National Atmospheric Emissions Inventory

Report

NAEI UK Emission Mapping Methodology 2005

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Executive Summary

Emission maps for the whole of the UK are routinely produced as part of the NAEI for 25 pollutants, listed below:

1,3-butadiene	N_2O
Benzene	Methane
Carbon monoxide	Arsenic
Carbon dioxide	Cadmium
Particulate matter (PM_{10} and $PM_{2.5}$)	Chromium
Nitrogen oxides (NO_x)	Copper
NMVOC	Lead
Sulphur dioxide	Mercury
Ammonia	Nickel
Benzo[a]pyrene	Selenium
Dioxins	Vanadium
Hydrogen chloride	Zinc

The maps are modelled estimates of emissions compiled at a 1km resolution. One set of maps is produced each year for the most recent NAEI year. The mapped emissions data are made freely available on the NAEI web site at www.naei.org.uk/data_warehouse.php and http://www.naei.org.uk/mapping/mapping_2005.php

The emission maps are used by AEA Energy & Environment and other organisations for a variety of Government policy support work at the national scale. In particular the maps are used as input into a programme of air pollution modelling studies. Local area statistics are also compiled from the maps and related data. For example Local Authority level data on carbon dioxide emissions and fuel use have been produced for 2003-2005) for Defra and BERR respectively using data from the NAEI mapping work (Goodwin et al 2005a and 2005b, King et al 2006, 2007a and 2007b and Bush et al 2007).

The geographical distribution of emissions across the UK is built up from distributions of emissions in each NAEI sector. These individual NAEI sector distributions are developed using a set of statistics appropriate to that sector. For large industrial 'point' sources, emissions are compiled from a variety of official UK sources (Environment Agency, Scottish Environmental Protection Agency, Local Authority data). For sources that are distributed widely across the UK (known as 'area' sources), a distribution map is generated using appropriate surrogate statistics for that sector. The method used for each source sector varies according to the data available. This report describes the methods used to map each of the NAEI sectors. Possible improvements to the methods are also suggested and summarised in order of priory at the end of the report.

Uncertainty analysis has been undertaken to consider the variability in quality of the emission maps for a selection of the pollutants listed above. Quality ratings have been calculated for point source emissions, area source emissions and the overall emission distribution for each pollutant. The pollutants with the highest quality ratings have a large proportion of emissions from point sources (SO_2, lead and mercury) whereas pollutants with a large amount of emissions from very disparate sources such as agriculture and waste burning have lower quality ratings (such as ammonia and benzo[a]pyrene).

The distribution of emissions presented in the NAEI maps has been verified for key pollutants for use in UK scale air quality modelling. The results for NO_x show good agreement between the rates of emissions from area sources and background ambient air concentrations at automatic air quality monitoring sites.

Contents

1. Introduction

The UK National Atmospheric Emission Inventory (NAEI) is compiled by the AEA Energy & Environment on behalf of the Department for Environment, Food and Rural Affairs (Defra) Air and Environment Quality Division and the Devolved Administrations. Related work on greenhouse gas emissions is also conducted for the Climate Energy and Ozone Science and Analysis division of the Defra.

This report describes the methodology used to compile spatially disaggregated 1km resolution emissions maps under the NAEI system. The NAEI is the standard reference air emissions inventory for the UK and includes annual emission estimates for a wide range of important pollutants. These include: greenhouse gases, regional pollutants leading to acid deposition and photochemical pollution, persistent organic pollutants and other toxic pollutants such as heavy metals. A spatial inventory is also produced each year.

A detailed report describing the methodology and outputs of the NAEI is published each year and can be found on the NAEI website at http://www.naei.org.uk/reports.php (Dore et al, 2006).

1.1 EMISSION MAPPPING SCOPE AND PURPOSE

Emission maps are routinely produced as part of the NAEI for the 25 pollutants, listed below:

1,3-butadiene	N_20
Benzene	Methane
Carbon monoxide	Arsenic
Carbon dioxide	Cadmium
Particulate matter (PM_{10} and $PM_{2.5}$)	Chromium
Nitrogen oxides (NO_x)	Copper
NMVOC	Lead
Sulphur dioxide	Mercury
Ammonia	Nickel
Benzo[a]pyrene	Selenium
Dioxins	Vanadium
Hydrogen chloride	Zinc

The maps are modelled estimates of emissions compiled at a 1x1 km resolution and are aggregated to UNECE Sectors using the SNAP reporting format as shown in **Table 1.1** below. Data for large point sources are reported separately.

Table 1.1 UNECE Emissions Sectors Classification

UNECE Sector Code	Description
1	Combustion in energy production and transfer
2	Combustion in commercial, institutions, residential and agricultural sectors
3	Combustion in industry
4	Production processes
5	Extraction / Distribution of fossil fuels
6	Solvent use
7	Road transport
8	Other transport and machinery
9	Waste Treatment and disposal
10	Agricultural, forests and landuse change
11	Other sources and sinks

The emission maps are used by AEA Energy & Environment and other organisations for a variety of Government policy support work at the national scale. In particular the maps are used as input into a programme of air pollution modelling studies.

Local area statistics are also compiled from the maps and related data. For example Local Authority level data on carbon dioxide emissions and fuel use have been produced since 2003 for Defra and BERR (Goodwin et al 2005a and 2005b, King et al 2006, 2007a and 2007b and Bush et al 2007).

The mapped emissions are made freely available on the NAEI web site at http://www.naei.org.uk/data_warehouse.php. They provide a valuable resource for those interested in local air quality:

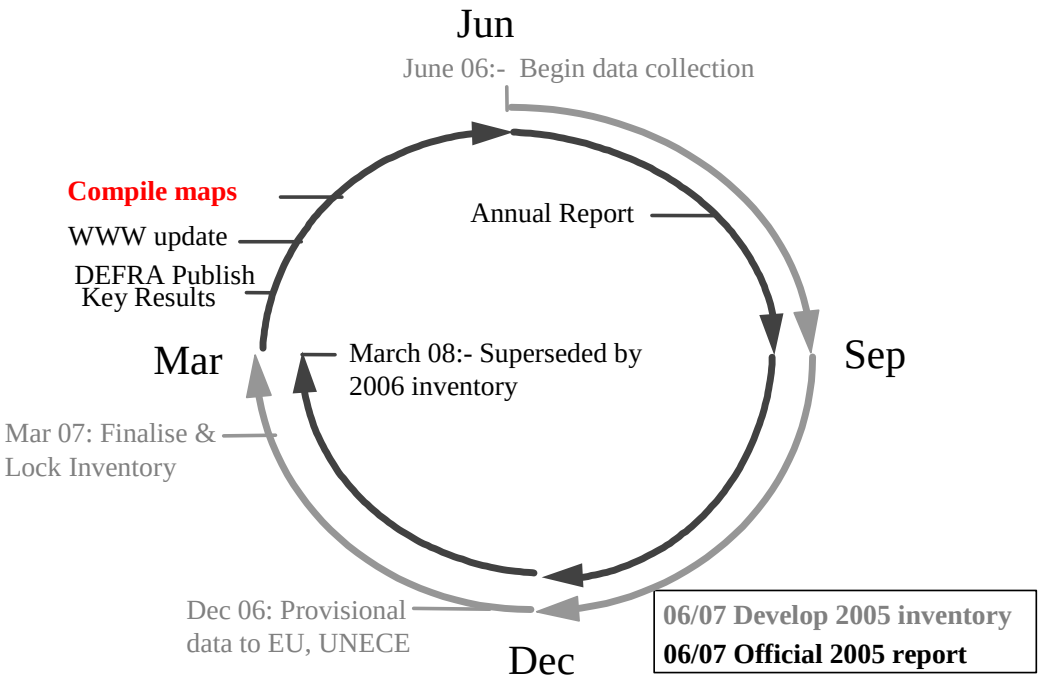
- The maps are frequently used as a starting point for many local emission inventories, which may then be used to assess current and future air quality.
- Emission estimates for point sources and emissions arising from the surrounding area are used in modelling studies as part of Environmental Impact Assessments by developers and their consultants.

1.2 ANNUAL CYCLE

The NAEI is compiled on an annual basis, each year the latest set of data are added to the inventory and the full time series (1970-2005) is updated to take account of improved data and any advances in the methodology used to estimate the emissions. Updating the full time series is an important process as it ensures that the entire dataset uses the methodology that is the most current, and hence considered to give the most accurate results and the most accurate indication of temporal trends. The new data are then reported to UN/ECE, UNFCCC and other international fora.

Emission maps are compiled for the latest year in the time series each year only. There is therefore no consistent set of historic emissions maps for the full time series (as the methodologies for both the mapping and the emissions inventory compilation are revised each year). The maps are compiled after the inventory is finalised in March each year. This annual cycle of activity is represented schematically in **Figure 1.1**.

Figure 1.1 The Annual NAEI Cycle



1.3 REPORT STRUCTURE

The next section of this report provides an overview of the emission sectors covered by the NAEI (section **2**). Section **3** then describes the methods used to calculate distribution maps for these sectors across the UK. The compilation of the final emission maps and data products are covered in section **4.** The quality and verification of the maps is assessed in section **5.** Section **6** provides a summary of recommendations for improvements to the maps.

2. National Inventory Compilation

The NAEI is divided into a large number of individual emission sectors in order to produce an accurate and detailed estimate of emissions across the UK. For each of these sectors a national total emission is compiled within the NAEI from a combination of reported emissions and estimated emissions. Reported emissions are obtained from the regulators of industrial processes: the Environment Agency, the Scottish Environmental Protection Agency (SEPA) and the Department of the Environment Northern Ireland (DOENI). Emission estimates are calculated by applying an emission factor to an appropriate activity statistic. That is:

$$\text{Emission} = \text{Factor} \times \text{Activity}$$

Emission factors are generally derived from measurements on a number of sources assumed to be representative of a particular source sector. Examples of emission factors are (a) the amount in tonnes of NO_x from a car per kilometre it travels and (b) the amount of SO_2 emitted from a power station per tonne of coal burned.

Activity statistics are obtained from Government statistical sources, such as the Digest of UK Energy Statistics (DTI, 2006), Transport Statistics Great Britain (Dft 2006a), and from other organisations such as trade associations and research institutes - for example the UK Petroleum Industries Association (UKPIA) provide data on the sulphur content of fuels, and the Institute of Grassland and Environmental Research (IGER) provide data on livestock numbers and fertilizer usage.

The level of detail chosen for defining the source sectors depends on available reported emissions or activity and emission factor data. A detailed breakdown of the NAEI source sectors for NO_x in 2005 is shown in **Table 2.1** and a summary aggregated to UNECE sectors is shown in **Figure 2.1**. Emission estimates of NO_x are in fact compiled at a considerably more detailed level, but the sectors presented in **Table 2.1** allow a clearer understanding of the mapping principles employed. The NO_x inventory will be used throughout this report to help explain and illustrate the mapping methods used.

Figure 2.1 UK NO_x Emissions in 2005 by UNECE Source Sector

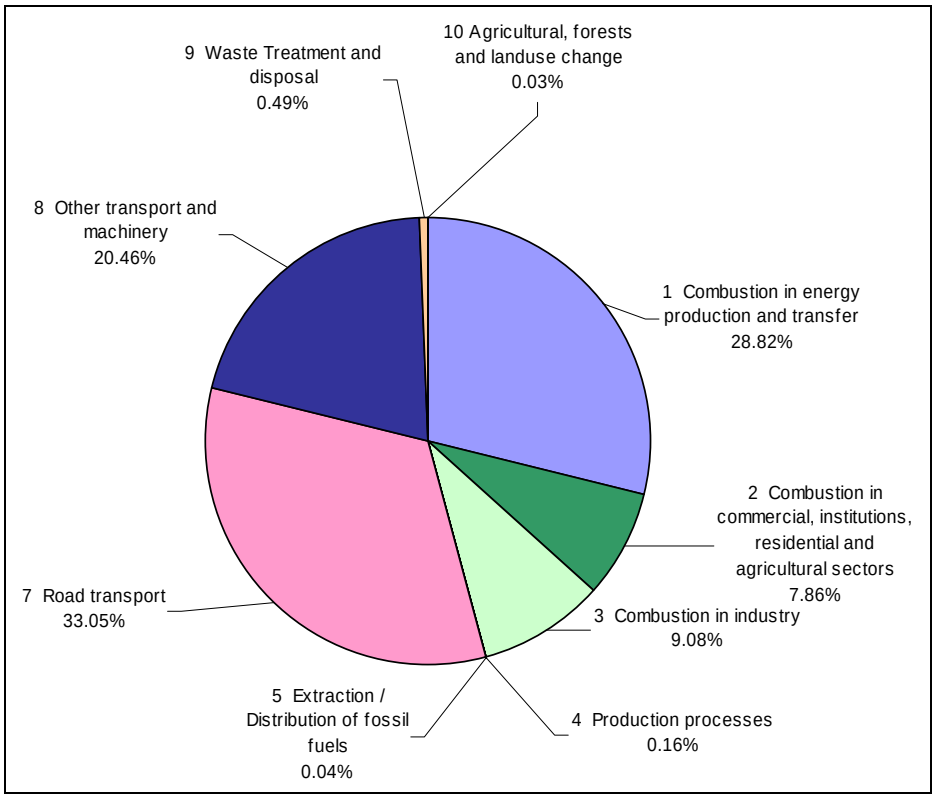


Table 2.1 Detailed source sector breakdown of UK emissions of NO_x in 2005

UNECE Source Sector	NAEI Detailed Source Sector	NO_x emission (tonnes)
1 Combustion in energy production and transfer	Coke production	4,463
	Collieries - combustion	205
	Landfill gas combustion	1,367
	Offshore oil and gas - own gas combustion	49,441
	Other industrial combustion	25,988
	Power stations	367,290
	Refineries - combustion	29,942
	Sewage gas combustion	218
1 Combustion in energy production and transfer Total		478,916
2 Combustion in commercial, institutions, residential and agricultural sectors	Agriculture - stationary combustion	701
	Domestic combustion	108,510
	Miscellaneous industrial/commercial combustion	7,187
	Public sector combustion	14,236
	Railways - stationary combustion	37
2 Combustion in commercial, institutions, residential and agricultural sectors Total		130,672
3 Combustion in industry	Ammonia production - combustion	1,473
	Blast furnaces	671
	Cement - non-decarbonising	33,224
	Iron and steel - combustion plant	10,401
	Lime production - non decarbonising	4,543
	Other industrial combustion	92,197
	Sinter production	8,420
3 Combustion in industry Total		150,928
4 Production processes	Basic oxygen furnaces	127
	Chemical industry - nitric acid use	204
	Electric arc furnaces	537

UNECE Source Sector	NAEI Detailed Source Sector	NO_x emission (tonnes)
	Nitric acid production	639
	Primary aluminium production - anode baking	86
	Primary aluminium production - general	286
	Solid smokeless fuel production	20
	Iron and steel - flaring	701
4 Production processes Total		2,599
5 Extraction / Distribution of fossil fuels	Offshore oil and gas - processes	554
	Offshore oil and gas - well testing	100
5 Extraction / Distribution of fossil fuels Total		654
7 Road transport	Road transport - cars - cold start	1,576
	Road transport - cars non catalyst - cold start	429
	Road transport - cars with catalysts - cold start	53,017
	Road transport - LGVs - cold start	1,896
	Road transport - LGVs non catalyst - cold start	18
	Road transport - LGVs with catalysts - cold start	757
	Road transport - major roads	371,381
	Road transport - minor roads	120,177
7 Road transport Total		549,252

UNECE Source Sector	NAEI Detailed Source Sector	NO_x emission (tonnes)
8 Other transport and machinery	Agriculture - mobile machinery	52,098
	Aircraft - military	5,540
	Aircraft - domestic take off and landing	2,260
	Aircraft - international take off and landing	8,620
	Aircraft - support vehicles	5,566
	House and garden machinery	912
	Industrial off-road mobile machinery	97,538
	Railways - freight	7,490
	Railways - intercity	6,010
	Railways - regional	13,994
	Shipping - coastal	92,143
	Shipping - naval	16,673
	Shipping - UK international	31,140
8 Other transport and machinery Total		339,983
9 Waste Treatment and disposal	Accidental fires - vehicles	27
	Crematoria	131
	Incineration - animal carcases	245
	Incineration - chemical waste	370
	Incineration - clinical waste	463
	Incineration - MSW	3,906
	Incineration - sewage sludge	233
	Offshore oil and gas - flaring	2,246
	Other industrial combustion	116
	Small-scale waste burning	396
9 Waste Treatment and disposal Total		8,133
11 Other sources and sinks	Accidental fires - dwellings	111
	Accidental fires - forests	113
	Accidental fires - other buildings	201
	Accidental fires - straw	44
	Accidental fires - vegetation	54
11 Other sources and sinks Total		524
Grand Total		1,661,661

The relative contributions of emissions from different sectors varies by pollutant. The NAEI report provides details of emissions by sector for all pollutants covered by the NAEI (Dore et al, 2007).

3. Methods for calculating emissions distributions

The overall geographical distribution of emissions across the UK is built up from the pattern of component distributions for each NAEI emission sector. These individual NAEI sectoral distributions are developed using a set of statistics appropriate to that sector. For large industrial 'point' sources, emissions are compiled from a variety of official UK sources (Environment Agency, Scottish Environmental Protection Agency, Local Authority data). For sources that are distributed widely across the UK (known as 'area' sources), a distribution map is generated using appropriate surrogate statistics for that sector. The method used for each source sector varies according to the data available. **Table 3.1** shows the types of mapping methods used within each of the UNECE sectors. The mapping methods are explained in the next sections.

Table 3.1 Mapping Methods used to map emissions in each of the 11 UNECE source sectors

1 Combustion in energy production and transfer	**6 Solvent use**
points	population
offshore	points
IDBR employment	IDBR employment
2 Combustion in commercial, institutions, residential and agricultural sectors	landuse
points	**7 Road transport**
domestic fuel use	road transport
IDBR employment	**8 Other transport and machinery**
IDBR agriculture	agriculture
IDBR commercial and public fuel use	airports
3 Combustion in industry	other
points	rail
IDBR employment	shipping
IDBR industry fuel use	IDBR employment
4 Production processes	population
points	**9 Waste Treatment and disposal**
IDBR employment	landfill
shipping	landuse
road transport	offshore
population	points
other	IDBR employment
5 Extraction / Distribution of fossil fuels	**10 Agricultural, forests and landuse change**
points	agriculture
offshore	landuse
other	**11 Other sources and sinks**
domestic fuel use	landuse
population	other
	population

3.1 POINT SOURCES

A point source is an emission source at a known location such as an industrial plant or a power station. Emissions from point sources represent sectors of the UK inventory either fully (such as power stations where the sector is made up of large operational facilities for which emission reporting is mandatory) or in part (such as combustion in industry, for which only the large sites within the sector

are required to report emissions). In the latter case, the remainder of the emissions for the sector are mapped as an area source.

Emissions for the point sources are compiled using a number of different data sources and techniques. For convenience, the point source data can be divided into four groups:

1. Point sources, largely regulated under the Integrated Pollution Control (IPC) or Integrated Pollution Prevention and Control (IPPC) regulatory regimes, for which emissions data are available to the NAEI from the Environment Agency's Pollution Inventory (PI), from the Scottish Environment Protection Agency's Scottish Pollutant Release Inventory (SPRI), from the Inventory of Sources and Releases (ISR) produced by the Department of the Environment (Northern Ireland) or direct from process operators or trade associations.
2. Point sources registered with and trading emission credits under the EU-Emissions Trading Scheme (EU-ETS)
3. Point sources, regulated under Local Authority Pollution Control/Air Pollution Control (LAPC/APC) in England and Wales, and in Scotland respectively, for which emissions data are estimated by AEA Energy & Environment on the basis of site-specific data collected from regulators.
4. Point sources where emissions are modelled by distributing national emission estimates over the known sources on the basis of capacity or some other 'surrogate' statistic.

For the first group, the most important source of information is the PI which includes emissions data for most pollutants covered by the NAEI. The PI covers processes regulated by the Environment Agency in England and Wales under IPC and IPPC. It does not include any data on processes regulated under LAPC or IPPC by local authorities in England and Wales. Reporting of emissions started in 1991 and is annual. The quality and quantity of reported data increases in recent years and the level of reporting is very high from the second half of the 1990s onwards. From 1998 onwards, emission reporting is only required if emissions exceed a 'reporting threshold' e.g. for carbon monoxide, the reporting threshold in 2003 was 100 tonnes and this means that some smaller point sources do not have to report emissions.

The SPRI includes data for 2002 and then from 2004 onwards. As with the PI, process operators do not need to report emissions which are below reporting thresholds.

The ISR contains annual data from 1999 onwards and also relies on a reporting threshold to eliminate the need for smaller sources to report emissions.

Since 2004, the NAEI has utilised information from the EU-ETS to characterise the types and quantities of fuels consumed by operators registered with this scheme. This approach was developed for mapping of CO_2 point source emissions as part of the work on the Local and Regional CO_2 estimates for 2004 (King et al 2006) and is now rolled out for the first time for estimation of emissions of all pollutants. In most cases the EU-ETS fuel consumption data were used to split PI/SPRI/ISR reported emissions between the various fuel types used at the facility. In other cases where PI/SPRI/ISR data were not available the EU-ETS data were used directly.

Additional data on NO_X and SO_2 emissions from processes subject to the Large Combustion Plant (LCP) Directive are available for Northern Ireland and Scotland for 1990 and for all years from 1992 onwards. The LCP data also includes data for processes in England and Wales although in many cases these data are also available from the PI.

Some process operators and trade associations also provide emissions data direct to AEA Energy & Environment. Notable examples include:

- Corus UK Ltd, who provide data for integrated steelworks broken down into emissions from sinter plant, blast furnaces, basic oxygen furnaces, and combustion plant. PI emissions data for the steelworks, does not give this breakdown and is far less useful;
- United Kingdom Petroleum Industry Association (UKPIA) supply emission data for process sources of VOC and combustion processes at crude oil refineries;

- United Kingdom Offshore Operators Association (UKOOA) provide emissions data for offshore oil and gas exploration and production installations as well as various onshore installations linked to the production of oil and gas.

Point source data for some processes regulated under LAPC/APC are based on information obtained on a periodic basis from regulators. This is an important approach for processes using solvents which are significant sources of VOC emissions but not included in the PI.

Point source data are not available for all processes. Sources may not need to report emissions if these are below a specified reporting threshold or, in the case of processes regulated by local authorities, the NAEI may not collect any emissions data from the regulator. In some cases, datasets are not complete, indicating that not all sources have reported as they should have. Furthermore, some point sources are not regulated. In these cases, point source data is generated using national emission factors and a 'surrogate' activity statistic. Examples of this approach are given below:

- Estimates of plant capacity, including estimates made by AEA Energy & Environment can be used to allocate the national emission estimate. This approach is, for example, used for bread bakeries where AEA Energy & Environment have estimated the capacity of each of about 70 large mechanised bakeries.
- Emission estimates for one pollutant can be used to disaggregate the national emission estimate of another pollutant. For example, emissions of PM_{10} from certain coating processes have been estimated by allocating the national total to sites based on their share of the national VOC emission.
- Assuming that plant which do not report emissions have similar rates of emissions as plant within the same sector which do report emissions. In cases where point source data are available for the sector from the PI, emissions data may be missing for a small proportion of sites, generally either because the process is small and emissions are below reporting thresholds or because the site closed that year and did not therefore submit a report. In these cases, emissions are calculated by assuming that these sites will emit at the same rate as other sites for which emissions data are available.
- Emissions can be distributed using surrogate data other than capacity. For example, in the case of Scotch malt whisky distilleries, emissions of VOC from distilling are distributed using the number of stills as a measure of the scale of operations and therefore emissions.
- Assuming that all plants in a given sector have equal emissions. In a few cases where there are relatively few plant in a sector but no activity data can be derived, emissions are assumed to be equal at all of the sites.

With the possible exception of using plant capacity, many of the approaches listed above will yield emission estimates which are subject to a degree of uncertainty. However, most of the emission estimates generated using these methods are, individually, relatively small and the generation of point source data by these means is judged better than mapping the emissions as area sources.

Table 3.2 shows the contribution to UK total emission by point sources for 25 pollutants. The table also shows the contribution of the various types of sources of these data, whether reported or estimates calculated by the NAEI team. In some cases, emissions data reported in the PI or similar sources must be 'interpreted' in order to yield point source data. An example would be the case of VOC emissions from a chemical process where emissions of individual VOC species might be reported but not emissions of total VOC. The NAEI team therefore need to decide whether to assume that the individual VOC species reported were the only VOCs emitted or whether to make an allowance for other species being emitted. In all such cases, point source data are treated as NAEI calculated emission estimates rather than reported data. The calculated emissions also include all point sources data based on data supplied by regulators for LAPC/APC processes.

The larger part of NO_X, SO_2, HCl and heavy metals point source emissions are mapped based on reported data. This is because the main sources are power stations and other large combustion plant where the level of reporting is extremely high. 59% of VOC point source data are based on NAEI calculations, reflecting the need for further processing of reported data to yield suitable data. $PM_{2.5}$ emissions are calculated from PM_{10} reported and estimated emissions based on particulate speciation factors for each source type. The points source data for $PM_{2.5}$ is therefore 100% estimated.

The table also shows the percentage of national emissions which are mapped as point sources. For SO_2, some of the heavy metals and HCl, a large proportion of emissions are treated as point sources. For most other pollutants this percentage is less than 50% and in nine cases, less than 20% of national emissions. This is due to the fact that a high proportion of emissions of these pollutants are from sources which cannot be treated as point sources (road transport, aircraft, shipping, domestic fires, small industrial combustion units, consumer-product use, agriculture, petrol stations, dry cleaning shops, gas pipelines etc.).

Table 3.2 Point source emission fraction of NAEI UK total emissions for 10 key pollutants and contributions of reported and estimated data.

Pollutant	% of national emissions treated as point sources	% of point source emissions from Reported data	% of point source emissions from Estimated data
13-butadiene	11%	98%	2%
Ammonia	2%	80%	20%
Arsenic	16%	36%	64%
Benzene	12%	90%	10%
Benzo[a]pyrene	5%	8%	92%
Cadmium	59%	47%	53%
Carbon Monoxide	21%	93%	7%
Carbon Dioxide	47%	91%	9%
Chromium	56%	72%	28%
Copper	29%	50%	50%
Dioxins (PCDD/F)	27%	64%	36%
Hydrogen Chloride	67%	97%	3%
Lead	74%	44%	56%
Mercury	70%	73%	27%
Methane	1%	97%	3%
Nickel	29%	60%	40%
Nitrogen Oxides as NO2	31%	98%	2%
Nitrous Oxide	10%	86%	14%
Non Methane VOC	22%	41%	59%
PM10 (Particulate Matter < 10µm)	19%	53%	47%
PM2.5 (Particulate Matter < 2.5µm)	17%	0%	100%
Selenium	66%	47%	53%
Sulphur Dioxide	78%	97%	3%
Vanadium	4%	58%	42%
Zinc	32%	31%	69%

Possible future improvements:
The current level of mapping using point source data is close to the maximum feasible level, the only exceptions being that some additional mapping of medium-sized combustion plant and industrial processes may be possible in future due to developments such as emission trading, reporting of emissions from IPPC processes not previously regulated under IPC, and use of local inventory data.

The existence of EU-ETS data, and some fuel usage data in the Pollution Inventory has aided the development of point source data for combustion plant. However, the processing of the data from these sources is time-consuming and complex, and the differences between data in the EU-ETS datasets, the PI, SPRI, and ISR, and national energy statistics given in DUKES present serious challenges. It is anticipated that further development of the point source data for medium-sized combustion plant will take a number of years and the extent of improvement in the quality of mapping that results, will depend upon developments in the EU-ETS, PI/SPRI/ISR and DUKES data sets.

The requirement for Part A2 processes, regulated by local authorities, to report emissions to the European Pollutant Release Inventory (EPER) has had a small beneficial impact on the mapping, with

some limited additional data becoming available. Due to the relatively high reporting thresholds used for EPER, few A2 processes need to provide emissions data, and this limits the usefulness of EPER for UK mapping work. The change from EPER to the European pollutant release and transfer register (E-PRTR) for the 2007 reporting year will have an impact on the quantity of data available for use in the mapping.

Local inventory data are potentially useful for national emission maps, however there are a number of barriers to the use of such data.

1. Obtaining data from local inventory studies is time-consuming since the detailed data are not readily available e.g. on the internet but must instead be obtained through negotiation with the data holders.
2. Once obtained, considerable resources would be required to convert the data into the formats used for national maps.
3. The quality of local inventory data is not known, but review of some local inventory data has indicated that, in a few cases where comparable data are available in the national inventory, the local data are probably not as reliable. These cases related to Part B processes emitting VOC.
4. Using data from local inventories creates a problem in that these inventories provide an incomplete picture of emissions from a sector. Unlike EPER, EU-ETS or PI/SPRI/ISR data which are available for the UK as a whole, using data from a few local inventories would mean that points data included processes from some areas but not for others. This would have to be addressed by the mapping process but it would make the process much more complicated.

In view of the difficulties listed above, no point source data from local inventories have been incorporated to date in the national maps. Use of this kind of data should not be ruled out in the future, but any work programme to incorporate local inventory point sources would have to reflect the resource-intensive nature of the task.

3.2 INDUSTRIAL AND COMMERCIAL SECTORS

The industrial sectors in the NAEI are mapped using a combination of site specific (point source) estimates of emissions and area source employment based distributions. For some sectors the NAEI UK total emissions estimate is entirely accounted for by point source emissions. In this instance all of the emissions are mapped across these points of known location.

In other sectors there are some usually smaller installations that are not included within the point source dataset. The remaining emission from these installations is then treated as an ‘area source’ and distributed across the UK using a combination of detailed employment and fuel use data. The method used is described in this section. The sector called “Other industrial combustion” is an example for which the area source distribution is particularly important.

In other sectors the entire emission is distributed as an area source, e.g.the “Miscellaneous industrial/commercial combustion” and the “Public sector combustion” sectors. These, sectors have no site specific data are available.

The following data sets are used to develop emissions distribution maps for Other industrial combustion, Miscellaneous industrial/commercial combustion, Public sector combustion and Agriculture stationary combustion:

- Office of National Statistics Inter-Departmental Business Register (IDBR) 2005 which provides data on employment at business unit level by Standard Industrial Classification (SIC) code;

- DTI Energy Consumption in the UK data on industrial and commercial sector fuel usage for 2002. (DTI 2002, Tables 4.6, 5.2 and 5.5)

The SIC codes in the IDBR database were matched with the DTI energy datasets in order to calculate total employment by DTI energy sector. From this a UK average fuel intensity per employee was

calculated. These intensities could then be applied to employment distributions across the UK to make maps of fuel use.

In the case of the industrial sectors this energy intensity calculation was done at the level of 4 figure SIC codes (over 250 separate industry types) to retain the level of detail required for the mapping. Any aggregation of SIC codes would have resulted in a reduction in the quality of the final distribution. The DTI fuel data was reported for coal, manufactured fuel (SSF), LPG, gas oil, fuel oil and natural gas. These were aggregated to calculate industry specific fuel intensities for Coal, SSF, Oil and Gas.

In the case of the commercial and public service sectors the employment data was aggregated to be equivalent to the energy data provided by DTI. These sectors are shown in **Table 3.3.** There was not sufficient data to be able to calculate a fuel specific fuel intensity factor for these sectors. Therefore a total fossil fuel intensity factor was calculated.

Table 3.3 Service sector energy consumption sub-sectors and NAEI sectors

Service sector energy consumption sub sectors	NAEI emissions sector
Commercial Offices	Commercial
Communication and Transport	Commercial
Hotel and Catering	Commercial
Other	Commercial
Retail	Commercial
Sport and Leisure	Commercial
Warehouses	Commercial
Education	Public admin and services
Government	Public admin and services
Health	Public admin and services

The IDBR employment data were aggregated to 4 figure SIC codes at 1km resolution using grid references provided as part of the database. The employment totals for each sector were then multiplied by the appropriate fuel intensity values to make fuel use distributions across the UK. These were then used to distribute emissions for the relevant sector from the NAEI for 2005. It has been assumed that fuel intensity for each sector is even across the sector. This is a simplification of reality but necessary because of lack of more detailed estimates of fuel use.

Assumptions were made about the spatial distribution of the different fuel types for all of the industrial and commercial sectors. Gas use was constrained to within gas consumption zones derived from a combination of Transco postcode sector level data and urban land cover data. Other fuels were assumed to be used only outside these zones. There is significant uncertainty in the assumptions regarding the spatial distribution of the solid and liquid fuels therefore reduced levels of accuracy for these distributions.

For some sectors a simple map of employment has been used instead of fuel use. These are mostly for sectors where process emissions are important but this method is also for estimating the distribution of industrial off-road emissions. These have been mapped using a distribution of employment in heavy industries. Emissions from clinical waste incineration are mapped according to the distribution of employment in hospitals.

The distribution of all gas consumed by industrial and commercial sectors derived from the methods described above has been compared at a local authority level with the gas consumption data published by DTI (DTI 2004). A good match was found.

Planned improvements for the 2006 dataset:

- Better data on fuel specific fuel consumption in the commercial and public services sectors would allow more accurate fuel intensity calculations for these sectors
- Better spatially resolved data on gas use would improve the distribution of the different fuel types. The current data can not be mapped accurately because of incompatible postcode sector definitions. This could also improve the solid and liquid fuel use distributions.

3.3 ROAD TRANSPORT

Hot exhaust emissions are calculated within the NAEI using fuel consumption and emission factors for each vehicle type. These in turn are calculated on the basis of the composition of the vehicle fleet (age profile and fuel mix) from the DVLA's national licensing data and are based on the assumption that the fleet mix is the same everywhere on the UK road network. There are no regional variations in either the age of the fleet or the fuel mix. Sensitivity analyses have been carried out to assess the effect of varying the fuel mix across the UK and concluded that the effects on emissions are very small even with a large increase in the proportion of diesel cars (Goodwin et al 2005b).

3.3.1 Emission factors and fuel consumption factors

Fuel consumption factors and emission factors combined with traffic data for 6 major classes of vehicles are used to estimate national fuel consumption and emissions from passenger cars, light goods vehicles (LGVs), rigid heavy good vehicles (HGVs), articulated HGVs, buses/coaches and mopeds/motorcycles. The vehicle classifications are further sub-divided according to fuel type (petrol or diesel) and the regulatory emission standard the vehicle or engine had to comply with when manufactured or first registered. The vehicle Euro emission standards apply to the pollutants nitrogen oxides, particulate matter, carbon monoxide and hydrocarbons and but to CO_2 or fuel consumption. Nevertheless, the Euro standards are a convenient way to represent the stages of improvement in vehicle or engine design that have led to improvements in fuel economy and are related to the age and composition profile of the fleet. For example, the proportion of pre-Euro I, Euro I, Euro II and Euro III vehicles in the national car fleet can be associated with the age of the car fleet (year-of-first registration).

Fuel consumption and emission factors are expressed in grams fuel or tonnes of emission respectively per kilometre driven for each detailed vehicle class and are taken from two distinct data sources.

- Vehicle emission test data provided by the Transport Research Laboratory (TRL) over different drive cycles from measurements on a limited sample of vehicles;
- Car manufacturers' data on CO_2 emissions and surveys with freight haulage companies on fuel efficiency of HGVs.

Emissions for the key air quality pollutants (NO_x, PM_{10}, $PM_{2.5}$, SO_2, NMVOC, Benzene, 1,3-butadiene, and CO) are calculated using speed related emission factors multiplied by vehicle flows on the road network. For other pollutants such as CO_2 and heavy metals, fuel consumption is used as a proxy for the distribution of emissions. The fuel consumption maps are calculated from speed related fuel consumption factors multiplied by vehicle flows. The method for calculating these maps is described in the next section.

3.3.2 Road transport mapping methodology

The base mapping for the hot exhaust road traffic emissions is derived from the Ordnance Survey Meridian dataset. This provides locations of all roads (motorways, A roads, B roads and Unclassified roads) in Great Britain. In addition a dataset of roads in Northern Ireland was obtained from the Department of Environment Northern Ireland (DoE NI). This provides all major roads and most minor roads (but not all unclassified roads).

Traffic flow data for major roads (A roads and motorways) is available on a census count point basis for both GB (DfT 2005b) and Northern Ireland (Roads Service 2006). However, the coverage in GB is considerably more dense than that for NI, although some new NI count points were available from 2004. The traffic flow data includes counts of each type of vehicle as an annual average daily flow. These have been aggregated up to annual flows by simply multiplying by 365. There is no seasonal variation assumed. Some Northern Ireland count points only record total vehicles, rather than a split of different vehicle types. An average vehicle split has therefore been applied to these. Each traffic count point has been allocated to a section of the major road network according to the road name and its proximity to the road – i.e each link has the nearest count point assigned to it. Calculations of

emissions and fuel use have been done at the 1km resolution level by splitting each road link using an intersection with a 1km grid.

Traffic flow data is not available for minor roads on a link by link basis. Instead regional average flows by vehicle type have been applied to each type of minor roads – B roads and C or unclassified roads. These data were obtained from Department for Transport (DfT pers comm. 2004). For Northern Ireland vehicle-specific minor road flows have been calculated from data in the Traffic and Travel Information 2003 report (Roads Service 2005) which provides average flows for all vehicle types by minor roads and also average vehicle splits by the same road types.

It has been assumed that there are no regional variations in either the age of the fleet or the fuel mix. The fuel splits for passenger cars and LGVs in 2005 are provided in **Table 3.4** below. For other vehicles, it has been assumed that 100% of motorcycles are fuelled by petrol and 100% of heavy goods vehicles and buses run on diesel.

Table 3.4 UK fuel split by vehicle type on minor roads 2005

Vehicle	Fuel type	% of fleet
Cars	Diesel	18.5
Cars	Petrol	81.5
LGVs	Diesel	90.1
LGVs	Petrol	9.9

Each road link has been assigned an area type using the DfT definitions of urban area types shown in **Table 3.5** below. Vehicle speeds have then been assigned to different road types (built up and non-built up A roads and motorways) within each area type based on information provided by DfT which is described in the Greenhouse Gas Inventory report for 2003 (Baggott et al 2005).

Vehicle kilometers of travel (VKM) by each vehicle type were calculated from the traffic flow rates, fuel splits and the lengths of each road type. VKM numbers are then multiplied by fuel consumption or emission factors taking into account the speed on the road of concern. These calculations were performed for each link in the road network resulting in maps of fuel use by fuel type and emissions by pollutant aggregated to 1km resolution across the UK.

For 2005 it was assumed that the spatial pattern of UK vehicle kilometres (VKMs) on minor roads was the same as that modelled for 2003. Total 2005 VKM totals for GB (DfT 2006a) and Northern Ireland (Roads Service 2006) were distributed across this pattern to generate revised minor road km maps for 2004.

Table 3.5 Department for Transport Urban Area Type Classification

Area Type ID	Description	Population
1	Central London	N/A
2	Inner London	N/A
3	Outer London	N/A
4	Inner Conurbations	N/A
5	Outer Conurbations	N/A
6	Urban Big	> 250,000
7	Urban Large	>100,000
8	Urban Medium	> 25,000
9	Urban Small	> 10,000
10	Rural	N/A

3.3.3 Other road transport related emissions

Cold start emissions are those emissions from vehicles that are produced before the engine has reached normal operating temperature. Estimates for Great Britain of the distance travelled by vehicles whilst producing cold start emissions are available for cars by average trip length and trip type using the method described in the Greenhouse Gas Inventory report for 2003 (Baggott et al 2005). Cold start emissions are assumed to have similar characteristics in Northern Ireland. This data enables estimates of the associated emissions to be determined at the UK level using the COPERT II methodology (COPERT II 1997).

The trip types used in the calculations are classified as 'home to work', 'home to other locations' and 'work based' trips. 'Home to work' related emissions are distributed across the UK using detailed population census data on whether people use their car as their method of transport to work. Emissions for trips from home to other locations are mapped using data on car ownership. Work based cold start emissions are mapped on a distribution of all employment across the UK.

Evaporative emissions of benzene and NMVOC from petrol vehicles have been distributed using a map of petrol fuel use on all roads, derived using the method described in section 3.3.2 above.

PM_{10} and $PM_{2.5}$ emissions from brake and tyre wear are distributed using a 1km resolution map of estimated total vehicle kilometres on major and minor roads.

Possible future improvements to road transport emissions distributions:

- Additional traffic census data at new locations for Northern Ireland would significantly improve the emissions distribution for Northern Ireland.
- Updates of the distributions of cold start emissions using 2001 Census data and 2005 employment distributions and incorporation of COPERT updates as appropriate.
- A review of regional/national vehicle fleet composition and speed assumptions, particularly for London.

3.4 DOMESTIC FUEL USE

The approach to modelling domestic fuel use for the 2005 NAEI draws heavily on recent work modelling of domestic fuel use with Great Britain for the 2004 Local and Regional CO_2 Emission Estimates (King et al 2006) and updates to the core datasets underlying the modelling approach for Northern Ireland undertaken for the 2002 NAEI and under other Defra studies (Pye and Vincent, 2003). In adopting these new approaches and updating the core datasets, substantial improvements in the estimate of domestic fuel use, its distribution and estimates of emissions for all pollutants from this sector have been achieved in the 2005 NAEI for the whole of the UK. A summary of the improved methodology is provided below.

Domestic fuel mapping in Great Britain.
The improved method for mapping domestic fuel use within Great Britain makes use of newly available data from DTI and BRE to enable significant improvements to be made to the distributions of domestic fuel use. New distributions of domestic gas, coal, oil and smokeless solid fuels were produced for Great Britain for the 2004 inventory emission maps.

New data made available by DTI provides high resolution maps of domestic gas use across Great Britain. This dataset characterises the number of gas customers and amounts of gas used per 1km square for 2005, and data on electricity use, specifically type 2 meters (economy 7 type meters).

In addition, data supplied by BRE on behalf of Defra for this work, provided estimates of total energy use by dwelling type and by fuel type and also regional data on the numbers of households using different fuels (BRE 2006). Gas consumption accounts for 72% of domestic non-electricity energy use therefore the new high resolution gas data from DTI provides a huge improvement in understanding the spatial distribution of fuel consumption in Great Britain.

In providing improved fuel use estimates, the method first calculated the amount of gas use in a 1km square and compared this with a theoretical quantity of gas consumption on the basis of complete gas take-up by the housing stock, i.e. every dwelling using the average gas demand for that dwelling type. The difference between the actual gas consumption and this theoretical amount was then calculated and the number of households this represented apportioned to different fuels. This apportionment was based on Economy 7 electricity use, assumptions about fuel use within and outside smoke control areas and regional data from BRE on fuel usage by household type.

It has been assumed that:

- Coal is burnt exclusively outside Smoke Control Areas

- Oil is burnt outside the biggest cities (of greater than 250,000 populations) but inside the smaller cities in grid squares where there is residual demand
- Smokeless solid fuels (SSF, coke, anthracite) are burnt exclusively within smoke control areas
- Wood consumption was assumed to have the same distribution as coal

The new maps represent a significant improvement on the previous domestic maps as result of the of new data sources and new modelling techniques. Initial validation of the results (King et al 2006) shows a relatively good correlation between the model results and the BRE regional data. There are still some quite large differences but given the uncertainties in this work this is not surprising. Further validation of modelled data is planned as part of the continued development of the emission maps. Full details of this mapping methodology can be found in King et al 2006.

Domestic fuel mapping in Northern Ireland
The new DTI gas consumption data and BRE fuel use data used in updating mapping approach in Great Britain are not available in Northern Ireland. As a result, and also taking into account availability of updates to the core datasets underlying existing approaches to domestic fuel mapping for Northern Ireland, it was decided to maintain this methodology and update the datasets used previously (Pye and Vincent, 2003).

The fuel use grids have been generated from a wide range of data sources including:

- Northern Ireland Housing Executive household data (supplied by the NIHE 2006 PRAWL property database)
- Gas household data (supplied by Phoenix Gas 2005)
- Belfast household data (from fuel use survey undertaken by Belfast City Council 2001)
- Northern Ireland Census output area households data (supplied by the 2001 Census)
- The Northern Ireland Interim House Condition Survey 2004.
- The Northern Ireland 2005 Home Energy Conservation Report
- Other household data not covered by the above (from number of sources, including Housing Condition Survey (HCS) data).
- Household fuel use survey data from 16 Northern Ireland Local Authorities collected under their obligations to Review and Assessment of air quality under the UK's Air Quality Strategy (AQS)

Using these data it was possible to update the bottom up approach developed by Pye and Vincent (2003). The fuels used by the Northern Ireland housing stock was characterised as follows:

1. Geographic household distribution. Derived from the 2001 Census at an output area level and scaled to 2004 using information from the 2004 HCS and 2005 HECA report for Northern Ireland.
2. Fuels used in the NIHE social housing stock. Derived from the NIHE's 2005 PRAWL database.
3. Fuels used in the private housing stock. Derived from the 2001 detailed HCS, scaled to 2004 using information from the 2004 HCS and 2005 HECA report for Northern Ireland.
4. Distribution of Households connected to gas. Derived from Phoenix Gas 2005.
5. Fuels used in in Belfast. Derived from 2001 Belfast City Council fuel use survey
6. Geographical distribution of Smoke Control Areas. Derived from GIS data provided by DoE Northern Ireland.

Using these data a detailed estimate of domestic fuel use across Northern Ireland was possible using datasets more appropriate to the timeframe covered by the 2005. Full details of the methodology that was followed for Northern Ireland are available in Pye and Vincent (2003).

Domestic House and Garden Machinery
The emissions in the NAEI source called Domestic house and garden machinery are distributed across the UK using the population density map derived from 2001 Census data. The most detailed geographic level of Census data for England, Wales Scotland and Northern Ireland were converted into a 1km resolution grid. In some rural areas where the census units were larger than 1km squares

populations were estimated for individual grid squares on the basis of equal area weighting, i.e. assuming an even distribution of population within each census area.

3.5 AGRICULTURE

Emissions of PM_{10} and $PM_{2.5}$ from agricultural livestock and poultry sources are distributed using agricultural census data. Very detailed farm level data was obtained from Defra to cover England (Defra 2002a) . This was used to generate 1km resolution datasets for different livestock types and for poultry. For Scotland, Wales and Northern Ireland Agricultural census data were only available for larger spatial units – Parishes in Scotland (Scottish Executive 2002), Districts in Northern Ireland (NISRA 2002) and Small Areas in Wales (Welsh Assembly 2002). Therefore land use data were used to generate a distribution of emissions within these spatial units. The distribution of grazing land was used to distribute cow and sheep numbers. All non-urban land was used to distribute pigs and poultry numbers. The resulting distributions for England, Scotland Wales and Northern Ireland were combined, weighted according to the relevant regional statistics on the number of livestock or poultry in these regions.

The distributions of ammonia, methane and N_2O emissions from agricultural sources have been mapped at a 5km resolution by the Centre for Ecology and Hydrology (CEH). This work is undertaken as a subcontract of the NAEI. Data from the Agricultural Census for England, Scotland, Wales and Northern Ireland were combined with emission factors for livestock and fertilizer use and CEH Land Cover Map 2000 data within the AENEID model to calculate emissions maps. Ammonia, methane and N_2O emissions from other non-industrial sectors have also been calculated by CEH as part of the same subcontract (Dragosits and Sutton 2005, Dragosits et al 2005). Updated methane and N_2O emissions maps from CEH were not available for the 2004 inventory therefore it has been assumed that the spatial patter of emissions for these sectors in the 2003 maps are applicable to 2004.

Emissions from agricultural off-road machinery and vehicle are distributed using a combination of arable, pasture and forestry land use data. Each of these land cover classes was weighted according to the off-road machinery activity on each land use. This used data on the number of hours of use of tractors and other machinery on these land use types, sourced by AEA Energy & Environment for improving the UK inventory in this sector.

Incineration of animal carcases are mapped partly as a point source but mainly across all UK arable land because the location of this source is very uncertain.

Land Cover Map 2000 data from the Centre for Ecology and Hydrology (CEH) is used to map a variety of other agricultural emissions. These are distributed evenly across the arable land cover map for the UK:

- Emissions of VOCs from agrochemical use;
- CO_2, emissions from agricultural soils;
- Dioxin and Benzo[a]pyrene emissions from agricultural waste burning.

Agricultural stationary combustion is mapped using IDBR employment data for the agricultural sector. Gas use is constrained to gas consumption zones as described in Section 3.2 and solid and liquid fuels are assumed to be used in other areas.

Possible future improvements:

- Increase in resolution of the CEH maps to 1km to integrate better with the NAEI maps.
- Update of livestock and poultry distributions used for particulate matter mapping.

3.6 RAIL

The UK total rail emissions are compiled using data for three journey types: freight, intercity and regional. Emissions are calculated based on fuel use reported in DUKES. Rail emissions from diesel locomotive are distributed across Great Britain using maps of rail links and details of the number of vehicle kilometres by the three journey types on each rail link (compiled for the NAEI by London

Research Centre). Emissions are distributed across the rail network by assigning an appropriate emission from each journey type to each rail link. The emissions along each rail link are assumed to be uniform along the length of the rail link, as no information on load variations is yet available.

Fuel consumption data for 2005 was provided from Translink and included weekly information for all the rail links of Northern Ireland. 2005 fuel use estimates have been distributed over a digital representation of the Northern Ireland rail network derived from Ordnance Survey Northern Ireland raster datasets to provide an accurate representation of the location of fuel used by rail transport in Northern Ireland

Possible future improvements:

- Updated GB train movements and the inclusion of fuel consumption estimates would also improve this distribution.

3.7 SHIPPING

UK shipping totals are calculated at a national level. These estimates include:

- Coastal shipping (fuel sales for ships confined to UK waters);
- Other UK shipping (UK bunker fuel sales corrected for estimation of emissions in port and cruise in UK waters only);

The shipping emissions are distributed over the UK as follows. Emissions are assigned to port areas and coastal zones according to ship arrival data provided by DfT (2004). The port area emissions are mapped on the approximate port locations. The cruise emissions are assigned to the area of the coastline nearest to the relevant port and within 12km of the shore, based on an inverse distance weighting. This gives a rough approximation of where shipping is likely to be.

Possible future improvements:

- Data on fuel consumption factors by vessel type could be combined with the ship movements data to improve the distribution of emissions between ports.
- Further modelling of 'sphere of influence' of each port along the coast would better distribute emissions from the significant ports. At present these emissions are often too concentrated around the ports because of assumptions about allocating parts of the coastal zone based on proximity to the nearest port.
- Estimation of fishing fuel use as a subset of total shipping fuel use so that the fishing emissions can be mapped separately.

3.8 AIRCRAFT

The NAEI includes national total aircraft emissions occurring below 1000m from the ground during take off and landing. These are calculated from the number of aircraft movements at UK airports on an individual airport basis according to the mix of aircraft types at each airport. Aircraft cruising emissions are also included in the NAEI but not in the maps because these cannot be assigned to grid squares on the ground.

Take off and landing emissions are allocated to the individual airports on the basis of the modelled emissions at each airport. At each airport the emissions are then distributed either across a pattern of take off and landing emissions routes which vary by pollutant (these patterns were modelled for the larger airports by London Research Centre for the NAEI), or for the smaller airports simply across the land area covered by the airport.

UK total emission estimates from airport support vehicles are distributed over the physical airport area based on aircraft arrival statistics for each airport.

Possible future improvements:

- Update of the take off and landing patterns for the large airports and the addition similar patterns for other airports.

3.9 ACCIDENTAL FIRES AND SMALL SCALE WASTE BURNING

The distribution of accidental fires across the UK is uncertain. Distribution maps have been made using the CEH Land Cover Map 2000. The land cover type has been matched to the type of accidental fire as shown in **Table 3.5**. Classes were added together on an equal basis to make aggregated land cover maps for each NAEI sector.

The 'Accidental fires – dwellings' and 'Accidental fires - other buildings ' sectors have been mapped using the Census 2001 population distribution described in section 3.4 above.

Table 3.5 Land cover data used to distribute emissions from fires

NAEI Source sector	Land Cover classes
Accidental fires - forests	Broad leaved/mixed woodland
	Coniferous woodland
Accidental fires - straw	Arable cereals
	Arable horticulture
	Arable non-rotational
Accidental fires - vegetation	Setaside grass
	Natural grass
	Calcareous grass
	Acid grass
	Bracken
	Bogs (deep peat)
	Dense dwarf shrub heath
	Open dwarf shrub heath
Accidental fires - vehicles	Suburban
Small scale waste burning	Suburban
Bonfires	Suburban

Possible future improvement:

- The land cover data could be augmented using regional fire statistics to improve the distribution of emissions.

3.10 LANDFILL SITES

Emissions from landfill sites feature in the NAEI in two different source sectors. The first is landfill gas combustion which is used for electricity generation and/or heating. These emissions are mapped as point sources. The second sector comprises emissions from the landfill sites themselves. Emissions are estimated for 1,3-butadiene, benzene, dioxins, ammonia and VOC. This sector is mapped as an area source.

Locations of landfill sites were obtained from the Environment Agency for England and Wales, from SEPA for Scotland and from DOENI for Northern Ireland. Very little quantitative information on the sizes of the sites were available and no information was available about closed sites. Therefore a simple map of landfill locations is used to distribute national total emissions from landfills.

Ammonia emissions from landfills have been mapped at 5km resolution by CEH as part of a subcontract to the NAEI to map all non industrial ammonia emissions (Dragosits and Sutton 2007). This uses a combination of landfill site locations where available and population distributions to fill gaps where the landfill site locations are not available.

Possible future improvement:

- Better data on the locations and sizes of landfill sites, both active and closed.

3.11 OFFSHORE

Emissions from offshore installations are provided by UKOOA. These include:

- Offshore flaring,
- Offshore loading,
- Offshore own gas use,
- Offshore oil and gas operations.

These estimates are aggregated for the UK totals. For the UK emission maps, the installation reported emissions are assigned to locations provided by the UK Hydrographic Office based on the Company Name and field location.

Diesel and Gas Oil fuel use at offshore facilities is incorporated in the NAEI coastal shipping sector as the majority of fuel burned by offshore operations is for shipping.

3.12 OTHER SECTORS

Natural emissions are distributed using 1km resolution land cover maps derived from the Land Cover Map 2000 data from the Centre for Ecology and Hydrology (CEH). For example emissions from forests comprise NMVOC emissions from natural processes. These are mapped using the CEH woodlands land cover types (broad leaved/mixed woodland and Coniferous woodland classes). The NAEI also includes emissions from land use change resulting from deforestation resulting in emissions of NO_x and CO_2. These emissions are mapped using the same woodlands map as above.

Emissions of PM_{10} from mines and quarries are distributed using data from the British Geological Survey on the locations of mines and quarries in the UK. This data set includes the location of the site and a brief description of products and commodities. There is no data on actual production amounts for each mine or quarry. Regional production statistics for the various commodities are therefore distributed across the sites in each region on an equal weight basis. Only open cast mining and quarrying activities are included. The production statistics are aggregated to 1km grid squares and PM_{10} emissions distributed on this basis.

4. Emission maps and data products

4.1 COMPILATION OF MAPS

The 1km resolution maps are compiled using a bespoke GIS tool. The maps for each sector are generated summing distributed proportions of the NAEI national total. Area source emissions are aggregated to the 11 UNECE source sectors. Emissions at point sources are then added to make a UK total emission map such as that shown in **Figure 4.1** below. **Figure 4.2** shows the locations of the point sources.

Figure 4.1 UK Total NO_x emissions for 2005 in tonnes per $1km^2$

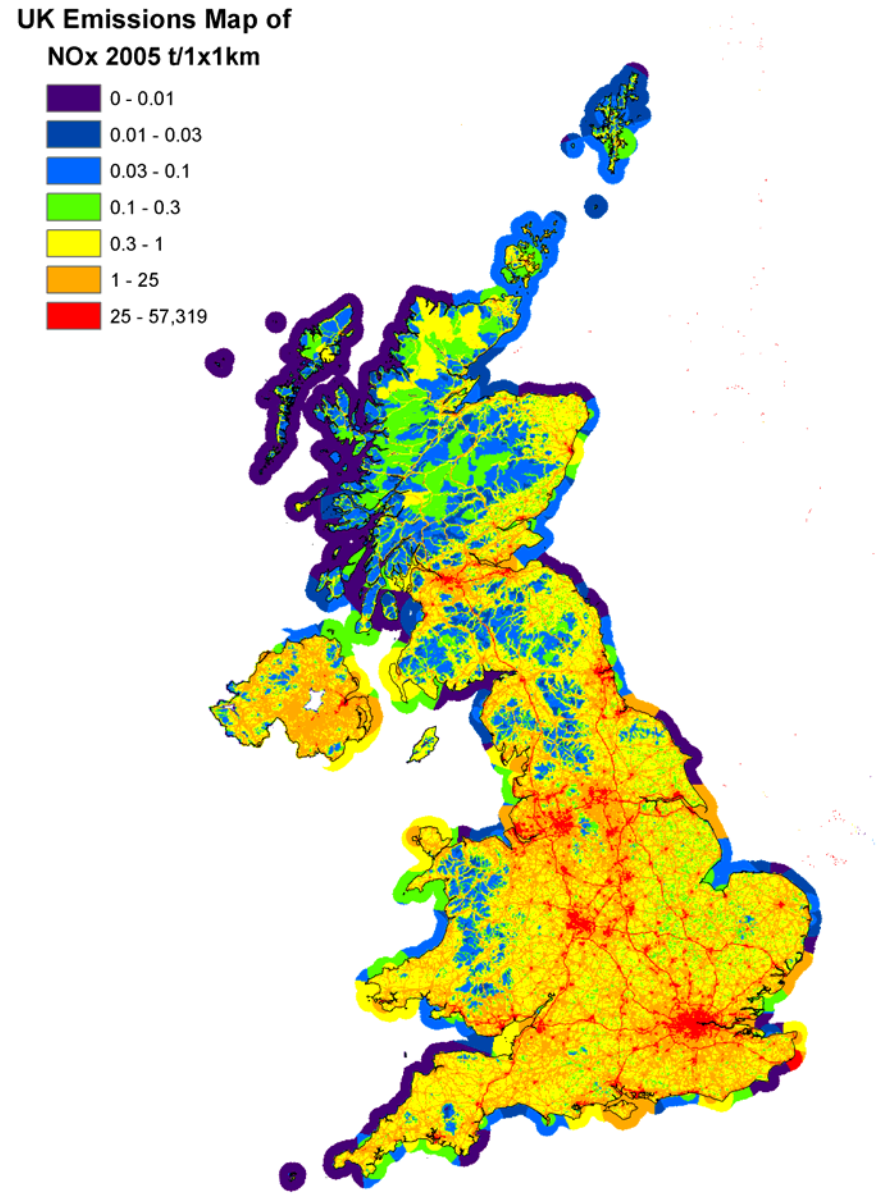
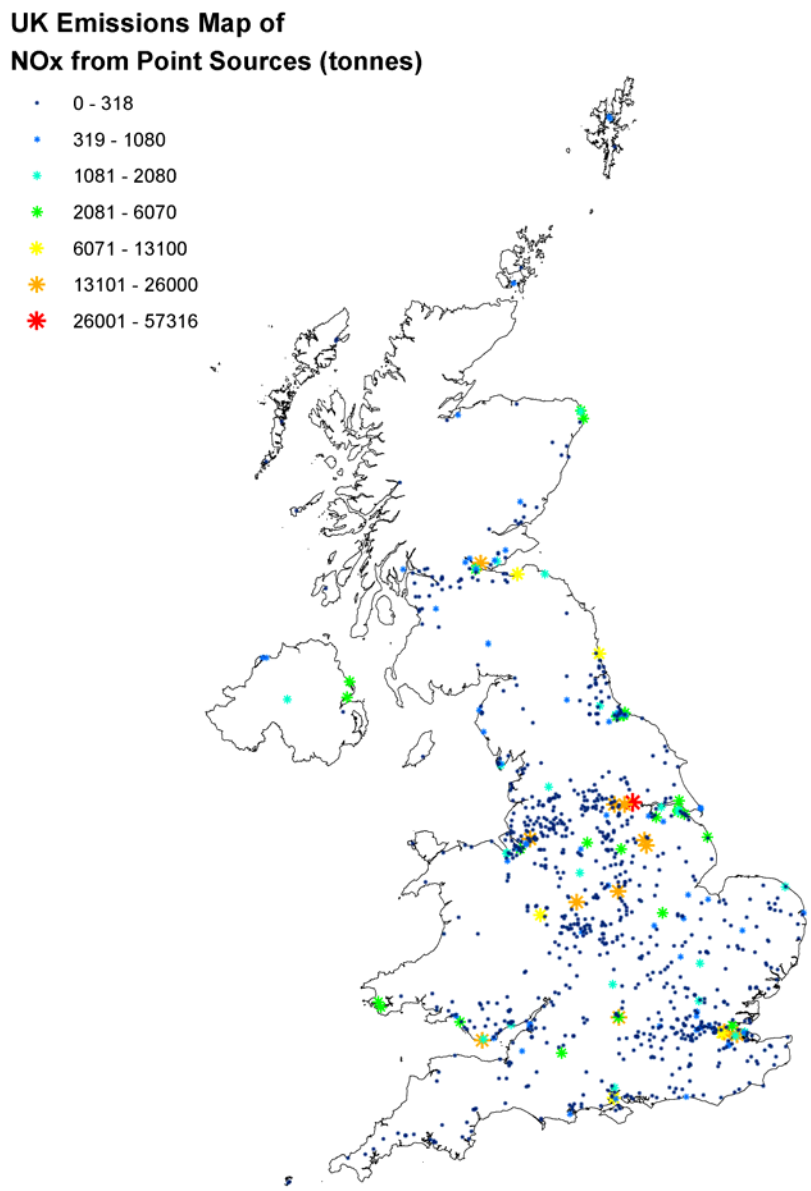


Figure 4.2 NO_x emissions at point sources in 2005 in tonnes



Further examples of the maps are shown in **Annex 1**.

4.2 DATA PRODUCTS

Local authority data:

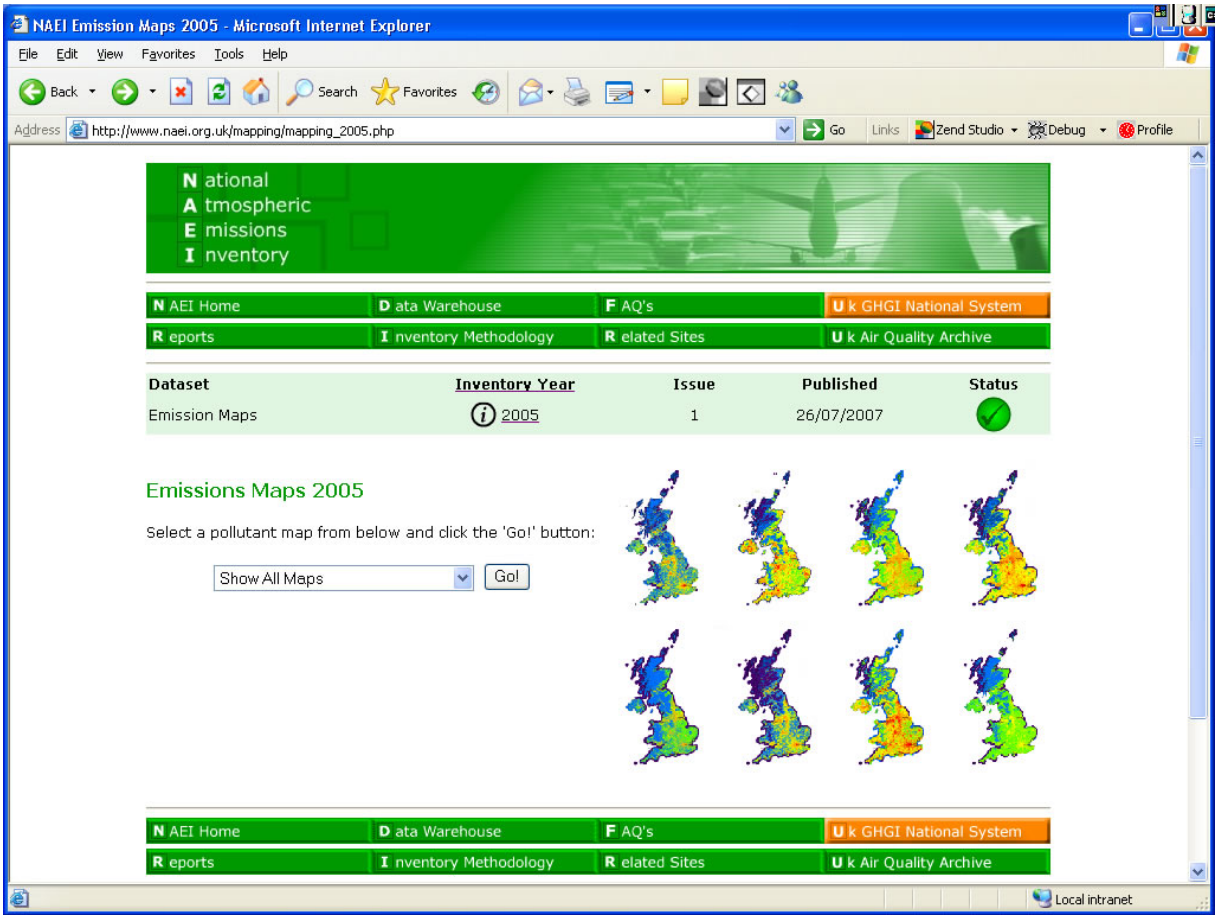
- The full spatial inventory is available on the NAEI website at http://www.naei.org.uk/datawarehouse
  The 1km resolution inventory is divided into separate files for each pollutant for each local authority. It is intended that these files are used to aid local authorities in developing their own emission inventories.

Public access to the mapped emissions:

- Website users can also find emissions data for individual postcode locations. This is available at http://www.naei.org.uk/mapping/mapping_2005.php.

Full UK maps:

- The full UK area emissions maps are also available individually by pollutant at http://www.naei.org.uk/mapping/mapping_2005.php (in Arc Interchange (.e00) format). Point source data is available in Excel files.
- The full mapped inventory for all pollutants is also available on CD (email air.emissions@aeat.co.uk)



5. Quality of Mapping and Verification

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Mapping of pollutant emissions has been divided into point and area source mapping. In general, mapping using point source data might be expected to give the most accurate results since it relies on a large quantity of generally reliable data. Area source emissions are mapped using a variety of types of data depending on the emission sector. Sometimes good quality relevant data are available and in other cases 'surrogate statistics' are used to distribute the national emissions. In some cases the surrogate statistics may be poorly suited to this task. One simple way of assessing the quality of mapping might therefore be to compare the proportion of the national emission of each pollutant which is mapped as point or area sources. **Table 5.1** shows these proportions for selected pollutants.

Table 5.1 Contribution of point sources to mapped emission totals (2005)

Pollutant	Points sources (%)	Area sources (%)
1,3 - butadiene	11%	89%
Benzene	12%	88%
Benzo[a]pyrene	5%	95%
CO	21%	79%
CO_2	47%	53%
Dioxins	27%	73%
HCl	33%	0%
Lead	74%	26%
Mercury	70%	30%
NH_3	2%	98%
NMVOC	22%	78%
NO_x	31%	69%
PM10	19%	81%
SO_2	78%	22%

Taking the proportion of point sources as a measure of quality, **Table 5.1** suggests that maps for SO_2, HCl, mercury, hydrogen chloride and lead are likely to be of higher quality than those for PM_{10} and VOC, for example. However, this assessment does not differentiate between point source data which are derived from good site-specific emissions data and that which is based on simple modelling, nor does it differentiate between area sources which are mapped using good appropriate statistics and those which use less appropriate surrogate ones.

A slightly more sophisticated approach therefore is to use 'data quality ratings' of between 1 (highest quality) to 5 (lowest quality) for the mapping of emissions of each pollutant and source. An overall 'confidence rating' can then be calculated for each pollutant map thus:

$$Emission_A \times Rating_A + Emission_B \times Rating_B \text{ etc.} / Emission_{Total}$$

Where:

$Emission_A$, $Emission_B$ etc. are the emissions of the pollutants from each of the sources in the inventory

$Rating_A$, $Rating_B$ are the data quality ratings applied to the mapping of emissions from each of the sources in the inventory

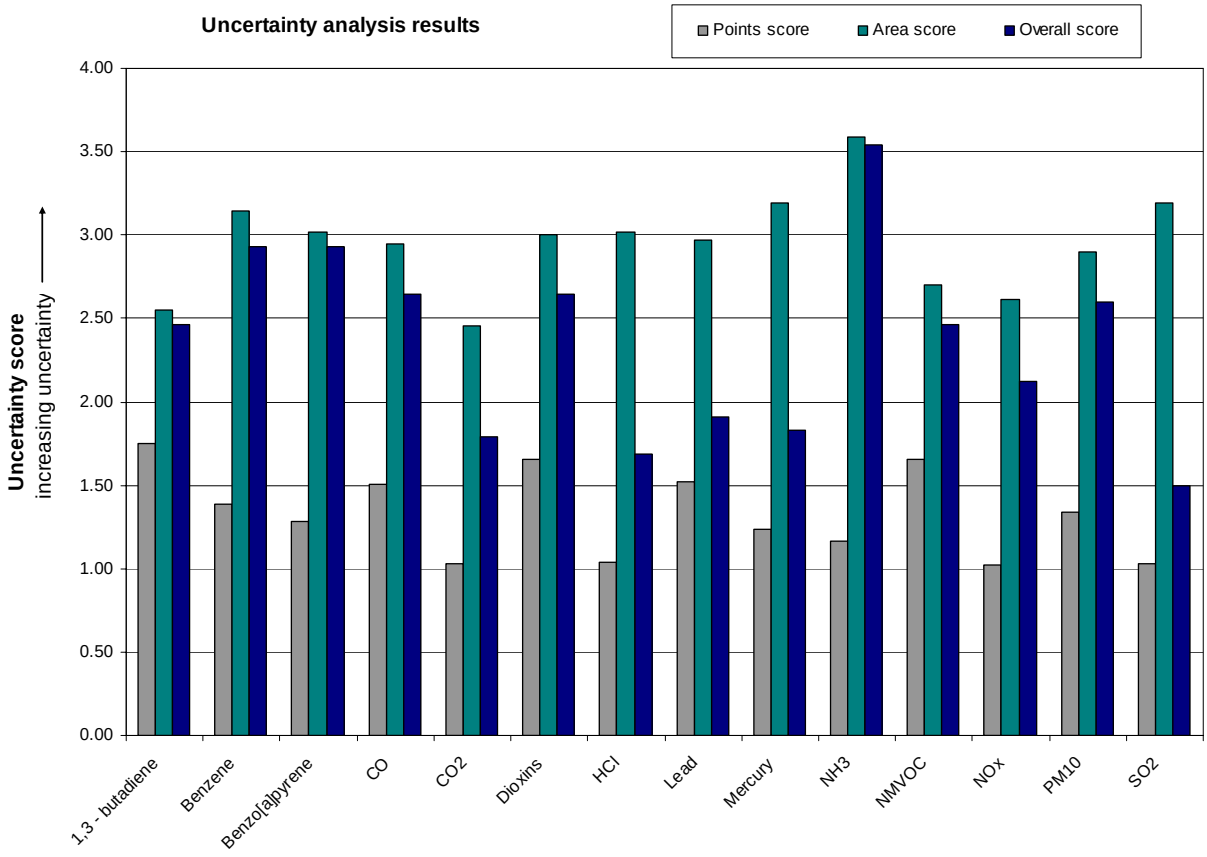
Some general rules of thumb have been followed when choosing data quality ratings for mapping procedures. Point source data from the PI, industry or regulators are given a rating of 1 because the locations of emissions are 'known' precisely. Modelled point source data are given a quality rating of 2

to reflect the fact that, although all point sources are known, there is uncertainty regarding the distribution of emissions over these sources. Mapping of area sources is by use of various 'grids' which are spatially resolved data such as traffic flows, population or employee numbers. Quality ratings for each set of area/line sources are allocated following assessment of:

- The quality of the spatially resolved data used to make the grid;
- The reliability of the grid as a measure of emissions from a source.

A rating is applied to each of the above and the mean is used as the data quality rating for that set of area source data. For example, a grid based on 2001 population has been allocated a rating of 2 since it is based on very accurate census data which is generalised across the 1km grid resolution. The use of such a grid to map emissions from decorative paint use is considered appropriate and has been assigned a rating of 1. The area source data for decorative paints therefore has an overall quality rating of 1.5. On the other hand, while a grid based on suburban land cover is also good quality and assigned a rating of 2, its use to map emissions from small scale waste burning (bonfires) is considered much less reliable and is given a rating of 4. Area source data for these emissions has an overall quality rating of 3. **Figure 5.1** shows the resulting confidence ratings for the NAEI pollutant maps.

Figure 5.1 Confidence ratings for mapping elements of the 2005 NAEI



These data quality ratings show a broadly similar pattern to the assessment of the proportions of point and area source data in **Table 5.1**, although there are some differences, for example the map for dioxins is considered of lower quality using the detailed assessment because although nearly a third of emissions are from point sources, many of the area source emissions are from sectors that are difficult to map accurately such as small scale waste burning. The map for 1,3-butadiene is found to be more satisfactory using this method because a large proportion of the emissions are from the road transport sector which has good quality spatial distributions.

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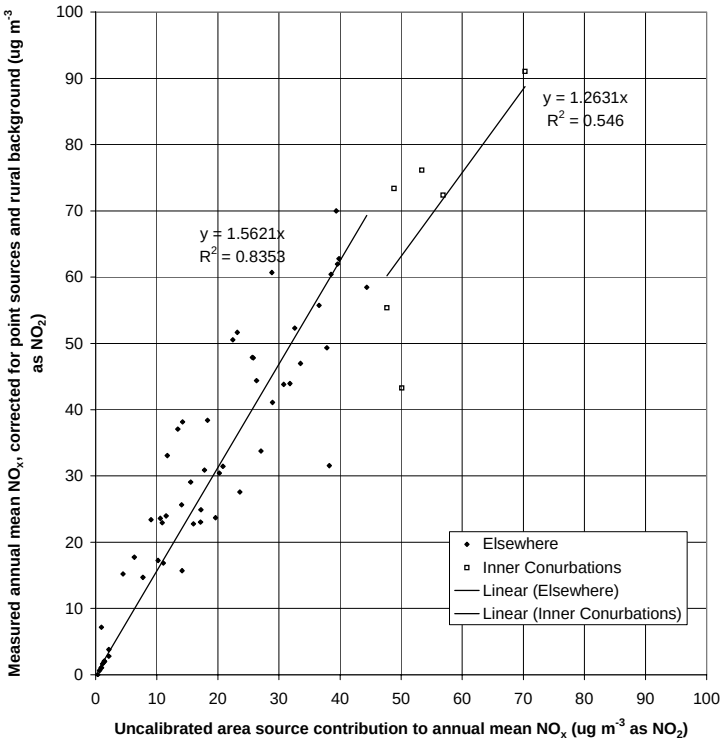
Maps of the spatial distribution of atmospheric emissions are a key input to any air quality assessment. The reliability of emissions maps should be verified if they are to be used to model potential exceedances of air quality objectives. It is helpful to draw a distinction between emission inventory validation and verification. Validation is the process of checking that emissions have been estimated using the appropriate protocols, while verification involves comparison with independently derived data such as ambient monitoring results.

Measured annual mean background concentrations can be considered to be made up of three parts:

- A rural contribution: from relatively distant major point and area sources such as power stations or large conurbations. Measurements from monitoring sites well away from local sources, from rural sites within the UK Acid Deposition Secondary Network, for example, provide good indications of the spatial variation of concentrations due to distant sources.
- A point source concentration: modelled using dispersion models based on data from individual industrial sites
- A contribution from more local emissions: emissions in the surrounding 25 km^2 area

The NAEI area source maps are used to model the local contribution using an empirical relationship to convert local emissions to concentrations. The strength of this relationship provides an indication of the quality of the emission distribution as it compares actual concentrations measured with the emissions mapped. **Figure 5.2** shows the result of the calibration of the area source NO_x model to find the empirical relationship between are source emissions and measured annual average air concentrations at urban automatic monitoring sites. The modelled local emission contribution to overall annual mean NOx concentration (on the X axis) is compared with the measured NO_x after removing the rural and point source contributions at each site (Y axis) (Stedman et al (2006)). The sites form two distinct clusters indicating a different relationship in inner conurbations and elsewhere but with strong relationships for each. 'Inner conurbations' includes Inner and Central London and central Birmingham and Manchester.

Figure 5.2. Calibration of area source NO_x model (μg m^{-3}, as NO_2)



The verification of the spatial distribution of other pollutants can also be carried out using similar methods to those described above. Inventory verification for pollutants such as PM_{10} is, however, more problematic due to the diverse nature of PM_{10} and the range of sources of primary combustion, secondary and mechanically generated coarse particles.

6. Summary of recommendations for improvements

This report has described the methods used to produce the NAEI emission maps for 2005. A number of recommendations have been made for improvements to the quality of the maps. These are listed below in order of priority.

Industrial and commercial area sources:

- Better spatially resolved data on gas use from BERR will be used for this sector to improve the distribution of the different fuel types.
- Better data on fuel specific fuel consumption in the commercial and public services sectors will improve fuel intensity calculations for these sectors.

Road transport:

- Additional traffic census data at new locations for Northern Ireland would significantly improve the emissions distribution for Northern Ireland.
- Updates of the distributions of cold start emissions using 2001 Census data and 2005 employment distributions.
- Additional vehicle fleet, speed and vehicle kilomerters and fuel consumption information from regional inventories

Shipping:

- Data on fuel consumption factors by vessel type could be combined with the ship movements data to improve the distribution of emissions between ports.
- Further modelling of 'sphere of influence' of each port along the coast would better distribute emissions from the significant ports. This could include locations of shipping lanes or fishing zones where appropriate.
- Estimation of fishing fuel use as a subset of total shipping fuel use so that the fishing emissions can be mapped separately.

Point sources:

- Full use will be made of the EU-ETS data for 2006.
- Reporting of fuel use by fuel type by installation in the Environment Agencies Pollution Inventory
- Consolidate emissions data for Local Authority regulated processes (Part B/A2s). This would also assist the national air pollution modelling, the EPER reporting and preparations for PRTR.

Railways:

- Updated GB train movements and the inclusion of fuel consumption estimates.

Agriculture:

- Increase in resolution of the CEH maps to 1km to integrate better with the NAEI maps.
- Update of livestock and poultry distributions used for particulate matter mapping, possibly using data from CEH or sourcing it direct from up to date agricultural census data.

Airports:

- Update of the take off and landing patterns for the large airports and the addition similar patterns for other airports.

Landfills:

- Better data on the locations and sizes of landfill sites, both active and closed.

Accidental fires:

- The land cover data could be augmented using regional fire statistics to improve the distribution of emissions.

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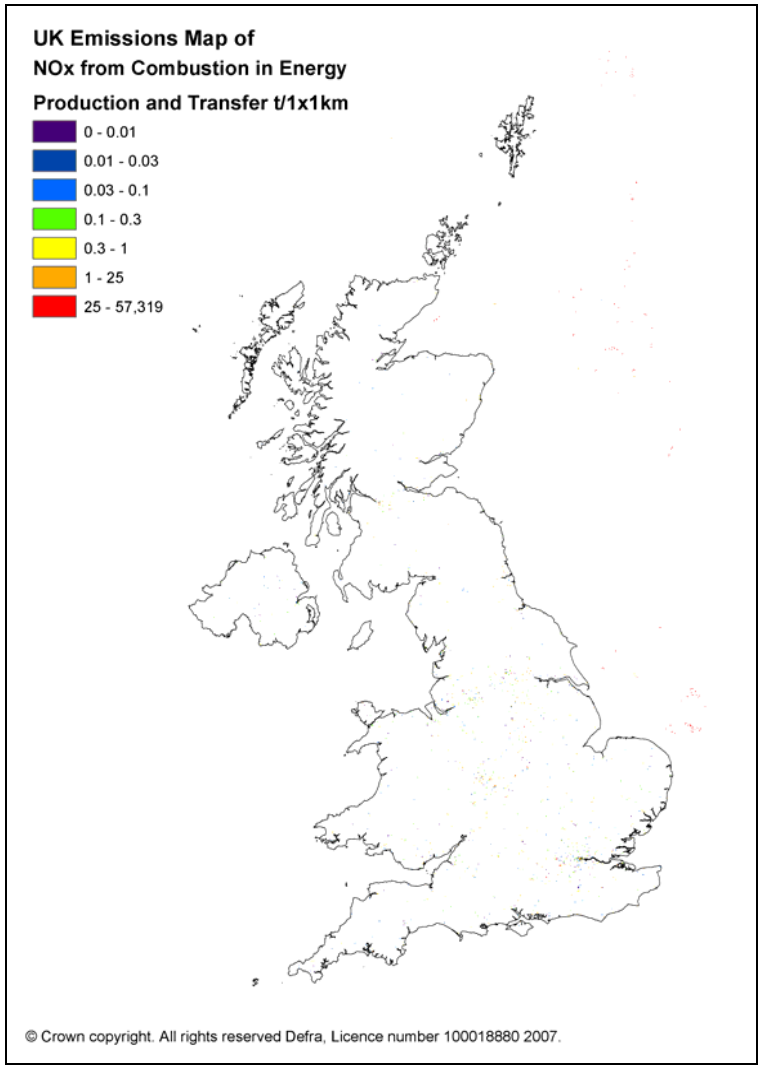

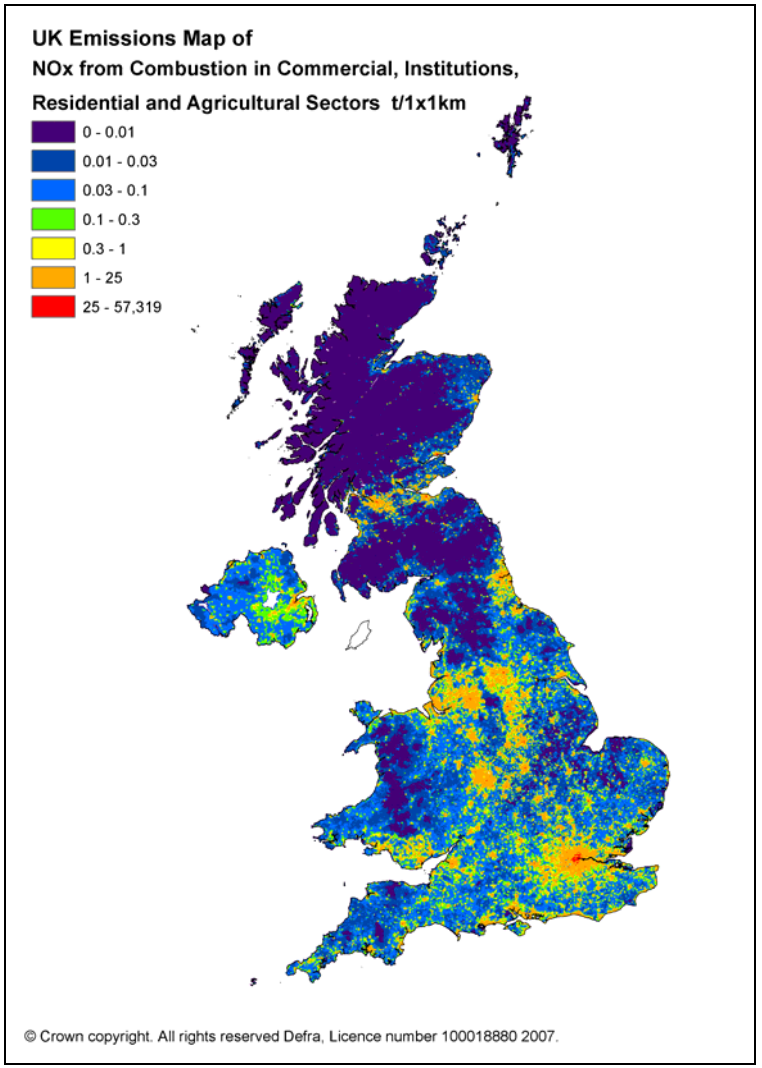

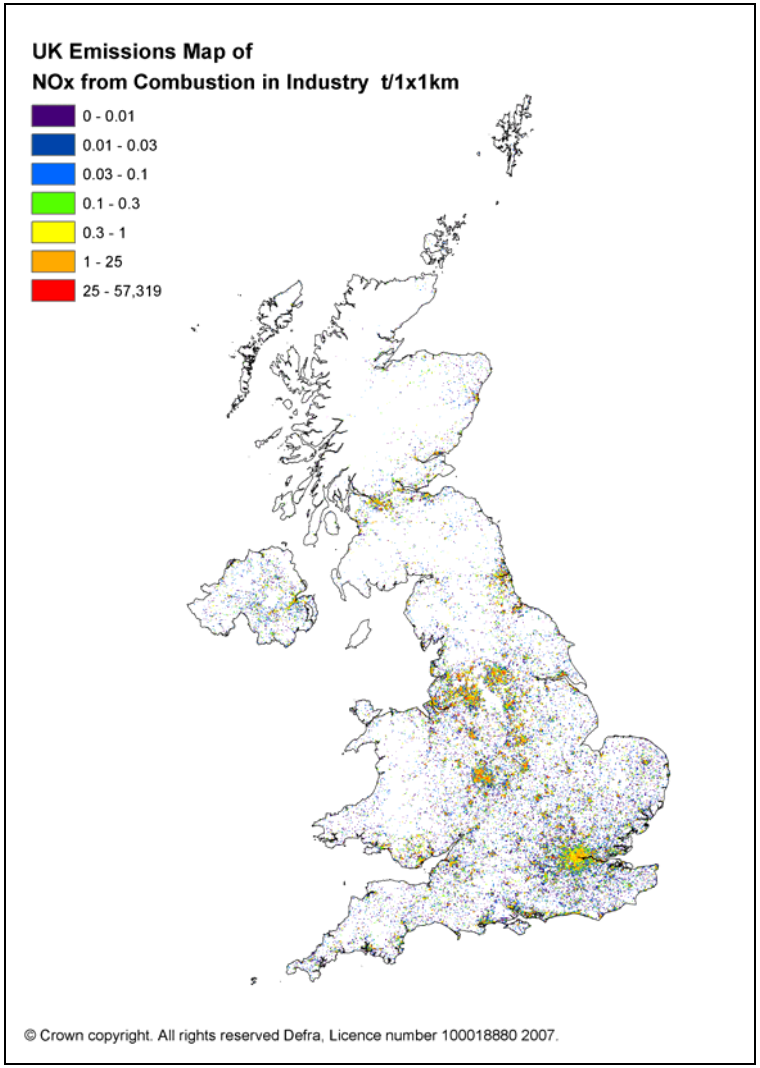
UK Emissions Map of
NOx from Combustion in Industry t/1x1km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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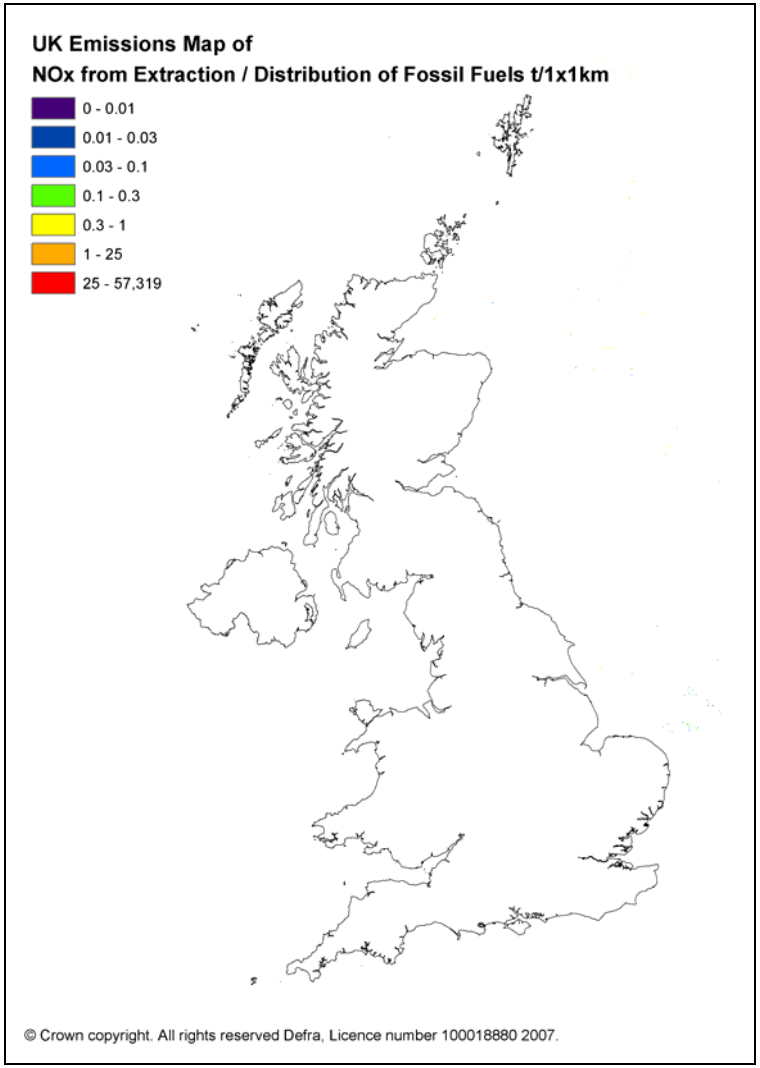
UK Emissions Map of
NOx from Extraction / Distribution of Fossil Fuels t/1x1km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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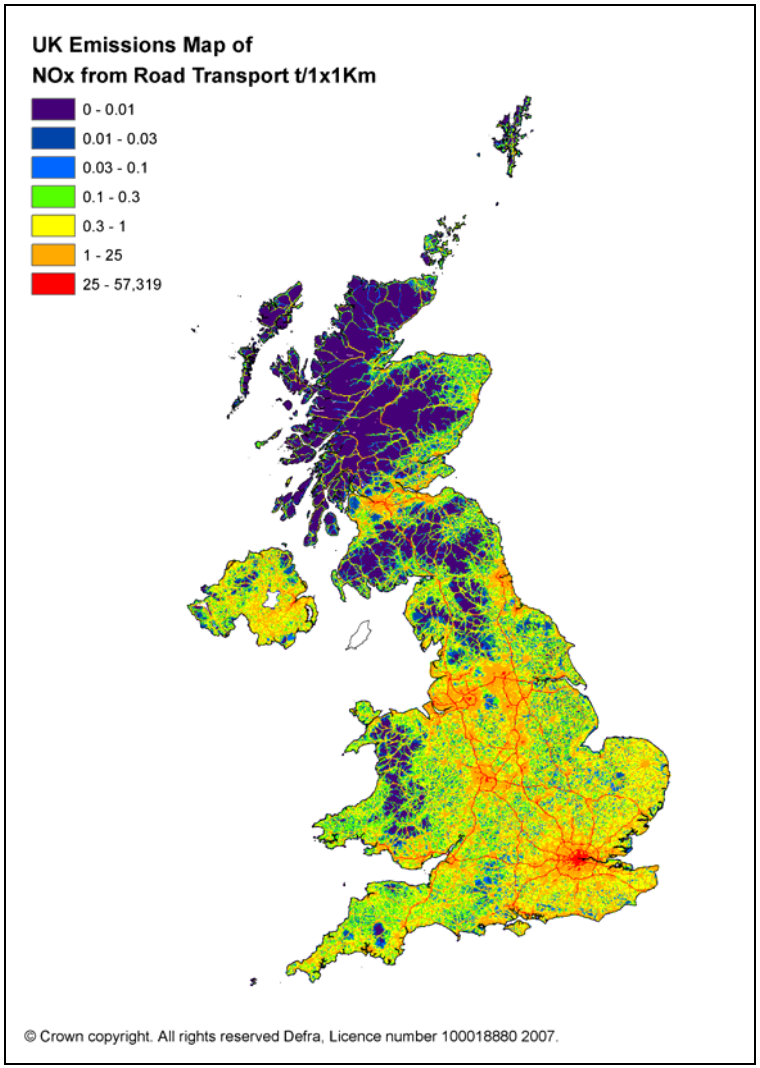
UK Emissions Map of
NOx from Road Transport t/1x1Km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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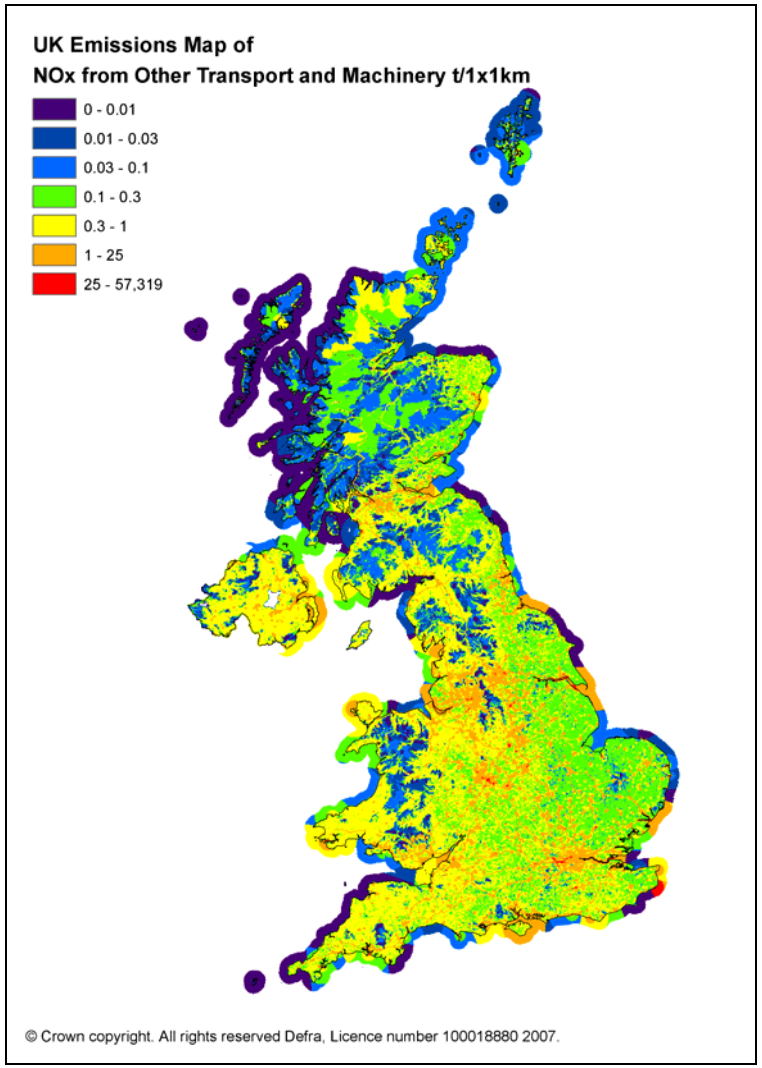
UK Emissions Map of
NOx from Other Transport and Machinery t/1x1km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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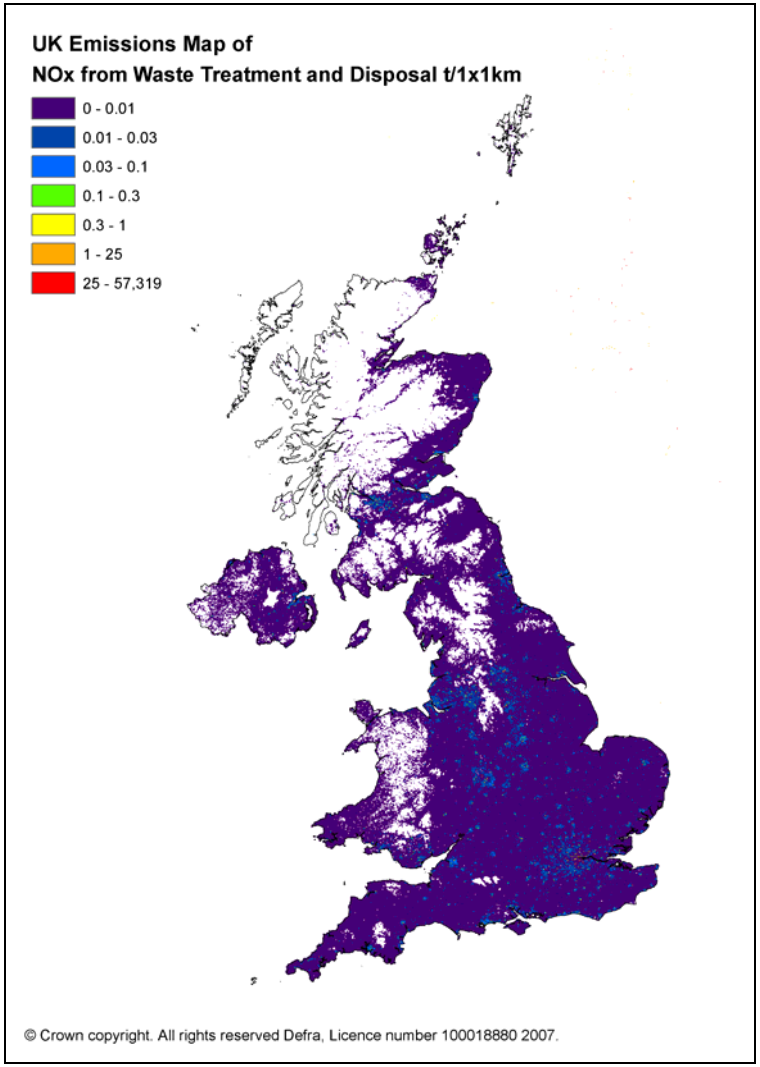
UK Emissions Map of
NOx from Waste Treatment and Disposal t/1x1km
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0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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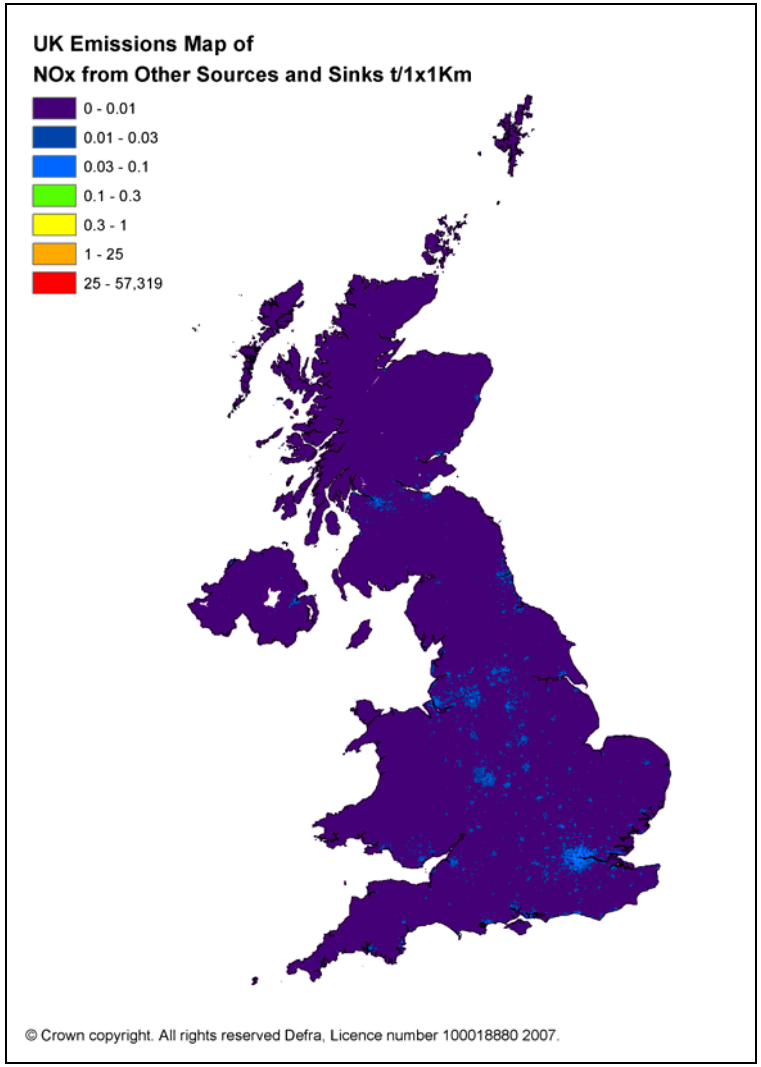
UK Emissions Map of
NOx from Other Sources and Sinks t/1x1Km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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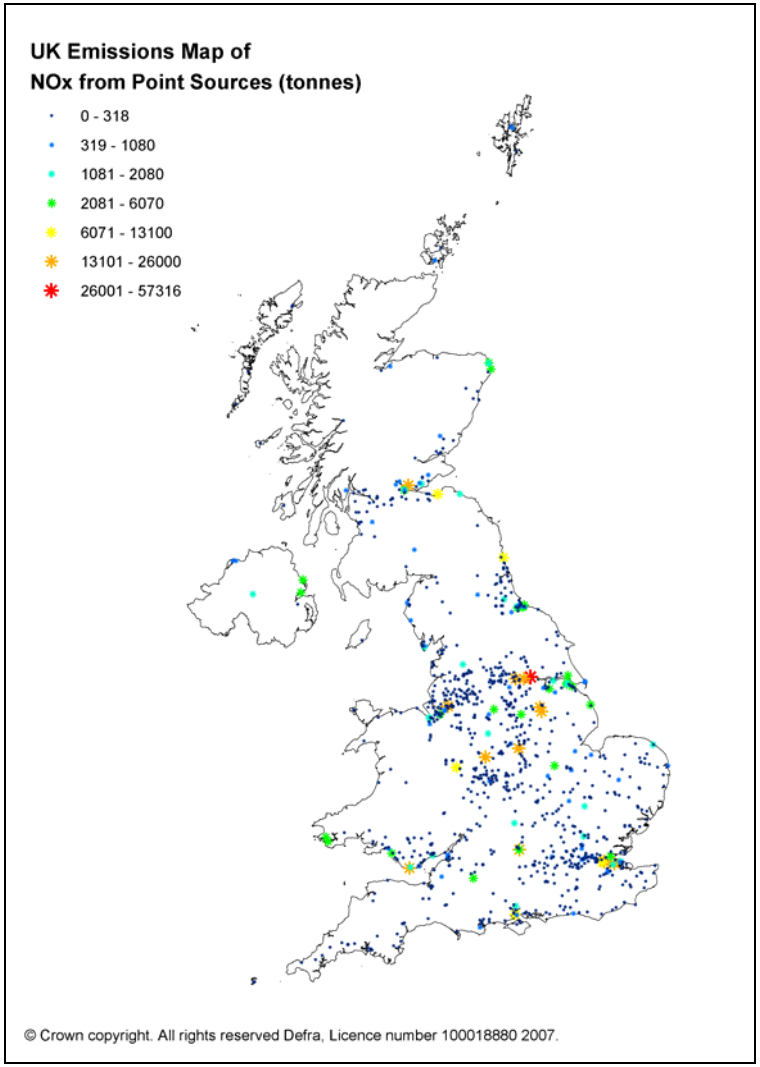
UK Emissions Map of
NOx from Point Sources (tonnes)
0 - 318
319 - 1080
1081 - 2080
2081 - 6070
6071 - 13100
13101 - 26000
26001 - 57316
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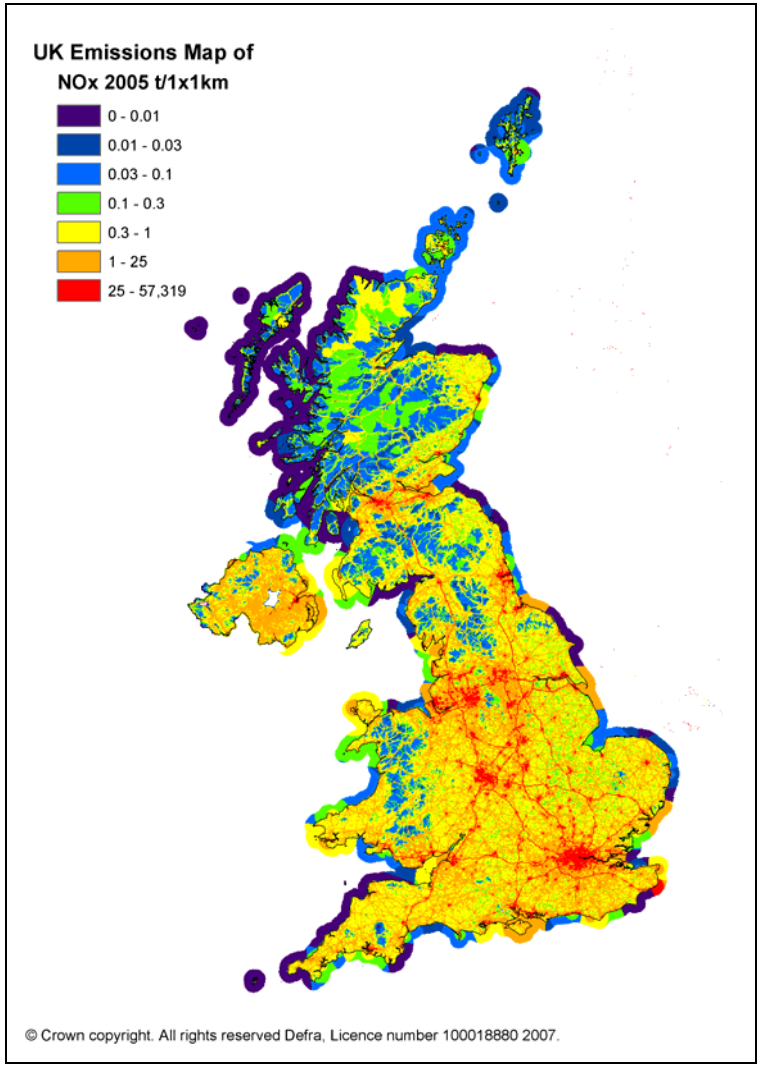
UK Emissions Map of
NOx 2005 t/1x1km
0 - 0.01
0.01 - 0.03
0.03 - 0.1
0.1 - 0.3
0.3 - 1
1 - 25
25 - 57,319
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