009, an extra 89 kt petrol was re-allocated from road transport to off-road and inland waterways (0.5% of all petrol) and an extra 336 kt DERV was re-allocated from road transport to off-road and inland waterways (1.7% of all DERV). This re-allocation affects emissions calculated from fuel consumption.

More details on these methodology changes and recalculations are given in Section 5.4.

13.4 RAIL

Changes to the emissions inventory for rail stem from changes in activity data, namely fuel consumption from passenger and freight trains using new information from rail operators and regulators. Changes were also made to the time-series to bring consistency with train km statistics from rail regulators

13.5 NAVIGATION

Changes in shipping emissions result from a new method developed to estimate domestic emissions from inland waterways so that this sector could be included explicitly in the inventory for Waterborne Navigation for the first time. The method is based on a study on the population and activities of different classes of vessels. A revised estimate for international marine emissions is derived by difference between total fuel consumption statistics for marine fuels and fuel consumption by domestic coastal shipping and inland waterways. This affects estimates for shipping emissions across the time series.

13.6 OFF-ROAD

Minor revisions to the emissions for industrial off-road machinery were made due to the re-allocation of small quantities of road diesel with lower sulphur content to this sector in place of gas oil. This mainly affected SO_2 emissions.

13.7 PLANNED IMPROVEMENTS

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

<u>NFR 1A1A</u>

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

In the case of the single straw-burning plant, all report emissions are currently allocated to the straw. However the 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.

<u>1A1C</u>

Use of natural gas and other fuels by the oil and gas industry is split in the NAEI into a number of categories:

- 'Gas production – gas consumption' – consumption of natural gas and gas oil by the upstream gas industry. This sector covers offshore gas exploration and production facilities (including mobile drill rigs), and terminals handling gas from offshore production facilities.
- 'Oil production – gas consumption' – consumption of natural gas and gas oil by the upstream oil industry. This sector covers offshore oil exploration and production facilities (including mobile drill rigs), and terminals handling oil from offshore production facilities.
- 'Gas production – combustion at gas separation plant' – consumption of LPG and OPG by the upstream oil and gas industry, probably mainly at oil and gas terminals

- ‘Gas production’ – combustion of natural gas and other fuels by the downstream gas industry, primarily at compressor stations.

The use of these four source categories will be reviewed before the next version of the inventory, and they will be renamed and/or restructured as necessary to ensure clarity within the inventory.

NFR 2C1

Emissions from sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces, 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 believe 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.

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 2011 under the NECD reporting requirements.

Emission projections are also submitted under the CLRTAP every 5 years, with the latest dataset being provided in February 2012.

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 2009.

Table 14-1: The UK's final 2010 (as reported in 2012 LRTAP submission) and targets for 2010 that the UK is committed to.

Pollutant	Emissions in 2010 (kt)	Gothenburg Protocol target in 2010 (kt)	NECD Emissions ceiling target in 2010 (kt)	Reduction required between 2009 and 2010 Emissions ceiling target
NOx	1,106	1,181	1,167	N/A
SO2	406	625	585	N/A
NMVOCs	789	1,200	1,200	N/A
NH3	284	297	297	N/A

14.2 METHODOLOGY

The NAEI projection methodology broadly follows the methodology outlined in the EMEP/EEA 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:

$E_{2009} = A_{2009} * EF_{2009}$

where E = emission, A = activity and EF = emission factor, all for the year 2009.

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 2011) and CLRTAP (15th Feb 2012) 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 2012. Hence the finalised 2009 UK inventory is used as the base year. The 2009 data in the projections template are thus taken from the 2009 UK inventory submitted to CLRTAP in February 2011.

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 UEP43. UEP 43 projections include the impacts of climate change policies and measures where funding has been agreed and where decisions on planed policies are sufficiently advanced to enable robust estimates or their impacts. Firm and funded climate change policies include all these reflected in the March 2010 Budget[19] forecast and their associated savings, revised carbon and fossil fuel projections, revised Office for Budget Responsibility growth projections, revised cost estimates for the power sector and updated estimates of the impact of the package of policies set out in the Low Carbon Transition Plan[20] and the Household Energy Management Strategy[21] They do not include policies that are still under consideration, such as the policies drafted to meet the 4th Carbon budget. .

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. 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.

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19 http://www.direct.gov.uk/prod_consum_dg/groups/dg_digitalassets/@dg/@en/documents/digitalasset/dg_186437.pdf

20 http://www.decc.gov.uk/publications/basket.aspx?FilePath=White+Papers%2fUK+Low+Carbon+Transition+Plan+WP09%2f1_20090724153238_e_%40%40_lowcarbontransitionplan.pdf&filetype=4#basket

21 http://www.energyandutilities.org.uk/industry_news/content/766/decc_sets_out_its_household_energy_management_strategy

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: Policies feeding into UEP43

Sector	Baseline (pre LCTP)	UK LCTP (UEP38)	UK LCTP Proposals (UEP40)
Residential sector	EEC1& EEC2 (re-evaluated)	Household Energy Management Strategy	
	Building regulations (re-evaluated)	Products policy	
	Warm Front and fuel poverty programmes	DCLG Zero-carbon homes	
		Residential RHI	
Business/ Public sector	Building regulations (re-evaluated)	Products policy	Energy-intensive industry (new CCAs)
	Carbon Trust measures total	Energy Performance of Buildings Directive	
	Climate Change Agreement (excluding overlaps)	Smart meters (SME)	
	Revolving loan	Carbon Reduction Commitment	
		RHI	
Industry	Building regulations (re-evaluated)		
	Carbon Trust measures total		
Transport	RTFO savings (5% by volume)	Interim Voluntary Agreement target to 130g/km CO_2	EU 95gCO_2/km for 2020 target
	EU Voluntary Agreements on new car CO2 to 2009, including supporting fiscal measures	RES Transport bio-fuel (from 5% volume to 10% by energy)	Complementary measures for cars
		Low carbon buses	Possible new EU van regulation
		SAFED bus driver training	Low rolling resistance tyres for HGVs
			Electricification of 750km of rail line
Agriculture & Waste		Landfill tax (non-CO_2)	Defra Agriculture policy (non-CO_2)
			Defra Waste policy (non-CO_2)

Source: UEP40 (2010)

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 UEP43) 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"[22] analysis of UEP43 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:

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

- 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.

15. References

AEA Technology (2002), Atmospheric Emissions from Small Carcass Incinerators, Report produced for the Department for Environment, Food and Rural Affairs by AEA Technology Environment, Culham Science Centre, Abingdon, Oxon. OX14 3ED, August 2002. Report AEAT/ENV/R/0920. http://www.airquality.co.uk/archive/reports/cat07/aeat-env-r-0920.pdf

AEA Technology (2005), Local Authority Waste Recycling, Recovery and Disposal (LAWRRD) model user guide. Report for the UK Department of Environment, Food and Rural Affairs prepared by AEA Technology, July 2005.

AEA (2011), UK Greenhouse Gas Inventory, 1990 to 2009. Annual Report for Submission under the Framework Convention on Climate Change prepared by AEA Technology, March 2011.

AQEG (2005). Particulate Matter in the United Kingdom. Report of the Air Quality Expert Group to Defra and Scottish Executive; Welsh Assembly Government; and Department of the Environment in Northern Ireland, 2005. http://www.defra.gov.uk/environment/quality/air/airquality/publications/particulate-matter/documents/contents.pdf

Aitchison EM, Milton MJT, Wenborn MJ, Meadows MP, Marlowe IT, Mikkelsen M, Harries C and Pocock R. (1996). A methodology for updating routinely the annual estimate of methane emissions from landfill sites in the UK. ETSU report number EPG/1/1/20, Energy Technology Support Unit, Harwell.

Barlaz *et al* (1997), Biodegradative analysis of municipal solid waste in laboratory scale landfills. Prepared for US Environmental Protection Agency Office of Research and Development, Washington DC 20460. Report EPA-600/R-97-071. USEPA, Washington DC.

Barlow, TJ, Hickman, AJ & Boulter, P (2001), Exhaust Emission Factors 2001: Database and Emission Factors, TRL Report PR/SE/230/00, September 2001

Barlow, TJ and PG Boulter (2009). Emission Factors 2009: Report 2 – a Review of the Average Speed Approach for Estimating Hot Exhaust Emissions. TRL Report PPR335 prepared for DfT, June 2009. http://www.dft.gov.uk/pgr/roads/environment/emissions/report-2.pdf

BCA (2010). British Cement Association, UK cement clinker production, emissions, and fuel consumption data, Personal Communication (Richard Leese).

Boulter, PG (1996), Factors Affecting Cold-Start Emissions: A Review, Transport Research Laboratory Report, PR/SE/183/96, September 1996.

Boulter PG, TJ Barlow and IS McRae (2009). Emission Factors 2009: Report 3 - Exhaust Emission Factors for Road Vehicles in the UK. TRL Project Report PPR 356, June 2009. http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-3.pdf

Boulter PG and S Latham (2009). Emission Factors 2009: Report 4 – A Review of Methodologies for Estimating Cold Start Emissions. TRL Project Report PPR 357, June 2009. http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-4.pdf

BR (1994), Research Report "Determination of Diesel Exhaust emissions on British Rail" Jan 1994

British Cement Association (2008), UK cement clinker production, emissions, and fuel consumption data, Personal Communication (Richard Leese).

British Coatings Federation (2008), UK production data, Personal Communication.

British Geological Survey (2010), UK Minerals Yearbook 2009

British Glass (2008), UK glass production and recycling data in 2007, Personal Communication (Rebecca Cocking).

British Rubber Manufacturers Association (2001), Personal Communication, September 2001

CAA (2010), UK Airport Statistics: 2009 – annual http://www.caa.co.uk/default.aspx?catid=80&pagetype=88&sglid=3&fld=2009Annual

Carslaw, D., Beevers, S., Westmoreland, E., Williams M., Tate, J., Murrells, TP., Stedman, J., Li, Y., Grice, S., Kent, A and Tsagatakis I (2011) Trends in NOx and NO2 emissions and ambient measurements in the UK. Report prepared for Defra, July 2011. http://uk-air.defra.gov.uk/reports/cat05/1108251149_110718_AQ0724_Final_report.pdf

CLG (Commmunities and Government) (2010), Table 401, Household projections, United Kingdom, 1961-2033 http://www.communities.gov.uk/housing/housingresearch/housingstatistics/housingstatisticsby/householdestimates/livetables-households/

CONCAWE (1987), "An Investigation into Evaporative Hydrocarbon Emissions from European Vehicles", Report 87/60.

CONCAWE (1990), "The Effects of Temperature and Fuel Volatility on Vehicle Evaporative Emissions", Report 90/51.

CIS (1991), Chem-Facts UK, Chemical Intelligence Services, Reed Telepublishing, Dunstable, Beds, UK.

Corus (2005), Personal Communication, Mick Briggs

Corus (2010), Site-specific breakdown of pollutant emissions, by source. Personal Communication, Peter Quinn

CSIRO (2005). Article "Metal Technologies: A Green Winner". Solve, Journal of the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). Issue 3, May 05. http://solve.csiro.au/0505/article1.htm

DECC (2011), Digest of United Kingdom Energy Statistics 2011, London, The Stationery Office.

DECC Oil & Gas (2010), Environmental Emissions Monitoring System. Oil & gas installation emissions dataset, Personal Communication (Ian Furneaux).

Defra (2008), Expenditure and Food Survey Report

Defra (2004), The National Food Survey 1990-03

DETR (1996a), data from "Continuous Survey of Road Goods Transport" communication, June 1996.

DETR (1998), Personal Communication from Dr T McMullen

DETR (1998a), Data from National Travel Survey, Transport Statistics communication, March 1998.

DETR (2000), Transport, Environment and Taxation Division communication (A Short), November 2000.

DfT (2001), New Car Fuel Consumption and Emission Figures, Vehicle Certification Agency, July 2001

DfT (2004), Transport, Environment and Taxation Division communication (C Parkin), February 2004

DfT (2007a), Road Statistics 2006: Traffic, Speeds and Congestion, Transport Statistics Bulletin SB(07) 20, 2007

DfT(2007b), National Travel Survey: 2006, Transport Statistics Bulletin, SB(07) 21, 2007

DfT (2008a), English Regional Traffic Growth and Speed Forecasts, Rev 1.1 April 2008, personal communication with Malcolm Jay, ITEA Division, DfT, April 2008

DfT (2008b), personal communication with Nick Barter, DfT, April 2008.

DfT (2008c), Transport Statistics Report, Maritime Statistics 2007. Department for Transport. Available from http://www.dft.gov.uk/pgr/statistics

DfT (2009a), personal communication with Annie Sorbie, Transport Statistics, DfT, November 2009

DfT (2009b), Transport Statistics Great Britain: 2009 edition, The Stationery Office. http://www.dft.gov.uk/pgr/statistics/datatablespublications/tsgb/

DfT (2009c), personal communication with Chris Parkin, Cleaner Fuels and Vehicles, Transport Statistics, DfT, March 2009

DfT (2010a), personal communication with Mike Dark, Vehicle Licensing Statistics, Department for Transport

DfT (2011a), Road Freight Statistics 2010, October 2011 Release, Department for Transport. http://www.dft.gov.uk/statistics/releases/road-freight-statistics-2010/

DfT (2011b), personal communication with Stephen Smith, Bus Service Operators Grant system, DfT, September 2011

DfT (2011c), Transport Statistics Great Britain 2011: Roads and traffic, December 2011 Release, Department for Transport. http://www.dft.gov.uk/statistics/releases/tsgb-2011-roads-and-traffic/

DfT (2011d), personal communication with Daryl Lloyd, Vehicle Licensing Statistics, Department for Transport, March 2011

DfT (2011e), Vehicle Licensing Statistics: 2011, April 2011Release, Department for Transport. http://www.dft.gov.uk/statistics/releases/vehicle-licensing-statistics-2010/

DOE (1994), UK Sewage Sludge Survey, CES Limited, HMSO.

DRDNI (2010a), "Traffic and Travel Information Report, 2009, Incorporating Annual Traffic Census and Vehicle Kilometres of Travel" Traffic Information and Control, Department for Regional Development, Northern Ireland, August 2010

DRDNI (2010b), personal communication with Leah Ginn, Central Statistics and Research Branch, Department for Regional Development, Northern Ireland, October 2010

DRDNI (2010c) "Northern Ireland Transport Statistics 2009-10", Department for Regional Development, Northern Ireland, 2010.
http://www.drdni.gov.uk/ni_transport_statistics_2009-10.pdf

DRDNI (2011a), personal communication with David Compston, Traffic Information and Control, Department for Regional Development, Northern Ireland, October 2011

DRDNI (2011b), personal communication with Leah Ginn, Central Statistics and Research Branch, Department for Regional Development, Northern Ireland, September 2011

DTI (2003), Energy White Paper, London, The Stationery Office.

Dragosits U and Sutton M (2004), Emission Estimates from Natural and Waste sources in the UK. Report provided under contract with AEA.

Drax Power Ltd, Application for a variation to the Integrated Pollution Control Authorisation AA2488 at Drax Power Station, Selby, and North Yorkshire for the use of coal blended with petroleum coke, April 2006

EA (2011), http://www.environment-agency.gov.uk/business/topics/pollution/32254.aspx

EEA (2000), COPERT III: Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors (Version 2.1), L. Ntziachristos and Z Samaras, European Topic Centre on Air Emissions, European Environment Agency, November 2000

EEA (2007), EMEP/EEA Emission Inventory Guidebook – 2007. Technical report No 16/2007. Group 7 – Road Transport, European Environment Agency August 2007. http://www.eea.europa.eu/publications/EMEPCORINAIR5/B710vs6.0.pdf http://www.eea.europa.eu/publications/EMEPCORINAIR5/B760vs4.0.pdf

EEA (2009). EMEP/EEA air pollutant emission inventory guidebook – 2009. Technical report No 9/2009. 1,A.3.b.vii Road surface wear, European Environment Agency June 2009. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-vi-road-tyre-and-brake-wear.pdf

EEA (2010), EMEP/EEA Emission Inventory Guidebook – 2009. Part B: sectoral guidance chapters, 1.A.3.b Road transport updated June 2010. European Environment Agency. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

EMEP (1990), European Monitoring and Evaluation Programme. Proceedings of the EMEP Workshop on Emissions from Ships. State Pollution Control Authority, Norway.

EMEP/CORINAIR (1996), Atmospheric Emission Inventory Guidebook, 1st Edition, ed. G McInnes.

EMEP/CORINAIR (1999), Atmospheric Emission Inventory Guidebook, 2nd Edition, ed. S Richardson.

EMEP/CORINAIR (2003), Atmospheric Emission Inventory Guidebook, 3rd Edition.

EMEP/EEA (2007), Atmospheric Emission Inventory Guidebook.

EMEP/EEA (2009). http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

EMEP (2009b). EMEP/EEA air pollutant emission inventory guidebook — 2009. Part B, Section 1A4 Other Mobile. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-other-mobile-tfeip-endorsed-draft.pdf

Entec (2002), Quantification of emissions from ships associated with ship movements between ports in the European Community", Report for European Commission, DG ENV. Belgium; Main Contributors Chris Whall, Karen Archer, Layla Twigger, Neil Thurston, David Ockwell, Alun McIntyre, Alistair Ritchie (Entec) and David Cooper (IVL).

Entec (2005). Service Contract on Ship Emissions: Assignment, Abatement and Market-based Instruments. Task 1 - Preliminary Assignment of Ship Emissions to European Countries. Final Report to European Commission Directorate General Environment, Entec UK Limited, August 2005. http://ec.europa.eu/environment/air/pdf/task1_asign_report.pdf

Entec (2010). UK Ship Emissions Inventory. Final Report to Defra, November 2010. http://uk-air.defra.gov.uk/reports/cat15/1012131459_21897_Final_Report_291110.pdf

Environment Agency (2010), Pollution Inventory.

European Environment Agency (1997), COPERT II: Computer Programme to Calculate Emissions from Road Transport - Methodology and Emission Factors, P Ahlvik et al, European Topic Centre on Air Emissions, European Environment Agency, April 1997.

Gregory, B, (2002), Landfill Gas Engine Exhaust and Flare Emissions, Land Quality Management Ltd

Hawkins & Coad (2004), Personal communication. John Hawkins & Nick Coad from the Association of Train Operating Companies (ATOC)

Hickman, AJ (1998), Transport Research Laboratory, communication, February 1998.

HMRC (2011), HM Revenue & Customs Hydrocarbon Oils Bulletin, Summary of Quantities Released for Consumption (2011) https://www.uktradeinfo.com/index.cfm?task=bulloil

IC Consultants (2000). Atmospheric Emissions of particulates from agriculture: a scooping study. Final Report for the Ministry of Agriculture, Fisheries and Food (MAFF), Research and Development, London UK. (Note: MAFF has now been incorporated into Defra).

IPCC (1997a), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 1, Greenhouse Gas Inventory Reporting Instructions, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997b), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 2, Greenhouse Gas Inventory Workbook, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (1997c), IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, Volume 3, Greenhouse Gas Inventory Reference Manual, IPCC WGI Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK.

IPCC (2000), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, ed. Penman, J, Kruger, D, Galbally, I, *et al*, IPCC National Greenhouse Gas Inventories Programme, Technical Support Programme Technical Support Unit, Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan.

Jones K. and Lee R. (2003) Report on PCDD/Fs in samples of bag dust collected from galvanising plants in the United" Report on behalf of Defra.

KH (1993), Notes on the Assessment of the Emissions of Off-Road Mobile Machinery in the European Community.

Latham, S and Boulter PG (2009). Emission Factors 2009: Report 7 – a Review of the NAEI Methodology for Modelling Evaporative Emissions. TRL Project Report PPR 360 (Version 3), May 2009. http://www.dft.gov.uk/pgr/roads/environment/emissions/report-7.pdf

Leese (2008). British Cement Association, UK cement clinker production, emissions, and fuel consumption data, Personal Communication (Richard Leese).

LRC (1998), London Research Centre, UK Emission Factor Database.

LT Buses (1998), "Buses: A Cleaner Future. Bus Emissions and Air Quality in London", London Transport Buses Report, 1998.

Metal Packing Manufacturers Association (MPMA) (2000), Personal Communication.

Misselbrook, T.H., Webb, J. and Gilhespy, S.L. (2006). Ammonia emissions from outdoor concrete yards used by livestock – quantification and mitigation. Atmospheric Environment 40, 6752-6763.

Misselbrook, T.H., Sutton, M.A. and Scholefield, D. (2004). A simple process-based model for estimating ammonia emissions from agricultural land after fertilizer applications. Soil Use and Management 20, 365-372.

Misselbrook, T. H., Smith, K. A., Johnson, R. A. and Pain, B. F. (2002). Slurry application techniques to reduce ammonia emissions: Results of some UK field-scale experiments. Biosystems Engineering 81, 313-321.

Misselbrook, T. H., Webb, J., Chadwick, D. R., Ellis, S. and Pain, B. F. (2001). Gaseous emissions from outdoor concrete yards used by livestock. Atmospheric Environment 35, 5331-5338.

Misselbrook, T. H., Pain, B. F. and Headon, D. M. (1998). Estimates of ammonia emission from dairy cow collecting yards. Journal of Agricultural Engineering Research 71, 127-135.

Misselbrook (2011). Inventory of ammonia emissions from UK agriculture 2010. Inventory submission report, September 2011. DEFRA Contract AC0112.

MMO (2009) UK Sea Fisheries Statistics 2009, Marine Management Organisation. http://marinemanagement.org.uk/fisheries/statistics/annual.htm

van der Most, P. F. J. & Veldt, C., Emission Factors Manual PARCOM-ATMOS, Emission Factors for Air Pollutants, TNO report No 92-235, December 1992

MoD (2005a), Defence Fuels Group, SO3 Aviation Fuel, Personal Communication (Patrick Gedge)

MoD (2009), personal communication with Kevin Pitt, Safety, Sustainable Development and Continuity Division , Defence Fuels Group, MoD, October 2009.

MoD (2010), personal communication with Kevin Pitt, Safety, Sustainable Development and Continuity Division, Defence Fuels Group, MoD, October 2010.

MoD (2011), personal communication with Jon Freeman, Sustainable Procurement Strategy Assistant Head, MoD, September 2011

Munday, PK (1990) UK Emissions of Air Pollutants 1970-1988, Warren Spring Laboratory, LR 764.

MoD (2011), personal communication with Jon Freeman, Sustainable Procurement Strategy Assistant Head, MoD, September 2011

Murrells, TP and Y Li (2008), "Road Transport Emissions from Biofuel Consumption in the UK", AEA Report for Defra and the Devolved Administrations, AEAT/ENV/R/2662, July 2008

Murrells T, John Norris, Glen Thistlethwaite, Neil Passant, Helen Walker, Nikki Webb (2011). Definitions of Gas Oil and DERV and Allocations to Sectors in the UK Greenhouse Gas Inventory. AEA Report for DECC under Task 5 of the 2011 UK GHG Inventory Improvement Programme. AEAT/ENV/R/3234, November 2011

National Rail Trends Year Book (2010). http://www.rail-reg.gov.uk/upload/pdf/nrt-yearbook-2009-10.pdf

Netcen (2004a), (Netcen is now known as AEA) "Non-Road Mobile Machinery Usage, Life and Correction Factors", Report to the Department for Transport, AEAT/ENV/R/1895, November 2004, www.airquality.co.uk/archive/reports/reports.php?report_id=304

Netcen (2004b), (Netcen is now known as AEA) "Emission factors programme Task 8c – emissions from non-road mobile machinery in the lawn and garden sector", Report to Defra, AEAT/ENV/R/1719, April 2004.

Northern Ireland Environment Agency (2010). Inventory of Statutory Releases 2009, Personal Communication (David Bell).

NSAA (2003), Sulphuric acid plant emissions data for 2002, Personal Communication

Off Highway Research Ltd (2000), International Database Service, March 2000Passant, N R (2003/4), Emission factors programme: Task 1 – Summary of simple desk studies, AEA Technology Plc, Report No AEAT/ENV/R/1715/Issue 1.

ONS (1995), UK Defence Statistics, 1994, Office for National Statistics.
Ogilvie, SM (1995), Opportunities and Barriers to Scrap Tyre Recycling, National Environmental Technology Centre, AEA/CS R1026/C, ISBN 0 856248647.

ONS (2002), National Statistics Code of Practice

Office of National Statistics (2009), Index of Production, Population Statistics and Prodcom data for 1990-2007, www.statistics.gov.uk

Office of National Statistics (2010) Construction Statistics Annual 2010
http://www.statistics.gov.uk/downloads/theme_commerce/CSA-2010/Opening%20page.pdf

Passant, NR (1993), Emissions of Volatile Organic Compounds from Stationery Sources in the UK: A review of Emission Factors by Species and Process (September 1993 Update), Warren Spring Laboratory, LR 990.

Passant NR (2002b), Estimation of Uncertainties in the National Atmospheric Emissions Inventory. AEA Technology. Report No. AEAT/ENV/R/1039 Draft.

Pearce et al. (1993). Externalities from Landfill and Incineration, CSERGE, Warren Spring Laboratory and EFTEL

PRI (1995), Communication from Precision Research International.

PRI (1998), Communication from Precision Research International. Samaras, Z & Zierock,

Rudd, HJ, Mikkelsen, M, (1996), Emissions of Volatile Organic Compounds from Ship Purging in the UK, AEA Technology Plc, Report No AEAT/20034001/REMA-208/Issue 2.

Samaras Z & Zierock KH (1993). Notes on the assessment of the emissions of off-road mobile machinery in the European Community.

Samaras, Z & Zierock, KH, (1994), Supplement to above.

Samaras, Z (1996), Personal Communication.

Scotch Whisky Association (2008), Statistical Report 2007.

SMMT (1999), Society of Motor Manufacturers and Traders, communication, November 1999.

SEPA (2010), Scottish Pollutant Release Inventory, Scottish Environment Protection Agency, Personal Communication (Bob Boyce).

Sheppard, A. (1998) The Structure of Pig Production in England and Wales. Results of the National Survey of Pig Production Systems. Special Studies in Agricultural Economics Report No. 40, University of Exeter.

Smith, K. A. and Chambers, B. J. (1995). Muck from waste to resource - utilization: the impacts and implications. Agricultural Engineer, 50, 33-38.

Smith, K. A. and Frost, J. P. (2000). Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 1: cattle and sheep. Bioresource Technology 71, 173-181.

Smith, K. A., Charles, D. R. and Moorhouse, D. (2000a). Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 2: pigs and poultry. Bioresource Technology 71, 183-194.

Smith, K. A., Jackson, D. R., Misselbrook, T. H., Pain, B. F. and Johnson, R. A. (2000b). Reduction of ammonia emission by slurry application techniques. Journal of Agricultural Engineering Research 77, 277-287.

Smith, K. A., Brewer, A. J., Dauven, A. and Wilson, D. W. (2000c). A survey of the production and use of animal manures in England and Wales. I. Pig manure. Soil Use and Management 16, 124-132.

Smith, K. A., Brewer, A. J., Crabb, J. and Dauven, A. (2001a). A survey of the production and use of animal manures in England and Wales. II. Poultry manure. Soil Use and Management 17, 48-56.

Smith, K. A., Brewer, A. J., Crabb, J. and Dauven, A. (2001b). A survey of the production and use of animal manures in England and Wales. III. Cattle manures. Soil Use and Management 17, 77-87.

Stewart & Walker (1997), Emissions to Atmosphere from Fossil Fuel Power Generation in the UK, AEAT-0746, January 1997

Stewart, R. (2002), Atmospheric Emissions from Small Carcass Incinerators, AEA report AEAT/ENV/R/0920/issue 3, 2002

Stewart, R, Murrells T and Li Y (2009). Improving the treatment of evaporative emissions in the road transport inventory. NAEI Report for Defra. April 2009.

The Cremation Society of Great Britain (2007), National Cremation Statistics 1960-2006, http://www.srgw.demon.co.uk/CremSoc4/Stats/

The National Household Waste Analysis Project (1994), Phase 2, Volume 3, Chemical Analysis data, Report CWM087/94.

TRL (1993), Evaporative Emissions from Petrol Fuelled UK Light Duty In-Service Vehicles, TJ Barlow, Transport Research Laboratory Report PR/ENV/022/93.

TSO (2009), Annual Abstract of Statistics, 2009.

UKPIA (1989), United Kingdom Petroleum Industry Association, Personal Communication.

UKPIA (2004), United Kingdom Petroleum Industry Association, Malcolm Watson communication on properties of UK fuels in 2004 (and correspondence in earlier years).

UKPIA (2005), Refinery production & emissions data, carbon emission factors, petroleum products data from the United Kingdom Petroleum Industry Association, Personal Communication (Ian McPherson, & Malcolm Watson)

UKPIA (2011), United Kingdom Petroleum Industry Association, Hugh Tucker communication on properties of UK fuels in 2010.

US EPA (1988), Second Supplement to the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-89-018. pp TO-13 to TO-97.

US EPA (1997), United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors, Vol 1, 5th Edition, AP-42, North Carolina.

US EPA (2009), Compilation of Air Pollutant Emission Factors, AP-42, via the internet at: www.epa.gov, 2009

Walker et al., (1985). Survey of nitrogen oxides, carbon monoxide and hydrocarbon emissions from industrial and commercial boilers in Scotland. Warren Spring Laboratory, LR 524.

Walker, H., Chris Conolly, John Norris and Tim Murrells. Greenhouse Gas Emissions from Inland Waterways and Recreational Craft in the UK. AEAT/ENV/R/3175, Task 25 of the 2010 DA / UK GHG Inventory Improvement Programme, June 2011. http://uk-air.defra.gov.uk/reports/cat07/1106231031_IP_Task_25_Inland_Waterways_Issue_1.pdf

Watterson, JD, Walker, C and Eggleston, S (2004) Revision to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory. Report to Global Atmosphere Division, UK Defra. Report number ED47052, July 2004. Netcen, The Gemini Building, Harwell, Didcot, Oxfordshire, OX11 0QR, UK.

Webb, J., and Misselbrook, T. H. (2004). A mass-flow model of ammonia emissions from UK livestock production. Atmospheric Environment 38, 2163-2176.

WS Atkins, Mercury Containing Products, Report for the UK Department of the Environment, Transport and the Regions, December 1997

Zachariadis, Th. & Samaras, Z, (1997), Int. J. of Vehicle Design, 18, 312.

Appendix 1

Treatment of Gas Oil in the inventory
Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but with high uncertainty and DUKES is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

The inventory estimates consumption of gas oil and emissions for off-road machinery using a bottom-up method based on estimates of population and usage of different types of machinery. However, this has led to a situation where the total amount of gas oil consumption across sectors exceeds that which is available as given in DUKES. Therefore consumption figures, mainly for stationary combustion in industry sectors, have had to be adjusted to obtain a total fuel balance.

The problem is extended when new sources of gas oil consumption are found. For example, the recent development of an inventory for the UK's inland waterways requires the allocation of gas oil to this sector (Walker et al, 2011). During the process of compiling the inland waterways inventory, it became clear that not all vessels with diesel engines use gas oil, but use road diesel (DERV) and that this may also be the case for other off-road machinery sources, especially those that consume small amounts of fuel on an irregular basis, e.g. for private or recreational use rather than commercial use. There are also inconsistencies in terminology used to define types of fuel; it became apparent that the terms "gas oil", "red diesel" and "diesel" are used interchangeably by fuel suppliers and consumers and this confuses the situation when considering fuel allocations across different sectors.

In light of this, a task was undertaken as part of the 2011 UK GHG Inventory Improvement Programme aimed to address the allocation of gas oil and DERV in the GHGI (Murrells et al., 2011). The methodology outlined in Murrells et al. (2011) has been used in the compilation of the 2010 inventory, and is summarised here.

Several fuel suppliers and experts in the petroleum industry and at the Department for Transport were consulted to understand terminologies used, the physical differences between gas oil and DERV, and to gauge opinions on what determines where the fuels are mainly used where it is possible to use either gas oil or DERV. The study concluded that while the majority of agricultural and industrial machinery will be using low tax gas oil (red diesel), a small amount of DERV is likely to be used by private recreational boat users and by equipment with small engines used for private or small-scale commercial use on an irregular basis and the gas oil fuel supply infrastructure makes it more convenient to use DERV.

The study provided new estimates of the amount of DERV and petrol consumed by non-road transport sources with small internal combustion engines. This reduces the overestimation of gas oil consumption and relieves the pressure on how much gas oil consumption by other sources has to be adjusted to match the total amount available as given in DUKES.

The study also considered the allocation of gas oil given in DUKES to different industry and other sectors and how these can be mapped to inventory reporting categories. The detailed bottom-up method is used to estimate gas oil consumption by different off-road machinery and marine vessel types. Independent sources were used to estimate gas oil used by the rail sector while data provided by industrial sites reporting under emission trading schemes (EU-ETS) were used to derive an allocation of gas oil consumption by stationary combustion sources in different industry, commercial and other sectors. Also, the UK energy statistics now include an allocation of gas oil for consumption by the oil and gas sector, but since only a partial time series was made available, the study included making estimates of gas oil for this category back to 1990.

A method of re-allocation was developed using an over-arching condition that the total sum of gas oil consumption across all sectors was consistent with the total consumption figures given in DUKES across all years. The method allowed the consumption estimates for industrial off-road machinery and stationary combustion by industry, commercial and public sector activities to vary in order to align the total consumption estimates with DUKES on the basis that the estimates for these sources are the most uncertain.

The work led to revisions in allocations of fuel consumption and emissions across the time series, as outlined below:

- A revised estimate of the amount of DERV used to power small off-road machinery;
- An estimate of the amount of gas oil, DERV and petrol used to power vessels on inland waterways;
- An overall, revised figure of 0.35 Mt of DERV and 0.35 Mt petrol used by non-road transport emission sources, representing 1.7% and 2.2% of all DERV and petrol consumed in the UK, respectively, in 2009.
- The allocation of gas oil to inland waterways led to a re-evaluation of gas oil used across different marine sectors, leading to a re-assignment of 0.132 Mt of gas oil previously assigned to international shipping to domestic UK marine activities in 2009. This increases the emissions assigned to domestic marine activities (shipping, fishing, naval and inland waterways) that are included in the UK totals and reduces the amount allocated to the international bunkers as a Memo Item.
- A revised allocation of gas oil consumption across all inventory sectors, including that used for stationary combustion in industry and the public sector, consistent with EU-ETS data and consumption by off-road machinery for all years between 1990 and 2010.

Table A1 shows the revised allocation of gas oil in the inventory between 1998 and 2010. Further details of the re-allocation are given in the inventory improvement report by Murrells *et al* (2011). The report considers the uncertainties in the sector allocations and makes recommendations on how these can be improved based on current activities known to be taking place in the UK to understand the allocation of gas oil across some sectors.

Table A1 Allocation of gas oil consumption to sectors in the 2010 inventory

Mt		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electricity generation		0.069	0.071	0.144	0.033	0.045	0.044	0.092	0.178	0.213	0.089	0.089	0.080	0.050
Cement		0.011	0.011	0.011	0.013	0.014	0.009	0.009	0.011	0.009	0.004	0.010	0.007	0.007
Oil and gas extraction		0.525	0.497	0.480	0.511	0.488	0.460	0.427	0.475	0.430	0.404	0.472	0.450	0.490
Marine	Inland waterways	0.099	0.098	0.099	0.097	0.098	0.098	0.100	0.102	0.103	0.104	0.103	0.097	0.099
	Naval	0.270	0.297	0.291	0.267	0.243	0.273	0.302	0.271	0.265	0.274	0.271	0.270	0.275
	Fishing	0.005	0.004	0.004	0.004	0.004	0.004	0.005	0.005	0.004	0.004	0.004	0.004	0.004
	Domestic shipping	0.181	0.181	0.169	0.163	0.170	0.166	0.168	0.172	0.163	0.388	0.378	0.359	0.341
	International shipping	1.824	1.481	1.489	1.645	1.233	1.440	1.343	1.258	1.686	1.073	0.929	0.925	0.862
Rail		0.503	0.504	0.504	0.528	0.539	0.546	0.569	0.581	0.580	0.594	0.604	0.601	0.610
Stationary combustion	Domestic	0.191	0.161	0.147	0.193	0.202	0.163	0.160	0.141	0.171	0.173	0.164	0.131	0.165
	Iron and steel	0.017	0.018	0.008	0.007	0.007	0.009	0.008	0.012	0.011	0.006	0.004	0.003	0.004
	Miscellaneous industrial/commercial	0.193	0.138	0.136	0.145	0.089	0.080	0.076	0.129	0.090	0.065	0.051	0.045	0.048
	Other industrial combustion	0.947	0.655	0.747	0.738	0.346	0.373	0.356	0.635	0.268	0.147	0.097	0.082	0.095
	Public sector	0.262	0.170	0.165	0.148	0.065	0.042	0.047	0.100	0.061	0.037	0.025	0.022	0.025
Off-road machinery	Industrial	2.084	2.084	2.084	2.089	2.093	1.984	2.001	2.151	1.970	2.136	1.986	1.573	1.538
	Agriculture&Forestry	1.428	1.400	1.359	1.336	1.331	1.321	1.250	1.264	1.177	1.130	1.113	1.140	1.148
	Airports	0.099	0.105	0.112	0.113	0.117	0.124	0.134	0.142	0.146	0.150	0.146	0.138	0.133
Non-energy use		0.760	0.844	0.936	0.411	0.205	0.287	0.249	0.229	0.259	0.238	0.201	0.143	0.142