UK Informative Inventory Report (1970 to 2008)

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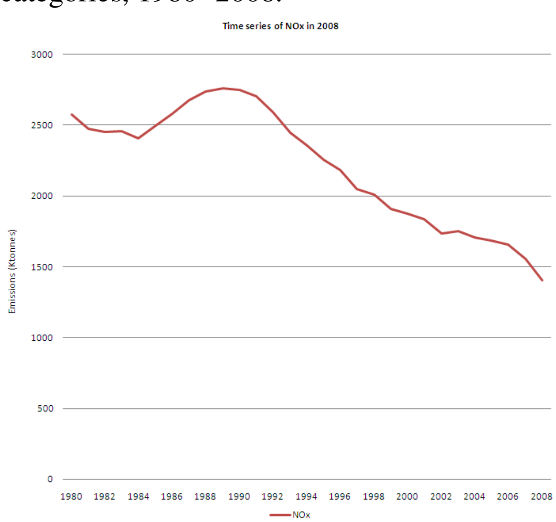
Executive Summary

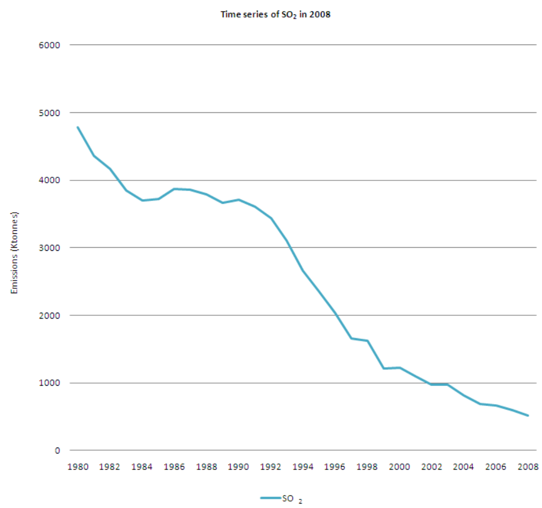
This 2008 IIR is the 5th Informative Inventory Report (IIR) from the UK National Atmospheric Emissions Inventory (NAEI) team. The report is compiled to accompany the UK's 2010 data submission under the UN/ECE under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and contains detailed information of the NAEI at the date of publication.

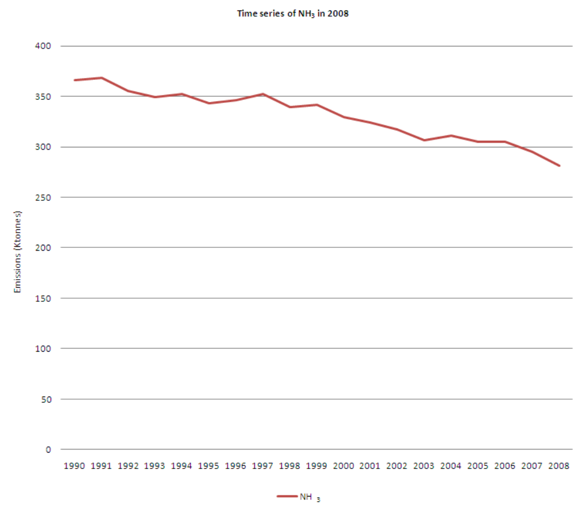
Estimates of emissions of nitrogen oxides, carbon monoxide, ammonia, sulphur dioxide, NMVOC, persistent organic pollutants and heavy metals between 1980 and the most recent inventory are submitted to the CLRTAP. As part of the commitments to the CLRTAP, countries are also required to submit emission projections for selected pollutants (under the Gothenburg Protocol). Selected pollutants under the CLRTAP are also covered under the Directive 2001/81/EC of the European Parliament and the Council on National Emissions Ceilings (NECD) which sets upper limits for each Member State for the total emissions in 2010. Under the NECD the UK submits the emissions for the previous five years and 2010 projections for Nitrogen Oxides (NO_x), Sulphur Dioxide (SO_x), Non-Methane Volatile Organic Compounds (NMVOC) and Ammonia (NH_3). These emission projections are compiled and reported as part of the UK inventory programme. In addition to the pollutants listed above, the NAEI compiles the Greenhouse Gas (GHG) inventory for the six gases covered under the UN Framework Convention on Climate Change (UNFCCC).

In the UK, NH_3 emission estimates are not made for the years prior to 1990, as there is insufficient data from industrial sources. This is currently being addressed. In addition, the UK does not make estimates of Total Suspended Particulate (TSP) as UK legislation uses the sub-10 micron Particulate Matter (PM_{10}) and sub-2.5 micron Particulate Matter ($PM_{2.5}$) metrics. There are currently no plans to address this.

Figure ES-1 Time series of NO_x, SO_x, NMVOC and NH_3 emissions from key source categories, 1980- 2008.







Reduction in the headline pollutants between 1980-2008 are summarised in the table below:

Table ES-1 Summary of % change in emissions between 1980 and 2008

Pollutant	% Change from 1980 to 2008
NO_x	-45.5%
SO_x	-89.3%
NH_3[1]	-23.1%
NMVOC	-54.2%
CO	-65.9%
PM_{10}	-59.5%

In principle, the emissions inventory attempts to make estimates of all known emissions to air, at as high a level of disaggregation as is possible. However, in accordance with international guidelines on emissions inventory reporting, there are a number of known sources that are excluded from the inventory emission estimates:

- Natural sources are not included in the national totals (although estimates of some sources are made)
- The inventory is a primary emissions inventory (as per international guidelines). Consequently resuspension of e.g. particulate material is not included in the national totals (although estimates for some resuspension terms are made).
- Cruise emissions from civil and international aviation are not included in the national totals.
- Natural sources and cruise emissions from civil and international aviation are not included in the national totals (although estimates of some sources are made).
- Estimates of "International" emissions such as shipping are made, and reported as memo items (excluded from the UK national totals).
- GHG emissions associated with short-term changes to the carbon cycle are not included within national inventory totals; whilst this is not of particular concern here, the principle is extended to other pollutants.

[1] NH3 emissions form 1990 to 2008

The national totals reported for the UK in the CLRTAP and the UNFCCC submissions differ, as the sources and territories included in the national totals differ under the CLRTAP and the UNFCCC reporting guidelines. For NECD and CLRTAP the submission totals match. The UNECE has revised the official inventory reporting template, and hence the NFR codes in the UK Inventory are disaggregated to a greater level of detail for some sources in the 2010 submission. Estimated emissions are allocated to the corresponding NFR codes. There are no 'IE' (Included Elsewhere) notation keys in the 2010 submission.

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 2008;
- Outline the latest emission projections for National Emission Ceiling Directive air quality pollutants, to 2010;
- Explain the methodologies used to compile the inventories, including a brief summary of the projections methodology;
- Provide supporting information pertinent to the LRTAP 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 LRTAP 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 LRTAP submission. The latest 2008 activity data, emission factors and emissions are available from http://www.naei.co.uk/data_warehouse.php.

Any revisions to inventory compilation methodology between the 2007 and 2008 inventory are discussed in Chapter 13, whilst the changes in emission estimates due to revisions in source data or estimation methodology are summarised in Appendix.1. The NAEI is subject to methodology revisions on an annual basis and some of the planned improvements that were outlined within the Informative Inventory Report (1970 to 2007) have been addressed in the 2008 inventory. Planned improvements for future national inventory compilation cycles are discussed in Chapter 13.7.

In addition, Table ES-2 gives an overview of differences in the 2010 submission compared to the 2009 LRTAP submission. The differences vary from pollutant to pollutant due to the different key sources for the pollutants. For example, the increase in carbon monoxide (CO) emissions is driven primarily by changes in the road transport sector. The difference between the 2009 and 2010 submission is considerably higher for CO than for other pollutants, due to the significant methodology revisions in the road transport sector. The changes in metal emissions are heavily impacted on by the reported emission data from individual plants. Changes in the Persistent Organic pollutants (POPs) estimates are due to revised activity data in the Digest of United Kingdom Energy Statistics (DUKES), and Renewable Energy Statistics (RESTATs). Hexachlorobenzene (HCB) emissions have decreased significantly due to the re-allocation of releases from air to land and water. NO_x, NH_3 and NMVOC emissions changes are mainly due to improved methodology for the time series in road transport. There were no revisions for key SO_x emission sources.

Table ES-2 Overview of Time series Revisions, Comparing the 2009 and 2010 LRTAP Data Submissions

Pollutant	2009 Submission	2010 Submission		Unit	Comment/Explanation (changes between the 2009 and 2010 LRTAP Submissions)
	2007	2007	2008		
NO_x	1486	1557	1403	kt	No significant changes for major sources. Slight increase in emissions from road transport. Details of the changes are further described in Chapter 13.
CO	2114	3052	2828	kt	Increase in emissions due to use of new TRL emission factors and revised catalyst failure assumptions from Road Transport sources. This impacts CO significantly because Road Transport is a major emission source contributing a high proportion of emissions to the total CO emissions. In addition, increased emissions were cause by the change in the distribution of aviation spirit use between territories. Revised emission factor for wood use in power stations from the power station database had a small impact on the emission increase.
NMVOC	942	1012	942	kt	Increase in emissions from petrol cars due to changes in the methodology further described in Chapter 13. In addition, emissions increased from updates in site specific data in the oil industry,
SO_x	591	595	512	kt	The number of plants reporting their emissions to the Pollution Inventory fluctuates from year to year. This causes significant differences in the emissions from the Power generation sector for each reporting year. This fluctuation impacts the overall SO_x emissions notably more relative to other pollutants due to the high proportion the power generation sector accounts for in the total emissions.
NH_3	289	295	282	kt	Increase in emissions from petrol cars due to changes in the methodology further described in Chapter 13.
TSP	NR	NR	NR		NR
PM_{10}	135	137	133	kt	Overall emissions increased due to the use of new activity drivers used to re-scale fuel use levels for industrial off-road machinery for the past years. Increased emissions are also due to changes in fleet turnover and emission degradation functions affecting diesel cars and vans.
$PM_{2.5}$	82.3	85.9	82.7	kt	Overall emissions increased due to the use of new activity drivers used to re-scale fuel use levels for industrial off-road machinery for the past years. Increased emissions are also due to changes in fleet turnover and emission degradation functions effecting diesel cars and vans. Also due to the increase in the $PM_{2.5}$ fraction of PM_{10} assumed for vehicle exhausts from 0.90 to 0.95 after consideration of information from DfT/TRL and other sources
Pb	70.1	71.6	66.8	tonnes	Updates to secondary lead production due to new plant data. Increase in emissions due to correction of error in copper alloy and semis production.
Cd	2.92	2.93	2.78	tonnes	No significant changes for major sources. Small increase in emissions occurred from secondary lead production due to updated emission factor from the pollution inventory and updates of fuel oil use in the iron and steel industry due to revisions in DUKES.
Hg	7.16	6.91	6.22	tonnes	Changes included updating of activity data to include process changes at Rhodia and Albion for chloralkali process in the chemical industry. Also, activity data were updated to consider new information on plant closures for chemicals and manmade fibre production causing a reduction in emissions. Slight decrease in emissions occurred in coal power plants due to revised activity data from DUKES.
As	13.6	13.4	13.3	tonnes	No significant changes for major sources. Slight decrease in emissions within the combustion sector due to updated activity values from revised methodology and updated activity data in the glass production sector.
Cr	29.1	29.1	28.6	tonnes	No changes in major sectors. Other improvements included updating activity data within the road transport sector. This affected the proportion of emissions each source and activity combination contributes to the overall emissions. Reductions occurred within the domestic glass production sector due to updates of activity data from British Glass Consultancy studies. Decrease in public

Pollutant	2009 Submission	2010 Submission		Unit	Comment/Explanation (changes between the 2009 and 2010 LRTAP Submissions)
					sector combustion of gas oil occurred due to revision of fuel allocation methodology.
Cu	57.7	57.5	59.5	tonnes	Changes included updating activity data within the road transport sector. This affected the proportion of emissions each source and activity combination contributes to the overall emissions. Decrease in public sector combustion of gas oil occurred due to revision of fuel allocation methodology.
Ni	80.3	83.4	98.7	tonnes	Emission increased due to revisions of the methodology of the use of petroleum coke in domestic combustion.
Se	35.3	35.4	36.3	tonnes	No significant changes for major sources. Emission increased due to revisions of the methodology of the use of petroleum coke in domestic combustion.
Zn	292	289	277	tonnes	Emissions decreased from electric arc furnaces in the steel production due to updating the methodology in the emission factor calculation.
Aldrin	NO	NO	NO		NO
Chlordane	NO	NO	NO		NO
Chlordecone	NO	NO	NO		NO
Dieldrin	NO	NO	NO		NO
Endrin	NO	NO	NO		NO
Heptachlor	NO	NO	NO		NO
Hexabromo-biphenyl	NO	NO	NO		NO
Mirex	NO	NO	NO		NO
Toxaphene	NO	NO	NO		NO
DDT	NO	NO	NO		NO
HCH	11313	11200	9856	kg	Slight decrease in emissions from major sources. Reduction in the wood and coal burnt in domestic combustion due to revision in RESTATs and DUKES respectively.
PCB	1003	1036	998	kg	Slight increase in emissions of treated and untreated wood burned in other industrial combustion sources due to revision of the activity data.
DIOX	197	224	236	grams TEQ	Dioxin emissions have increased. UK POPs emissions have been the subject of an inventory review by Defra in 2009. This established gaps in the data which have been added as new sources (in particular tobacco smoke, and dioxin contamination of PCB fluids in transformers and capacitors). It also reviewed existing emission factors and activity for improvement and amendment, which has caused increased emissions overall.
benzo(a)pyrene	3.75	3.33	3.56	tonnes	Decrease in emissions due to the reductions in the amount of wood and coal burnt in domestic combustion due to revision in RESTATs and DUKES respectively. This decrease was slightly offset by increase in emissions from petrol cars due to increase in catalyst failure rate assumed.
benzo(b)fluoranthene	3.74	3.01	3.12	tonnes	Decrease in emissions due to revised emission factor for coke production using updated site specific data. In addition, reduction occurred in domestic combustion in the wood and coal used due to revision in RESTATs and DUKES respectively. This decrease was slightly offset by increase in emissions from petrol cars due to increase in catalyst failure rate assumed.
benzo(k)fluoranthene	2.45	1.50	1.54	tonnes	The overall emissions decreased due to revised emission factor for coke production using updated site specific data and reduction in wood and coal use in domestic combustion due to revision in RESTATs and DUKES respectively. This decrease was slightly

Pollutant	2009 Submission	2010 Submission		Unit	Comment/Explanation (changes between the 2009 and 2010 LRTAP Submissions)
					offset by increase in emissions from petrol cars due to increase in catalyst failure rate assumed.
Indeno(1,2, 3-cd)pyrene	1.71	1.56	1.60	tonnes	The overall emissions decreased due to revised emission factor for coke production using updated site specific data and reduction in wood and coal use in domestic combustion due to revision in RESTATs and DUKES respectively. This decrease was slightly offset by increase in emissions from petrol cars due to increase in catalyst failure rate assumed.
HCB	813	91	91	kg	HCB emissions have been significantly reduced. This has occurred as previous estimates for HCB contamination of pesticide spraying assumed that 100% of release was emitted to air. This has now been reviewed and adjusted to split total emissions by air (70.2%), land and water based on a simple distribution model. The emission factors in use have also been reviewed and in the case of Chlorthalonil and Quintozene reduced to typical concentrations for HCB contamination of products on the market.
PCP	NR	NR	NR	kg	
SCCP	NR	NR	NR	kg	

NO: Not Occurring
NR: Not Reported

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

- Road Transport;
- Rail;
- Emissions of Ammonia for non-agricultural sources;
- Ultrafine Particles;
- Emissions from Heavy Metals for various sources;
- Burning of Treated Wood;
- Industrial, Commercial & Public Sector Combustion;
- Revisions to DUKES Energy Data;
- Industrial Process Emissions;
- Solvent Use;
- Fireworks and Munitions;
- Persistent Organic Pollutants;
- Industrial Use of Coke and Petroleum Coke.

(I) CONTACTS AND ACKNOWLEDGEMENTS

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

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

NH_3 emissions from agriculture are provided for Defra under contract AC0112 by a consortium led by North Wyke Research in Okehampton, Devon.

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A copy of this report and related documentation may be found on the NAEI website maintained by AEA for Defra: http://www.naei.org.uk/

(II) GLOSSARY

Emission Units

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

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

Acronyms and Definitions

ABI	Annual Business Inquiry
AS	Aviation Spirit
ATF	Aviation Turbine Fuel
ATM	Air Traffic Movement
ATOC	Association of Train Operating Companies
AUP	Auxiliary Power Unit
BAU	Business as usual
BCA	British Cement Association
BCF	Bureau for Computer Facilities
BERR	Department for Business, Enterprise & Regulatory Reform
BGS	British Geological Survey
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
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
EMEP	European Monitoring and Evaluation Program
EE	Energy Efficiency
EU ETS	European Union Emissions Trading Scheme
EEMS	Environmental Emissions Monitoring System
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
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
LGV	Larger Goods Vehicles
LPG	Liquefied petroleum gas
LRTAP	Convention on Long-Range Transboundary Air Pollution
LTO	Landing & Take Off
MPP	Major Power Producers (i.e. most power station operators)
MSW	Municipal Solid Waste
NFR	Nomenclature for Reporting
NAEI	National Air Emissions Inventory
NEC	National Emission Ceiling Directive
NMVOC	Non-Methane Volatile Organic Compounds
OCGT	Open Cycle Gas Turbine
ONS	Office for National Statistics
OT	Overseas Territories
PAMs	Policies and Measures
PI	Pollution Inventory (of the Environment Agency of England & Wales)
POC	Port of call
PRODCOM	PRODuction COMmunautaire
PSDH	Project for the Sustainable Development of Heathrow
QA/QC	Quality Control/Quality Assurance
RASCO	Regional Air Services Co-ordination
RESTATs	Renewable Energy Statistics (published by DECC)
RTFO	Renewable Transport Fuels Obligation
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
UKMY	UK Minerals Yearbook
UKPIA	UK Petroleum Industries Association
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_x
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
Dioxins and Furans	PCDD/F
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 1-1.

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.

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 Chapter 1.4.

1.1.2 Reporting Requirements: NECD and LRTAP

The UK emissions inventory 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 (LRTAP).

NECD

Directive 2001/81/EC of the European Parliament and the Council on National Emissions Ceilings for NO_x, SO_x, 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 for the four already regulated substances and the primary emissions of $PM_{2.5}$.

LRTAP

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 are listed in Table ES-2.

The main difference between the reporting requirements of the NECD and LRTAP are the number of pollutants and the years covered in the reporting template. Under the NECD the UK submits the emissions for the pollutants for the previous five years and under the LRTAP, a time series between 1980 to the most recent reported year.

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

1.1.3 LRTAP Reporting: UK Completeness

With regards to the LRTAP requirements, the scope of the UK emissions inventory is incomplete in only two ways:

- The UK does not make estimates of TSP emissions
- NH_3 emissions are only available from 1990 onwards (LRTAP requires 1980 onwards)

Table 1-1 Scope of NAEI Reporting: Pollutants by Type, Timeseries

Pollutant		Inventory Timeseries[1]	Type of Pollutant[2]
Nitrogen Oxides	NO_x (NO_2 + NO)	1970-2008	NAQS, AC, IGHG, O
Sulphur Dioxide	SO_x	1970-2008	NAQS, AC, IGHG
Carbon Monoxide	CO	1970-2008	NAQS, O
Non-Methane Volatile Organic Compounds *	NMVOC	1970-2008	NAQS, O, IGHG
Black Smoke	BS	1970-2008	NAQS
Particulates < 10 µm	PM_{10}	1970-2008	NAQS
Particulates < 2.5 µm	$PM_{2.5}$	1970-2008	-
Particulates < 1 µm	PM_1	1970-2008	-
Particulates < 0.1 µm	$PM_{0.1}$	1970-2008	-
Total Suspended Particulates	TSP	NE	-
Ammonia	NH_3	1990-2008	AC
Hydrogen Chloride	HCl	1970-2008	AC
Hydrogen Fluoride	HF	1970-2008	AC
Lead	Pb	1970-2008	NAQS, TP
Cadmium	Cd	1970-2008	TP
Mercury **	Hg	1970-2008	TP
Copper	Cu	1970-2008	TP
Zinc	Zn	1970-2008	TP
Nickel **	Ni	1970-2008	TP
Chromium **	Cr	1970-2008	TP
Arsenic	As	1970-2008	TP
Selenium	Se	1970-2008	TP
Vanadium	V	1970-2008	TP
Beryllium	Be	2000-2008	TP
Manganese	Mn	2000-2008	TP
Tin	Sn	2000-2008	TP
Polycyclic Aromatic Hydrocarbons *	PAH	1990-2008	TP
Dioxins and Furans	PCDD/F	1990-2008	TP
Polychlorinated Biphenyls *	PCB	1990-2008	TP
Lindane (gamma-HCH)	HCH	1990-2008	TP
Pentachlorophenol	PCP	1990-2008	TP
Hexachlorobenzene	HCB	1990-2008	TP
Short-chain chlorinated paraffins	SCCP	1990-2008	TP
Polychlorinated Naphthalene	PCN	NE	TP
Polybrominated diphenyl ethers	PBDE	SE	TP
Sodium	Na	1990-2008	BC
Potassium	K	1990-2008	BC
Calcium	Ca	1990-2008	BC
Magnesium	Mg	1990-2008	BC

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

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

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

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

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

1.1.4 Sources

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

- Natural sources are not included in the national totals (although estimates of some sources are made)
- The inventory is a primary emissions inventory (as per international guidelines). Consequently resuspension of e.g. particulate material is not included in the national totals (although estimates for some resuspension terms are made).
- Cruise emissions from civil and international aviation are not included in the national totals.
- Natural sources and cruise emissions from civil and international aviation are not included in the national totals (although estimates of some sources are made).
- Estimates of “International” emissions such as shipping are made, and reported as memo items (excluded from the UK national totals).
- GHG emissions associated with short-term changes to the carbon cycle are not included; whilst this is not of particular concern here, the principle is extended to other pollutants.

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

The sources included in the national totals under the NECD and the LRTAP differ from sources included in the national totals reported under the Kyoto Protocol to the UNFCCC. A list of the sources covered under the Kyoto Protocol can be found in the annual UK Greenhouse Gas Inventory 1990-2007 report (AEA 2009)

1.1.5 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 LRTAP. 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 LRTAP Convention.

Note that the NECD submission uses the LRTAP reporting templates (as requested). The UK does not make emission estimates from inland waterways.

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

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

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

1.2.1 Defra ALE

The Science and Evidence Team, Atmosphere and Local Environment Programme (ALE) of the Department for Environment, Food and Rural Affairs (Defra), is the single national entity with overall responsibility to meet the UK Government's commitments to international reporting on air quality pollutant emissions, and as such has the following roles and responsibilities:

National Level Management & Planning

- Overall control of the inventory programme development & function;
- Management of contracts & delivery of emissions inventories;
- Definition of performance criteria for key organisations.

Development of Legal & Contractual Infrastructure

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

1.2.2 AEA Group

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

Planning

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

Preparation

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

Management

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

Inventory Compilation

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

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

- Agricultural emissions of NH_3 are prepared by a consortium led by North Wyke Research, under contract to Defra;

- Emissions of NH_3 from non-agricultural sources are prepared by the UK Centre for Ecology and Hydrology (CEH), under subcontract to AEA.

Information Dissemination

Data from the NAEI is made available to national and international bodies in a number of different formats. An annual report is produced, giving the most recent emissions data and other information such as: temporal trends, new pollutants and methodology changes. 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. A large amount of information is made available on the Internet. The NAEI web pages may be found at: http://www.naei.org.uk

These web pages are arranged to allow easy access to the detailed emissions data, but also general overview information on air pollutants and emissions inventories in general. 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 NAEI annual report is made available in electronic format, along with a host of other reports compiled by the inventory team, and reports on related subjects.

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

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

http://www.defra.gov.uk/environment/quality/air/airquality/index.htm

and

http://www.defra.gov.uk/environment/climate/index.htm

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 head office in Oxfordshire), and in electronic format.

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

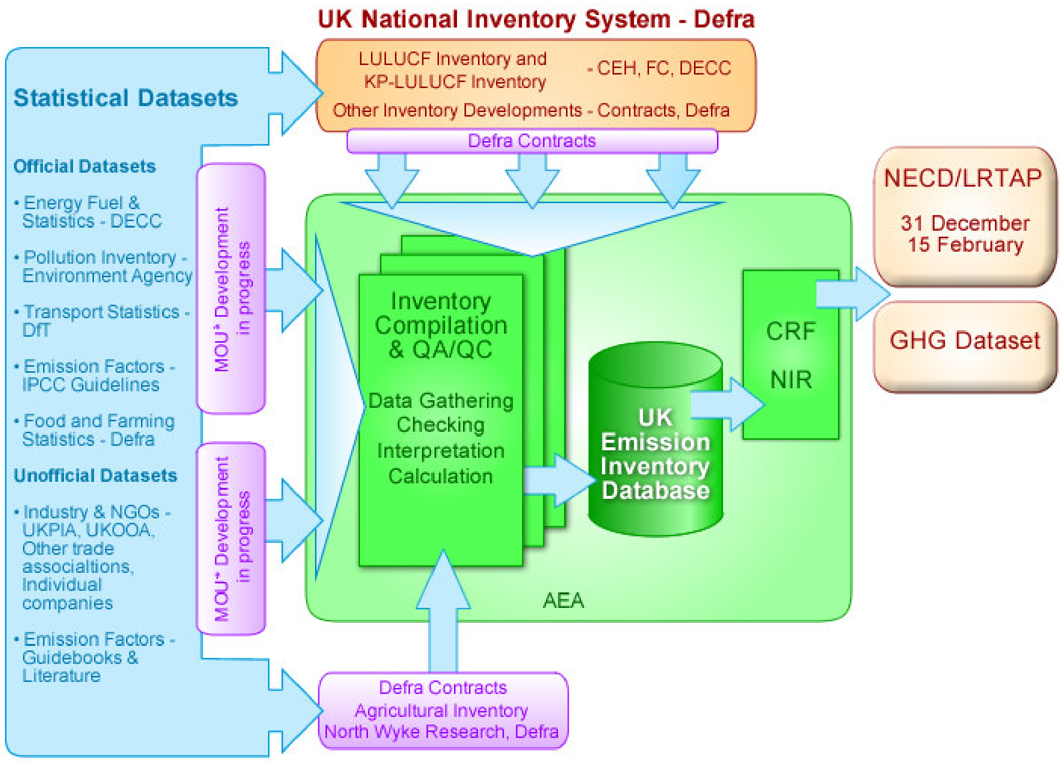
1.3 INVENTORY PREPARATION PROCESS

1.3.1 Introduction

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

- Defra is the UK Government Department responsible for submitting the UK's emission inventories under the NEC Directive and the LRTAP Convention.
- AEA compiles the emissions inventory on behalf of Defra.

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



Key Data Providers are also included on this figure, and include other government departments, including the Department for Energy and Climate Change (DECC) and Department for Transport (DfT), non-departmental public bodies such as the Environment Agency for England and Wales (EA), the Scottish Environment Protection Agency (SEPA), the Northern Ireland Department of Environment (DoENI), the Office of National Statistics (ONS), the Centre for Ecology and Hydrology (CEH), North Wyke Research, private companies such as Corus, and business organisations such as UK Petroleum Industry Association (UKPIA), the British Cement Association (BCA) and Oil & Gas UK.

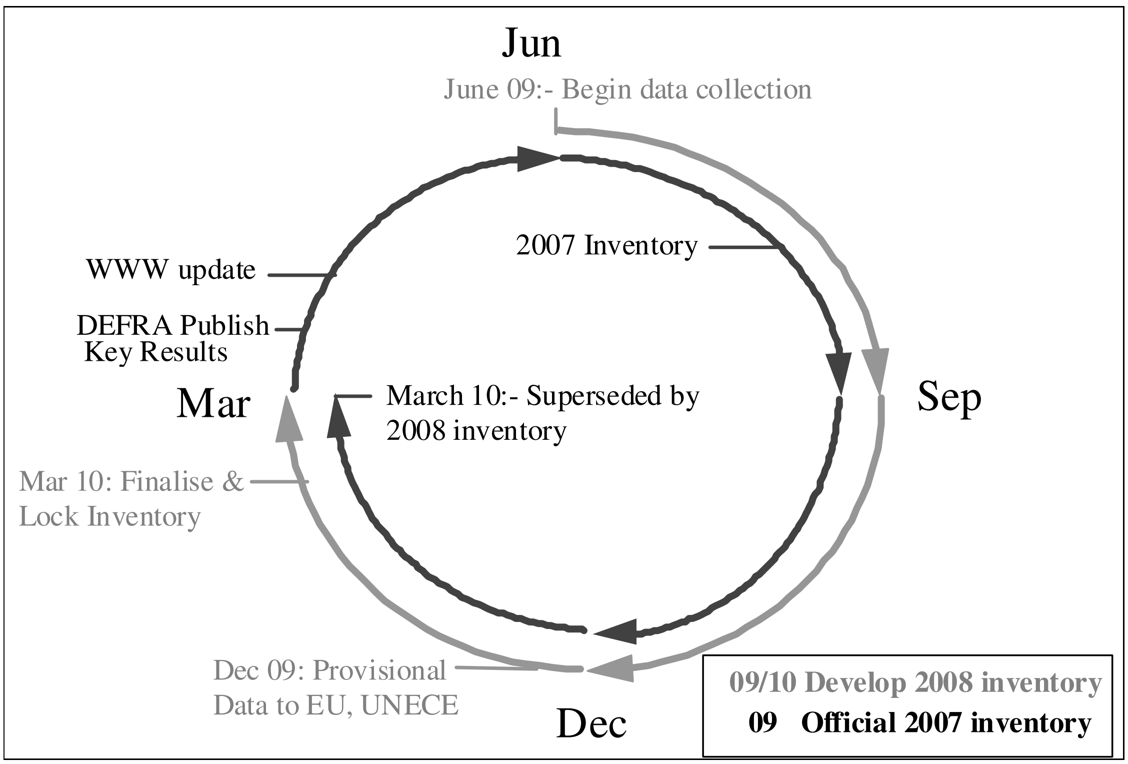
1.3.2 The Annual Cycle of Inventory Compilation

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

- the full NAEI dataset is based on the latest available data, using the most recent research, methods and estimation models available in the UK;
- the inventory estimates for a given source are calculated using a consistent approach across the full time-series and the full scope of pollutants;
- all of the NAEI data are subject to an annual review, and findings of all internal & external reviews and audits are integrated into the latest dataset.

This annual cycle of activity is represented schematically in Figure 1-2, and is designed to ensure that the UK inventory data are compiled and reported to meet all quality requirements and reporting timescales of the UN/ECE, UNFCCC and other international fora.

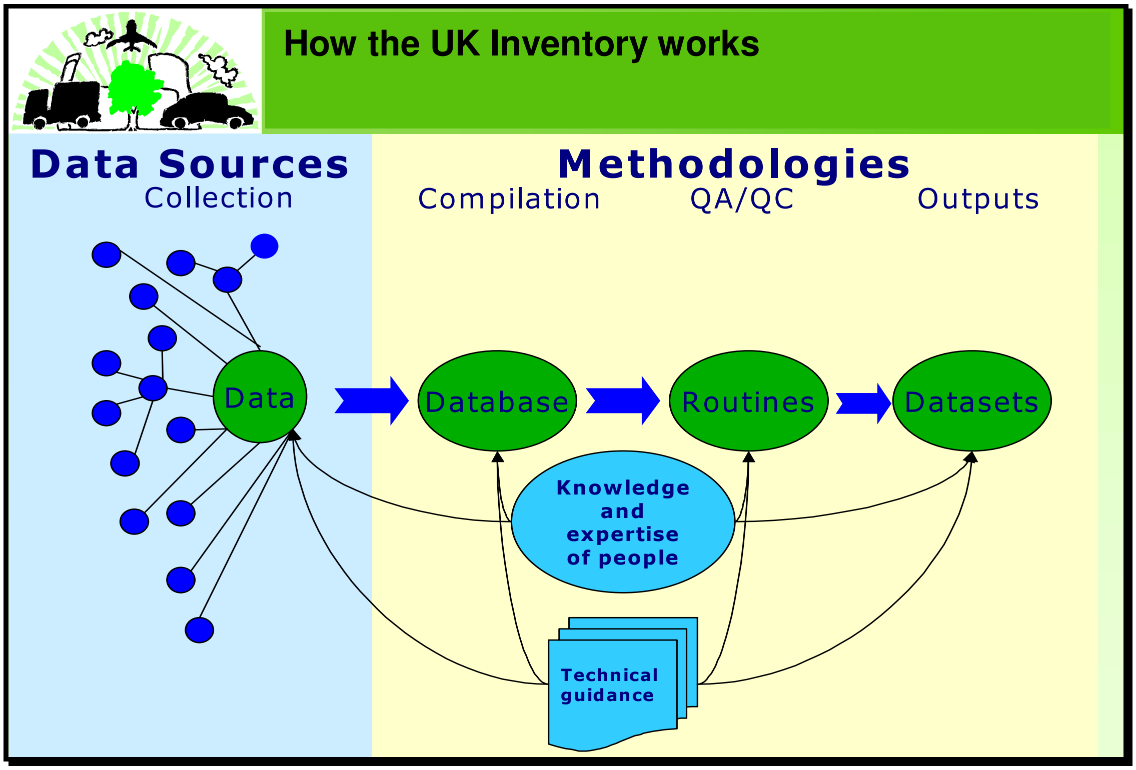
Figure 1-2 The Annual Inventory Cycle in the UK



1.3.3 Data Flows and Infrastructure Organisation

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

Figure 1-3: Summary of 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.

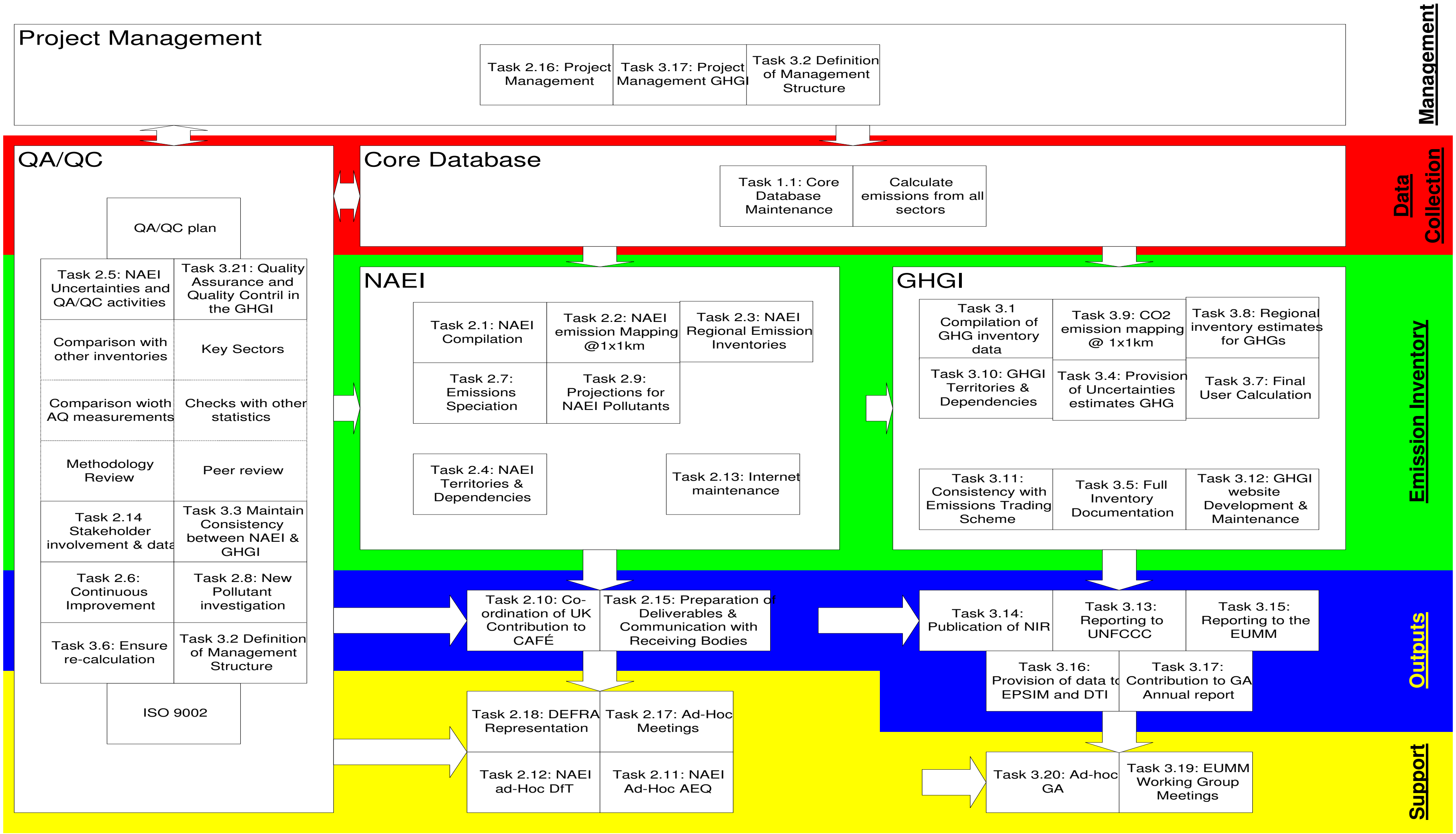
The five-stage summary of the inventory cycle provides a simplistic overview. In practice there are considerably more tasks and the cycle is more complex. For example, some other tasks within the programme would be associated with:

- 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

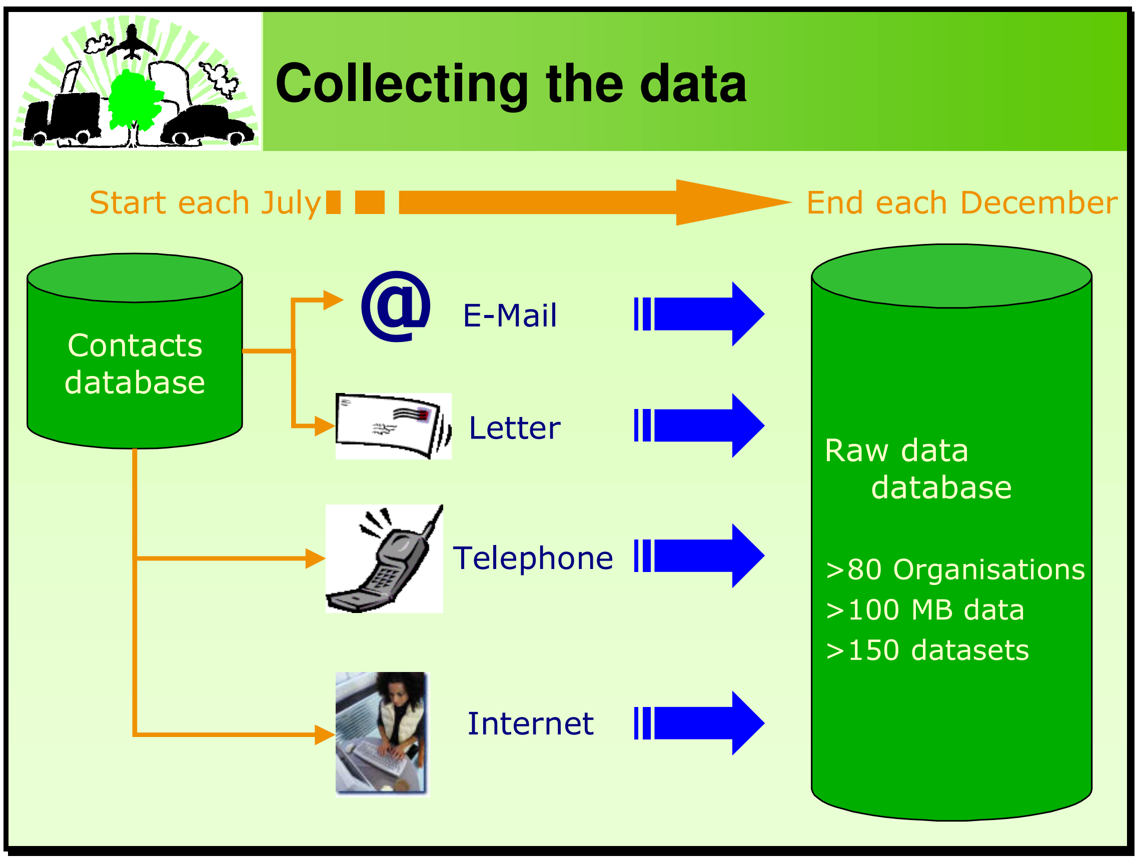


1.3.4 Stage 1: Data Collection

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 currently being introduced to secure the data provision to the emissions inventory (via the GHG inventory), there is currently no obligation for these organisations to provide data. 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 should lead 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, and coal. In each case, a similar approach is used to ensure that overall consumption of each fuel is consistent with the figures given in DUKES

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

1. **The Environment Agency of England & Wales - Pollution Inventory**

The Environment Agency of England & Wales compiles a Pollution Inventory (PI) of emissions from around 2,000 major point sources in England and Wales. This requires the extensive compilation of data from a large number of different source sectors. This valuable source of information is incorporated into the NAEI wherever possible, either as emissions data, or surrogate data for particular source sectors. The information held in the PI is also extensively used in the generation of the NAEI maps, as the locations of individual point sources are known. The NAEI and the Environment Agency work closely to maximise the exchange of useful information. The PI allows access to air emissions through postcode interrogation with a map facility, and may be found on the Environment Agency website:

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

2. **The Scottish Environment Protection Agency – SPRI Inventory**

The Scottish Environment Protection Agency (SEPA) compiles an emissions inventory for emissions reporting under the Integrated Pollution Prevention and Control (IPPC) Directive and the European Pollutant Emission Register (EPER and now EPRTR). The reporting of emissions is required for all activities listed in Annex I of the IPPC Directive. Industrial process emissions are reported to the Scottish Pollutant Releases Inventory (SPRI), and the data covers emissions in 2002 and from 2004 onwards. As with the data from the Environment Agency Pollution Inventory, the point source emissions data provided via the SPRI is used within the NAEI in the generation of emission totals, emission factors and mapping data. The SEPA inventory can be found at:

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

3. The Northern Ireland Department of Environment – ISR Inventory

The Environment & Heritage Service of the Northern Ireland Department of Environment compiles an inventory of industrial emissions for the purposes of EPER and this point source data, although not as yet available via the web, is readily available to the public via the Department itself. The NAEI utilises this valuable point source emissions data for the development of emissions totals, factors and mapping data. Information can be found at:

http://www.ehsni.gov.uk/environment/industrialPollution/ipc.shtml

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

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

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

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

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 LRTAP 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 4) and submitted.

1.4 METHODS AND DATA SOURCES

Overview information on primary data providers and methodologies has been included in the above sections. Table 1-2 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 1-2 Overview of Methodologies by NFR

NFR Category	Activity	EFs	Comment
1A1a Public Electricity & Heat Production	UK statistics	Points	
1A1b Petroleum refining	UK statistics	Points	
1A1c Manufacture of Solid Fuels etc.	UK statistics	Points	
1A2a Iron & Steel	UK statistics	UK factors	
1A2b Non-ferrous Metals	-	-	Reported under 1A2f
1A2c Chemicals	-	-	Reported under 1A2f
1A2d Pulp, Paper & Print	-	-	Reported under 1A2f
1A2e Food Processing, Beverages & Tobacco	-	-	Reported under 1A2f
1A2f Other	UK statistics	UK factors & points	
1A3ai(i) International Aviation (LTO)	UK statistics	Generic	
1A3aii(i) Civil Aviation (Domestic, LTO)	UK statistics	Generic	
1A3b Road Transportation	UK statistics	UK factors	
1A3b vii R.T., Automobile road abrasion	-	-	Not estimated
1A3c Railways	Estimated	UK factors	
1A3d ii National Navigation	UK statistics	Generic	
1A3e Other	-	-	Not estimated
1A3e i Pipeline compressors	-	-	Reported under 1A2f
1A3e ii Other mobile sources & machinery	Estimated	Generic	
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	Generic	
1A4c iii National Fishing	-	-	Reported under 1A3d ii
1A5a Other, Stationary (including Military)	-	-	Reported under 1A4a
1A5b Other, Mobile (Including military)	UK statistics	Generic	
1B1a Coal Mining & Handling	UK statistics	UK factors	
1B1b Solid fuel transformation	UK statistics	Points	
1B1c Other	-	-	Not estimated
1B2Oil & natural gas	UK statistics & Industry	Industry & Points	
2 A Mineral Products	Industry & Estimated	Industry & Points	
2 B Chemical Industry	Industry & Estimated	Points	
2 C Metal Production	UK statistics & Industry	Industry & Points	
2 D Other Production	UK statistics & Industry	UK factors	
2 G Other	Estimated	UK factors	

NFR Category	Activity	EFs	Comment
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	
4A Enteric Fermentation	UK statistics	UK factors	
4B Manure Management	UK statistics	UK factors	
4C Rice Cultivation	-	-	Not occurring
4D Agricultural Soils	Estimated	Generic	
4F Field Burning Of Agricultural Wastes	-	-	Not occurring
4G Other	UK Statistics & Estimated	UK factors	
5B Forest & Grassland Conversion	Derived	Generic	
5E Other	-	-	Not estimated
6A Solid Waste Disposal On Land	Reported	UK factors	
6B Waste-Water Handling	Reported	UK factors	
6C Waste Incineration	UK Statistics & Estimated	Points & UK factors	
6D Other Waste	Reported	UK factors	
7 Other	Estimated	UK factors	
1A3aii (ii) Civil Aviation (Domestic, Cruise)	UK Statistics	Generic	
1A3ai (ii) International Aviation (Cruise)	UK Statistics	Generic	
1A3di (i) International maritime Navigation	Estimated	Generic	
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:

- **Points**: 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, typically from published sources such as AP-42 (US EPA, 2009).

- **Industry**: Process operators or trade associations have provided emissions data directly

- **Estimated**: Emissions have been estimated by the NAEI team for some sources of NMVOC, based on detailed information on solvent consumption at each plant and abatement systems in place.

The specific emission factors used in the calculation for all sources and pollutants for the latest inventory can be found under the data warehouse of the NAEI website:

http://www.naei.co.uk/emissions/index.php

1.5 KEY SOURCE ANALYSIS

Table 1-3 provides an overview of the most important sources for selected pollutants reported under the LRTAP Convention in the 2008 inventory. The top 10 sources or the top sources that add up to 95% of the national total in 2008 are defined as being a key source for each pollutant in the table.

For SOx and NOx the single dominant source is 1A1a Public Electricity and Heat Production. This is also the case for Hg emissions, specifically from the combustion of coal in this sector. Eight of the ten key sources for NH3 are from the agriculture sector, with 47% of the emission due from cattle. NMVOC sources are dominated by the use of domestic solvents including fungicides. 48% of CO emissions arise from passenger cars in the road transport sector, which has been a dominant source throughout the time series, however the share of the emissions it accounts for has increased from 1970-2008 due to the decrease in the emissions from the combustion of coal in the household sector.

For PM_{10} and B[a]P emissions, the dominant source remains the combustion of fuel in the residential sector, although the percentage contribution of that source to overall emissions have decreased significantly since 1970. The sinter production in the Iron and Steel Production sector is the highest source for Pb and Cd emissions in 2008. There are only three key source categories for HCBs, which are from the use of pesticides in the agriculture sector and the chemical industry. The major sources for dioxins are small scale waste burning, other waste sources and lead production. Further details of the trend in emissions and the key sources will be included in the annual UK Emissions of Air Pollutants report 1970 to 2008 due in summer 2010. One of the improvements made in this year's inventory was the further disaggregation of the NFR codes (discussed in Chapter 12). For this reason, the number of NFR codes categorised as being a key source has increased relative to last year's inventory. This has led to an increase in the NFR codes in the 'not listed' column in Table 1-3. However, all key source categories for these pollutants are listed in Table 2-4.

Table 1-3 Key NFR sources of selected pollutants in 2008

Pollutant	Key source categories (Sorted from high to low from left to right)										Total (%)	Not listed
SO_x	1 A 1 a (41.6%)	1 A 1 b (14.1%)	1 A 2 f i (12.7%)	1 A 3 d ii (10.5%)	1 A 4 b i (4.8%)	2 A 7 d (3.3%)	2 C 1 (2.0%)	1 B 1 b (1.9%)	1 A 2 (1.4%)	1 A 5 b (1.2%)	93.5	2
NO_x	1 A 1 a (19.8%)	1 A 3 b iii (15.9%)	1 A 3 b i (12.2%)	1 A 2 f i (8.8%)	1 A 3 d ii (8.5%)	1 A 4 b i (7.3%)	1 A 2 f ii (6.2%)	1 A 3 b ii (3.9%)	1 A 1 c (3.6%)	1 A 3 c (2.6%)	88.8	2
NH_3	4 B 1 a (24.9%)	4 B 1 b (21.9%)	4 D 1 a (11.4%)	4 B 9 d (8.1%)	4 B 8 (7.0%)	4 B 13 (6.4%)	1 A 3 b i (4.2%)	4 B 3 (3.8%)	4 B 9 a (2.8%)	6 B (2.0%)	92.5	3
NMVOC	3 D 2 (13.6%)	1 A 3 b i (10.8%)	3 D 3 (10.1%)	2 D 2 (8.6%)	1 B 2 a i (6.8%)	3 A 1 (5.6%)	3 A 2 (5.2%)	1 A 4 b i (4.9%)	1 B 2 b (3.7%)	1 B 2 a v (3.5%)	72.8	14
CO	1 A 3 b i (48.3%)	1 A 4 b i (10.7%)	2 C 1 (10.2%)	1 A 2 f ii (7.0%)	1 A 2 f i (3.2%)	1 A 1 a (2.8%)	1 A 4 b ii (2.4%)	1 A 3 b ii (2.4%)	1 A 3 b iv (2.3%)	1 A 3 b iii (1.5%)	90.7	5
PM_{10}	1 A 4 b i (14.5%)	1 A 3 b vi (7.2%)	1 A 3 d ii (6.6%)	1 A 1 a (6.4%)	2 A 7 a (6.2%)	1 A 2 f ii (5.4%)	4 B 9 b (4.8%)	1 A 3 b i (4.7%)	2 C 1 (4.6%)	1 A 3 b ii (3.4%)	63.6	18
Pb	2 C 1 (51.5%)	1 A 2 f i (8.1%)	2 C 5 e (6.3%)	1 A 4 b i (6.1%)	2 B 5 a (5.2%)	1 A 1 a (4.1%)	1 B 1 b (3.8%)	1 A 1 b (2.2%)	2 C 5 a (2.0%)	2 C 5 b (1.9%)	91.1	3
Hg	1 A 1 a (29.0%)	2 B 5 a (15.3%)	1 A 2 f i (14.6%)	6 C d (14.1%)	2 C 1 (7.3%)	6 A (5.9%)	2 C 5 e (4.8%)	1 A 4 b i (2.4%)	1 A 4 a i (1.2%)	6 C a (1.2%)	95.7	0
Cd	2 C 1 (32.7%)	1 A 3 b i (8.2%)	1 A 2 f i (7.9%)	1 A 3 d ii (7.8%)	1 B 1 b (5.4%)	1 A 4 b i (5.4%)	1 A 1 a (4.1%)	2 C 3 (3.9%)	2 C 5 e (3.6%)	1 A 3 b iii (3.2%)	82.2	7
DIOX	6 C e (22.3%)	6 D (17.4%)	2 C 5 b (15.4%)	2 C 1 (13.1%)	1 A 2 f i (4.8%)	6 C d (4.5%)	7 A (2.9%)	1 A 4 c i (2.9%)	2 C 3 (2.5%)	1 A 1 a (2.4%)	88.2	5
B[a]P	1 A 4 b i (64.8%)	1 A 3 b i (5.4%)	7 A (4.5%)	6 D (3.6%)	2 C 3 (3.3%)	1 B 1 b (3.2%)	2 C 1 (2.8%)	1 A 3 b ii (2.3%)	1 A 3 b i v (2.1%)	1 A 3 b iii (1.6%)	93.7	1
HCB	4 G (65.3%)	2 B 5 a (25.8%)	1 A 1 a (7.9%)								99.0	0

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- 12. To monitor and improve the quality and robustness of the inventory, uncertainty analysis and QA/QC activities are carried out throughout the entire inventory compilation. These activities include:

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

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

1.6.2 QA/QC Procedures and Development

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

While the Inventory is being compiled:

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

2. **Internal peer review:** The inventory undergoes continual peer review by senior inventory personnel. A small team of reviewers are on hand to ensure that new or variant methodologies (changed because of availability of different datasets) are consistent with the guidelines for inventory reporting and under the UNFCCC and UNECE and are scientifically sound.
3. **ISO 9001** AEA has accreditation to this. AEA uses a project management system that meets required and auditable standards and is subject to independent review.
4. **Stakeholder Involvement and data collection / interpretation:** It is extremely important to involve stakeholders in the data collection process. Often those who use the data for a particular purpose have access to useful information that can be used to improve the inventories. Through a programme of stakeholder engagement during the inventory cycle, the inventory team works to ensure that available data are used appropriately within the inventory compilation, for example to ensure that the scope of activity and/or emissions data from data providers are understood and applied accordingly within national inventory.
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 LRTAP review process.
11. **Independent checks with other statistics:** AEA perform basic consistency checks between published UK statistics. Some datasets can be used to check inventories and their trends. For example, production-based emission estimates are compared with sales data to check that the trends and values seem reasonable.
12. **Uncertainties:** The UK inventory uncertainty analysis highlights the sources that are significantly contributing to overall uncertainties. The development of sectoral

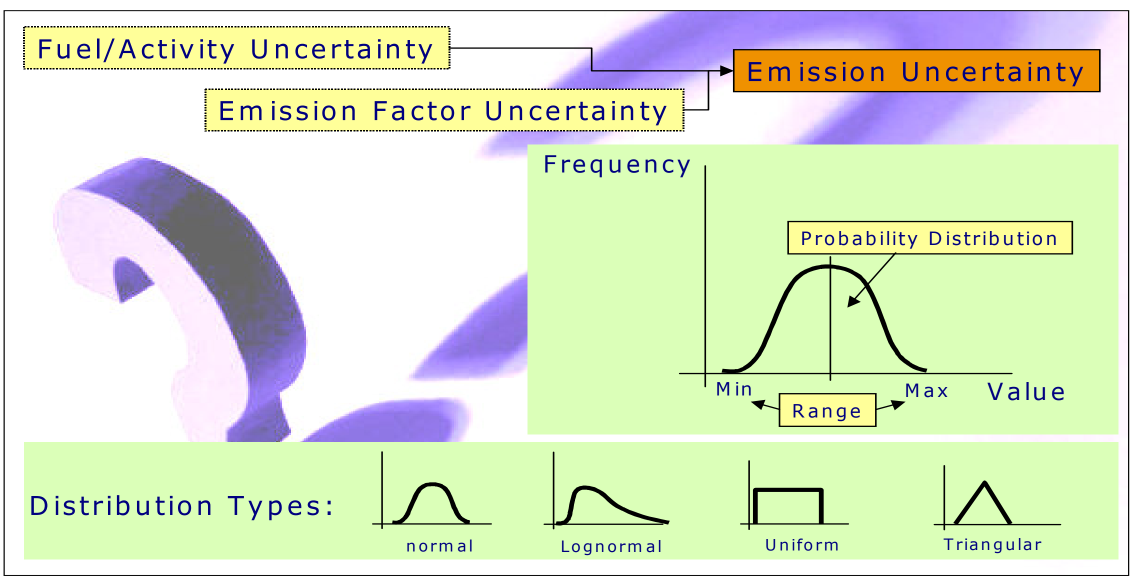
uncertainty estimates requires a good understanding of the methods used to develop the emission factors, and the uncertainties associated with those methods.

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

1.6.3 Uncertainty assessments

Uncertainty analysis for national estimates of NAEI pollutants are carried out using a Monte Carlo technique. As summarised in Figure 1-6 the uncertainty analysis identifies ranges of uncertainty for each source for both the emission factor and the activity statistic. Each uncertainty range will also be associated with a probability distribution.

Figure 1-6 Illustration of uncertainty assessment techniques

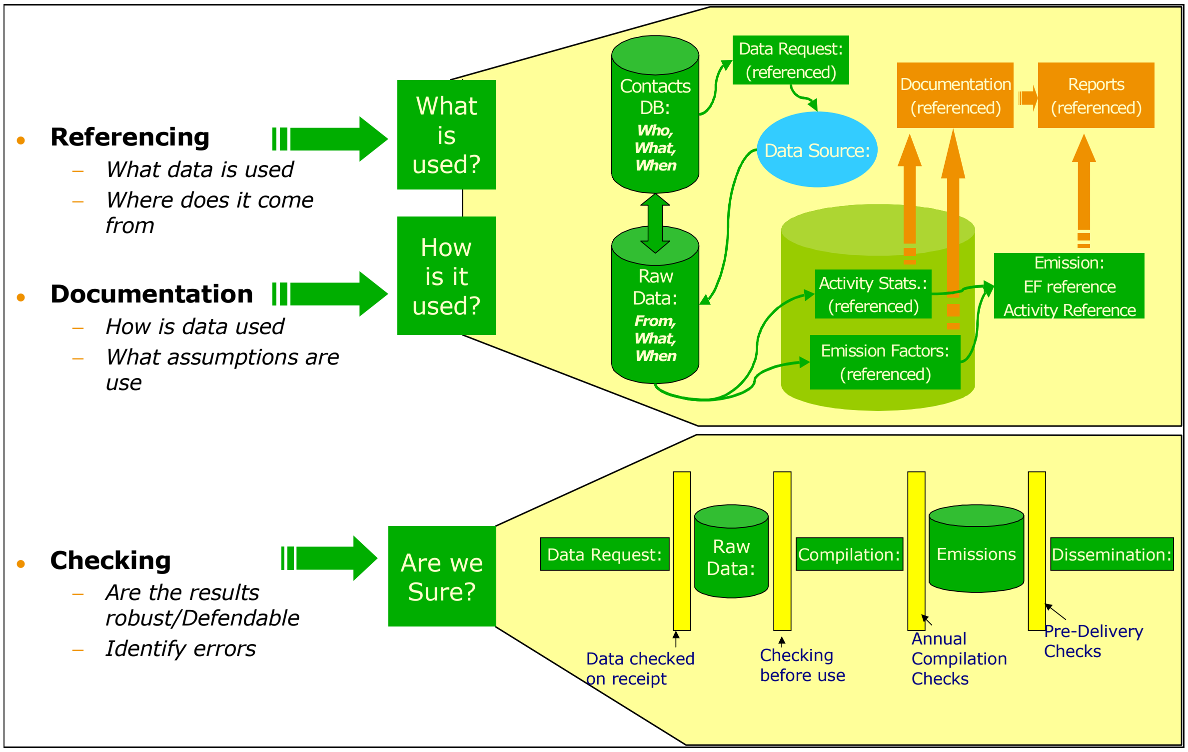


This determines the impact of uncertainty of individual parameters (such as emission factors and activity statistics) upon the uncertainty in the total emission of each pollutant. All analyses are consistent with the IPCC good practice guidance. Uncertainties are assessed for each year's inventory by 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 GHGs are categorised as Tier 1 and Tier 2. Tier 1 procedures should be applied to the whole inventory at all times. Tier 2 procedures require more effort and it is acceptable that these should be applied to key sources at intervals, though these intervals are unspecified.

The main requirements of Tier 1 are:

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

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

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

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

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

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

The emissions inventory programme incorporates a process of external expert peer review. Whilst most of this focuses on the GHG emission inventory there are also activities relating to the LRTAP pollutants. These include 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.

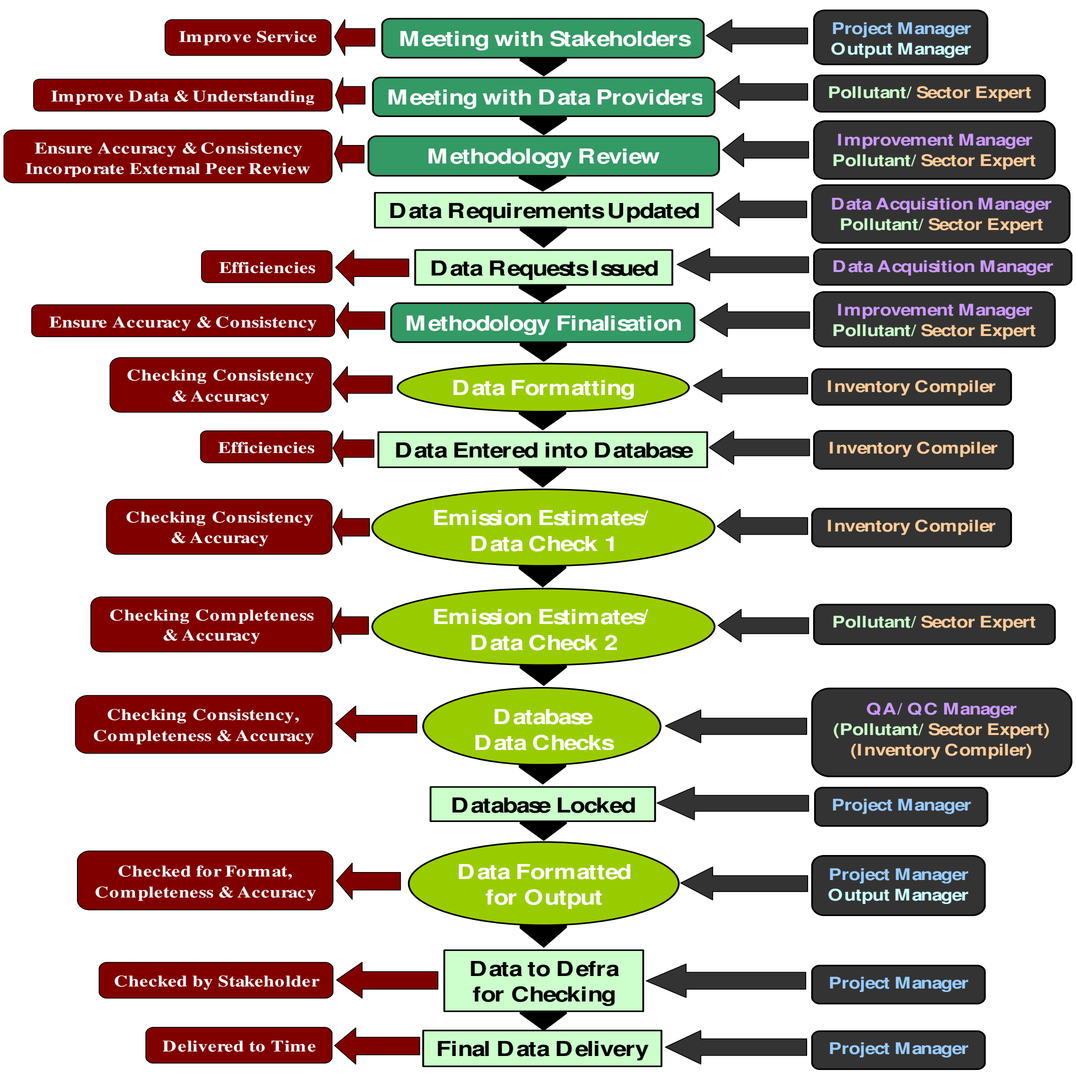
Figure 1-8 Inventory Team Organisation and Responsibilities

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.

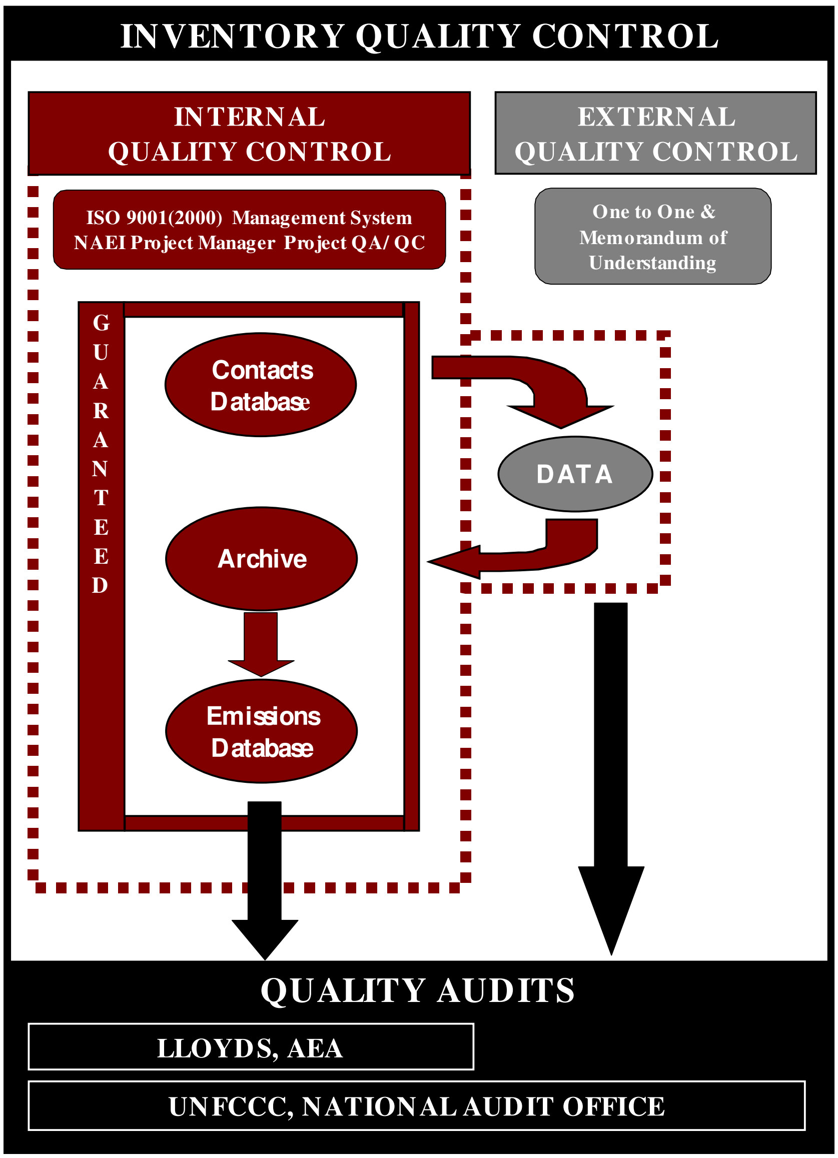
Figure 1-9 Data Flows and QA/QC



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: Internal and External Quality Control



Stage 3: Spreadsheet Compilation
There are therefore 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 LRTAP 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 LRTAP 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 workshops, conferences and meetings such as the TFEIP/EIONET or the USEPA emissions inventories workshops.
- Ongoing data collection and inventory compilation.
- Ongoing stakeholder consultation.
- Assessment of results from the annual uncertainty assessments.
- Recommendations from external and internal review.
- Inconsistencies identified in verification work.

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

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

AEA have a programme of research that includes the following:

- A programme of stakeholder consultation with trade associations, process operators and regulators to resolve specific issues such as verification/updating of individual assumptions used in methodologies, gap filling etc.
- Improvement of the methodology for PM_{10} emissions from processes regulated under LAPC, currently based on use of emission factors developed in the mid 1990s and expressed in terms of emission per process.
- Periodic review of emission factors for small combustion plant, particularly for pollutants such as NO_x, CO, PM_{10} & POPs.
- Improvement of the methodology for estimation of NMVOC emissions from adhesives use and cleaning solvents, paying particular attention to improving the estimation of solvent abatement and providing more detailed sectoral breakdowns.

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

1.7 UNCERTAINTY EVALUATION

Evaluation of uncertainty is carried out by a Monte-Carlo uncertainty assessment and is detailed in Section 1.6.3.

Quantitative estimates of the uncertainties in emission inventories are based on calculations made using a direct simulation technique, which corresponds to the methodology proposed in draft guidance produced by the UN/ECE Taskforce on Emission Inventories. This work is described in more detail by Passant (2002b). Uncertainty estimates are shown in Table 1-4. These estimated uncertainties are one of the indicators used to derive where improvements are required in the NAEI.

Table 1-4 Uncertainty of the Emission Inventories for pollutants covered under the NAEI excluding GHGs

Pollutant	**Estimated Uncertainty %**
Carbon monoxide	-20 to +30
Benzene	-30 to + 50
1,3-butadiene	-20 to +40
PM_{10}	-20 to +30
$PM_{2.5}$	-20 to +30
$PM_{1.0}$	-20 to +30
$PM_{0.1}$	-20 to +30
Black smoke	-30 to +50
Sulphur dioxide	+/- 4
Nitrogen oxides	+/- 10
Non-Methane Volatile Organic Compounds	-9 to +10
Ammonia	+/- 20
Hydrogen Chloride	+/- 20
Hydrogen Fluoride[a]	+/- 20
Arsenic	-60 to +200
Cadmium	-20 to +50
Chromium	-30 to +70
Copper	-40 to +80
Lead	-30 to +50
Mercury	-30 to +40
Nickel	-30 to +50
Selenium	-20 to +30
Vanadium	-20 to +30
Zinc	-30 to +60
Beryllium	-40 to +80
Manganese	-30 to +40
Benzo[a]pyrene	-60 to +200
Dioxins and furans	-50 to +200
Polychlorinated biphenyls	-40 to + 90
Pentachlorophenol	-80 to +200
Hexachlorocyclohexane	-100 to +400
Hexachlorobenzene	-50 to +200
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_x, NO_x and NMVOC largely due to the nature of the major agricultural sources. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques. Hence emissions are affected by a large number of factors, which make the interpretation of experimental data difficult and emission estimates uncertain (DOE, 1994). Emission estimates for non-agricultural sources such as wild animals are also highly uncertain. Unlike the case of NO_x and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

1.7.2 Benzene and 1,3-butadiene
There has been much improvement in the benzene and 1,3-butadiene emission estimates in recent years. Information gained in speciating the emissions of NMVOC (see Section **Error! Reference source not found.**) has helped the generation of more robust emission inventories for both benzene and 1,3-butadiene. However, due in particular to the uncertainty in the levels of both pollutants in NMVOC emissions from road transport and other combustion processes, the uncertainty in these inventories is much higher than the uncertainty in the NMVOC inventory.

1.7.3 Carbon monoxide
Carbon monoxide emissions occur almost exclusively from combustion of fuels, particularly by road transport. Emission estimates for road transport are highly uncertain, due to the relatively small number of emission measurements made and the highly variable results. Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. The emission factors used in the inventory have been derived from relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_x, CO_2 and SO_x which are also emitted mainly from combustion processes.

1.7.4 Hydrogen Chloride
The hydrogen chloride inventory is equally as uncertain as the ammonia inventory. As with ammonia, a few sources dominate the inventory and the levels of uncertainty in these sources is generally quite high.

1.7.5 Hydrogen Fluoride
Uncertainty analysis has not been performed on the hydrogen fluoride inventory as this is not a core part of the NAEI. However, the sources of hydrogen fluoride are very similar to those for hydrogen chloride and the level of uncertainty in emission factors might also be expected to be similar. As a result it seems reasonable to assume the same level of overall uncertainty as for hydrogen chloride.

1.7.6 Nitrogen oxides
NO_x emission estimates are less accurate than SO_x because, although they are calculated using measured emission factors, these emission factors can vary widely with combustion conditions. Hence, emission factors given in the literature for combustion sources show large variations. In the case of road transport emissions, while the inventory methodology takes into account variations in the amount of NO_x emitted as a function of speed and vehicle type,

significant variations in measured emission factors have been found even when keeping these parameters constant.

From the above, one might expect the NO_x inventory to be very uncertain, however the overall uncertainty is in fact lower than for any pollutant other than SO_x. This is largely a result of two factors. First, while emission factors are uncertain, activity data used in the NO_x inventory is very much less uncertain. This contrasts with inventories for pollutants such as volatile organic compounds, PM_{10}, metals, and persistent organic pollutants, where some of the activity data are very uncertain. Second, the NO_x inventory is made up of a large number of emission sources with many of similar size and with none dominating (the largest source category contributes just 24% of emissions, and a further 28 sources must be included to cover 90% of the emission). This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector. The other extreme is shown by the inventories for PCP, HCH and HCB where one or two sources dominate and the inventories are highly uncertain.

1.7.7 Non-Methane Volatile Organic Compounds

The NMVOC inventory is more uncertain than those for SO_x and NO_x. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. As with NO_x, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

1.7.8 Particulate Matter Estimates

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

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

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

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

1.7.9 Black Smoke Estimates

Black smoke emissions are less accurate than those for PM_{10} due to the fact that, since its importance as a policy tool has declined, the black smoke inventory methodology has not been revised for many years and the relevance of the emission factors used in the inventory to current sources such as road transport and industrial technology is in doubt.

1.7.10 Sulphur Dioxide

Sulphur dioxide emissions can be estimated with most confidence as they depend largely on the level of sulphur in fuels. Hence the inventory, being based upon comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture, industry and domestic sectors, contains accurate emission estimates for the most important sources.

1.7.11 Heavy Metals

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

1.7.12 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, coupled with a lack of good activity data for some important sources. The inventory for polychlorinated biphenyls is less uncertain than those for other persistent organic pollutants. However the overall uncertainty is still high. The uncertainty of HCB has improved this year due to the disaggregation of pesticides emissions to air, land and water. The uncertainty in emission estimates for polychlorinated naphthalenes has not been estimated since no emission estimates are made.

1.8 ASSESSMENT OF COMPLETENESS

1.8.1 Not Estimated

NH_3 emissions are not estimated prior to 1990 as there is insufficient data to make reliable emission estimates for all sources. Rather than publish an incomplete inventory, which could be misleading, the UK does not report emissions data prior 1990. A plan to extend the NH_3 inventory back to 1980 is currently being reviewed.

TSP is not estimated by the UK emissions inventory team, as PM_{10} (and other PM size fractions) are used in national policy instead.

No other data are reported as "NE" (not estimated).

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

1.8.2 Included Elsewhere

In the latest 2008 inventory, the need to further disaggregate the NFR codes was addressed. The implication of this is that all the emissions are now disaggregated to very detailed categories within the NFR and hence do not require the use of the notation key 'IE'. 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 2010 LRTAP submission[2].

1.8.3 Other Notation Keys

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

[2] http://cdr.eionet.europa.eu/gb/un/cols3f2jg/envs3f2vq

2. Explanation of Key Trends

2.1 SIGNIFICANT CHANGES IN THE TIME TREND FOR KEY SOURCES

This section discusses the key sources of selected pollutants (NO_x, SO_x, NMVOC, NH_3, PM_{10}, CO) and where there have been significant changes in emissions between 1980 and 2008. Further information and analysis on the time trend of all pollutants reported under the CLRTAP will be included in the UK Emissions of Air Pollutants 1970-2008 annual report which is due to be published in summer 2010.

2.1.1 Power Generation

Power generation is a key source of emissions for CO, NO_x, PM_{10} and SO_x during 1980 and it remains so during 2008. However, there has been significant reduction in emissions between 1980 and 2008 (see Table 2-1).

Table 2-1 Summary of % contribution of power stations to various pollutants emissions and the overall change in emissions between 1980 and 2008.

Pollutant	NFR Code	% of total emissions in 2008	% Change from 1980 to 2008
SO_x	1A1a	41.6%	-92.9%
NO_x	1A1a	19.8%	-67.7%
CO	1A1a	2.8%	-34.7%
PM_{10}	1A1a	6.4%	-88.7%

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

Since 1988 the electricity generators have adopted a programme of progressively fitting low NO_x burners to their 500 MWe (megawatt electric) or larger coal fired units. Since 1990, the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas have further reduced NO_x emissions. The emissions from the low NO_x turbines used are much lower than those of pulverised coal fired plant even when low NO_x burners are fitted at coal plant. Moreover, CCGTs are more efficient than conventional coal and oil stations and have negligible SO_x emissions, which accelerated the decline of SO_x 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_x and particulate emissions further. Power station emissions are expected to fall further primarily as a result of fuel switching, more CCGT stations and the implementation of the Large Combustion Plant Directive leading to flue gas desulphurisation being fitted at more sites.

Figure 2-1 Time series of SO_x emissions from key source categories, 1980 to 2008

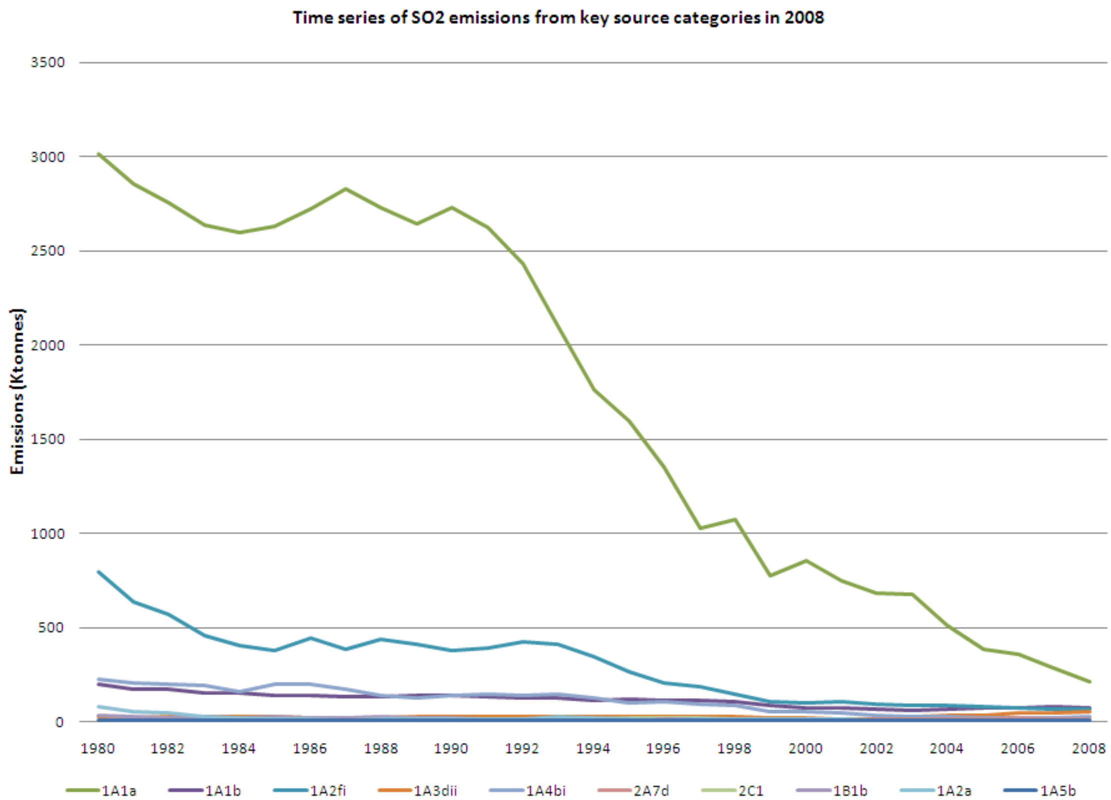
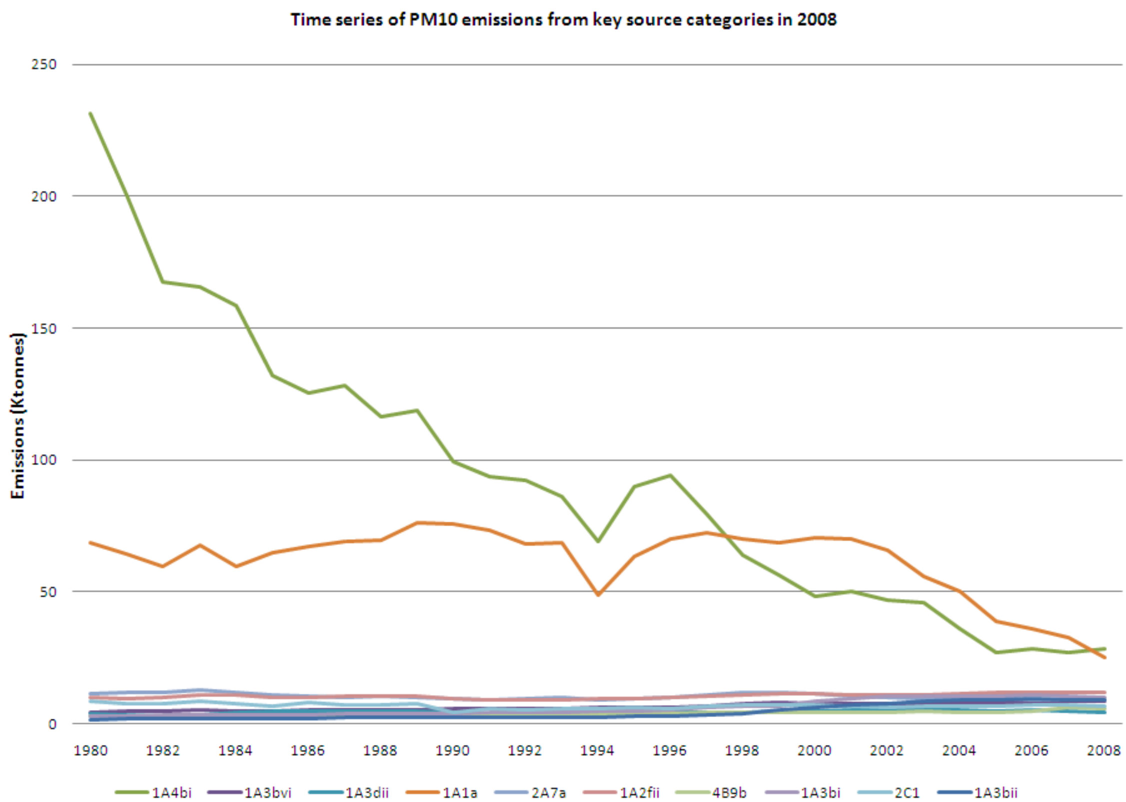
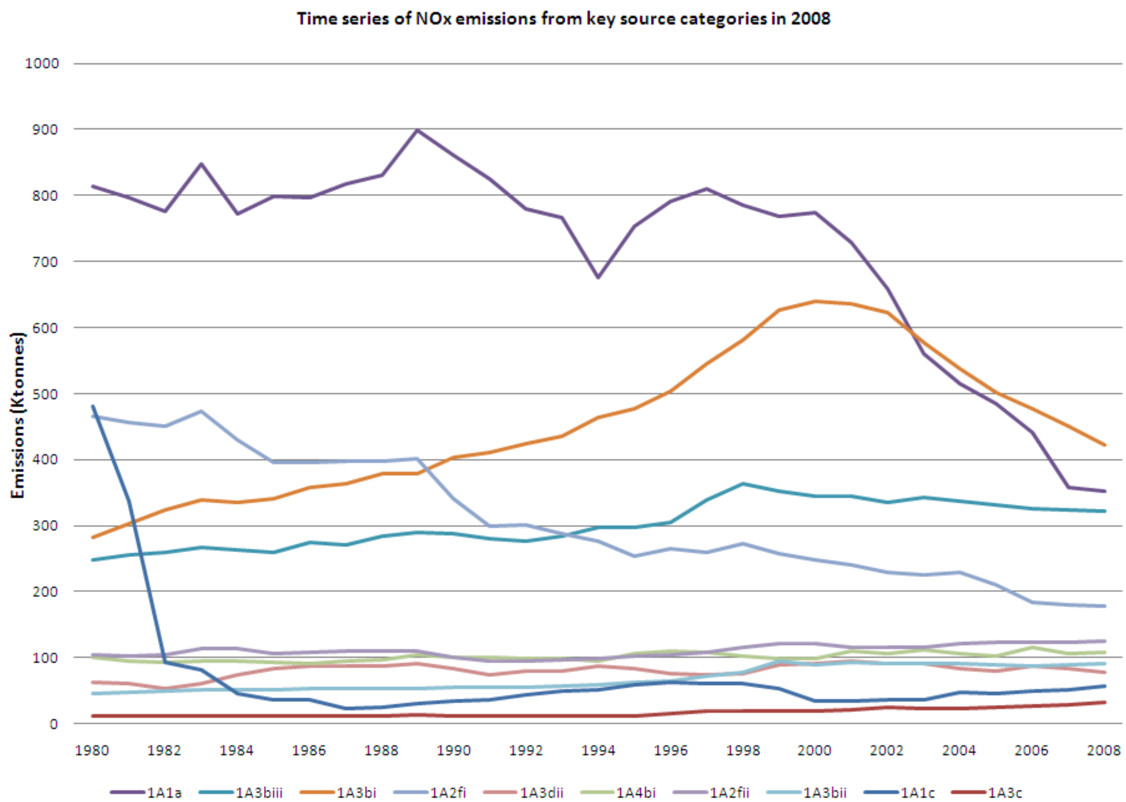


Figure 2-2 Time series of PM_{10} emissions from key source categories, 1980 to 2008



Key :
1 A 1 a Public Electricity and Heat Production
1 A 1 b Petroleum refining
1 A 2 a Iron and Steel
1 A 2 f i Stationary combustion in manufacturing industries and construction: other
1 A 2 fii Mobile Combustion in manufacturing industries and construction
1 A 3 b i R.T., Passenger cars
1 A 3 b ii R.T., Light duty vehicles
1 A 3 b vi R.T., Automobile tyre & brake wear
1 A 3 d ii National Navigation
1 A 4 b i Residential plants
1 A 5 b Other, Mobile (including military)
1 B 1 b Solid fuel transformation
2 A 7a Quarrying and mining minerals other than coal
2 A 7 d Other Mineral products
2 C 1 Iron and steel production
4 B 9 b Broilers

Figure 2-3 Time Series of NO_x emissions from key source categories, 1980 to 2008



Keys
1 A 1 a Public Electricity and Heat Production
1 A 1 c Manufacture of Solid Fuels and Other Energy Industries
1 A 2 f i Stationary combustion in manufacturing industries and construction: Other
1 A 2 f ii Mobile combustion in manufacturing industries and construction: Other
1 A 3 d ii National Navigation
1 A 3 b i R.T., Passenger cars
1 A 3 b ii R.T., Light duty vehicles
1 A 3 b iii R.T., Heavy duty vehicles
1 A 3 c Railways
1 A 4 b i Residential plants

2.1.2 Domestic and Commercial Sectors

Domestic combustion is a key source of CO, NO_x, NMVOC, PM_{10} and SO_x emissions during 2008 (see Table 2-2). There have been reductions in emissions of the above pollutants from this sector, mainly because of a decline in the use of solid fuels in favour of gas and electricity. Domestic coal combustion has been the major source of particulate emissions in the UK. However, the use of coal for domestic combustion has been restricted in the UK by the Clean Air Acts. Between 1980 and 2008, 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.

Table 2-2 Summary of % contribution of domestic sector to various pollutants emissions and the overall change in emissions between 1980 and 2008.

Pollutant	NFR Code	% of total emissions in 2008	% Change from 1980 to 2008
SO_x	1A4bi	4.8%	-89.1%
NO_x	1A4bi	7.3%	+2.4%
CO	1A4bi	10.7%	-84.4%
PM_{10}	1A4bi	14.5%	-80.7%
NMVOC	1A4bi	4.9%	-67.5%

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 2008 (see Table 2-3). Emissions from the food and drink industry comprised 8.6% of the total NMVOC emission in 2008. The largest source is whisky maturation although animal feed manufacture, fat and oil processing, barley malting and bread baking are also important. Emissions from the sector peaked in 1980 before falling again to reach the lowest emissions in 1987. Since then, emissions have been generally increasing to this year. The trends with time are primarily driven by production in these sectors. Emissions from the chemical industry grew steadily until 1989, since then tightening emission controls have led to a reduction in emissions. The overall reduction in emissions from the chemical industry of NMVOC between 1980 and 2008 is 80%. The chemical industry is a key source category of CO contributing to 0.8% of the emissions. For other pollutants, the two industries are not key source categories.

Table 2-3 Summary of % contribution of food and drink industry and chemical industry to pollutant emissions and the overall change in emissions between 1980 and 2008.

Pollutant	NFR Code	% of total emissions in 2008	% Change from 1980 to 2008
SO_x	2B5a	0.8%	-92.1%
CO	2B5a	0.8%	-64.5%
NMVOC	2D2	8.6%	-1.2%
NMVOC	2B5a	2.7%	-79.9%
NH_3	2B5a	1.1 %	-48.5%

2.1.4 Transport

Transport is a key source of CO, NH_3, NMVOC, NO_x, PM_{10} and SO_x emissions in the UK.

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

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

Diesel engine vehicles emit a greater mass of particulate matter per vehicle kilometre than petrol-engined 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.

2.1.5 Agriculture

Agricultural sources with emissions from livestock and their wastes are the major source of NH_3 emissions, contributing 76.7% of total emissions in 2008. 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 2008 represent a decrease of 23.1% on the 1990 emissions (emission estimates for NH_3 are only available from 1990 onwards).

Field burning of agricultural waste (4F) was one of the key sources of CO and NMVOC emissions in 1980, contributing 5.4% and 2.2% of total emissions respectively. Emissions from the agricultural sector occur for NO_x, CO and NMVOC until 1993 only. During 1993, agricultural stubble burning was stopped in England and Wales and therefore emissions of NO_x, CO and NMVOC are no longer recorded post 1993.

2.1.6 Waste

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

A summary table of all the key sources and their contributions to overall pollutant emissions is provided in Table 2-4 below.

Table 2-4 Summary of all key sources and their contributions to overall pollutant emissions

Pollutant	Key sources during 2008	NFR Name	% of total emissions in 2008	% Change from 1980 to 2008
SO_x	1A1a	1 A 1 a Public Electricity and Heat Production	41.6%	-92.9%
	1A1b	1 A 1 b Petroleum refining	14.1%	-63.4%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	12.7%	-91.8%
	1A3dii	1 A 3 d ii National Navigation	10.5%	112.9%
	1A4bi	1 A 4 b i Residential plants	4.8%	-89.1%
	2A7d	2 A 7 d Other Mineral products (Please specify the sources included/excluded in the notes column to the right)	3.3%	58.0%
	2C1	2 C 1 Iron and steel production	2.0%	0.6%
	1B1b	1 B 1 b Solid fuel transformation	1.9%	-71.3%
	1A2a	1 A 2 a Iron and Steel	1.4%	-90.9%
	1A5b	1 A 5 b Other, Mobile (Including military)	1.2%	-32.2%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1.1%	-97.2%
	Overall change for all sources			**-89.3%**
NO_x	1A1a	1 A 1 a Public Electricity and Heat Production	19.8%	-67.7%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	15.9%	-22.8%
	1A3bi	1 A 3 b i R.T., Passenger cars	12.2%	-57.3%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	8.8%	-63.9%
	1A3dii	1 A 3 d ii National Navigation	8.5%	42.9%
	1A4bi	1 A 4 b i Residential plants	7.3%	2.4%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	6.2%	-13.7%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	3.9%	-1.2%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	3.6%	49.6%
	1A3c	1 A 3 c Railways	2.6%	207.7%

Pollutant	Key sources during 2008	NFR Name	% of total emissions in 2008	% Change from 1980 to 2008
NO_x continued	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	2.6%	-49.9%
	1A5b	1 A 5 b Other, Mobile (Including military)	2.2%	-26.7%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	1.8%	-47.5%
	1A1a	1 A 1 a Public Electricity and Heat Production	19.8%	-67.7%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	15.9%	-22.8%
	Overall change for all sources			**-45.5%**
CO	1A3bi	1 A 3 b i R.T., Passenger cars	48.3%	-64.4%
	1A4bi	1 A 4 b i Residential plants	10.7%	-84.4%
	2C1	2 C 1 Iron and steel production	10.2%	13.8%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	7.0%	16.8%
	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	3.2%	-41.1%
	1A1a	1 A 1 a Public Electricity and Heat Production	2.8%	-34.7%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	2.4%	5.3%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	2.4%	-87.7%
	1A3biv	1 A 3 b iv R.T., Mopeds & Motorcycles	2.3%	-58.3%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	1.5%	-39.5%
	2C3	2 C 3 Aluminium production	1.2%	20.6%
	1A3aii(i)	1 A 3 a ii Civil Aviation (Domestic, LTO)	1.1%	-33.9%
	2B5a	2 B 5 a Other chemical industry (Please specify the sources included/excluded in the notes column to the right)	0.8%	-64.5%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	0.7%	-15.1%
	1A1c	1 A 1 c Manufacture of Solid Fuels and Other Energy Industries	0.6%	61.1%
	Overall change for all sources			**-65.9%**
PM_{10}	1A4bi	1 A 4 b i Residential plants	14.5%	-80.7%
	1A3bvi	1 A 3 b vi R.T., Automobile tyre and brake wear	7.2%	68.9%
	1A3dii	1 A 3 d ii National Navigation	6.6%	91.9%
	1A1a	1 A 1 a Public Electricity and Heat Production	6.4%	-88.7%
	2A7a	2 A 7 a Quarrying and mining of minerals other than coal	6.2%	-14.9%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	5.4%	-25.0%
	4B9b	4 B 9 b Broilers	4.8%	81.5%
	1A3bi	1 A 3 b i R.T., Passenger cars	4.7%	53.5%
	2C1	2 C 1 Iron and steel production	4.6%	47.2%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	3.4%	78.8%
	3A2	3 A 2 Industrial coating application	3.3%	-26.4%

Pollutant	Key sources during 2008	NFR Name	% of total emissions in 2008	% Change from 1980 to 2008
PM_{10} continued	1A2fi	1 A 2 f i Stationary combustion in manufacturing industries and construction: Other (Please specify in your IIR)	3.1%	-77.7%
	6Ce	6 C e Small scale waste burning	3.1%	0.0%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	2.8%	-75.0%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	2.8%	-55.0%
	2A7d	2 A 7 d Other Mineral products (Please specify the sources included/excluded in the notes column to the right)	2.6%	-14.4%
	4G	4 G OTHER (d)	1.9%	24.8%
	1A4ci	1 A 4 c i Stationary	1.7%	-11.9%
	4B9d	4 B 9 d Other poultry	1.5%	4.2%
	2G	2 G OTHER (Please specify in a covering note)	1.4%	-13.5%
	7A	7 A Other (included in national total for entire territory)	1.3%	6.2%
	1A5b	1 A 5 b Other, Mobile (Including military)	1.2%	-21.5%
	6D	6 D OTHER WASTE (f)	1.0%	-10.7%
	4B8	4 B 8 Swine	0.9%	-39.5%
	1A1b	1 A 1 b Petroleum refining	0.9%	-75.7%
	1B2c	1 B 2 c Venting and flaring	0.8%	-60.6%
	2A7b	2 A 7 b Construction and demolition	0.7%	-14.7%
	1A4ai	1 A 4 a i Commercial / institutional: Stationary	0.6%	-83.3%
		Overall change for all sources		**-59.5%**
NMVOC	3D2	3 D 2 Domestic solvent use including fungicides	13.6%	57.9%
	1A3bi	1 A 3 b i R.T., Passenger cars	10.8%	-74.1%
	3D3	3 D 3 Other product use	10.1%	-32.3%
	2D2	2 D 2 Food and Drink	8.6%	-1.2%
	1B2ai	1 B 2 a i Exploration Production, Transport	6.8%	-36.0%
	3A1	3 A 1 Decorative coating application	5.6%	1.8%
	3A2	3 A 2 Industrial coating application	5.2%	-54.6%
	1A4bi	1 A 4 b i Residential plants	4.9%	-67.5%
	1B2b	1 B 2 b Natural gas	3.7%	-7.3%
	1B2av	1 B 2 a v Distribution of oil products	3.5%	-55.2%
	1B2aiv	1 B 2 a iv Refining / Storage	3.2%	-70.0%
	3B1	3 B 1 Degreasing	2.7%	-71.6%
	2B5a	2 B 5 a Other chemical industry (Please specify the sources included/excluded in the notes column to the right)	2.7%	-79.9%
	1B2c	1 B 2 c Venting and flaring	2.5%	-49.3%
	1A2fii	1 A 2 f ii Mobile Combustion in manufacturing industries and construction: (Please specify in your IIR)	2.1%	6.3%
	3D1	3 D 1 Printing	1.7%	-58.1%

Pollutant	Key sources during 2008	NFR Name	% of total emissions in 2008	% Change from 1980 to 2008
NMVOC (continued)	3C	3 C CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING	1.5%	-72.8%
	1A3bv	1 A 3 b v R.T., Gasoline evaporation	1.1%	-88.7%
	6A	6 A SOLID WASTE DISPOSAL ON LAND	1.0%	-50.6%
	1A4bii	1 A 4 b ii Household and gardening (mobile)	0.8%	-42.3%
	1A3bii	1 A 3 b ii R.T., Light duty vehicles	0.8%	-86.0%
	1A3biii	1 A 3 b iii R.T., Heavy duty vehicles	0.7%	-71.5%
	1A4cii	1 A 4 c ii Off-road Vehicles and Other Machinery	0.7%	-37.7%
	3A3	3 A 3 Other coating application (Please specify the sources included/excluded in the notes column to the right)	0.6%	-15.3%
	Overall change for all sources			**-54.2%**
NH_3	4B1a	4 B 1 a Dairy	24.9%	-14.1%
	4B1b	4 B 1 b Non-Dairy	21.9%	-15.3%
	4D1a	4 D 1 a Synthetic N-fertilizers	11.4%	-49.9%
	4B9d	4 B 9 d Other poultry	8.1%	-12.8%
	4B8	4 B 8 Swine	7.0%	-53.6%
	4B13	4 B 13 Other	6.4%	-6.0%
	1A3bi	1 A 3 b i R.T., Passenger cars	4.2%	1653.0%
	4B3	4 B 3 Sheep	3.8%	-25.0%
	4B9a	4 B 9 a Laying hens	2.8%	-42.2%
	6B	6 B WASTE-WATER HANDLING	2.0%	0.9%
	4B6	4 B 6 Horses	1.7%	83.1%
	6D	6 D OTHER WASTE (f)	1.2%	204.5%
	Overall change for all sources			**-23.1%**

3. NFR 1A1: Combustion in the Energy Industries

3.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

The NAEI utilises energy statistics published annually in the Digest of UK Energy Statistics (DUKES, 2009). The source categories and fuel types used in the NAEI therefore reflect those used in DUKES. Table 3-1 lists the fuels used in the inventory.

Table 3-2 relates the detailed NAEI base categories used in the inventory to the equivalent NFR source categories. In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR (Nomenclature for Reporting) source category, however there are some instances where the scope of NAEI and NFR categories is different to a significant degree. Instances of this are discussed below. The NAEI base 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 LRTAP.

Differences in scope of NAEI and NFR categories mainly affect NFR sector 1A2 (Industrial Combustion). The NAEI groups almost all industrial combustion together in a single source "Other industrial combustion" due to a lack of detailed energy statistics across the entire NAEI time series. This NAEI category is mapped to 1A2f, but in reality also contains emissions that would be more correctly reported under 1A2b, 1A2c, 1A2d, and 1A2e. In addition, NAEI source categories mapped to 1A2a, 1A2b, and 1A2f include a number of categories which are used for reporting both combustion and process-related emissions, with process-related emissions generally being a significant source. Examples include:

- Iron and Steel (Sinter Plant) and Iron and Steel (Blast Furnaces) in 1A2a;
- Categories relating to manufacture of cement and lime in 1A2f

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

Table 3-1 Fuel types used in the NAEI

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

Table 3-2 Mapping of NFR Source Categories to NAEI Source Categories: Stationary Combustion

NFR Source Category	NAEI Source Category
1A1a Public Electricity and Heat Production	Power Stations
1A1b Petroleum Refining	Refineries (Combustion)
1A1c Manufacture of Solid Fuels and Other Energy Industries	SSF Production Coke Production Collieries Gas Production Gas Separation Plant (Combustion) Offshore Own Gas Use Production of Nuclear Fuel Town Gas Production
1A3ei Pipeline Compressors	Included under 1A1c - Gas Production

Almost all of the NFR Source Categories listed in Table 3-2 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 form the Pollution Inventory (PI), the Scottish Pollutant Release Inventory (SPRI), or 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 DoE NI (2009). The reported emissions are split by fuel and/or sub-source where necessary and fuel data are obtained from DUKES.

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

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

3.3 FUEL CONSUMPTION DATA

As stated previously, fuel consumption data are taken from DUKES. 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 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 (EU ETS). Partly, this is due to the use of recovered waste oils as 'fuel oil', but the DUKES figures are still considered too low. The operators' data are used in the NAEI and split into consumption of 'waste oil' and 'fuel oil'. Overall consistency between NAEI and DUKES is maintained by reducing the NAEI estimate for fuel oil consumed by the industrial sector.
2) Similarly, DUKES data for consumption of gas oil in power stations is also lower than data for recent years taken from EU ETS. As with fuel oil, a re-allocation of gas oil is made so that the NAEI is consistent with the EU ETS data for power stations, but also consistent with overall demand for gas oil, given in DUKES. The EU ETS data also shows that small quantities of burning oil are used at power stations, but DUKES does not include any data. The NAEI includes a similar re-allocation to that used for fuel oil and gas oil.
3) DUKES does not include any energy uses of petroleum coke, other than the burning of catalyst coke at refineries. 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 EU ETS).

3.4 METHODOLOGY FOR POWER STATIONS (NFR 1A1A)

NFR Sector 1A1a is a key source for NO_x, SO_x, 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 46 Mtonnes of coal were burnt at 17 power stations during 2008, while approximately 11,600 Mtherms of natural gas were consumed at 38 large power stations and 10 small (<50MWth) regional stations (almost all gas plant are Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 3 large facilities, and gas oil or burning oil was used by 4 large and 13 small power stations.

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

Electricity is also generated at 22 Energy from Waste (EfW) plants in the UK. 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 therefore reported under CRF source category 1A1 (electricity generation) and 1A4 (heat generation), rather than 6C (Waste Incineration). This has been the case since 1997; prior to that year at least some MSW was burnt in older plant without energy recovery.

Practically all UK power stations 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 i.e.

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

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 EU ETS data held by UK regulators, or estimated from carbon emissions in a few cases where no other data are available. The allocation of reported emissions of a given pollutant across fuels is then achieved as follows:

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

The approach described above is used for most pollutants, however in the case of emissions of persistent organic pollutants, reporting of emissions in the PI, SPRI, and ISR is limited and/or highly variable, so it has been thought preferable to calculate emissions from literature emission factors and activity statistics.

3.5 METHODOLOGY FOR REFINERIES (NFR 1A1B)

NFR Sector 1A1b is a key source for SO_x, PM_{10}, Cd, Pb and PCDD/PCDF.

The UK has 12 oil refineries, 3 of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 9 complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke. The crude oils processed, refining techniques, and product mix will differ from one refinery to another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

All of these sites are required to report emissions in either the Pollution Inventory (PI), the Scottish Pollutant Release Inventory (SPRI), or Northern Ireland's Inventory of Sources and Releases (ISR). Additional data for CO, NO_x, SO_x, and PM_{10} are supplied annually by process operators via the United Kingdom Petroleum Industry Association (UKPIA, 2009). These split the emissions for the 9 complex refineries into those from large combustion plant (burning fuel oil and OPG) and those from processes (predominantly catalyst regeneration involving the burning of petroleum coke). Emission estimates for the sector can be based on the emission data reported for individual sites i.e.

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

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 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_x, and PM_{10} from catalyst regeneration involving the burning of petroleum coke are calculated directly from the data provided by UKPIA.

The approach described above is used for most pollutants, however in the case of emissions of persistent organic pollutants, reporting of emissions in the PI, SPRI, and ISR is limited and/or highly variable, so it has been thought preferable to calculate emissions from literature emission factors and activity statistics.

3.6 METHODOLOGY FOR OTHER ENERGY INDUSTRIES (NFR 1A1C)

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

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2008, 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 either 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.

Emission = Σ Reported Site Emissions

There are instances of sites not reporting emissions of some pollutants, generally because those emissions are below the reporting threshold, or because a site is closed down partway through a year and therefore does not submit an emissions report. However, estimates can be made of the capacity of each individual plant, so it is possible to extrapolate the emissions data to cover non-reporting sites as well. This extrapolation of data does not add significantly to emission totals.

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

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

Emissions of other pollutants will either be significant both from combustion and process-related sources, or will predominantly occur from process sources. In the case of SO_x, 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 dioxins, we have no actual emissions data on which to base a split and so all emissions are allocated to a non-fuel specific source category covering both types of emissions. These emissions are reported under NFR Sector 1B1b.

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

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

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

3.7 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

The core publication for Activity Data is the annual DECC publication –The Digest of UK Energy Statistics- which is produced in accordance with QA/QC requirements stipulated within the UK Government's -National Statistics Code of Practice- and as such is subject to regular QA audits and reviews. Where emissions data are provided by plant operators to the UK environmental regulatory agencies (EA, SEPA, DOENI) and reported via their respective inventories of pollutant releases (and then used in the UK's GHG emission inventory) 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 DOENI, with some routine checking procedures already in place.

4. NFR 1A2: Combustion in Industry

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 3-1 and relates the detailed NAEI base categories used in the inventory to the equivalent NFR source categories. In most cases it is possible to obtain a precise mapping of an NAEI source category to a NFR (Nomenclature for Reporting) source category, However there are some instances where the scope of NAEI and NFR categories is different to a significant degree. Instances of this are discussed below. The NAEI base 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 LRTAP.

The NAEI groups almost all industrial combustion together in two sources "Stationary combustion in manufacturing industries and construction: Other" and "Mobile combustion in manufacturing industries and construction: Other" due to a lack of detailed energy statistics across the entire NAEI time series. This NAEI category is mapped to 1A2fi and 1A2fii, but in reality also contains emissions that would be more correctly reported under 1A2b, 1A2c, 1A2d, and 1A2e. Previously, these emissions were mapped under one NAEI category 1A2f however, this has been disaggregated to two categories from the 2010 LRTAP submission. In addition, NAEI source categories mapped to 1A2a, 1A2b, 1A2fi and 1A2fii include a number of categories which are used for reporting both combustion and process-related emissions, with process-related emissions generally being a significant source. Examples include:

- Iron and Steel (Blast Furnaces) in 1A2a;
- Categories relating to manufacture of cement and lime in 1A2fi

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

Table 4-1 Mapping of NFR Source Categories to NAEI Source Categories: Stationary Combustion

NFR Source Category	NAEI Source Category
1A2a Iron and Steel	Iron and Steel (Combustion) Iron and Steel (Blast furnaces)
1A2c Chemicals 1A2d Pulp, Paper and Print 1A2e Food Processing, Beverages, Tobacco	Included under Other industrial combustion
1A2fi Stationary Combustion in manufacturing industries and construction: Other 1A2fii Mobile Combustion in manufacturing industries and construction: Other	Ammonia production – combustion Autogenerators Cement – non-decarbonising Cement production – combustion Lime production – non decarbonising Other industrial combustion

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

4.2 GENERAL APPROACH FOR 1A2A AND 1A2FI

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

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

4.3 FUEL CONSUMPTION DATA

As stated previously, fuel consumption data are 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 are as follows:

1) The NAEI splits fuel use by cement kilns and lime kilns from other industrial use of fuels. Fuel use data for cement kilns are provided by the British Cement Association (Leese, 2009), while we make our own 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 by 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 is likely in future.

4.4 METHODOLOGY FOR CEMENT & LIME KILNS

The UK had 14 sites producing cement clinker during 2008, although 3 sites were closed or mothballed during the 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 14 UK sites during 2008. Two of these produce lime for use on-site in the Solvay process and four produce lime for use on-site in sugar manufacturing. Lime kilns are fired with natural gas, coke, anthracite or coal.

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

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

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

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

4.5 METHODOLOGY FOR BLAST FURNACES

Emissions data are supplied by the process operator (Corus, 2009). In the case of NO_x, emissions are allocated to the 'hot stoves' which burn blast furnace gas, coke oven gas, and natural gas to heat the blast air. For other pollutants, reported emissions are allocated to a non-fuel specific source category which is reported under NFR category 2C1.

4.6 METHODOLOGY FOR OTHER INDUSTRIAL COMBUSTION

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

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

Where:

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

Emissions data are reported in the PI, SPRI, and ISR for the 'large combustion plant' and the methodology allows for these reported data to be used in the case of NO_x only. Data are also available for SO_x 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_x. Reported data for other pollutants are much more limited and are not used either.

In most cases where literature emission factors are used, a single factor is applied for a given source category and pollutant but, in the case of carbon monoxide, NO_x and PM_{10} emissions, a more detailed approach is taken. This is done because these source categories consist of a wide range of sizes and types of combustion appliances and emission rates are expected to vary between these different appliances. The more detailed approach therefore allows source/fuel combinations to be further broken down by a) thermal input of combustion devices; b) type of combustion process e.g. boilers, furnaces, turbines etc, and for emission factors to be applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (USEPA, 2007), the EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 2007) and UK emission factor surveys (Walker *et al*, 1985). Emissions data for NO_x reported in the Pollution Inventory (Environment Agency, 2008) are also used in the generation of emission factors for larger combustion plants in the autogeneration, iron and steel – combustion plant, and other industrial combustion source categories.

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

4.7 SOURCE SPECIFIC QA/QC AND VERIFICATION

The QA/QC procedure for this sector is covered by the general QA/QC of the NAEI in Section 1.6. Specific additional QA/QC exists for 1A2.

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 unverified Emission Trading Scheme baseline datasets (covering 1998 to 2003). As discussed above, there have been instances where such information has lead to amendments to fuel allocations reported by DECC (through fuel re-allocations between sectors).

5. NFR 1A3: Transport

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 5-1. The detailed NAEI source categories used in the inventory for transport are related to equivalent NFR source categories in Table 5-1 below.

Table 5-1 Mapping of NFR Source Categories to NAEI Source Categories: Transport

NFR Source Category	**NAEI Source Category**
1A2f Other	Industrial off-road mobile machinery
1A3ai(i) International Aviation (LTO)	International Aviation- LTO
1A3ai(ii) International Aviation (Cruise)	International Aviation- Cruise
1A3aii(i) Domestic Aviation (LTO)	Domestic Aviation- LTO
1A3aii(ii) Domestic (Cruise)	Domestic Aviation- Cruise
1A3b Road Transportation	Road Transport
1A3c Railways	Railways (Freight) Railways (Intercity) Railways (Regional)
1A3di(i) International Marine	International Marine
1A3di(ii) International Inland Waterways	Not Estimated
1A3dii Internal Navigation	Coastal Shipping
1A3eii Other Transport	Aircraft Support
1A4bii Residential Off-road	Domestic, House & Garden
1A4cii Agriculture/Forestry/Fishing (Off-road Vehicles and Other Machinery)	Agriculture Power Units
1A4ciii Agriculture/Forestry/Fishing (Fishing)	Fishing
1A5b Other: mobile	Aircraft Military Shipping Naval

Almost all of the NFR Source Categories listed in Table 5-1 are key sources for one or more pollutants and so the description of the methodology will cover the whole of this NFR sector.

5.2 AVIATION

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

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

The current method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport. 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 Regional Air Services Co-ordination (RASCO) study (23 regional airports, with a 1999 case calculated from CAA[3] movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NO_x and fuel use from the Heathrow inventory have been used to verify the results of this study.

In 2006, the Department for Transport (DfT) published its report “Project for the Sustainable Development of Heathrow” (PSDH). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002.

For departures, the PSDH made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights. In 2007, these recommendations for Heathrow were incorporated into the UK inventory. In 2009, these recommendations were incorporated into the UK inventory for all airports, along with further recommendations relating to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and Auxiliary Power Unit (APU) emission indices and running times.

For arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. In 2007, these recommendations for Heathrow were incorporated into the UK inventory. In 2009, these recommendations were incorporated into the UK inventory for all airports, along with further recommendations relating to: the interpolation to intermediate thrust settings; approach thrusts and times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

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

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

[3] Civil Aviation Authority

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.

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

  A summary of aircraft movement data is given in
Table **5-3**.

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

  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DECC (2009). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

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

  Total consumption by military aviation is given in ONS (1995) and MOD (2005a) and is assumed to be aviation turbine fuel.

Table 5-3 Aircraft Movement Data

Year	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	410.1	318.1	635.4	98.8
1991	397.4	312.6	623.9	97.0
1992	432.8	331.0	705.9	102.8
1993	443.6	338.0	717.3	106.5
1994	461.9	316.3	792.6	102.2
1995	480.9	329.6	831.9	107.4
1996	507.2	341.2	871.5	113.1
1997	537.7	346.0	948.9	118.3
1998	576.4	360.0	1034.6	124.3
1999	610.1	368.1	1101.4	129.1
2000	646.8	378.8	1171.3	134.1
2001	653.8	393.1	1186.4	142.5
2002	650.2	391.6	1178.7	141.9
2003	669.3	401.7	1230.7	145.2
2004	700.6	434.2	1335.1	155.4
2005	739.4	458.0	1427.3	165.3
2006	762.4	458.4	1492.6	165.9
2007	788.4	450.9	1547.6	163.0
2008	776.4	438.9	1534.6	158.6

Notes

Gm Giga metres, or 10^9 metres

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

Emission factors used

The following emission factors were used to estimate emissions from aviation. The emissions of SO_x and metals depend on the sulphur and metal contents of the aviation fuels. Emissions factors for SO_x 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 Sulphur Dioxide Emission Factors for Civil and Military Aviation for 2008 (kg/t)

Fuel	SO_x
Aviation Turbine Fuel	0.87
Aviation Spirit	0.87

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2008)
Carbon emission factor as kg carbon/tonne
Military aviation only uses ATF

For the LTO-cycle calculations, emissions per LTO cycle are required for each of a number of representative aircraft types. Emission factors for the LTO cycle of aircraft operation have been taken from the ICAO database. The cruise emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

Table 5-5 Non-CO_2 Emission Factors for Civil and Military Aviation

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

Notes

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

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 the mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year.

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

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

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

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

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

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP/CORINAIR Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data has been assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al*. (2004).

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

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

Where:

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

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

Classification of domestic and international flights

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

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

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

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

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 (1997) and EMEP/CORINAIR (1999) cruise defaults shown in Table 1 of EMEP/CORINAIR (1999). The EMEP/CORINAIR (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons, casual uplift at civilian airports, but not fuel uplifted at foreign military airfields or *ad hoc* uplift from civilian airfields.

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

Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DECC publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. The ATF consumptions presented in DECC DUKES include the use of both civil and military ATF, and the military ATF use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil ATF consumption has been used in the fuel reconciliation. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

Geographical coverage of aviation emission estimates

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

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

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

5.3 RAILWAYS

The UK NAEI reports emissions from both stationary and mobile sources. The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported under NFR code 1A4a Commercial/Institutional. Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity. These emissions are based on fuel consumption data from DECC (2009).

The UK NAEI reports emissions from diesel trains in three categories: freight, intercity and regional. 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). As a result of issues regarding the availability of gas oil consumption data by passenger trains, fuel consumption in 2007 and 2008 was estimated on the basis of reported train kilometres travelled. For freight trains, the data are estimated by combining fuel consumption factors with train kilometre data from the UK's national rail trends yearbook. Emissions from diesel trains are reported under the category 1A3c Railways.

Sulphur dioxide is calculated using fuel-based emission factors and fuel consumption data. The fuel consumption is distributed according to train km data taken from the National rail trends yearbook (2008) http://www.rail-reg.gov.uk/upload/pdf/375.pdf for the three categories[4]; assumed mix of locomotives for each category; and fuel consumption factors for different types of locomotive (LRC (1998), BR (1994) and Hawkins & Coad (2004)).

Emissions of CO, NMVOC, and NO_x are based on the train km estimates and emission factors for different train types. The emission factors shown in Table 5-6 are aggregate implied factors so that all factors are reported on the common basis of fuel consumption.

Compared with the last version of the inventory, very minor changes to implied emission factors are noted for regional and intercity passenger rail with respect to NO_x and CO with the emission factors for both categories increasing slightly from the values used in 2007. These changes to the implied factors are a net result of minor changes in estimated km travel and fuel consumed.

The emission factor for SO_x has decreased from 2.67 kt/ Mt fuel in 2007 to 1.63 kt/ Mt fuel in 2008 in line with UKPIA's Table of the S-content in fuels in 2008 (UKPIA, 2009).

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

	NO_x	CO	NMVOC	SO_x
Freight	80.1	8.9	4.5	1.63
Intercity	42.2	13.2	5.7	1.63
Regional	33.1	36.7	6.4	1.63

5.4 ROAD TRANSPORT

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel-based emission factors, or from a combination of drive related emission factors and road traffic data. Not all specific detail and emission factors are included in this report, however further information on the methodology can be found in the UK GHGI, 1990 to 2008: Annual Report for submission under the Framework Convention on Climate Change (AEA 2010).

Fuel consumption data are taken from DUKES, with corrections made for road fuels used in off-road vehicles and mobile machinery (see Section 4.6 for details of the estimates made for fuels used by these sources) and the small amount of fuel consumed by the Crown

[4] For TOC where train km data was not available for 2007, the data was assumed to be unchanged from the previous year (2006).

Dependencies included in DUKES (emissions from the Crown Dependencies are calculated elsewhere). Emissions of SO_x are estimated from the fuel consumption using the sulphur content of the fuel supplied by the UK oil industry. Metal emission factors are taken from literature sources.

In 2008, 16.68 Mtonnes of petrol and 20.61 Mtonnes of diesel fuel (DERV) were consumed in the UK (a very small proportion of this was used in the Crown Dependencies). For both fuels, this is a decrease in consumption compared with 2007. It was estimated that of this, around 1.5% of petrol was consumed by off-road vehicles and machinery and 0.4% used in the Crown Dependencies, leaving 16.35 Mtonnes of petrol consumed by road vehicles in the UK in 2008. Around 0.05% of road diesel is estimated to be used by off-road vehicles and machinery (the bulk of these use gas oil) and 0.3% used in the Crown Dependencies, leaving 20.55 Mtonnes of diesel consumed by road vehicles in the UK in 2008. According to figures in DUKES (DECC 2009), 0.125 Mtonnes of LPG were used for transport in 2008, up from 0.119 Mtonnes the previous year and back to levels in 2006.

Table 5-7 Sulphur Dioxide Emission Factors for Road Transport (kg/tonne fuel used)

Fuel	**SO_x**[a]
Petrol	0.047
Diesel	0.014

a 2008 emission factor calculated from UKPIA (2009) – figures based on the weighted average sulphur-content of fuels delivered in the UK in 2008

Emissions of SO_x 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.

Fuel consumption factors for petrol and diesel vehicles

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

Fuel consumption factors in g of fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types. The methodology and the figures are provided in detail in the UK GHGI, 1990 to 2008: Annual Report for submission under the Framework Convention on Climate Change (AEA 2010).

Fuel reconciliation and normalisation

A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data. These "bottom-up" calculated estimates of petrol and diesel consumption are then compared with DECC figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by off-road machinery and consumption in the Crown Dependencies. The bottom-up estimated fuel consumption differs from the DUKES-based figures and so it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total consumption of petrol and diesel equals the DUKES-based figures. The normalisation process introduces uncertainties into the fuel consumption and hence SO_x emission estimates for individual vehicle classes even though the totals for road transport are known with high accuracy. The impact of the reconciliation on each vehicle type is explained further in the UK GHGI, 1990 to 2008: Annual Report for submission under the Framework Convention on Climate Change (AEA 2010).

Traffic-based emissions

Emissions of other pollutants such as NMVOCs, NO_x, PM_{10} and CO are calculated from measured emission factors expressed in grammes per kilometre and road traffic statistics from the Department for Transport (DfT, 2007a). 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 in 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.

Emissions from motor vehicles fall into three different types, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions and, for NMVOCs, evaporative emissions.

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. The emission factors for all pollutants were reviewed and updated where necessary in light of the release of the new DfT/TRL emission factors in 2009 (Boulter et al, 2009).

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

Vehicle and fuel type

Emissions are calculated for vehicles of the following types:

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

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

Vehicle kilometres by road type

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

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

The 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 2009a). The DfT Report "Transport Statistics Great Britain" (DfT 2009a) provides vehicle kilometres data up to 2008. Additional information discussed later was used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland Road Services (DRDNI, 2002, 2003, 2006, 2007, 2008, 2009a). These provided a consistent time-series of vehicle km data for all years up to 2008. A slight revision was made to the vehicle km time-series for 1990-2007 due to new information from Northern Ireland about the split between cars and Larger Goods Vehicles (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, 2009b).

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 2008 as shown in
Table **5-8**.

Table 5-8 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petrol cars	urban	142.9	139.7	139.1	138.7	140.0	136.1	133.7	129.7	127.5	125.0	120.6
	rural	138.2	128.1	127.2	127.3	127.0	124.4	122.5	118.4	117.0	113.4	109.5
	m-way	47.7	46.0	48.4	48.8	48.2	46.3	45.9	44.0	43.1	41.5	39.8
Diesel cars	urban	4.8	13.9	21.3	22.9	25.9	28.4	31.3	34.0	37.1	40.1	42.3
	rural	8.1	22.9	35.2	38.2	42.6	46.9	51.9	56.2	61.4	65.7	69.1
	m-way	4.2	11.9	19.1	20.8	23.0	24.9	27.7	29.8	32.4	34.4	36.1
Petrol LGVs	urban	11.2	7.7	4.4	3.7	3.0	2.6	2.3	2.0	1.9	1.8	1.6
	rural	11.5	8.4	4.8	4.1	3.7	3.2	2.7	2.3	2.3	2.2	2.0
	m-way	4.0	3.0	2.0	1.8	1.5	1.2	1.1	0.9	1.0	0.9	0.8
Diesel LGVs	urban	6.0	10.7	16.5	17.6	17.8	19.6	21.1	21.9	22.5	23.5	23.7
	rural	6.6	12.0	18.6	19.9	22.3	24.0	25.5	26.8	27.8	29.9	30.1
	m-way	2.1	4.1	7.6	8.3	8.5	9.1	10.0	10.5	11.0	11.6	11.6
Rigid HGVs[5]	urban	4.7	4.4	4.2	4.2	4.1	4.3	4.4	4.3	4.2	4.0	4.0
	rural	7.5	7.0	7.6	7.6	8.1	8.3	8.2	8.2	8.3	8.5	8.3
	m-way	3.7	3.5	4.3	4.3	4.3	4.3	4.4	4.3	4.3	4.3	4.3
Artic HGVs	urban	1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.0	1.0	1.0	0.9
	rural	4.3	5.1	5.6	5.6	5.3	5.3	5.3	5.3	5.5	5.6	5.6
	m-way	4.7	5.6	7.0	7.0	7.5	7.4	8.0	7.9	8.0	8.3	8.0
Buses	urban	2.4	3.0	3.0	3.0	3.0	3.2	3.2	3.2	3.3	3.4	3.2
	rural	1.7	1.5	1.6	1.6	1.8	1.8	1.6	1.5	1.6	1.8	1.6
	m-way	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.5
M/cycle	urban	3.3	1.9	2.2	2.4	2.6	3.1	2.8	3.0	2.7	3.2	2.7
	rural	2.0	1.6	2.0	2.1	2.1	2.2	2.1	2.2	2.1	2.2	2.1
	m-way	0.3	0.3	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5

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

[5] Heavy Goods Vehicles

different areas were taken from the following main sources: Transport Statistics Great Britain (DfT 2009a) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008b) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned.
Table **5-9** shows the speeds used in the 2008 inventory for light duty vehicles, Heavy Goods Vehicles (HGVs) and buses.

Table 5-9 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. DfT Vehicle Licensing Statistics (DfT 2009b) provide the number of vehicles licensed on the road by fuel type. This information is combined with data on the relative mileage done by petrol and diesel cars (DfT, 2008c, pers. comm.). This indicates that diesel cars do on average 60% more annual

mileage than petrol cars. The information originated from the National Travel Survey (DfT, 2007b). It has been assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, the petrol car/diesel car mix on urban roads is assumed to be that indicated by the population mix according to vehicle licensing data (i.e. that there is no preferential use of diesel or petrol cars on urban roads) and the mix on rural and motorways adjusted to give an overall mileage pattern over all roads in the UK that leads to an average 60% higher annual mileage by diesel cars compared with petrol cars. This leads to the vehicle km data for petrol and diesel cars on different road types shown in
Table **5-8**.

The new 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 2009b). In addition, the relative mileage done by different size of vehicles was factored into the ratios, this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2008c).

To utilise the new DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the new emission factors cover three different weight classes of LGVs, eight different size classes of rigid HGVs, five different weight classes of artic HGVs, five different weight classes of buses and coaches and seven different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types was obtained from vehicle licensing statistics and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles. Only limited information on the sizes of buses and coaches by weight exists and it was assumed based on analysis of local bus operator information that 72% of all bus and coach km on urban and rural roads are done by buses, the remaining 28% by coaches, while on motorways all the bus and coach km are actually done by coaches. 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 in the fleet. Research on the motorcycle fleet indicated that 2-stroke motorcycles are confined to the <150cc class.

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems. Table 5-10 shows the regulations that have come into force up to 2008 for each vehicle type.

The average age profile and the fraction of petrol and diesel cars and LGVs in the fleet each year are based on the composition of the UK vehicle fleet using DfT Vehicle Licensing Statistics. The Transport Statistics Bulletin "Vehicle Licensing Statistics: 2008" (DfT, 2009b) either gives historic trends in the composition of the UK fleet by age directly or provides sufficient information for this to be calculated from new vehicle registrations and average vehicle survival rates. Thus, year-of-first registration data for vehicles licensed in each year from 1990 to 2008 have been taken to reflect the age distribution of the fleet in these years. Statistics are also available on the number of new registrations in each year up to

2008, reflecting the number of new vehicles entering into service in previous years. The two sets of data combined allow an average survival rate to be determined for each type of vehicle. A more detailed examination of vehicle licensing data was undertaken since the last version of the inventory to refine the survival rate assumptions for use with the new emission factors.

Table 5-10 Vehicles types and regulation classes

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

This has the effect of revising the turnover in the fleet and therefore the composition of the fleet by Euro standard. Particularly detailed information is available on the composition of the HGV stock by age and size. The age composition data are combined with data on the change in annual vehicle mileage with age to take account of the fact that newer vehicles on average travel a greater number of kilometres in a year than older vehicles. For cars and LGVs, such mileage - by age data, are from the National Travel Survey (DETR, 1998a); data for HGVs of different weights are taken from the Continuous Survey of Road Goods Transport (DETR, 1996a).

Separate vehicle licensing statistics for private and light goods vehicles (PLG) in Northern Ireland are available from the Central Statistics and Research Branch of the Department of Regional Development in Northern Ireland (DRDNI, 2009c). These show a higher proportion of diesel cars than in Great Britain. Unlike other regional licensing statistics, it is more likely that these statistics reflect the actual fuel mix of cars on the road in Northern Ireland and so this information was used in the inventory. The mix of petrol and diesel cars in the Northern Ireland fleet were revised since the last version of the inventory after DRDNI were able to further interrogate the licensing data held (DRDNI, 2009b).

Assumptions are 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 since the last version of the inventory, these assumptions have been revised. It is now 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 new 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.

Voluntary measures and retrofits to reduce emissions

The inventory takes account of the early introduction of certain emission standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro 3 emission standards for passenger cars (98/69/EC) came into effect from January 2001 (new registrations). However, some makes of cars sold in the UK already met the Euro 3 standards prior to this (DfT, 2001). Figures from the Society of Motor Manufacturers and Traders suggested that 3.7% of new cars sold in 1998 met Euro 3 standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro 3 standards in 1999 increasing to 10% in 2000. In 2001, an assumption was made that 15% of all new petrol cars sold in the UK met Euro 4 standards, increasing to 81% in 2004 even though the mandatory date of introduction of this standard is not until 2006 (DfT, 2004). The remaining new petrol car registrations in 2001 - 2005 would meet Euro 3 standards. From 2006, all new cars must fully comply with Euro 4 standards.

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, 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 NO_x, CO and NMVOC emissions.

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 ppm S), 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 Ultra-low Sulphur Diesel (ULSD), as this fuel was not widely available in UK filling stations.

Hot Emission Factors

The emission factors for all pollutants were reviewed and updated where necessary in light of the release of the new DfT/TRL emission factors in 2009 (Boulter et al, 2009).

Emission factors for NO_x were updated in the previous year's inventory using the preliminary DfT/TRL compilation of emission factors released in 2008 for consultation. The finalised set of emission factors for these and also for total hydrocarbons (THC), CO and other pollutants were published in 2009 and are used in the 2008 inventory. The emission factors are represented as equations relating emission factor in g/km to average speed (Boulter et al, 2009).

As stated earlier, the DfT/TRL emission factors are provided for a more extensive range of vehicle types, sizes and Euro standards than had previously been available and were based on more up-to-date emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. Scaling factors are also provided to take into account the effects of fuel quality since some of the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. Table 5-13 - Table 5-15 summarise the NO_x, CO and NMVOC emission factors for all vehicle types under typical urban, rural and motorway road conditions in g/km normalised to 50,000km accumulated mileage and current fuels. These are derived from the tables at http://www.dft.gov.uk/pgr/roads/environment/emissions/ for detailed vehicle size classes and averaged according to the proportion of different vehicle sizes in the UK fleet according to vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for methane from the corresponding THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in
Table **5-9**. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

The inventory takes into account the change in emissions with mileage using the TRL functions and change in mileage with age data and uses the TRL fuel scaling factors to take into account the prevailing fuel quality in different years. Note that the new TRL compilation lumps together emission factors for all the pre-Euro 1 classes of petrol cars that were previously separated. This would only affect the time-series trends in the 1970's and 1980's.

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

The emission factors used for NMVOCs, NO_x and CO 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 (2009) 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 assumed effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in Table 5-11.

Table 5-11 Scale Factors for Emissions from a Euro II Bus Running on Fitted with an Oxidation Catalyst or DPF

		NO_x	**CO**	**NMVOCs**
Oxidation catalyst	Urban	0.97	0.20	0.39
	Rural	0.95	0.22	0.55
DPF	Urban	0.90	0.17	0.19
	Rural	0.88	0.19	0.27

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

Euro II HGVs equipped with DPFs have their emissions reduced by the amounts shown in Table 5-12.

Table 5-12 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

		NO_x	**CO**	**NMVOCs**
DPF	Urban	0.81	0.10	0.12
	Rural	0.85	0.10	0.12

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.

Previously, the inventory used the COPERT II methodology (EEA, 1997) for estimating cold start emissions, but this was revised in light of a review of alternative methodologies and the recommendations made by TRL on behalf of DfT (Boulter and Latham, 2009). Their main conclusion was that the current inventory approach based on COPERT II ought to be updated 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 Lathan (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 CORINAIR Emissions Inventory Guidebooks still utilises the approach in COPERT III (EEA, 2000). COPERT III was developed in 2000 and is a methodology similar to the COPERT II methodology currently used in the UK inventory, but is rather more detailed in terms of vehicle classes and uses more 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 like COPERT II 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.

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, 2007a). A key issue seems to be what the definition of a trip is according to motorist surveys. The mid-point seems to be a value of 10 km given for the UK in the CORINAIR Emissions Inventory Guidebook, so this figure was adopted (EEA, 2007).

The COPERT III method provides pollutant-specific reduction factors 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, 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).

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

Data for estimating cold start effects on methane emissions are not available and are probably within the noise of uncertainty in the hot exhaust emission factors. Cold start effects are mostly an issue during the warm up of three-way catalyst on petrol cars when the catalyst is not at its optimum efficiency in reducing hydrocarbon, NO_x and CO emissions.

Evaporative emissions

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The procedure for estimating evaporative emissions of NMVOCs takes account of changes in ambient temperature and fuel volatility.

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.

Evaporative emissions are dependent on ambient temperature and the volatility of the fuel and, in the case of diurnal losses, on the daily *rise* in ambient temperature. Fuel volatility is usually expressed by the empirical fuel parameter known as Reid vapour pressure (RVP). For each of these mechanisms, equations relating evaporative emissions to ambient temperature and RVP were developed by analysis of empirically based formulae derived in a series of CONCAWE research studies in combination with UK measurements data reported by TRL. Separate equations were developed for vehicles with and without evaporative control systems fitted such as carbon canister devices. The overall methodology is similar to that reported by COPERT II (EEA, 1997), but the data are considered to be more UK-biased.

Evaporative emissions are calculated using monthly average temperature and RVP data. Using this information, evaporative emissions are calculated from the car fleet for each month of the year and the values summed to derive the annual emission rates. Calculating emissions on a monthly basis enables subtle differences in the seasonal fuel volatility trends and differences in monthly temperatures to be better accounted for. Monthly mean temperatures from 1970-2008 were used for the calculations based on Met Office for Central England (CET data), the same data as used for the cold start calculations. The monthly average, monthly average daily maximum and monthly average diurnal rise in temperatures were required. The monthly average RVP of petrol sold in the UK used historic trends data on RVP and information from UKPIA on the RVP of summer and winter blends of fuels supplied in recent years and their turnover patterns at filling stations (Watson, 2001, 2003). The average RVP of summer blends of petrol in the UK in 2008 was 68 kPa, 2 kPa below the limit set by European Council Directive 98/70/EC for Member States with “arctic” summer conditions (UKPIA, 2009).

All the equations for diurnal, hot soak and running loss evaporative emissions from vehicles with and without control systems fitted developed for the inventory are presented in UK GHGI, 1990 to 2008: Annual Report for submission under the Framework Convention on Climate Change (AEA 2010). The inventory uses equations for Euro 1 cars with “first generation” canister technology, based on early measurements, but equations taken from COPERT III leading to lower emissions were used for Euro 2-4 cars as these better reflected the fact that modern cars must meet the 2g per test limit on evaporative emissions by the diurnal loss and hot soak cycles under Directive 98/69/EC.

Table 5-13 NO_x Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable).

g NOx (as NO2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.558	1.982	2.600
	Euro 1	0.301	0.319	0.371
	Euro 2	0.143	0.154	0.189
	Euro 3	0.064	0.066	0.079
	Euro 4	0.046	0.043	0.045
Diesel cars	Pre-Euro 1	0.578	0.613	0.805
	Euro 1	0.523	0.550	0.809
	Euro 2	0.617	0.647	0.922
	Euro 3	0.477	0.491	0.660
	Euro 4	0.297	0.328	0.471
Petrol LGVs	Pre-Euro 1	1.496	2.025	2.731
	Euro 1	0.350	0.384	0.462
	Euro 2	0.091	0.089	0.123
	Euro 3	0.050	0.058	0.079
	Euro 4	0.034	0.028	0.025
Diesel LGV	Pre-Euro 1	1.649	1.769	2.353
	Euro 1	1.143	1.339	1.980
	Euro 2	1.247	1.491	2.260
	Euro 3	0.736	0.921	1.478
	Euro 4	0.368	0.461	0.739
Rigid HGVs	Pre-Euro I	8.094	8.229	8.717
	Euro I	5.400	5.540	5.810
	Euro II	5.675	5.738	5.959
	Euro III	4.431	4.390	4.572
	Euro IV	2.729	2.748	2.895
	Euro V	1.608	1.612	1.700
Artic HGVs	Pre-Euro I	14.440	13.426	14.223
	Euro I	10.122	9.430	9.987
	Euro II	10.440	9.714	10.296
	Euro III	8.267	7.654	8.113
	Euro IV	5.101	4.745	5.014
	Euro V	2.989	2.775	2.932
Buses & coaches	Pre-Euro I	11.182	10.106	10.199
	Euro I	7.471	6.658	7.663
	Euro II	7.977	7.047	8.288
	Euro III	6.431	5.366	6.573
	Euro IV	3.935	3.353	4.030
	Euro V	2.361	1.976	2.409
Mopeds, <50cc, 2st	Pre-Euro 1	0.030		
	Euro 1	0.030		
	Euro 2	0.010		
	Euro 3	0.010		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.026	0.039	
	Euro 1	0.041	0.054	
	Euro 2	0.048	0.062	
	Euro 3	0.023	0.036	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.223	0.446	0.569
	Euro 1	0.229	0.443	0.569
	Euro 2	0.127	0.306	0.664
	Euro 3	0.065	0.155	0.337

Table 5-14 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

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

Table 5-15 Total Hydrocarbons (THC) Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable). NMVOC emission factors are derived by subtracting methane factors from the THC factors.

g HC/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.242	0.847	0.644
	Euro 1	0.124	0.091	0.115
	Euro 2	0.045	0.041	0.051
	Euro 3	0.020	0.020	0.027
	Euro 4	0.014	0.010	0.013
Diesel cars	Pre-Euro 1	0.124	0.093	0.076
	Euro 1	0.072	0.048	0.035
	Euro 2	0.054	0.039	0.031
	Euro 3	0.020	0.013	0.010
	Euro 4	0.018	0.015	0.013
Petrol LGVs	Pre-Euro 1	1.444	0.935	0.669
	Euro 1	0.190	0.128	0.151
	Euro 2	0.037	0.038	0.057
	Euro 3	0.028	0.028	0.039
	Euro 4	0.014	0.014	0.019
Diesel LGV	Pre-Euro 1	0.160	0.136	0.124
	Euro 1	0.083	0.057	0.042
	Euro 2	0.082	0.076	0.085
	Euro 3	0.034	0.025	0.024
	Euro 4	0.029	0.022	0.021
Rigid HGVs	Pre-Euro I	0.993	0.836	0.894
	Euro I	0.397	0.355	0.364
	Euro II	0.254	0.225	0.231
	Euro III	0.225	0.200	0.205
	Euro IV	0.011	0.010	0.010
	Euro V	0.011	0.010	0.010
Artic HGVs	Pre-Euro I	0.711	0.609	0.651
	Euro I	0.676	0.589	0.629
	Euro II	0.430	0.372	0.398
	Euro III	0.370	0.322	0.344
	Euro IV	0.018	0.016	0.017
	Euro V	0.019	0.016	0.017
Buses & coaches	Pre-Euro I	1.014	0.676	0.409
	Euro I	0.589	0.413	0.431
	Euro II	0.384	0.271	0.273
	Euro III	0.346	0.245	0.270
	Euro IV	0.018	0.012	0.013
	Euro V	0.018	0.012	0.014
Mopeds, <50cc, 2st	Pre-Euro 1	13.910		
	Euro 1	2.730		
	Euro 2	1.560		
	Euro 3	1.200		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.407	8.113	
	Euro 1	2.341	3.273	
	Euro 2	1.243	1.738	
	Euro 3	0.777	1.084	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.527	1.218	1.726
	Euro 1	0.853	0.753	0.807
	Euro 2	0.381	0.439	0.577
	Euro 3	0.238	0.275	0.362

5.5 SHIPPING

The UK NAEI provides emission estimates for coastal shipping, naval shipping and international marine. Coastal shipping is reported within 1A3dii National Navigation and includes emissions from diesel use at offshore oil & gas installations. A proportion of this diesel use will be for marine transport associated with the offshore industry but some will be for use in turbines, motors and heaters on offshore installations. Detailed fuel use data is no longer available to determine emissions from diesel use in fishing vessels, as the DTI gas oil dataset was revised in the 2004 inventory cycle. All emissions from fishing are now included within the coastal shipping sector, 1A3dii National Navigation.

The emissions reported under coastal shipping and naval shipping are estimated according to the base combustion module using the emission factors given in Table A2-1 in Appendix 2.

The NAEI category International Marine is a memo item in NFR code z_1A3di(i) International maritime navigation. The estimate used is based on the following information and assumptions:

(i) Total deliveries of fuel oil, gas oil and marine diesel oil to marine bunkers are given in DECC (2009);

(ii) Naval fuel consumption is assumed to be marine diesel oil (MOD, 2009). Emissions from this source are not included here but are reported under 1A5 Other; and

(iii) The fuel consumption associated with international marine is the marine bunkers total minus the naval consumption. The emissions were estimated using the emission factors shown in Table A2-1.

Emissions from z_1A3di(i) International maritime navigation are reported for information only and are not included in national totals. Bunker fuels data for shipping are provided to DECC by UKPIA, and are based on sale of fuels to UK operators going abroad and overseas operators (assumed to be heading abroad) (DTI 2004, per. comm.[6]).

Emissions from navigation are based on emission factors for different types of shipping and a detailed examination of their activities in UK waters. In particular, detailed information on shipping emission factors has been used from the study done by Entec UK Ltd for the European Commission (Entec, 2005) and from the more recent EMEP/CORINAIR Handbook (EMEP/CORINAIR, 2003).

Lloyds Marine Intelligence Unit (LMIU) publishes ship arrivals at UK ports by type and dead weight for four different vessel types: tankers, Ro-Ro ferry vessels, fully cellular container vessels and other dry cargo vessels. Fuel use between different vessel types has been apportioned on the basis of the vessels' main engine power as well as number of port arrivals. The main engine power for the Gross Registered Tonnage (GRT) groups used in the LMIU table was estimated. Then the product of vessel (type, GRT) port visits multiplied by the estimated main engine power was calculated and summed for each of the four vessel types. The distribution of total engine power summed over a year was then used to distribute the DUKES fuel consumption among the four vessel types.

[6] DTI (2004). Personal communication from Martin Young, DTI.

Different engine types when fuelled with fuel oil, marine gas oil or marine diesel oil have different emission factors (kg pollutant emitted /tonne of fuel used). For NO_x and NMVOCs, it was possible to use data from the Entec study to produce a weighted mean emission factor for each of the four LMIU vessel types based on their average engine size and fuel type. Aggregated emission factors for the whole UK shipping activity were then calculated by weighting each vessel type's factor with the proportion of fuel consumed by each vessel type. Emissions of CO are not covered in the Entec report, so emission factors quoted in the Corinair handbook were used. Emissions of SO_x are based on the fuel sulphur content and amount of each type of fuel used.

Emissions from naval shipping have been revised due to the use of a revised, but consistent time series of naval fuel consumption (naval diesel and marine gas oil) from the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the Ministry of Defence (MoD, 2009). Fuel data for each financial year from 2003/04 to 2007/08 were provided. Figures for 2008/09 were not complete so data for 2007/08 were used. Adjustments were made to the data to derive figures on a calendar year basis. Fuel consumption for earlier years were re-scaled from the new 2003 figures on the basis of trends in data previously provided by the MoD.

5.6 OFF-ROAD SOURCES

Emissions from military aircraft and naval vessels are reported under 1A5b Other Mobile (including military). Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data. Emissions from off-road sources are estimated and are reported under the relevant sectors, i.e. Other Industry, Residential, Agriculture and Other Transport.

For 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 NAEI they are grouped into four main categories:

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

Aircraft support is mapped to Other Transport and the other categories map to the off-road vehicle subcategories of Residential, Agriculture and Manufacturing Industries and Construction.

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

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

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

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:

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

where

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

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by AEA Energy & Environment 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 2005-2008. For industrial machinery, manufacturing output statistics were used to scale 2005-2008 activity rates relative to 2004; for domestic house and garden machinery, trends in number of households were used; for airport machinery, statistics on number of terminal passengers at UK airports were 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 and some updates were made to the inventory to give a better match of each of the 77 different machinery types to the relevant regulation in terms of implementation date and limit value.

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

Aggregated emission factors for the four main off-road machinery categories in 2008 are shown in Table 5-16 by fuel type. The fleet-average (aggregated) emission factors for most machinery types are lower than in the 2007 inventory because of the expiry of old machinery and penetration of new machinery into the fleet as well as the reduction in the sulphur content of fuels.

Table 5-16 Aggregate Emission Factors for Off-Road Source Categories in 2008 (t/kt fuel)

Source	Fuel	NO_x	CO	NMVOC	SO_x[3]
Domestic House&Garden	DERV	47.96	4.3	2.6	0.014
Domestic House&Garden	Petrol	4.02	667.9	74.9	0.048
Agricultural Power Units	Gas Oil	32.28	17.0	5.6	1.63
Agricultural Power Units	Petrol	1.45	716.3	248.6	0.048
Industrial Off-road	Gas Oil	38.02	16.6	6.3	1.63
Industrial Off-road	Petrol	6.16	1020.8	40.7	0.048
Aircraft Support	Gas Oil	31.25	12.5	5.3	1.63

1 Emission factors reported are for 2008
2 Emission factor as kg carbon/t, UKPIA (2004)
3 Based on sulphur content of fuels in 2007 from UKPIA (2008).

5.7 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

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

6.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

The NAEI utilises energy statistics published annually in the Digest of UK Energy Statistics (DECC, 2009). The source categories and fuel types used in the NAEI therefore reflect those used in DUKES. In Chapter 3,Table 3-1 lists the fuels used in the inventory.

Table 6-1 relates the detailed NAEI base categories used in the inventory 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 base 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 LRTAP.

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

NFR Source Category	NAEI Source Category
1A3ei Pipeline Compressors	Included under Gas Production
1A4ai Commercial/Institutional	Miscellaneous Public Services Railways (Stationary Sources)
1A4bi Residential	Domestic
1A4ci Agriculture/Forestry/Fishing (Stationary)	Agriculture
1A5a Other: Stationary	No comparable category – any emissions likely to be included in 1A4a

Almost all of the NFR Source Categories listed in Table 3-2 in Chapter 3 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 1A4bi are key sources for NO_x, SO_x, PM_{10}, Cd, Pb, Hg. Sector 1A4bi is also a key source for CO, NMVOC, B[a]P and PCDD/PCDF. Sector 1A4ci 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 a bottom-up approach utilizing reported emissions is not possible. In these cases, therefore, literature emission factors are used together with activity data taken from DUKES.

6.3 FUEL CONSUMPTION DATA

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

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

The most important of these deviations are as follows:

- DUKES does not include any energy uses of petroleum coke. Instead, all consumption of petroleum coke is allocated to ‘non-energy uses’ in the commodity balance tables for petroleum products (although DUKES does include some information on energy use of petroleum coke in the notes accompanying the tables). AEA include estimates of petroleum coke burnt by the domestic sector (based on the notes given in DUKES).
- Gas oil is used in large quantities as a fuel for off-road vehicles and mobile machinery. These devices are not treated as a separate category in DUKES and the fuel they use is included in the DUKES data for agriculture, industry, public administration, railways, and industry. AEA generate independent estimates of gas oil use for off-road vehicles and mobile machinery from estimates of the numbers of each type of vehicle/machinery in use, and the fuel consumption characteristics. Overall consistency with UK consumption of gas oil, as given in DUKES, is maintained by reducing NAEI estimates for gas oil consumed by the sectors listed above.

6.4 METHOD FOR COMMERCIAL/DOMESTIC/PUBLIC SECTOR COMBUSTION

Individual combustion plants range in scale from domestic appliances such as central heating boilers and open fires, up to a few 'large combustion plant' with thermal inputs exceeding 50 MW_{th}. Because of the smaller plant, it is not possible to derive bottom-up estimates and emissions can best be estimated using an appropriate emission factor applied to national fuel consumption statistics taken from DUKES i.e. emissions are calculated according to the equation:

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

Where:

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

Emissions data are reported in the PI, SPRI, and ISR for the 'large combustion plant' and the methodology allows for these reported data to be used in the case of NO_x only. Data are also available for SO_x 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_x. Reported data for other pollutants are extremely limited and are not used either.

For most pollutants, a single factor is applied for a given source category but, in the case of carbon monoxide, NO_x and PM_{10} emissions, a more detailed approach is taken. This is done because these source categories consist of a wide range of sizes and types of combustion appliances and emission rates are expected to vary between these different appliances. The more detailed approach therefore allows source/fuel combinations to be further broken down by a) thermal input of combustion devices; b) type of combustion process e.g. boilers, furnaces, turbines etc, and for emission factors to be applied at this more detailed level. Emission factors are mostly taken from literature sources such as the US EPA Compilation of Air Emission Factors (USEPA, 2007), the EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 2007) and UK emission factor surveys (Walker *et al*, 1985). Emissions data for NO_x reported in the Pollution Inventory (Environment Agency, 2008) are also used in the generation of emission factors for larger combustion plants in the public and commercial sector source categories.

6.5 SOURCE SPECIFIC QA/QC AND VERIFICATION

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

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

7.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

Table 7-1 relates the detailed NAEI base categories used in the inventory to the equivalent NFR source categories. A number of these NAEI base 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. Most of these NAEI base categories are linked to only a single activity category. In these cases, the choice of activity category will either be determined by the units specified by the emission factors being used or, if emissions data are available directly from industry or regulators, will not be critical since activity data would then be needed only to calculate an emission factor for the source. In the case of emissions from distribution of oil products, all of the NAEI source categories are broken down into emissions from the distribution of leaded petrol and unleaded petrol.

Table 7-1 Mapping of NFR Source Categories to NAEI Source Categories: Fugitive Emissions from Fuels.

NFR Source Category	NAEI Source Category
1B1a Coal Mining and Handling	Deep-Mined Coal Coal Storage & Transport Open-Cast Coal
1B1b Solid Fuel Transformation	Coke Production (Fugitive) SSF Production (Fugitive) Flaring (Coke Oven Gas)
1B1c Other	Not Estimated
1B2a Oil i Exploration, Production and Transport	Offshore Oil and Gas (Well Testing) Offshore Oil and Gas Offshore Loading Onshore Loading
1B2a Oil iv Refining/Storage	Refineries (drainage) Refineries (tankage) Refineries (Process) Oil Terminal Storage Petroleum Processes
1B2a Oil v Distribution of oil products	Petrol Stations (Petrol Delivery) Petrol Stations (Vehicle Refuelling) Petrol Stations (Storage Tanks) Petrol Stations (Spillages) Petrol Terminals (Storage) Petrol Terminals (Tanker Loading) Refineries (Road/Rail Loading) Ship Purging
1B2a Oil vi Other	Not Estimated
1B2b Natural Gas	Gasification Processes Gas Leakage
1B2c Venting and Flaring	Offshore Oil and Gas (Venting) Offshore Flaring Refineries (Flares)

The following NFR source categories are key sources for major pollutants: 1B1b, 1B2a(i), 1B2a(iv), 1B2a(v), 1B2b, 1B2c. Description of the inventory methodology will focus on these categories.

7.2 NFR 1B1B: SOLID FUEL TRANSFORMATION

NFR Sector 1B1b is a key source for SO_x, Cd, Pb and B[a]P.

Solid fuel transformations include the manufacture of coke and other solid smokeless fuel (SSF). 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. Overall emissions at UK coke ovens and SSF manufacturing sites are reported in the PI, 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. Section 3.6 has described the approach used to derive emission estimates from reported data, and so no further detail is given here.

The reported data do not include some pollutants which emissions estimates are based on a mass-balance approach; eg, in the case of SO_x factors for SSF, but are otherwise derived either using literature emission factors (e.g. factors for NMVOC and metals from SSF manufacture and all factors for flaring of coke oven gas) or using emissions data reported in the Pollution Inventory (e.g. for most pollutants from coke manufacture).

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2008, there were five coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last six years, due to closure of associated steelworks or closure of other coke consumers. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes employing thermal techniques are included in the inventory since only these give rise to significant emissions. Currently, there are two sites manufacturing SSF using such processes.

All of these sites are required to report emissions in one of the Pollution Inventory (PI), the Scottish Pollutant Release Inventory (SPRI), or Northern Ireland's Inventory of Sources and Releases (ISR). Emission estimates for the sector can be based on the emission data reported for individual sites i.e.

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

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 and PM_{10} only.

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. Table 7-2 summarises the sources of emissions data for these source categories.

Table 7-2 Sources of Emission Estimates for Oil & Gas Industry Processes

NAEI Source Category	Method
Offshore Oil and Gas (Well Testing) Offshore Oil and Gas Offshore Loading Onshore Loading Oil Terminal Storage Offshore Oil and Gas (Venting) Offshore Flaring	Emissions data supplied by Oil & Gas UK and derived by process operators using industry standard methods.
Refineries (Drainage) Refineries (Tankage) Refineries (Process) Refineries (Road/Rail Loading) Refineries (Flares)	Emissions data supplied by UK Petroleum Industry Association (UKPIA) and derived by process operators using industry standard methods.
Petrol Stations (Petrol Delivery) Petrol Stations (Vehicle Refuelling) Petrol Stations (Storage Tanks) Petrol Stations (Spillages) Petrol Terminals (Storage) Petrol Terminals (Tanker Loading)	Emissions derived by AEA using methods developed by the Institute of Petroleum and CONCAWE.
Ship Purging	Emission estimate taken from Rudd & Mikkelsen, 1996
Gasification Processes Petroleum Processes	Emissions taken directly from the Pollution Inventories of the UK environmental regulatory agencies.
Gas Leakage	Emissions data supplied by operators.

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.

1B2

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

The data gaps & inconsistencies evident within the latest (2008) data submission indicate that there is still some further improvement required to the QA/QC of the source data by operators and regulators alike, but improvements compared to the 2007 dataset are evident.

There are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms. For example different NMVOC and methane emission totals have been reported by terminal operators under IPPC compared to those submitted under the EEMS system. It is unclear whether these reporting inconsistencies are due to a different scope of operator activities being reported via these two systems, or due to operator errors.

8. NFR 2: Industrial Processes

8.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

Table 8-1 relates the detailed NAEI base categories used in the inventory to the equivalent NFR source categories. A number of these NAEI base 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.

As reported in section 4, there are a number of emission sources that are currently reported under NFR categories 1A2a, 1A2b and 1A2f but where the emissions derive mainly from industrial processes rather than from fuel combustion. It is envisaged that some or all of these emissions will in future be reported under NFR Sector 2 and, since the methodologies used to derive these emission estimates are closely related to those used for many of the sources already reported under NFR Sector 2, they are discussed in this chapter rather than chapter 4 of this report. Emissions of kerosene solvent used in cutback bitumens are currently reported under 2A6 but it is envisaged that these emissions be transferred to 3D in future versions of the inventory and the methodology for this sector is discussed in this chapter.

Table 8-1 Mapping of NFR Source Categories to NAEI Source Categories: Industrial Processes.

NFR Source Category	NAEI Source Category
2A1 Cement Production	Cement (Decarbonising) Slag Cement Production
2A2 Lime Production	Lime Production (Decarbonising)
2A3 Limestone and Dolomite Use	Glass- General Basic Oxygen Furnaces Blast Furnaces Sinter Production Power Stations – FGD
2A4 Soda Ash Production and Use	Glass Production: Soda Ash Chemical industry: Soda Ash
2A5 Asphalt Roofing	Not estimated
2A6 Road Paving with Asphalt	Road dressings Other industry – Asphalt manufacture
2A7a Quarrying and Mining of Minerals other than Coal	Quarrying Dewatering of lead concentrates
2A7b Construction and Demolition	Construction
2A7c Storage, Handling & Transport of Mineral Products	Cement and concrete batching

NFR Source Category	NAEI Source Category
2A7d Other Mineral Products	Brick manufacture – Fletton Brick manufacture – non Fletton Coal, tar & 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 Refractories – chromite based Refractories – non chromite based Unglazed ceramics
2B1 Ammonia Production	Ammonia Production – Feedstock Use of Gas
2B2 Nitric Acid Production	Nitric Acid Production
2B3 Adipic Acid Production	Adipic Acid Production
2B4 Carbide Production	Not occurring
2B5a Other Chemical Industry	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 - chloralkali process Chemical industry - chromium chemicals Chemical industry - ethylene Chemical industry - general Chemical industry - magnesia Chemical industry - methanol 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 - tetrachloroethylene Chemical industry - titanium dioxide Chemical industry - trichloroethylene Coal tar distillation Solvent and oil recovery Sulphuric acid production
2B5b Storage, Handling and Transport of Chemical Products	Emissions included with 2B5a

NFR Source Category	NAEI Source Category
2C1 Iron & Steel Production	Basic oxygen furnaces Blast furnaces Cold rolling of steel Electric arc furnaces Hot rolling of steel Integrated steelworks - other processes Integrated steelworks - stockpiles Iron and steel - flaring Iron and steel - steel pickling Ladle Arc Furnaces Sinter production
2C2 Ferro-alloys Production	Not estimated
2C3 Aluminium Production	Alumina production Primary aluminium production - anode baking Primary aluminium production - general Primary aluminium production - PFC emissions Primary aluminium production - pre-baked anode process Primary aluminium production - vertical stud Søderberg process Secondary aluminium production
2C5a Copper Production	Copper alloy and semis production Secondary copper production
2C5b Lead Production	Lead battery manufacture Secondary lead production
2C5c Nickel Production	Nickel production
2C5d Zinc Production	Primary lead/zinc production Zinc alloy and semis production Zinc oxide production
2C5e Other Metal Production	Foundries Magnesium alloying Other non-ferrous metal processes SF6 cover gas Tin production
2D1 Pulp and Paper	Paper Production

NFR Source Category	NAEI Source Category
2D2 Food and Drink	Bread baking Brewing - fermentation Brewing - wort boiling Cider manufacture Malting - brewers' malts Malting - distillers' malts Malting - exported malt Other food - animal feed manufacture Other food - cakes biscuits and cereals Other food - coffee roasting Other food - margarine and other solid fats Other food - meat fish and poultry Other food - sugar production Spirit manufacture - casking 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
2D3 Wood Processing	Wood Products Manufacture
2F Consumption of POPs	PDBE Use Capacitors Fragmentisers Previously Treated Wood SCCP Use Textile Coating Transformers
2G Other	Other Industry – Part B Processes

The following NFR source categories are key sources for major pollutants: 2A7a, 2A7d, 2B5a, 2C1, 2C3, 2C5a, 2C5b, 2C5d, 2C5e, 2D2. Description of the inventory methodology will focus on these categories.

8.2 ACTIVITY DATA

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

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

In a few cases where emissions data are available directly (for example from the Pollution Inventory)and where activity data cannot easily be estimated, an arbitrary figure (usually 1) is used as the activity data in the inventory and the emission factor is then equal to the reported emissions.

8.3 METHODOLOGY FOR MINING AND QUARRYING (NFR 2A7A)

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

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). 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 quality of the emission estimates is considered to be very low but alternative data have not been found.

8.4 METHODOLOGY FOR CONSTRUCTION (NFR 2A7B)

NFR Sector 2A7b is a key source for PM_{10} only.

Emission estimates for PM_{10} are based on the use of literature-based emission factors combined with national activity data. Emission factors are UK specific, but based on factors given in the US EPA Compilation of Emission Factors (AP-42).

8.5 METHODOLOGY FOR OTHER MINERAL PROCESSES (NFR 2A7D)

NFR Sector 2A7d is a key source for SO_x and PM_{10}. The sector covers the manufacture of bricks, refractories and glass.

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), have 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_x respectively.

Most emissions from these industries are relatively trivial, the exception being emissions of SO_x 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_x 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_x emissions. AEA estimate the use of coal at this plant and then calculate a combustion-related SO_x 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}.

8.6 METHODOLOGY FOR CHEMICAL PROCESSES (NFR 2B5A)

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

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.

Emission estimates for HCB are based on the use of literature values.

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

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

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

UK integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. Emissions from these three processes, as well as other minor processes such as slag processing, are reported under 2C1, but excluding emissions from combustion of blast furnace gas, together with coke oven gas and/or natural gas in the hot stoves used to heat blast air. Those emissions are instead reported under 1A2a.

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_x.

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 data from i) the operator of all UK integrated works and one large electric arc steelworks and ii) emissions reported in the PI & SPRI for other electric arc steelworks. Literature emission factors are used for some minor emission sources.

8.8 METHODOLOGY FOR ALUMINIUM PROCESSES (NFR 2C3)

NFR Sector 2C3 is a key source for CO, Cd, Pb, B[a]P and PCDD/PCDF.

The UK had three primary aluminium producers at the start of 2008, although one has now ceased operation, and a larger number of secondary aluminium processes. All of the operational sites use the pre-baked anode process, and anodes are baked at two sites in the UK. 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 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).

Emission estimates are based on a bottom-up approach using emissions reported in the PI, ISR & SPRI.

8.9 METHODOLOGY FOR NON-FERROUS METAL PROCESSES (NFR 2C5)

NFR Sector 2C5a is a key source for Pb, Sector 2C5b is a key source for Cd, Pb, and PCDD/PCDF and 2C5e is a key source for Cd, Pb and Hg.

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.

8.10 METHODOLOGY FOR FOOD AND DRINK PROCESSES (NFR 2D2)

NFR Sector 2D2 is a key sector for NMVOC.

Emissions occur from a variety of processes including bakeries, malting, animal feed manufacture and production of fats and oils, but the most significant emissions are those from manufacture of Scotch Whisky and other spirits. Emission factors for spirits manufacturing, brewing and bakeries are UK-specific and derived based on information supplied by industry. Emission factors for other significant sources are taken from the EMEP/CORINAIR Guidebook.

8.11 METHODOLOGY FOR OTHER PROCESSES (NFR 2G)

NFR Sector 2G is a key sector 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.

8.12 SOURCE SPECIFIC QA/QC AND VERIFICATION

For most industrial process sources, the QA/QC procedure is covered under the general QA/QC of the NAEI in Section 1.6. Additional procedures are given below for the indicated categories.

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.

9. NFR 3: Solvent and Other Product Use

9.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

Table 9-1 relates the detailed NAEI base categories used in the inventory to the equivalent NFR source categories. The use of kerosene as a solvent in cutback bitumens is currently reported under NFR Category 2A6 but would more correctly be reported under 3D. It is envisaged that this will be rectified for the next version of the inventory.

Table 9-1 Mapping of NFR Source Categories to NAEI Source Categories: Solvent and other product use.

NFR Source Category	NAEI Source Category
3A1 Decorative Coating Application	Decorative paint - retail decorative Decorative paint - trade decorative
3A2 Industrial Coating Application	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
3A3 Other Coating Application	Industrial coatings - high performance
3B1 Degreasing	Leather degreasing Surface cleaning - 111-trichloroethane Surface cleaning - dichloromethane Surface cleaning - hydrocarbons Surface cleaning - oxygenated solvents Surface cleaning - tetrachloroethylene Surface cleaning - trichloroethylene
3B2 Dry Cleaning	Dry cleaning
3C Chemical Products, Manufacture & Processing	Coating manufacture - adhesives Coating manufacture - inks Coating manufacture - other coatings Film coating Leather coating Other rubber products Paper coating Textile coating Tyre manufacture
3D1 Printing	Agrochemicals use Creosote use Industrial Adhesives Printing - flexible packaging Printing - heatset web offset Printing - metal decorating

NFR Source Category	NAEI Source Category
	Printing - newspapers Printing - other flexography Printing - other inks Printing - other offset Printing - overprint varnishes Printing - print chemicals Printing - publication gravure Printing - screen printing
3D2 Domestic Solvent Use	Aerosols (car care) Aerosols (cosmetics & toiletries) Aerosols (household products) Agrochemicals use Non-aerosol products (automotive) Non-aerosol products (cosmetics & toiletries) Non-aerosol products (domestic adhesives) Non-aerosol products (household) Non-aerosol products (paint thinner)
3D3 Other	Industrial adhesives - other Industrial adhesives – pressure sensitive tapes Other solvent use Road dressings Seed oil extraction Wood impregnation – creosote Wood impregnation - LOSP

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

NAEI Source Category	General method
Industrial coatings – wood Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Other rubber products Other solvent use Printing – newspapers Printing - other flexography Printing - other inks Printing - other offset Printing - overprint varnishes Printing - print chemicals Printing - screen printing Surface cleaning - hydrocarbons Surface cleaning - oxygenated solvents Leather degreasing	
Industrial coatings – automotive Printing - heatset web offset Printing - metal decorating Surface cleaning - 111-trichloroethane Surface cleaning – dichloromethane Surface cleaning - tetrachloroethylene Surface cleaning – trichloroethylene	Solvent consumption data for the sector, with adjustments to take account of likely abatement of solvent.
Industrial coatings - coil coating Industrial coatings – drum Industrial coatings - metal packaging Printing - flexible packaging Film coating Industrial adhesives (pressure sensitive tapes) Leather coating Paper coating Textile coating Tyre manufacture	Solvent consumption data at individual site level with adjustments to take account of abatement at each site.
Printing - publication gravure Seed oil extraction	Mass balance data at individual site level
Coating manufacture – adhesives Coating manufacture - inks Coating manufacture - other coatings Wood Impregnation Creosote use	Emission factor (assumed percentage loss of solvent)

Some solvent using processes have the potential to emit dust, for example when coatings are applied by spraying. UK-specific emission factors for industrial coating processes have been developed based on a limited set of data for individual sites and these factors are used to calculate UK wide emissions.

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 base 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.

Table 10-1 Mapping of NFR Source Categories to NAEI Source Categories: Agriculture.

NFR Source Category	NAEI Source Category
4A1 Enteric Fermentation: Cattle	Dairy Cattle Enteric Other Cattle Enteric
4A2 Enteric Fermentation: Buffalo	Not Occurring
4A3 Enteric Fermentation: Sheep	Sheep Enteric
4A4 Enteric Fermentation: Goats	Goats Enteric
4A5 Enteric Fermentation: Camels & Llamas	Not Occurring
4A6 Enteric Fermentation: Horses	Horses Enteric
4A7 Enteric Fermentation: Mules & Asses	Not Occurring
4A8 Enteric Fermentation: Swine	Pigs Enteric
4A9 Enteric Fermentation: Poultry	Not Occurring
4A10 Enteric Fermentation: Other: Deer	Deer Enteric
4B1a Manure Management: Dairy Cattle 4B1b Manure Management: Non-Dairy Cattle	Dairy Cattle Wastes[7] Other Cattle Wastes
4B2 Manure Management: Buffalo	Not Occurring
4B3 Manure Management: Sheep	Agriculture Livestock: Sheep Goats and Deer wastes
4B4 Manure Management: Goats	Included under 4B3 Sheep
4B5 Manure Management: Camels & Llamas	Not Occurring
4B6 Manure Management: Horses	Agriculture Livestock: Horses Wastes
4B7 Manure Management: Mules & Asses	Not Occurring
4B8 Manure Management: Swine	Agriculture Livestock: Pigs Wastes
4B9 Manure Management: Poultry	Broilers Wastes Laying Hens Wastes Other Poultry
4B13 Other	Domestic pets Non-agriculture livestock - horses wastes
4C Rice Cultivation	Not Occurring
4D 1 Agricultural Soils	Agricultural soils Composting - NH_3 House and garden machinery
4E Prescribed Burning of Savannahs	Not Occurring
4F Field Burning of Agricultural Residues: Cereals	Barley Residue Wheat Residue Oats Residue

[7] Includes emissions from all cattle located in overseas territories and crown dependencies.

NFR Source Category	NAEI Source Category
	Linseed Residue
4G Other	Agricultural pesticide use - chlorthalonil Agricultural pesticide use - chlorthal-dimethyl Agricultural pesticide use - quintozine Agriculture - agrochemicals use

The following NFR source categories are key sources for major pollutants: 4B1a, 4B1b, 4B3, 4B6, 4B8, 4B9, 4D1 & 4G. Description of the inventory methodology will focus on these categories.

10.2 ACTIVITY STATISTICS

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

http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/default.htm.

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

Statistics relating to farm management practices (e.g. livestock housing systems, manure storage systems, manure application methods and timings) are derived from a number of sources including Defra Farm Practices Surveys:
https://statistics.defra.gov.uk/esg/publications/fps/default.asp published literature, ad-hoc surveys and expert opinion.

10.3 METHODS FOR ESTIMATING EMISSIONS

Agricultural sources are most significant in the case of the ammonia inventory. For ammonia, emission from livestock sources, estimates are derived using the NARSES model (Webb and Misselbrook, 2004) and for fertilisers following the approach of Misselbrook et al. (2004). A detailed description of the methodology for the estimate of ammonia emissions from UK agriculture for 2007 and the derivation of specific emission factors is given by Misselbrook et al. (2008). The approach in NARSES is essentially to model the flow of total ammoniacal nitrogen (TAN) through each stage of livestock production and livestock waste processing. Emissions of ammonia from each stage are calculated as a proportion of TAN present at that stage. The emission calculations are made to a high level of detail, with in depth consideration of the different emission factors at each stage for over 20 livestock classes.

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

Table 10-2 Implied emission factors (kg NH_3 per head) and emission as a percentage of total N excretion for different livestock categories

NARSES livestock category	**Housing emission**	**Storage emission**	**Spreading emission**	**Grazing/ outdoor emission**	**Total emission**	**As %N excreted**
Dairy cows & heifers	16.0	5.0	8.6	1.9	31.5	22%
Dairy heifers in calf, 2 years and over	4.8	1.6	2.0	1.9	10.3	13%
Dairy heifers in calf, less than 2 years	4.8	1.6	2.0	1.9	10.3	13%
Beef cows & heifers	6.4	1.9	2.7	2.1	13.1	14%
Beef heifers in calf, 2 years and over	4.6	1.3	1.9	1.5	9.3	14%
Beef heifers in calf, less than 2 years	4.6	1.3	1.9	1.5	9.3	14%
Bulls >2 years	4.0	1.2	1.7	1.5	8.4	13%
Bulls 1-2 years	4.3	1.3	1.8	1.6	8.9	13%
Other cattle, over 2 years	4.4	1.3	1.8	1.5	9.1	13%
Other cattle, 1-2 years	4.5	1.3	1.9	1.5	9.3	14%
Other cattle, under 1year	1.0	1.6	1.8	0.9	5.3	12%
Sheep	0.1	0.0	0.0	0.4	0.6	5%
Lambs, under 1 year old	0.0	0.0	0.0	0.0	0.0	4%
Sows in pig & other sows (sows)	2.1	1.7	1.2	1.5	6.5	28%
Gilts in pig & barren sows for fattening	0.0	0.0	0.0	0.0	0.0	0%
Gilts > 50 kg not yet in pig (maiden gilts)	2.0	1.1	1.0	0.9	5.1	27%
Boars	3.6	1.1	1.4	1.4	7.5	26%
Other pigs, >110 kg	3.6	1.5	1.5	0.0	6.6	33%
Other pigs, >80-110 kg	3.6	1.5	1.5	0.0	6.6	33%
Other pigs, >50-80 kg	3.1	1.3	1.3	0.0	5.7	33%
Other pigs, >20-50 kg	2.1	0.9	0.8	0.0	3.8	33%
Other pigs, < 20 kg	0.5	0.4	0.3	0.1	1.3	30%
Layers	0.2	0.0	0.1	0.0	0.3	35%
Breeding birds	0.2	0.0	0.2	0.0	0.4	29%
Broilers	0.0	0.0	0.1	0.0	0.1	19%
Pullets	0.0	0.0	0.1	0.0	0.1	29%
Turkeys	0.3	0.0	0.2	0.0	0.5	24%
Other poultry	0.2	0.0	0.3	0.0	0.6	29%
Horses	0.0	0.0	0.0	12.8	12.8	21%
Goats	0.3	0.2	0.0	0.8	1.3	5%
Deer	0.5	0.3	0.1	0.4	1.3	8%

Table 10-3. Implied emission factors (kg NH_3 per kg N applied) for different fertiliser types

Fertiliser type	**EF for use on tillage**	**EF for use on grassland**
Ammonium nitrate	0.017	0.018
Urea	0.091	0.099
Urea ammonium nitrate	0.047	0.051
Ammonium sulphate/ Di ammonium phosphate	0.028	0.030
Other compound N	0.017	0.018

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

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

10.4 SOURCE SPECIFIC QA/QC AND VERIFICATION

The inventory spreadsheet model includes some internal nitrogen mass balance checks to capture calculation errors. Data are input by one member of North Wyke staff and checked by a second member. Trends in emission per sub-category and activity data are plotted (from 1990 - 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 AEAT and Defra for further checking prior to inclusion in the UK NAEI.

11. NFR 6: Waste

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.

Table 11-1 Mapping of NFR Source Categories to NAEI Source Categories: Waste

NFR Source Category	NAEI Source Category
6A Managed Waste Disposal on Land	Application to land Landfill Waste disposal - batteries Waste disposal - benzole & tars Waste disposal - electrical equipment Waste disposal - lighting fluorescent tubes Waste disposal - measurement and control equipment
6B Wastewater Treatment	Sewage Sludge Disposal
6C Waste Incineration	Crematoria Foot and mouth pyres Incineration Incineration - animal carcases Incineration - chemical waste Incineration - clinical waste Incineration - sewage sludge Regeneration of activated carbon Small-scale waste burning
6D Other Waste	Accidental fires - dwellings Accidental fires - other buildings Accidental fires - vehicles Infant emissions from nappies Other industrial combustion RDF manufacture

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 Pollution Inventory and these emissions data are used in the national inventory. Gap filling methods similar to those already described in Section 7.3 are used. The Pollution Inventory data for sewage sludge and clinical waste incinerators are somewhat 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.

Animal carcass incinerators are not required to report emissions in the Pollution Inventory and so the NAEI contains estimates for these plants taken from Stewart, 2002.

Crematoria are significant sources of mercury and emissions are calculated using cremation statistics and mercury emission factors calculated using dental health statistics.

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.

Emissions from accidental fires are key sources for dioxins 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

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

12. Other

12.1 CLASSIFICATION OF ACTIVITIES AND SOURCES

Table 12-1 relates the detailed NAEI source categories for other sources used in the inventory to the equivalent NFR source categories.

Table 12-1 Mapping of NFR Source Categories to NAEI Source Categories: Other Sources

NFR Source Category	NAEI Source Category
7A Other	Bonfire night Cigarette smoking Fireworks

NFR source category 7 is a key source for PM_{10}, dioxins and PAH 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 dioxins) 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 revisions 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. Some changes have led to major changes for the revised source. A short description of the most important revisions is given below.

13.1 PERSISTENT ORGANIC POLLUTANTS MULTI-MEDIA INVENTORY

Major improvements have been carried out this year in the POPs inventory. On behalf of Defra, AEA established the first UK multi-media inventory for hexachlorobenzene and updated previous dioxin and polychlorinated bi-phenyls multi-media inventories in May 2009. This included a full review of the air emissions quoted within the NAEI, and was part of the development to produce a full set of up to date emissions for air, land and water. The revisions impact POPs emissions in general and are not sector specific.

In line with this work the emission data quoted in the NAEI has also been updated, where improved data has been found. This has also included the addition of some new sources not previously reported within the NAEI, addressing the points highlighted in the 2007 IIR as needing development. New sources now reported within the NAEI are:

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

Along with the addition of new substances to the inventory the existing emission estimates have also been amended, with quite significant changes made to a number of sources.

The key change will be for HCB emissions associated with pesticide use. Historically the use of HCB as a pesticide has been banned since 1975, but continued to be an issue as a contaminant in other pesticides. The previous set of emissions quoted with the NAEI assumed that all emissions from pesticide use would be to air. This is unlikely to be the case, and the emissions have now been scaled for emissions to air, land and water based on modelling of the likely distribution in a typical agricultural use. The emission factors have also been reviewed, previously they were based on legal limits for contamination of chlorthalonil, quintozine and chlorthal-dimethyl, ‘working concentrations’ are likely to be lower and more suitable factors have been adopted. The impact of this has been that HCB emissions from agricultural pesticides use (chlorothalonil/chlorthal-dimethyl/quintozine use) has decreased by 13 fold for the 2007 HCB emissions between this inventory and the 2008 inventory.

Table 13-1 Comparison of emissions of HCB emissions due to agricultural pesticides use between the 2007 and 2008 inventory

	Units	2004	2005	2006	2007	2008
4G (2008 inventory)	**Kg**	61.7	61.7	60.3	59.5	59.5
4G (2007 inventory)	**Kg**	821.8	811.6	787.5	786.3	

Along with pesticide usage, the other key change will be to agricultural waste burning, and the emission of dioxins and PAHs (Polycyclic Aromatic Hydrocarbons). The burning of most agricultural wastes was banned in 2006 with a two year phase-out plan. The emissions have now been adjusted to represent this fact, and will see a significant reduction in emissions.

Other changes to the inventory include an improvement in the method the calculation of dioxins emissions from accidental fires to move away from estimates based on population to estimates based on numbers of fires. This has seen a reduction in emissions.

Table 13-2 Reduction in dioxin emissions in the 2008 inventory from accidental fires from dwellings and other buildings relative to the 2007 inventory

2004	2005	2006	2007
-30%	-34%	-33%	-69%

The emission factors used for HCB emissions from incineration processes have also been reviewed and amended with a reduction in resultant emissions.

13.2 FURTHER DISAGGREGATION OF NFR CODES

For the 2008 CLRTAP submission, the NFR codes that the UK reports have been further disaggregated to provide additional detail of source emissions. Previously, the NFR codes below were summarised at high level NFR codes but have now been allocated to their individual codes. This has increased the transparency and the completeness of the UK inventory.

Table 13-3 NFR codes disaggregated in the 2010 LRTAP submission

NFR code	NFR Name	Substance(s)	Previous Included Elsewhere
1A2fii	Mobile Combustion in manufacturing industries and construction	All	Included in 1A2fi
2 A 7 b	Construction and demolition	All	Included in 2A7a
2 A 7 c	Storage, handling and transport of mineral products	All	Included in 2A7a

NFR code	NFR Name	Substance(s)	Previous Included Elsewhere
2 A 7 d	Other Mineral products	All	Included in 2A7a
2 C 2	Storage, handling and transport of chemical products	All	Included in 2C1
2 C 3	Aluminium production	All	Included in 2C1
2 C 5 a	Copper production	All	Included in 2C1
2 C 5 b	Lead production	All	Included in 2C1
2 C 5 c	Nickel production	All	Included in 2C1
2 C 5 d	Zinc production	All	Included in 2C1
2 C 5 e	Other metal production	All	Included in 2C1
2 C 5 f	Storage, handling and transport of metal products	All	Included in 2C1
2 D 3	Wood processing	All	Included in 2D1
3 D 2	Domestic solvent use including fungicides	All	Included in 3D1
3 D 3	Other product use	All	Included in 3D1
6 C b	Industrial waste incineration	All	Included in 6Ca
6 C c	Municipal waste incineration	All	Included in 6Ca
6 C d	Cremation	All	Included in 6Ca
6 C e	Small scale waste burning	All	Included in 6Ca
7 A	Other	All	Included in 7
2A6	Road paving with asphalt	PM10 PM2.5	Road paving were not differentiated from construction, and are therefore included under 2 A 7 Mineral Products, Other.

In addition to the further disaggregation of the NFR codes, in the 2008 inventory the allocation of the sources to NFR codes was revised to better reflect the description of the category. This improves the transparency of the inventory.

Table 13-4 Reallocation of source activity combinations to NFR codes

Source Name	Activity Name	NFR Code in 2007 Inventory	New NFR Code in 2008 Inventory
Other industrial combustion	Energy recovery - chemical industry	7	1A1a
Sinter production	Coke	1A2a	2C1
Sinter production	Iron production	1A2a	2C1
Aircraft - support vehicles	Gas oil	1A3eii	1A5b

Source Name	Activity Name	NFR Code in 2007 Inventory	New NFR Code in 2008 Inventory
Gasification processes	Gas production (onshore)	1B2b	1B2ai
Cement and concrete batching	Process emission	2A1	2A7c
Bitumen use	Non fuel bitumen use	2A5	2A6
Other industry - asphalt manufacture	Asphalt produced	2A7	2A6
Ship purging	Process emission	2B5	1B2av
SCCP use	SCCP use	2B5	2F
Coal tar and bitumen processes	Process emission	2B5	2A7d
PDBE use	PBDE use	2B5	2F
Transformers	Dielectric fluid (transformers etc) PCBs	2G	2F
Capacitors	Dielectric fluid (transformers etc) PCBs	2G	2F
Fragmentisers	Dielectric fluid (transformers etc) PCBs	2G	2F
Textile coating	PCP use in textile industry	3C	2F
Textile coating	Cloth imports	3C	2F
Leather degreasing	Leather and leather products	3C	3B1
Paper coating	Solvent use	3D	3C
Previously treated wood	HCH in previously treated wood	3D	2F
Previously treated wood	NaPCP for wood treatment as PCP	3D	2F
Agriculture - stationary combustion	Non-fuel agriculture	4D1	4G
Agriculture - stationary combustion	Limestone	4D1	4G
Agriculture - stationary combustion	Agricultural operations	4D1	4G
Composting - NH_3	Process emission	4D1	6D
Cropland - Liming	Limestone	4D1	4G
Cropland - Liming	Dolomite	4D1	4G
Grassland - Liming	Limestone	4D1	4G
Grassland - Liming	Dolomite	4D1	4G
Infant emissions from nappies	Population 0to4yrs	6D	7A

The reallocation of sources to NFR codes does not impact the total emissions within the inventory. However, for some NFR codes and pollutants, this has a large impact on the emission levels relative to the 2007 inventory. For example, the reallocation of sinter production from 1A2a to 2C1 has led to a decrease in PM_{10} emissions to a third of the value in the 2007 inventory for 1A2a. As a result of this, the emissions in NFR code 2C1 has increased by 35% due to the addition of sinter production. This reallocation of sinter production has an even higher impact on the metal emissions where the sinter production accounted for a higher % of 1A2a.

13.3 REVISIONS TO 2007 DATA FROM UPDATED EEMS INFORMATION PROVIDED IN AUTUMN 2009

Revisions to data from offshore oil & gas operators within the latest Environmental Emissions Monitoring System (EEMS), as regulated by the DECC Oil & Gas team, has led to a number of changes to 2007 emission estimates within the latest inventory, including:

- Two oil companies have revised the emissions on gas flaring and gas consumption from their offshore sites, through applying installation-specific emission factors rather than industry defaults.
- New operator emissions data were provided for a small number of offshore sites, the emissions from which had previously been estimated by AEA from historic data. The revised data have led to notable increases of around 1kt NO_X and 7kt NMVOC.
- New emissions data for three platforms of another oil company have been provided for fugitive and gas venting emissions, and these data have been used to over-write the AEA estimates used for the previous 2007 inventory.
- Revisions to oil loading emissions from offshore ships have also led to increases in NMVOC emissions by around 5kt.

13.4 ROAD TRANSPORT

There have been a number of significant improvements made to the road transport inventory, combining methodological changes with new emission factors and in some cases revised activity data. These improvements supplement the ones that were initiated last year following release of new emission factors, further research on the activity data in relation to the UK fleet and intensive discussions with officials at the Department for Transport (DfT) during 2009. There have been improvements that have affected all pollutants however for NO_x the revised emission numbers are less noticeable in the overall sector total because the different improvements have mostly cancelled each other out. The slight increase in NO_x emissions can be explained by the effect of revised catalyst failure assumptions. For SO_x, the changes are based on sulphur content of the fuel consumed hence, although there have been re-allocation of the fuel consumption between the different modes within the road transport sector the overall emissions from this sector have remained consistent to last year. The key changes are summarised below:

13.4.1 Changes affecting both AQ and GHG emissions

- COPERT III cold start method was adopted affecting emissions for all pollutants for all years apart from NH_3 emissions (addressed as requiring improvement in the 2007 IIR).
- Revised catalytic failure assumptions based on new evidence on fitting of replacement catalyst and taking into account of Regulations Controlling Sale and Installations (affecting all years).
- Revised survival based on a recent NAEI study (2009) on reviewing vehicle turnover assumptions used in the NAEI road transport emission projections. This affects how the vehicle-kilometres are distributed by the age of the vehicles.
- Revised assumptions on the vehicle km split based on research from literatures:
  - LGV N1 (II) and N1 (III) classes
  - 2 stroke and 4 stroke motorcycles

13.4.2 Changes affecting AQ emissions

- New NH_3 emission factors from the Emission Inventory Guidebook (23rd August 2007) have been used and this also provides NH_3 emission factors for cold start for petrol cars and light duty vehicles for all years

- NO_x emissions have been revised due to the incorporation of the degradation method, (use of the equations describing accumulated vehicle mileage as a function of age, provided by TRL).

- NMVOC emissions:
  - Updated trip length assumed in the evaporative emission calculations
  - New TRL speed-related emission factors and degradation method used as a result of data recently published by DfT in 2009

- SO_x emissions have been revised as a result of the new TRL fuel consumption speed-related function for cars, LGVs and motorcycles adopted in the 2008 inventory. For HGVs, the average miles per gallon fuel efficiency data as provided by DfT are continued to be used but they are now used in conjunction with the new TRL speed-related functions to define the variation in fuel consumption with speed. For buses, new information from Bus Service Operating Grant as provided by DfT are used to define the fuel efficiency for buses and coaches; again, these dataset is used in conjunction with the new TRL speed-related functions to define the variation in fuel consumption with speed. These changes lead to revision of the SO_x emissions by vehicle type but do not impact the overall emissions for the sector as a whole.

13.5 AVIATION

In 2006, the Department for Transport (DfT) published its report "Project for the Sustainable Development of Heathrow" (PSDH). This laid out recommendations for the improvement of emission inventories at Heathrow and lead to a revised inventory for Heathrow for 2002.

For departures, the PSDH made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights. In 2007, these recommendations for Heathrow were incorporated into the UK inventory. In 2009, these recommendations were incorporated into the UK inventory for all airports, along with further recommendations relating to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

For arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. In 2007, these recommendations for Heathrow were incorporated into the UK inventory. In 2009, these recommendations were incorporated into the UK inventory for all airports, along with further recommendations relating to: the interpolation to intermediate thrust settings; approach thrusts and times; taxiing thrust and times; engine deterioration and APU emission indices and running times.

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

13.6 REVISIONS TO NAEI ENERGY DATA

The NAEI relies upon the Digest of UK Energy Statistics (DUKES) to provide the fuel-use data that are used to calculate emissions. Total UK usage of any fuel should be the same in DUKES as in the NAEI. Many of the sector-specific fuel usage figures also tally, however, over the past 10 or 15 years the NAEI has had to abandon the use of DUKES data for certain sectors when alternative data sources showed that DUKES was inaccurate. Most importantly, the NAEI includes independent estimates of fuel oil burnt by power stations (based on AEA analysis of operators' fuel consumption) and all fuel types burnt at cement works (from the British Cement Association, and based on EUETS and other industry data) and at lime kilns (based on an AEA estimate). In addition, the NAEI includes our own estimates of the use of waste oils and petroleum coke as fuels.

NAEI estimates of renewable fuel use have been given increasing attention over the past 3 years and one new source was introduced for the 2008 cycle. Liquid bio-fuels such as tall oil or bioethanol have been co-fired in coal-fired power stations for a few years, and although quantities burnt are small, these fuels have been included in the NAEI for this cycle.

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.

- **Road Transport**

The future development of the road transport emission estimates will focus on:

- Incorporation of a new methodology for evaporative emissions of NMVOCs from vehicles
- Inclusion of PM emissions from road abrasion
- Re-review NO_x EFs given recent evidence that suggests EFs for diesel vehicles
- Use of the new inventory from Entec based on actual shipping movement data

- **Rail**

Research is recommended to develop a more detailed, comprehensive series of emission factors to better represent the full range of rail rolling stock. The current method and assumptions are in need of review given the ongoing development of the fleet. In addition, the method for estimating emissions from the freight stock ought to be developed to reflect the variable emissions from carrying variable loads. Alternative activity datasets used by the LAEI (ACTRAFFF) should also be evaluated to determine whether their use might lead to improved inventory estimates.

- **Aviation**

Periodically AEA produce inventories for the major British airports. Data from these inventories get incorporated into the NAEI. AEA is currently producing an inventory for Heathrow for 2008/9. These data are likely to be incorporated into the 2009 NAEI. In addition to this, the NAEI currently includes no fugitive particulate emissions from aircraft brake and tyre wear. This is an improvement that is required to be addressed in future inventories.

- **Revisions to DUKES Energy Data**

Sector-specific fuel use and fuel quality data within DUKES is periodically reviewed, impacting upon the NAEI emission estimates from combustion sources. The revisions to DUKES are expected to stem primarily from the increased availability of data on fuel use and quality from the EUETS reporting system. There are a number of areas that are known to require further attention:

- The treatment of coke use by industry needs to be revised
- More information is needed on fuels burnt in lime kilns
- Pet coke consumption estimates need to be reviewed and improved where possible
- Refinery fuel use data to be reviewed

- **Industrial Process Emissions**

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

- **Solvent Use**

Review and update of emission estimates from industrial solvent use is considered a high priority, to maintain the quality of the estimates. Priorities include: (1) the use of solvents in adhesive coating processes, and (2) miscellaneous use of solvents that are not dealt with in specific source categories (e.g. solvents used in firelighters and barbeque fluids).

Furthermore, a review of the estimates for non-aerosol consumer products may be useful particularly in the areas of household and car-care products where detailed activity statistics are not available, and the current method is based on extrapolation of out-dated information on the basis of growth in household numbers, population, or vehicle numbers.

- **Persistent Organic Pollutants**

AEA is currently working with Defra to further extend and improve the POPs all media inventory; this will provide new measurement data for pesticide emissions and sewage sludge (dioxin, PCBs and HCB) particularly to agricultural releases. It will also involve a national survey of waste burning habits, in particular open burning of waste. Further work will also review the waste streams for incinerators and non-ferrous metal sectors. This work will also include the development of release estimates for the nine new POPs added to the Stockholm convention, which are largely made up of flame retardants (Hexabromobiphenyl and Polybrominated diphenyl ethers) and pesticides (Chlordecone, Lindane and Hexachlorocyclohexane).

- **Industrial Use of Coke and Petroleum Coke**

In order to better comply with GHG reporting guidance, the NAEI method is moving away from treating coke as an activity within the industrial combustion source, and towards treating it as an activity within a series of industrial processes. Some emissions from the use of coke are currently treated as process emissions but further revision of the methodology will be necessary in future cycles. The change in reporting will help to eliminate some potential double-counting of emissions in the NAEI, although it must be stressed that this double-counting will not be significant at a national level. A related-issue is that some lime kilns which were previously thought to burn coke, now appear to burn anthracite. More information is needed on the timing of the switch in fuels so that NAEI time series can be improved.

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 2009 under the NECD reporting requirements. Emission projections are also submitted under the Long-range Transboundary Air Pollution (LRTAP) convention every 5 years, with the latest dataset being provided in February 2006.

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_x, NMVOCs and NH_3 by 2010. The target emissions are provided in Table 14-1 below together with the UK's actual emissions in 2008 (the latest year available). These targets are to be achieved in 2010 and subsequent years. The data shows that the NH_3, SO_x and NMVOC ceiling has already been met in 2008. However, further emission reductions are needed between 2008 and 2010 for NO_x if the UK is to meet its emission ceilings for these pollutants.

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

Pollutant	Emissions in 2008(Ktonnes)	Emissions ceiling target in 2010 (Ktonnes)	Reduction required between 2008 and 2010
NO_x	1,403	1,167	17%
SO_x	512	585	N/A
NMVOCs	942	1,200	N/A
NH_3	281	297	N/A

14.2 METHODOLOGY

The NAEI projection methodology broadly follows the methodology outlined in the EMEP / CORINAIR Emission Inventory Guidebook 2008.

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:

$$E_{2007} = A_{2007} * EF_{2007}$$

where E = emission, A = activity and EF = emission factor, all for the year 2007.

For projected emissions:

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

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

14.2.1 ACTIVITY DATA FORECASTS

To produce a projection, each source in the NAEI is linked to an activity driver. Examples of drivers may include forecasts of fuel use, vehicle kilometres, animal numbers or broader indicators such as forecasts of population, or economic indicators such as Gross Domestic Product (GDP) or Gross Value Added (GVA). The latest activity drivers are derived from a number of sources including the Department of Energy & Climate Change (DECC) latest energy forecasts from UEP37, a description of which was published as an addendum to the November 2008 forecasts in April 2009 (available at http://www.berr.gov.uk/files/file51132.pdf). The energy projections take account of the projected impacts of government policies that are deemed "firm and funded" at the time the projections are produced. The projections include those policies outlined in the 2007 Energy White Paper and the estimated net impact of the recent European Commission proposals on the EU Emission Trading System. They do not include policies that are still under consideration, for example any policies that may be derived from the recent UK Climate Change Act, the proposed EU Industrial Emissions Directive or the proposed EU Renewable Target for the UK.
Other sources that are used to derive activity drivers include (but are not limited to) information from the Department for Transport (DfT) for the road transport and aviation sectors and information from trade associations.

14.2.2 FUTURE EMISSION FACTORS

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

- The Large Combustion Plant Directive
- The IPPC Directive
- The Solvent Emissions Directive
- MARPOL VI
- Sulphur Content of Liquid Fuels Regulations 2007
- European Directives & UK Regulations on Non Road Mobile Machinery, and
- European Directives & UK Regulations on vehicle emissions and fuel quality (legislation up to and including Euro 5 & 6 for light duty vehicles and Euro VI for heavy duty vehicles).

The impacts of these measures are discussed in more detail in Section 3 of this report.

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 UEP37) 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"[8] analysis of UEP37 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. The projections also contained only limited impacts of recent economic events.

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.

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

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

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

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

14.4 PROGRESS TOWARDS NECD TARGETS

The (UEP37, 2007) emission projections show that the UK is likely to meet the NECD targets in 2010 for SO_x, NMVOCs and NH_3 (see Table 14-2). Emission estimates for NO_x however were forecast to be higher than the ceiling in 2010. It is however forecast, that the ceiling will be met prior to 2015.

Table 14-2. Predicted emissions for those sectors covered under the NECD using DECC's UEP37 energy projections (Ktonnes).

Projected Year	2010
NO_x	1,210
SO_x	390
NMVOC	814
NH_3	289

Road transport and Industry are the key sector contributing to NO_x emission in 2010. The latest UK emission projections indicate that NO_x emissions will not be reduced below the ceiling target by 2010 despite planned measures and policies, although the full impact of the current economic downturn are not certain within emission estimates and industry forecasts.

14.4.1 Uncertainty Analysis

The following results were obtained:

Table 14-3: Summary of Uncertainty Analysis results (emissions are shown in Ktonnes)

Pollutant	2010	
	2.5 percentile	97.5 percentile
NH_3	244	342
NO_x	1054	1384
SO_x	383	433
NMVOC	750	911

Overall the results suggest:

- There is a 100% chance that the SO_x ceiling will be met in 2010;
- There is close to a 100% chance that the NMVOC ceiling will be met in 2010;
- There is a 59% chance that the NH_3 ceiling will be met in 2010;
- There is only a 35% chance that the NO_x ceiling will be met in 2010.

As might be expected, the analysis shows that future emissions of SO_x can be estimated with most confidence as emission factors are relatively certain, being largely based on the sulphur content of fuels, and these are well characterised. In comparison, projections for nitrogen oxides, NMVOC and ammonia are considerably more uncertain and this means that a much greater range of future emissions is predicted by the uncertainty analysis. In the case of NMVOC and ammonia, whilst the central 'with measures' projection is that the UK will meet its commitments, the uncertainty analysis suggests that there is a possibility that this will not happen (although this possibility is extremely slight in the case of NMVOC). In the case of NO_x, where the 'with measures' projection suggests that the UK will miss the NECD target in 2010, the uncertainty analysis suggests that this is also not certain, and that there is around a 1 in 3 chance that the ceiling will actually be met.

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Appendix 1

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

Source	Change made to	Data Source	Comments
Aerosols	Activity data	BAMA	Updated data from BAMA for annual aerosol production for 2008
Agricultural waste burning	Activity data	Due to regulation	Emissions updated to incorporate ban on agricultural waste burning from 2006 onwards. PCB emissions now calculated for this source.
Cleaning	Activity Data	ONS	ONS Index of production whole timeline changed in 2009
CO Factors	Emission Factor	DUKES	Updated DUKES data
Coal	Activity data	DUKES	Updated DUKES data
Coke & SSF	Activity Data	DUKES	Updated DUKES data
Construction	Activity Data	Construction Statistics Annual	New method in 2008 for new houses. This is now split by bedrooms.
Consumer	Activity Data	CTPA	Change in cosmetics and toiletries data from CTPA website
Feedstock	Activity Data	DUKES	Revisions to acetic acid production
Gas	Activity Data	OT	Natural gas and LPG data now available for Isle of Man. Revisions made to Guernsey and Jersey data affecting the distribution of gas use between UK, CD and OT.
Gas Oil	Activity Data	DUKES	Update to DUKES data, the naval gas oil data from defence fuels group, UK aircraft arrivals/departure data and OT data for 2007 and 2008.
Ink	Activity Data	British Coatings Federation	Changes to category of ink production and changes in the data.
Metal Factors	Emission Factor	USEPA AP-42	Update to PM10 emission factor from the use of butane and propane in industrial and commercial boilers.
NH_3 Factors	Emission Factor	IGER CEH	Changes to muirburn emission factor from 7.65 to 0.42. Slight amendments to emission factors for cattle and poultry as per changes in IGER data. Also new EF update for adult breath and sweat from CEH.
NO_x Factors	Emission Factor	USEPA AP-42	Updated NO_x factors for butane and propane in industrial and commercial boilers due to new reference in USEPA AP-42.
Offshore	Emission Factor Activity Data	EEMS	Many site specific revisions to data within the EEMS system for 2007.
Other oil	Activity Data	DUKES	Updated DUKES data
Pesticides	Activity Data	Literature review	Redistribution activity to air, land and water.
Petrocoke	Activity Data	DUKES	Updated use of petrocoke at power stations.

Source	Change made to	Data Source	Comments
Petrol	Emission Factor Activity Data	DUKES	Change of petrol density values. Changes in DUKES figures from 2004 onwards due to LRP/super premium unleaded data no longer being reported separately.
Rail		ORR	Updated data from ORR on freight rail. Updates applied directly to years 2003-2007 and data scaled for years 1970-2002.
Refine	Emission Factor	PI	New emission factor derived from new data from the pollution inventory for sites.
Sulphur-coal	Emission Factor Activity Data	DUKES	New data from DUKES and sales data from Scottish Coal and UK Coal for 2008. Updates made to the sulphur content of coal for 2007 and 2008.
Sulphur-oils	Emission Factor Activity Data	DUKES	New emission factor due to new value for sulphur content in petrol, fuel oil, kerosene and DERV. New activity data from DUKES.
NMVOC Factors	Emission Factor	US EPA AP-42	Updated emission factors for NMVOC for industrial/commercial boilers for propane and butane. Updated calorific values from DUKES.
Bonfire night	Emission Factor	ODMP	New emission factor derived from updated number of households with bonfires in the UK.

See the Glossary for notes on Abbreviations & Acronym

Appendix 2

Table A2-1 Emission Factors for the Combustion of Liquid Fuels for 2008[1] (kg/t)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
ATF	Aircraft Military	840[a]	0.103[ad]	0.1[g]	8.5[ad]	8.2[ad]	1.1[ad]	0.87[z]
Burning Oil	Domestic	859[a]	0.462[g]	0.0277[g]	3.23[l]	1.85[l]	0.047[f]	0.59[z]
Burning Oil	Other Industry	859[a]	0.0924[g]	0.0277[g]	3.34[l]	0.19[l]	0.028[e]	0.59[z]
Burning Oil	Public Service, Railways (Stationary)	859[a]	0.462[g]	0.0277[g]	2.05[l]	0.16[l]	0.047[f]	0.59[z]
Burning Oil	Miscellaneous	859[a]	0.462[g]	0.0277[g]	2.70[l]	0.16[l]	0.047[f]	0.59[z]
Gas Oil	Agriculture	870[a]	0.455[g]	0.0273[g]	0[ap]	0[ap]	0.048[f]	1.6[z]
Gas Oil	Domestic	870[a]	0.455[g]	0.0273[g]	3.19[l]	1.82[l]	0.047[f]	1.6[z]
Gas Oil	Fishing, Coastal Shipping, Naval, International Marine	870[a]	0.05[ap]	0.08 [ap]	72.3 [aq]	7.4[ap]	3.5 [aq]	19.6 [ar]
Gas Oil	Iron&Steel	870[a]	0.0910[g]	0.0273[g]	20.80[l]	8.26[l]	0.028[f]	1.6[z]
Gas Oil	Refineries	870[a]	0.136[g]	0.0273[g]	4.55[k]	0.24[i]	0.028[f]	1.6[z]
Gas Oil	Other Industry	870[a]	0.0910[g]	0.0273[g]	4.84[l]	0.83[l]	0.028[f]	1.6[z]
Gas Oil	Public Service	870[a]	0.455[g]	0.0273[g]	2.44[l]	0.38[l]	0.047[f]	1.6[z]
Gas Oil	Miscellaneous	870[a]	0.455[g]	0.0273[g]	1.21[1]	0.16[l]	0.047[f]	1.6[z]
Fuel Oil	Agriculture	879[a]	0.433[g]	0.026[g]	7.69[l]	0.31[1]	0.14[f]	18.0[z]
Fuel Oil	Public Service	879[a]	0.433[g]	0.026[g]	7.35[l]	0.77[l]	0.14[f]	18.0[z]
Fuel Oil	Miscellaneous	879[a]	0.433[g]	0.026[g]	0.93[l]	0.038[l]	0.14[f]	18.0[z]
Fuel Oil	Fishing; Coastal Shipping, International Marine	879[a]	0.05[ap]	0.08 [ap]	72.3 [aq]	7.4[ap]	3.5 [aq]	52.9 [ar]
Fuel Oil	Domestic	879[a]	0.433[g]	0.026[g]	0[ap]	0[ap]	0.14[f]	18.0[z]
Fuel Oil	Iron&Steel	879[a]	0.087[g]	0.026[g]	7.14	0.81[1]	0.035[f]	18.0[z]
Fuel Oil	Railways (Stationary)	879[a]	0.433[g]	0.026[g]	7.35[l]	0.77[l]	0.14[f]	18.0[z]
Fuel Oil	Other Industry	879[a]	0.087[g]	0.026[g]	10.56[l]	1.50[l]	0.035[f]	18.0[z]
Fuel Oil	Refineries (Combustion)	871.6[at]	0.130[g]	0.026[g]	3.69[ag]	0.66[ag]	0.035[f]	30.3[ag]
Lubricants	Other Industry	865[x]	0.091[e]	0.027[e]	4.55[k]	0.25[f]	0.13[f]	11.4[x]
Petrol	Refineries	855[a]	0.138[an]	0.028[g]	4.62[k]	0.24[e]	0.028[e]	0.046[z]

Table A2-2 Emission Factors for the Combustion of Coal for 2008[1] (kg/t)

Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
Agriculture	639.1[ao]	0.011[o]	0.147[w]	4.75[l]	8.25[l]	0.05[o]	17.3[aa]
Collieries	685.0[ao]	0.011[o]	0.148[w]	4.75[l]	8.25[l]	0.05[o]	22.0[aa]
Domestic	683.5[ao]	15.7[o]	0.122[w]	2.34[l]	160.0[l]	14[o]	24.8[aa]
Iron and Steel (Combustion)	693.8[a]	0.011[o]	0.237[w]	IE	IE	0.05[o]	17.34[aa]
Lime Production (Combustion)	640.6[ao]	0.011[o]	0.214[w]	51.82[v]	7.81[v]	0.05[o]	17.34[aa]
Miscellaneous	710.0[ao]	0.011[o]	0.148[w]	4.74[l]	8.11[l]	0.05[o]	17.34[aa]
Public Service	710.0[ao]	0.011[o]	0.148[w]	4.71[l]	7.45[l]	0.05[o]	17.34[aa]
Other Industry	640.6[ao]	0.011[o]	0.214[w]	4.24[l]	2.03[l]	0.05[o]	17.34[aa]
Railways	710.0[ao]	0.011[o]	0.148[w]	4.71[l]	7.45[l]	0.05[o]	17.34[aa]
Autogenerators	581.3[at]	0.02[o]	0.0660[w]	5.57[l]	1.68[l]	0.03[o]	17.34[aa]

Table A2-3 Emission Factors for the Combustion of Solid Fuels 2008[1] (kg/t)

Fuel	**Source**	**C[aj]**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_x**
Anthracite	Domestic	840.0[ap]	2[o]	0.14[w]	3.47[k]	208.2[k]	1.7[o]	15.2[aa]
Coke	Agriculture	814.5[r]	0.011[p]	0.150[w]	5.15[l]	1.20[l]	0.05[p]	19[ab]
Coke	SSF Production	814.5r	0.011[p]	0.230[w]	IE	IE	0.05[p]	19[ab]
Coke	Domestic	814.5r	5.8[o]	0.117[w]	3.04[l]	118.6[l]	4.9[o]	15.2[aa]
Coke	I&S[ak] (Sinter Plant)	814.5r	1.52[ae]	0.230[w]	12.81[ae]	299[ae]	0.46[ae]	14.3[ae]
Coke	I&S[ak] (Combustion)	814.5r	0.011[p]	0.230[w]	0.87[l]	226[l]	0.05[p]	19[ab]
Coke	Other Industry	814.5r	0.011[p]	0.230[w]	5.15[l]	1.20[l]	0.05[p]	19[ab]
Coke	Railways	814.5r	0.011[p]	0.150[w]	5.15[l]	1.20[l]	0.05[p]	19[ab]
Coke	Miscellaneous; Public Service	814.5r	0.011[p]	0.150[w]	5.15[l]	1.20[l]	0.05[p]	19[ab]
MSW	Miscellaneous	75[ah]	2.85[g]	0.038[g]	0.90[v]	1.20[v]	0.0049[v]	0.089[v]
Petroleum Coke	Domestic	930[a]	NE	NE	3.95[k]	118[k]	4.9[am]	142.4[as]
Petroleum Coke	Refineries	930[at]	0.107[ai]	0.281[w]	6.67[ag]	1.17[ag]	0.054[ai]	34.8[ag]
Petroleum Coke	Cement Production – Combustion	819	0.107	0.143				
SSF	Miscellaneous; Public Service	766.3[n]	0.011[p]	0.151[w]	4.58[k]	124.4[k]	4.9[o]	16[ab]
SSF	Domestic	774.2[n]	5.8[o]	0.118[w]	3.05[k]	46.7[k]	0.05[p]	19[ab]
SSF	Other Industry	766.3[n]	0.011[p]	0.232[w]	4.58[g]	46.7[g]	0.05[g]	19
Straw	Agriculture	418[g]	4.5[g]	0.06[g]	1.5[k]	75[g]	9[k]	
Wood	Domestic	387[g]	4.17[g]	0.06[g]	0.7[k]	69.5[k]	23.6[o]	0.11[aa]

Table A2-4 Emission Factors for the Combustion of Gaseous Fuels 2008[1] (g/GJ gross)

Fuel	Source	C[aj]	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
Blast Furnace Gas	Coke Production	82137[r]	112[k]	2.0[k]	79[k]	39.5[k]	5.6[k]	0
Blast Furnace Gas	I&S[ak] (Combustion), I&S[ak] (Flaring)	82137[r]	112[k]	2.0[k]	79[k]	39.5[k]	5.6[k]	0
Blast Furnace Gas	Blast Furnaces	82137[r]	112[k]	2.0[k]	50.7[v]	39.5[k]	5.6[k]	0
Coke Oven Gas	Other Sources	11089[r]	57.25[k]	2.0[k]	80.5[k]	40.0[k]	4.35[k]	280[v]
Coke Oven Gas	I&S[ak] Blast Furnaces	11089[r]	57.25[k]	2.0[k]	50.7[v]	40.0[k]	4.35[k]	280[v]
Coke Oven Gas	Coke Production	11089[r]	57.25[k]	2.0[k]	360[v]	40.0[k]	4.35[k]	280[v]
LPG	Domestic	16227[a]	0.889[f]	0.10[g]	62.1[f]	8.9[f]	3.77[f]	0
LPG	I&S[ak], Other Industry, Refineries, Gas Production	16227[a]	0.889[f]	0.10[g]	62.1[f]	15.1[f]	3.77[f]	0
Natural Gas	Agriculture	13975[r]	5.0[g]	0.10[g]	39.2[l]	2.13[l]	2.22[f]	0
Natural Gas	Miscellaneous	13975[r]	5.0[g]	0.10[g]	55.14[l]	10.8[l]	2.22[f]	0
Natural Gas	Public Service	13975[r]	5.0[g]	0.10[g]	58.7[l]	13.15[l]	2.22[f]	0
Natural Gas	Coke Production, SSF Prodn[al],	13975[r]	1.0[g]	0.10[g]	175.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Refineries	13975[r]	1.0[g]	0.10[g]	70.0[k]	2.37[l]	2.22[f]	0
Natural Gas	Blast Furnaces	13975[r]	5.0[g]	0.10[g]	50.7[v]	2.37[l]	2.22[f]	0
Natural Gas	Domestic	13975[r]	5.0[g]	0.10[g]	69.2[l]	30.8[l]	2.22[f]	0
Natural Gas	Gas Prodn[al],	13975[r]	1.0[g]	0.10[g]	86.5[l]	17.4[l]	2.22[f]	0
Natural Gas	I&S[ak]	13975[r]	5.0[g]	0.10[g]	177.4[l]	167.6[l]	2.22[f]	0
Natural Gas	Railways	13975[r]	5.0[g]	0.10[g]	86.53[l]	33.8[l]	2.22[f]	0
Natural Gas	Other Industry	13975[r]	5.0[g]	0.10[g]	134.94[l]	63.5[l]	2.22[f]	0
Natural Gas	Nuclear Fuel Prodn[al], Collieries	13975[r]	1.0[g]	0.10[g]	134.94[l]	63.5[l]	2.22[f]	0

Fuel	Source	C^{aj}	CH_4	N_2O	NO_x	CO	NMVOC	SO_x
Natural Gas	Autogenerators	13975[r]	5.0[g]	0.10[g]	68.4[l]	19.62[l]	2.22[f]	0
Natural Gas	Ammonia (Combustion)	13975[r]	5.0[g]	0.10[g]	146.1[d]	NE	2.22[f]	0
OPG	Gas production	15582[a]	1.0[g]	NE	70.0[k]	2.37[i]	3.77[f]	0
OPG	Refineries (Combustion)	15582[a]	1.0[g]	NE	91.0[ag]	12.0[z]	3.77[f]	0
OPG	Other Industry	15582[a]	5.0[g]	NE	70.0[k]	2.37[i]	3.77[f]	0
Colliery Methane	Other Industry	13933[a]	5.0[s]	0.10[g]	70.0[k]	2.37[i]	2.21[f]	0
Colliery Methane	Coke Production, Gas Production	13933[a]	1.0[s]	0.10[g]	70.0[k]	2.37[i]	2.21[f]	0
Sewage Gas	Public Services	27405[g]	5.0[g]	0.10[g]	66.78[f]	7.1[f]	2.42[f]	0
Landfill Gas	Miscellaneous	27405[g]	5.0[g]	0.10[g]	39.0[f]	122.4[f]	3.62[f]	0

Footnotes to Tables A2-1 to A2-4:

a Carbon Factor Review (2004), Review of Carbon Emission Factors in the UK Greenhouse Gas Inventory. Report to UK Defra. Baggott, SL, Lelland, A, Passant and Watterson, JW, and selected recent updates to the factors presented in this report.
b CORINAIR (1992)
b+ Derived from CORINAIR(1992) assuming 30% of total NMVOC is methane
c Methane facto r estimated as 12% of total hydrocarbon emission factor taken from EMEP/CORINAIR(1996) based on speciation in IPCC (1997c)
d Based on operator data: Terra Nitrogen (2008), Invista (2008), BP Chemicals (2008)
e As for gas oil
f USEPA (2005)
g IPCC (1997c)
h EMEP (1990)
i Walker *et al* (1985)
j As for fuel oil.
k EMEP/CORINAIR (2003)
l AEA Energy & Environment estimate based on application of literature emission factors at a greater level of detail than the sector listed (see Section A.3.3.1).
m USEPA (1997)
n British Coal (1989)

o Brain *et al,* (1994)
p As for coal
q EMEP/CORINAIR (2003)
r AEA Energy & Environment estimate based on carbon balance
s As for natural gas
t EMEP/CORINAIR (1996)
u IPCC (2000)
v Emission factor derived from emissions reported in the Pollution Inventory (Environment Agency, 2008)
w Fynes *et al* (1994)
x Passant (2005)
y UKPIA (1989)
z Emission factor derived from data supplied by UKPIA (2006, 2007, 2008)
aa Emission factor for 2005 based on data provided by UK Coal (2005), Scottish Coal (2006), Celtic Energy (2006), Tower (2006), Betwys (2000)
ab Munday (1990)
ac Estimated from THC data in CRI (Environment Agency, 1997) assuming 3.% methane split given in EMEP/CORINAIR (1996)
ad EMEP/CORINAIR (1999)
ae AEA Energy & Environment estimate based on data from Environment Agency (2005) and Corus (2005)
af UKPIA (2004)
ag AEA Energy & Environment estimate based on data from Environment Agency (2005), UKPIA, DUKES, and other sources
ah Royal Commission on Environmental Pollution (1993)
ai DTI (1994)
aj Emission factor as mass carbon per unit fuel consumption
ak I&S = Iron and Steel
al Prodn = Production
am As for SSF
an As for burning oil
ao AEA Energy & Environment estimate based on carbon factors review
ap EMEP/CORINAIR
aq AEA Energy & Environment estimate
ar Directly from annual fuel sulphur concentration data
as Based on sulphur content of pet coke used in Drax trials (Drax Power Ltd, 2008)
at Based on factors presented in EU-ETS returns
NE Not estimated
NA Not available

IE Included elsewhere

[1] These are the factors used the latest inventory year. The corresponding time series of emission factors and calorific values may are available electronically [on the CD accompanying this report]. Note that all carbon emission factors used for Natural Gas include the CO_2 already present in the gas prior to combustion.