Appendix 1E: Air Quality

A1e.1 Introduction

Whilst air quality is not monitored routinely at offshore sites, estimated emissions are reported though the DECC EEMS process which provide some indication of inputs of air pollutants, and regular air quality monitoring is carried out by local authorities in coastal areas adjacent to each Regional Sea. The air quality of all local authority areas is generally within national standards set by the UK government's air quality strategy (DEFRA 2007), though several Air Quality Management Areas (AQMAs) have been declared to deal with problem areas. Industrialisation of the coast and inshore area adjacent to certain parts of the central North Sea has led to increased levels of pollutants in these areas which decrease further offshore, though oil and gas platforms provide numerous point sources of atmospheric pollution.

Generally, emissions from all pollutants have decreased since the earliest year the data is available from (1970, 1980, 1990 and 2000, depending on pollutant) partly as a result of policies put in place to control certain emissions and a decline in the use of solid and liquid fuels in the domestic and power generation sectors (NAEI website).

A1e.2 UK context

The most recent Air Quality Strategy for England, Scotland, Wales and Northern Ireland of 2007 set national air quality standards with the objective of protecting human health. In the longer term, these standards along with other strategies connected with climate change could significantly improve air quality and achieve reductions in carbon dioxide (CO_2) by 2050 (DEFRA 2007). Many of the standards set in the strategy are derived from EU obligations for the reduction or non-exceedance of a particular pollutant[1]. The pollutant concentration levels have their origin in the 1996 Air Quality Framework Directive (1996/62/EC) and subsequent 'daughter' directives. The most recent version of this directive, the 2008 ambient air quality directive (2008/50/EC) set legally binding limits for concentrations in outdoor air of major air pollutants that impact public health, including sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and oxides of nitrogen (NO_X), particulate matter (e.g. PM_{10}), lead, benzene and carbon monoxide (CO).

The 2008 directive replaced nearly all the previous EU air quality legislation and was transposed into law in England through the *Air Quality Standards Regulations 2010*, which also incorporated the 4th air quality daughter directive (2004/107/EC) that set targets for levels in outdoor air of certain toxic heavy metals and polycyclic aromatic hydrocarbons (PAHs). Equivalent regulations exist in Scotland, Wales and Northern Ireland.

The UK has statutory monitoring networks in place to meet the requirements of the EU Directives, with air quality modelling used to supplement monitored data. The UK is divided into 43 zones for air quality assessment – 28 agglomeration zones (large urban areas) and 15 non-agglomeration zones. The most recent compliance report (Bush *et al.* 2014) indicated that for 2013:

[1] See http://uk-air.defra.gov.uk/assets/documents/National_air_quality_objectives.pdf

- The UK met the EU limit values for SO_2.

- The UK met the limit value for hourly mean NO_2 in all but one zone. Twelve zones were compliant with the limit value for annual mean NO_2 (or the limit value plus margin of tolerance where a time extension was in place). Of these 12 compliant zones, five were within the limit value, and a further seven were covered by a time extension and were within the limit value plus the applicable margin of tolerance. The remaining 31 zones exceeded the limit value (or limit value plus margin of tolerance where applicable).

- After subtraction of the contribution from natural sources all zones met the limit value for daily mean concentration of PM_{10} particulate matter. All zones met the limit value for annual mean concentration of PM_{10} particulate matter.

- All zones and agglomerations were compliant with the limit values for CO, benzene and lead.

- All zones and agglomerations met the target values for arsenic and cadmium. Two zones exceeded the target value for nickel which was attributed to industrial sources.

- Six zones exceeded the target value for benzo[a]pyrene, attributed to emissions from industrial and domestic solid fuel sources.

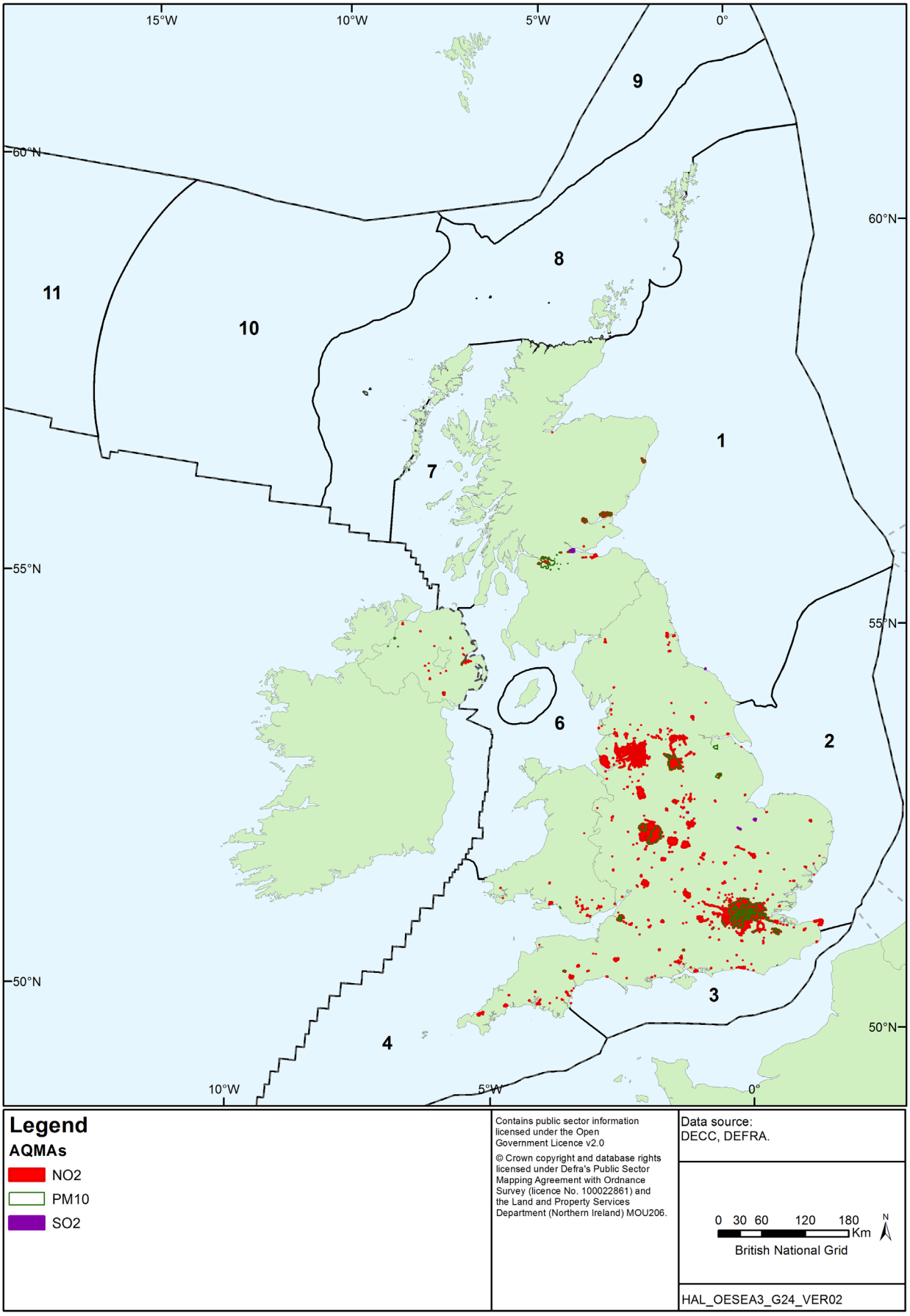
Part 4 of the *Environment Act 1995* requires local authorities to review and assess the air quality in their areas and its probable future trajectory. Since 1997 each local authority in the UK has been assessing their air quality and making projections on how it might change in years to come, with the aim of meeting the national air quality objectives by the relevant deadlines. An Air Quality Management Area (AQMA) must be declared where the local authority finds that it is unlikely to meet the objective of reducing pollution by the specified amount, and in accordance with the Air Quality Directive, a Local Air Quality Action Plan must be used to coordinate and improve air quality. There are a number of AQMAs in the UK for NO_2, SO_2 and PM_{10} and these are indicated in Figure A1e.1. Most AQMAs in the UK are in urban areas and result from traffic emissions of NO_2 or PM_{10}. Transport is the main source in 97% of the AQMAs declared for NO_2 (see also Section A1e.6); this is predominantly road transport but may include some other types, e.g. trains or shipping. A further 2% result from transport mixed with either domestic or industrial sources, and only 1% result from non-traffic sources (Bush *et al*. 2014). Section A1e.6 further describes environmental issues associated with exceedances of air quality limit values.

A1e.3 Atmospheric emissions of pollutants

A1e.3.1 Gaseous and particulate matter emissions

The National Atmospheric Emissions Inventory (NAEI) contains a database listing the emissions of a range of pollutants across the UK. Emission inventories are estimates of the amount and type of pollutants that are emitted to the air each year from all sources (e.g. industrial point sources, shipping, rail, road traffic). The details of a number of pollutants are described below and their emissions are graphically represented in Figures A1e.2-9.

Figure A1e.1: AQMAs in the UK



A1e.3.1.1 Offshore emissions

In the offshore area, Oil and Gas UK provide NAEI with data relating to offshore flaring, gas use and other operations (see Figures A1e.2-9). Offshore oil and gas installation emissions are also reported annually to OSPAR. The latest OSPAR report for 2012 emissions indicates: UKCS SO_2 emissions increased about 33% (to 2,561 tonnes) between 2011 and 2012; emissions of CO_2 decreased by approximately 7% (to *ca*. 13.1 million tonnes) and emissions of NO_X were more or less stable (*ca*. 47,000 tonnes, OSPAR 2014a). SO_2 emissions vary greatly year on year, as they are largely dependent on consumption of diesel for power generation which is determined by periods of shut down and as fields deplete there is a greater reliance on diesel to replace fuel gas. The increase in diesel consumption from this aspect of operations is likely to have been partially compensated for by an increasing usage of low sulphur diesels (OSPAR 2014b). CO_2 accounts for the greatest proportion of emissions to air from offshore installations with around 29 million tonnes emitted in the OSPAR area in 2012. Emissions of CO_2, nitrogen oxides (NO_X) and methane have been relatively stable or decreased slightly since 2003, while SO_2 emissions have been more variable. Emissions of non-methane volatile organic compounds (NMVOC) have decreased significantly largely as a result of measures taken by operators to reduce fugitive emissions and the use of vapour recovery systems at off-loading facilities (OSPAR 2010).

Emissions from shipping, due to the combustion of marine fuels with high sulphur content, contribute significantly to air pollution in the form of sulphur dioxide and particulate matter. The *Merchant Shipping (Prevention of Air Pollution from Ships) and Motor Fuel (Composition and Content) (Amendment) Regulations 2014* which came into force in December 2014, partly implements EU Directive 2012/33/EU on the sulphur content of marine fuel. The Regulations include limits to the sulphur content of fuel oil used or intended to be used in sulphur oxide emission control areas (defined by Annex VI of the MARPOL Convention and including the North Sea and English Channel), to not more than 0.1% by mass from January 2015.

Entec (2010) developed an atmospheric emissions inventory from ship movements within UK waters based on year 2007 ship movements. The inventory provided estimates of shipping for journeys that could be classified as domestic, for those departing from or arriving at UK ports on international journeys and for those passing through UK shipping waters, but not stopping at UK ports, nor using UK fuels. Proxy data was used to hindcast movements and fuel consumption to 1990 and forward cast to 2009. Misra *et al.* (2015) utilised a similar methodology to forward-cast shipping emissions to 2013. For consistency with other emissions data presented, SO_2 emissions from shipping for 2012 are highlighted in Figure A1e.2. Corbett *et al.* (2007) modelled ambient particulate matter (PM) concentrations from oceangoing ships' exhausts and provided estimates of global and regional mortalities resulting from ambient PM increases due to vessel emissions; PM concentrations were to found to be significantly elevated in the Channel and southern North Sea, reflecting the density of shipping using the area. In response to this issue a revised MARPOL Annex VI included more stringent limits on sulphur content of marine fuels (to 3.5% from 2012 followed by a further reduction to 0.5% from 2020, subject to a feasibility study) to reduce emissions of SO_x and NO_x from vessel exhausts. The EU Sulphur Directive came into force in January 2015 and mandated cuts in the maximum sulphur content in marine fuels from 3.5% to 0.5% by 2020, but for the Baltic Sea and North Sea, including the English Channel, a limit of 0.1% applied from 2015 onwards.

A1e.3.1.2 Onshore emissions

Sulphur dioxide (SO_2)

The largest source of SO_2 emissions is electricity generation, which accounted for 53% of total UK emissions in 2012 (total of 427 kilotonnes, the latest year for which data was available, Figure A1e.3). Since 1970 SO_2 emissions have declined by 93%, largely due to switching to

alternative fuels (e.g. natural gas) from solid fuels, improved abatement technology and more stringent legislation on the sulphur content of some fuels. Annual sulphur emissions have remained stable since 2009 and in some years have increased slightly, mostly due to the recent economic downturn which has caused an increase in the use of relatively cheap solid fuels (NAEI website).

Nitrogen oxides (NO_X)

All combustion processes in air produce NO_X. Nitrogen dioxide (NO_2) and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NO_X. Road transport is the largest source of NO_X in the UK, with industrial combustion and power generation also accounting for a large fraction of the emission total (1,062 kilotonnes in 2012, NAEI website). Since 1990 there has been a steady decline in road transport emissions due to the introduction of catalytic converters on cars and stricter regulations on truck emissions (Figure A1e.4). Similarly, the fitting of low-NO_X burners to coal fired power generator units and increased use of nuclear generation and natural gas burning plants have further reduced NO_X emissions (Salisbury *et al.* 2014).

Carbon monoxide (CO)

CO arises from incomplete fuel-combustion and is of concern mainly because of its effect on human health and its role in tropospheric ozone formation. The decline in UK CO emissions since 1990 from 9,081 kilotonnes to 1,978 kilotonnes in 2012 has been driven by reductions in emissions from sources including road transport, agricultural field burning and the domestic sector (Figure A1e.5).

Non-Methane Volatile Organic Compounds (NMVOCs)

NMVOCs are emitted to air as combustion products, as vapour arising from handling or use of petroleum distillates, solvents or chemicals, and from numerous other sources. There is a wide diversity of processes which emit NMVOCs covering not only industry, but also transport, agriculture and domestic sources. The two major sources of NMVOC emissions are the use of solvents and other product use (41% of 2012 UK emissions - 757 kilotonnes) and extraction and distribution of fossil fuels (19% of 2012 emissions, Figure A1e.6). NMVOC emissions have shown a steady reduction during the 1990s, largely a result of increasingly stringent emission limits across a range of sectors (NAEI website).

Particulate matter (PM_{10})

Particulate matter is generally categorised on the basis of the size of the particles (for example PM_{10} consists of particles measuring 10µm or less). Concentrations of PM comprise primary particles emitted directly into the atmosphere from combustion sources and secondary particles formed by chemical reactions in the air. The main source of road transport emissions is exhaust gases from diesel engines. Since around 1992, emissions from diesel vehicles have been decreasing due to the penetration of new vehicles meeting tighter PM_{10} emission regulations. Emissions from power stations have declined despite a significant growth in electricity generation capacity, due to a shift in the fuel mix for power generation from coal to natural gas, nuclear and renewable generation, and also due to abatement being fitted at coal-fired power stations (Figure A1e.7, Salisbury *et al.* 2014).

Figure A1e.2 – Emissions of SO_2 from shipping in 2012

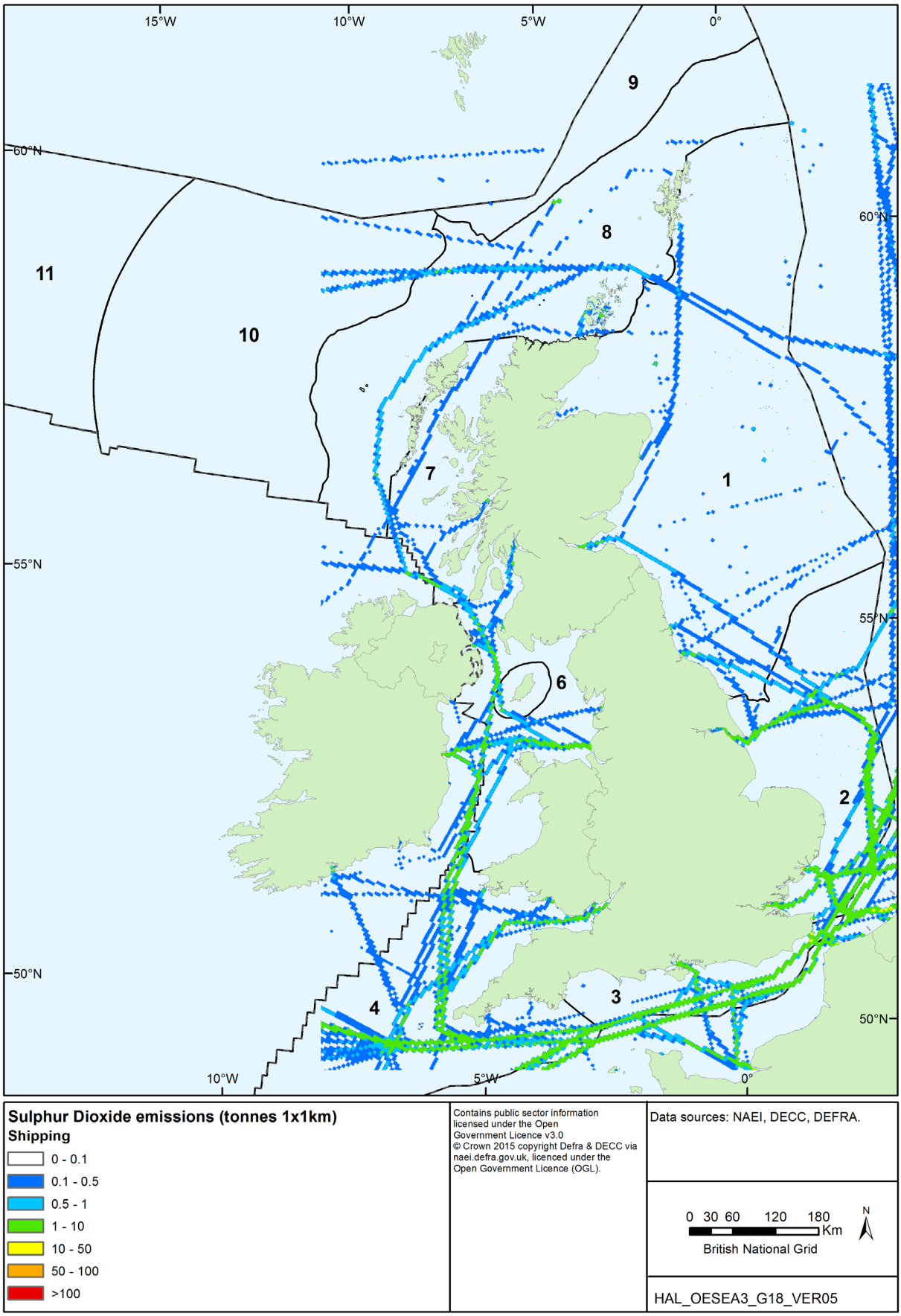
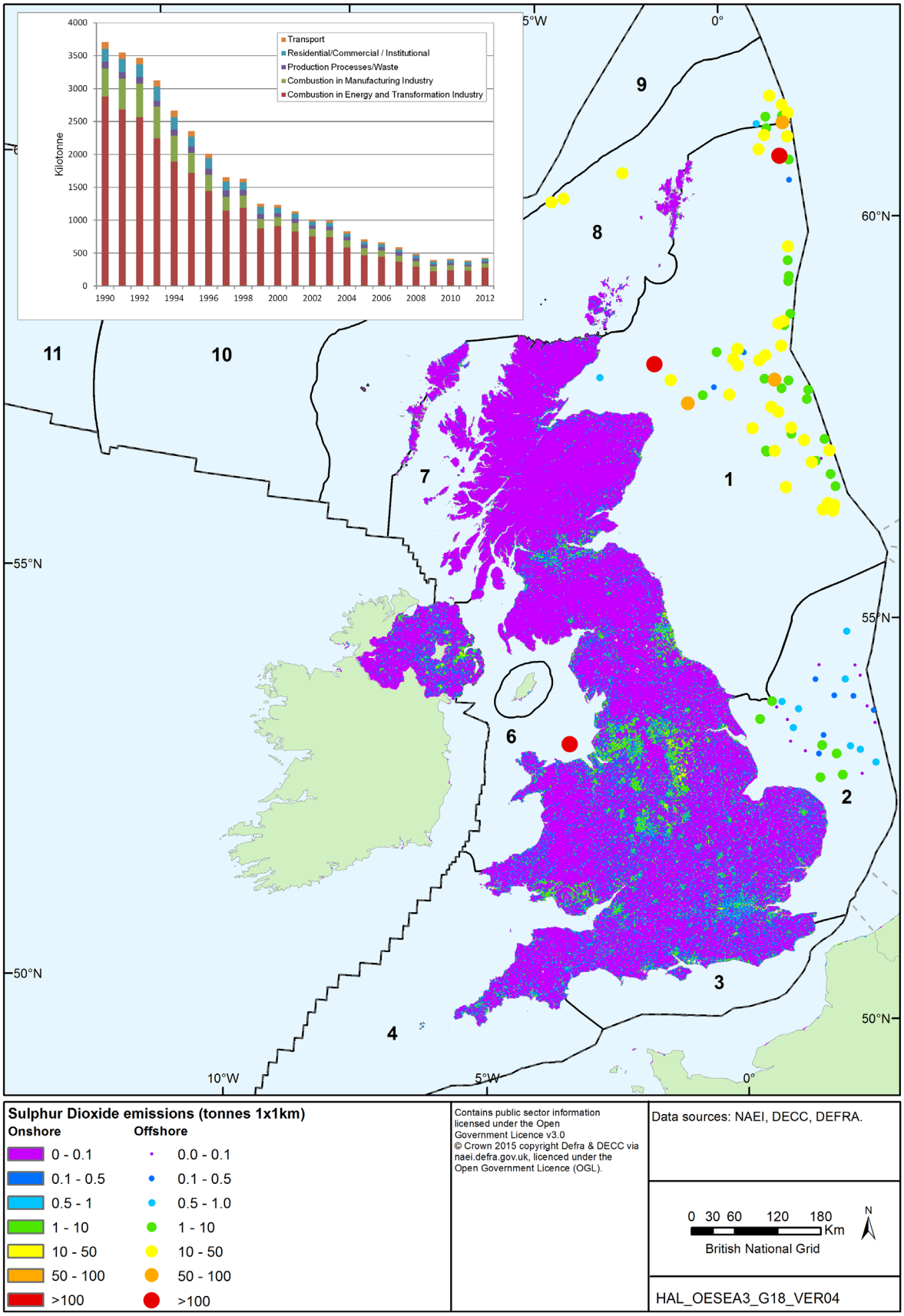
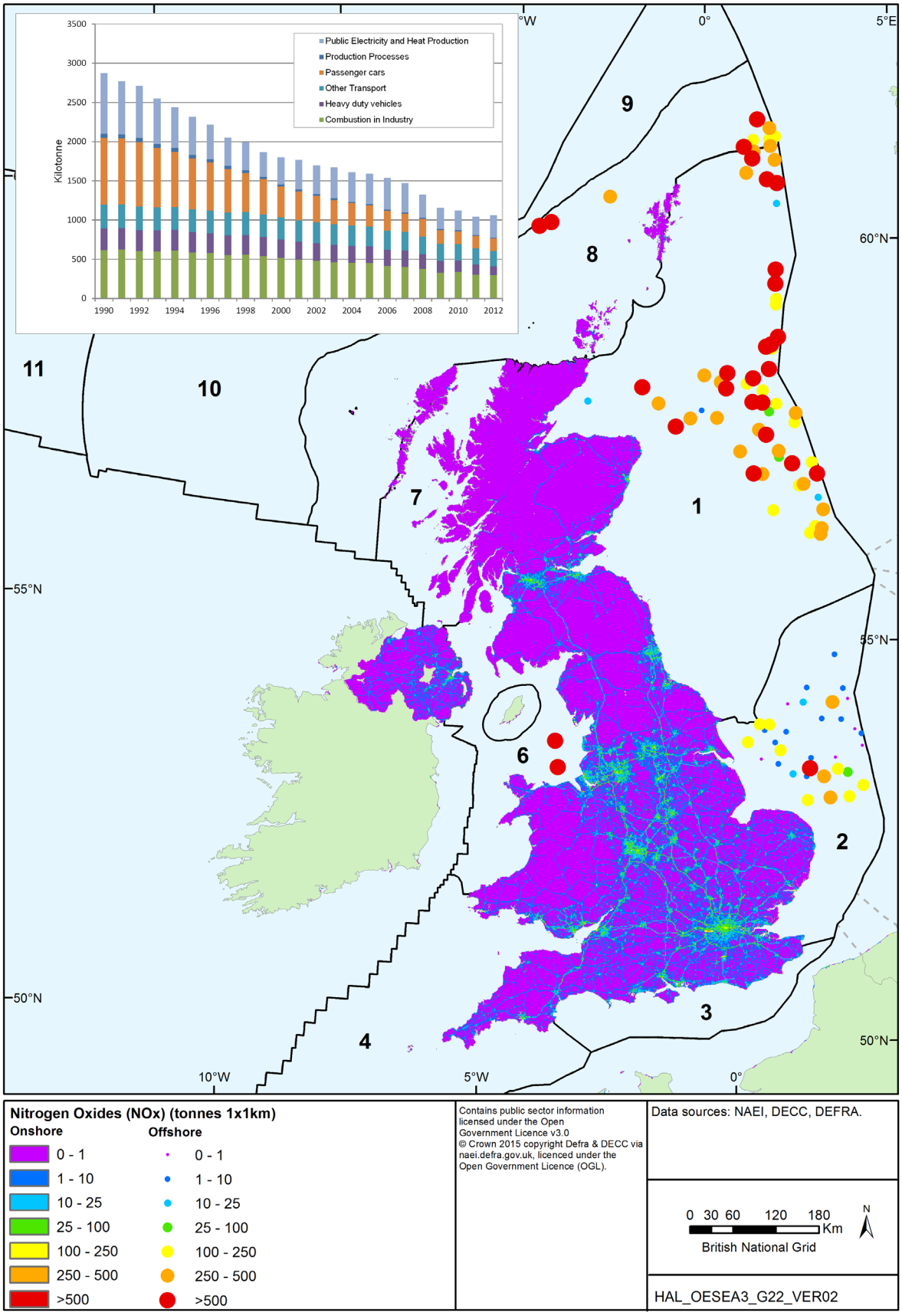


Figure A1e.3 – Emissions of SO_2 in 2012 and as a timeseries, 1990-2012



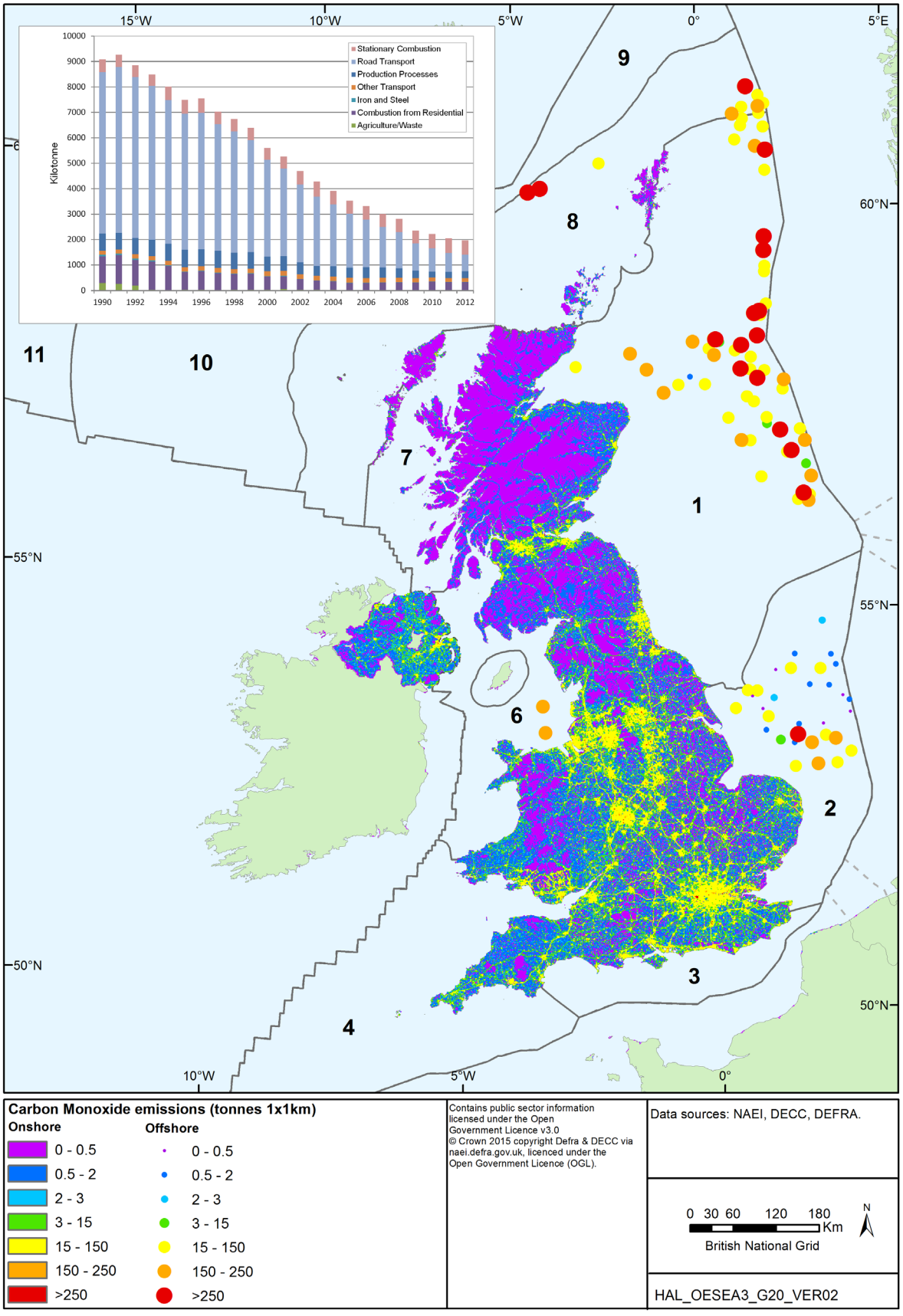
Note: Onshore emissions are provided as raster data but since offshore emissions would not show up due to the scale of the figure, these are presented as point sources. The size of the point source is proportional to the level of emissions and chosen for clarity at a UK scale rather than being representative of the area of emissions.

Figure A1e.4: Emissions of NO_X in 2012 and as a timeseries, 1990-2012



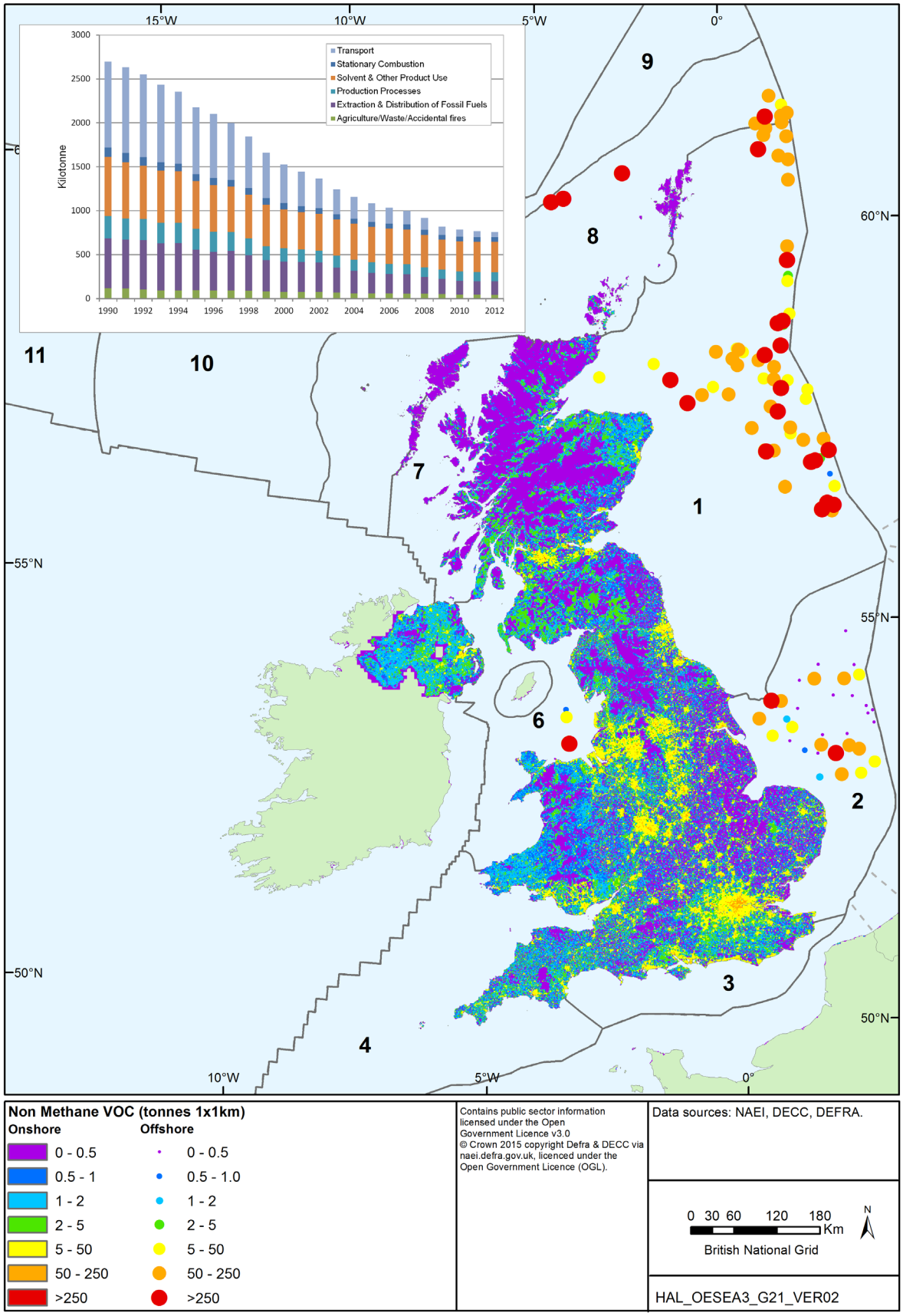
Note: See note for Figure A1e.3.

Figure A1e.5: Emissions of CO in 2012 and as a timeseries, 1990-2012



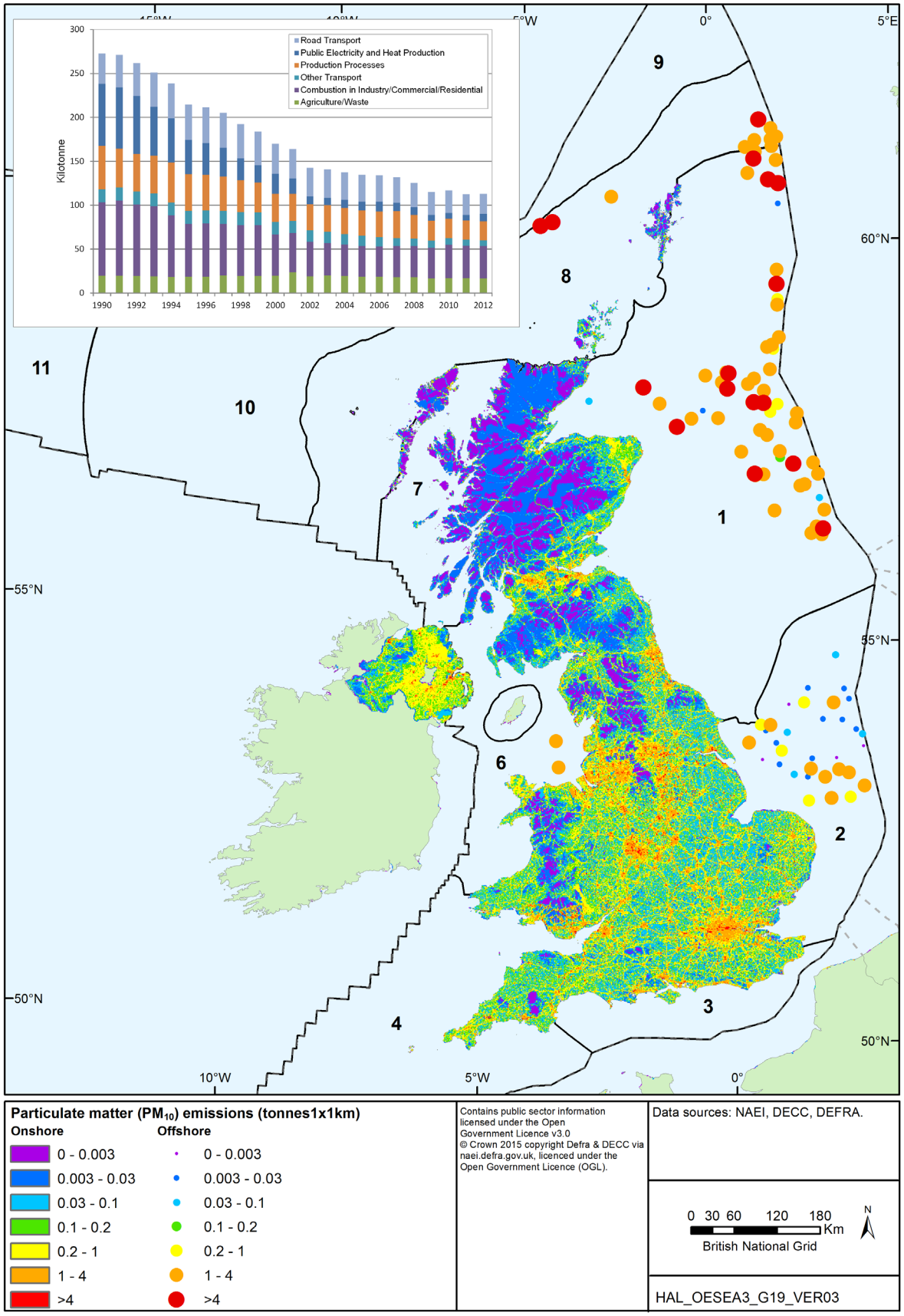
Note: See note for Figure A1e.3.

Figure A1e.6: Emissions of NMVOCs in 2012 and as a timeseries, 1990-2012



Note: See note for Figure A1e.3.

Figure A1e.7: Emissions of PM_{10} in 2012 and as a timeseries, 1990-2012



Note: See note for Figure A1e.3.

A1e.3.2 Metals

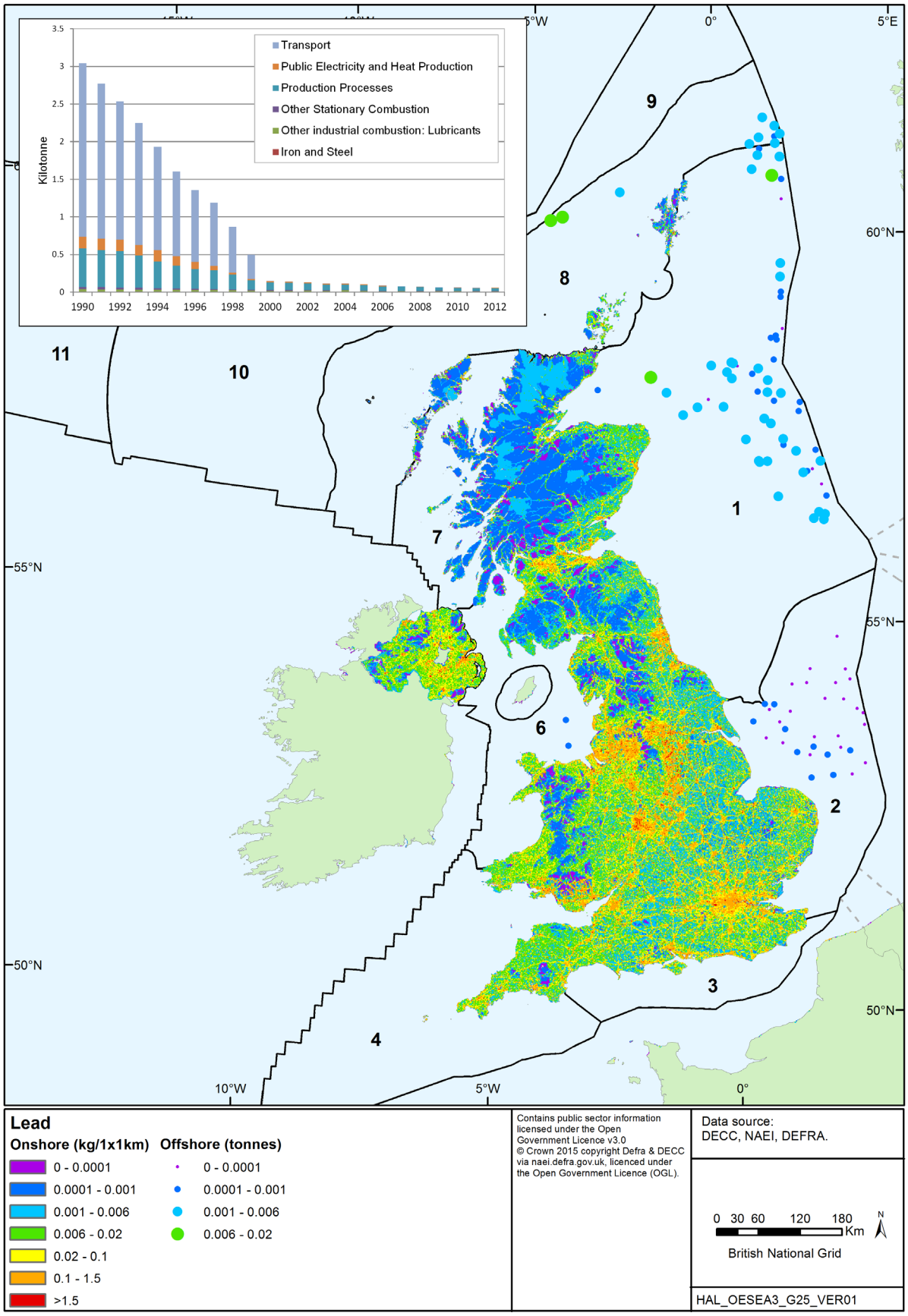
Heavy metal emissions arise from a number of different sources, but in general fuel combustion and certain industrial processes that produce dust are the main contributors. Emissions also arise from trace concentrations in fuels or in the case of industrial processes, the raw materials. In combustion, metals are emitted either as vapour or particulate matter or both. For example, one of the more toxic metals historically emitted in relatively large amounts has been lead with the largest source until 1999 coming from lead additives in petrol. From about 1990, sales of unleaded petrol increased, particularly as a result of the increased use of cars fitted with three-way catalysts. Leaded petrol was then phased out from general sale at the end of 1999 with a consequent decline in associated lead emissions (see Figure A1e.8). There has also been a significant reduction in emissions from metal production due to declining production, and from public electricity and heat production due to improved abatement measures. Emissions have also declined as a result of the decreasing use of coal (NAEI website).

A1e.3.3 Persistent Organic Pollutants (POPs)

POPs comprise a group of semi-volatile toxic chemicals characterised by resistance to degradation, significant potential to long-range transport, and harmful effects to human and wildlife health (Gusev *et al*. 2014).

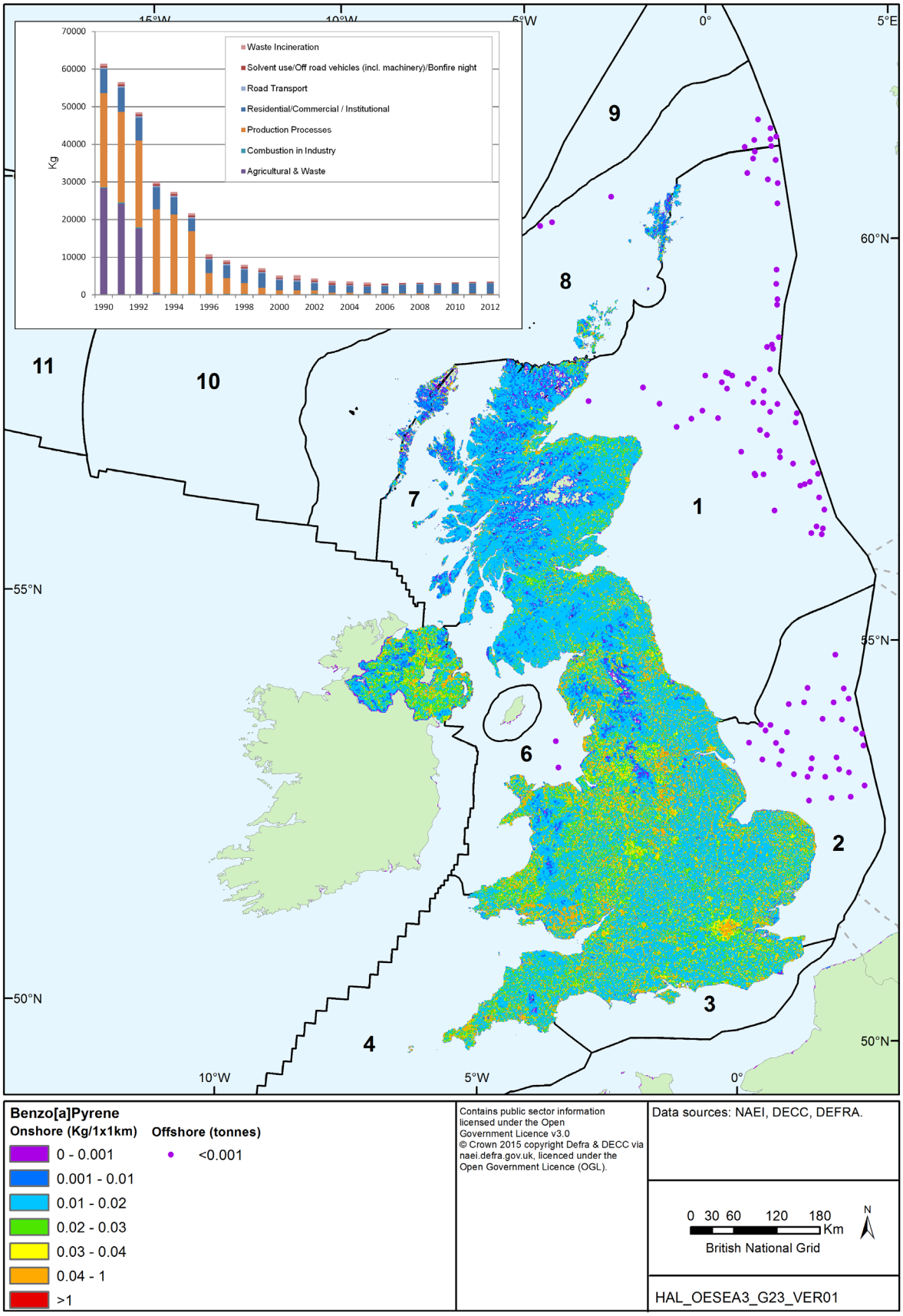
Benzo[a]pyrene (B[a]P) is used as a 'marker' for a group of compounds known as polycyclic aromatic hydrocarbons (PAHs). The main sources of B[a]P in the UK are domestic coal and wood burning, fires (e.g. accidental fires, bonfires, forest fires, etc.), and industrial processes such as coke production (DEFRA 2007). UK emissions of B[a]P have decreased by 94% since 1990 (from 61,448kg to 3,510kg in 2012); almost all of this reduction is due to the reduction in emissions from industrial processes and the banning of stubble burning in 1993. Since 2006 emissions have stabilised predominantly due to increases in emissions from domestic combustion of coal (Figure A1e.9). The areas of highest concentration reflect the distribution of industrial sources, and also areas where there is widespread domestic use of oil and solid fuels for heating (Bush *et al*. 2014).

Figure A1e.8: Emissions of lead in 2012 and as a timeseries, 1990-2012



Note: See note for Figure A1e.3.

Figure A1e.9: Emissions of B[a]P in 2012 and as a timeseries, 1990-2012



Note: See note for Figure A1e.3.

A1e.4 Atmospheric deposition of pollutants

A1e.4.1 Nitrogen

Nitrogen is an important component of air pollution due to its influence on ecosystem nutrient balance. For mid-latitude shelf seas such as the North Sea the relevant atmospheric nutrients derive mostly from nitrogen oxides (NO_X) and ammonia (NH_X) emissions, which are mainly related to combustion (traffic, industry) and agriculture. When emitted to the atmosphere, these eutrophying pollutants may remain in air for several days and therefore be dispersed and carried over long distances by winds. In the atmosphere NO_X is transformed to a range of secondary pollutants, including nitric acid (HNO_3), nitrates (NO_3^-) and organic compounds, such as peroxyacetyle nitrate. Both the primary and secondary pollutants may be removed by wet deposition (scavenging of gases and aerosols by precipitation) and by dry deposition (direct turbulent deposition of gases and aerosols) (Troost *et al*. 2013).

Modelled atmospheric deposition of nitrogen has decreased in the Greater North Sea region over the period 1995-2006 largely due to the emission reductions of NO_X in major contributing countries like the UK (OSPAR 2009). The deposition of nitrogen (oxidized and reduced nitrogen) shows a clear geographical gradient, with the largest values close to land areas and largely decreasing towards the open sea. The deposition density close to land is about an order of magnitude higher than the values for the open sea (OSPAR 2009). Figure A1e.10 shows the modelled[2] atmospheric deposition of nitrogen over the North Sea in 2013.

In general, oxidized nitrogen originates from combustion emissions (for the Greater North Sea region these contributed approximately 23% to the total nitrogen deposited in 2006) and transportation emissions (shipping contributed approximately 15% to the Greater North Sea total in 2006), whilst the reduced nitrogen originates from agricultural activities (contributed approximately 41% to the total nitrogen deposition in the region, OSPAR 2009).

A1e.4.2 Metals

With the exception of mercury, the deposition of all metal components in the OSPAR area has fallen since 1990 (OSPAR 2015). The reduced use of lead in fuels has resulted in a substantial reduction in its emission (approximately 90% between 1990 and 2013) and associated deposition across the UK.

The long range transport and deposition of a range of heavy metals across Europe has been modelled using the EMEP[3]/Meteorological Synthesizing Centre-East regional heavy metal transport model[4]. This provides information on the spatial distribution of deposition fluxes of a number of heavy metals with an example of the modelled distribution of lead deposition to both the UK and North Sea in 2013 shown in Figure A1e.10 (given that lead emissions were described in Section A1e.3.2). Figure A1e.11 highlights the general reduction in the atmospheric deposition of lead offshore though the proximity of the southern North Sea to industrialised areas on land exposes certain areas to higher levels of atmospheric deposition

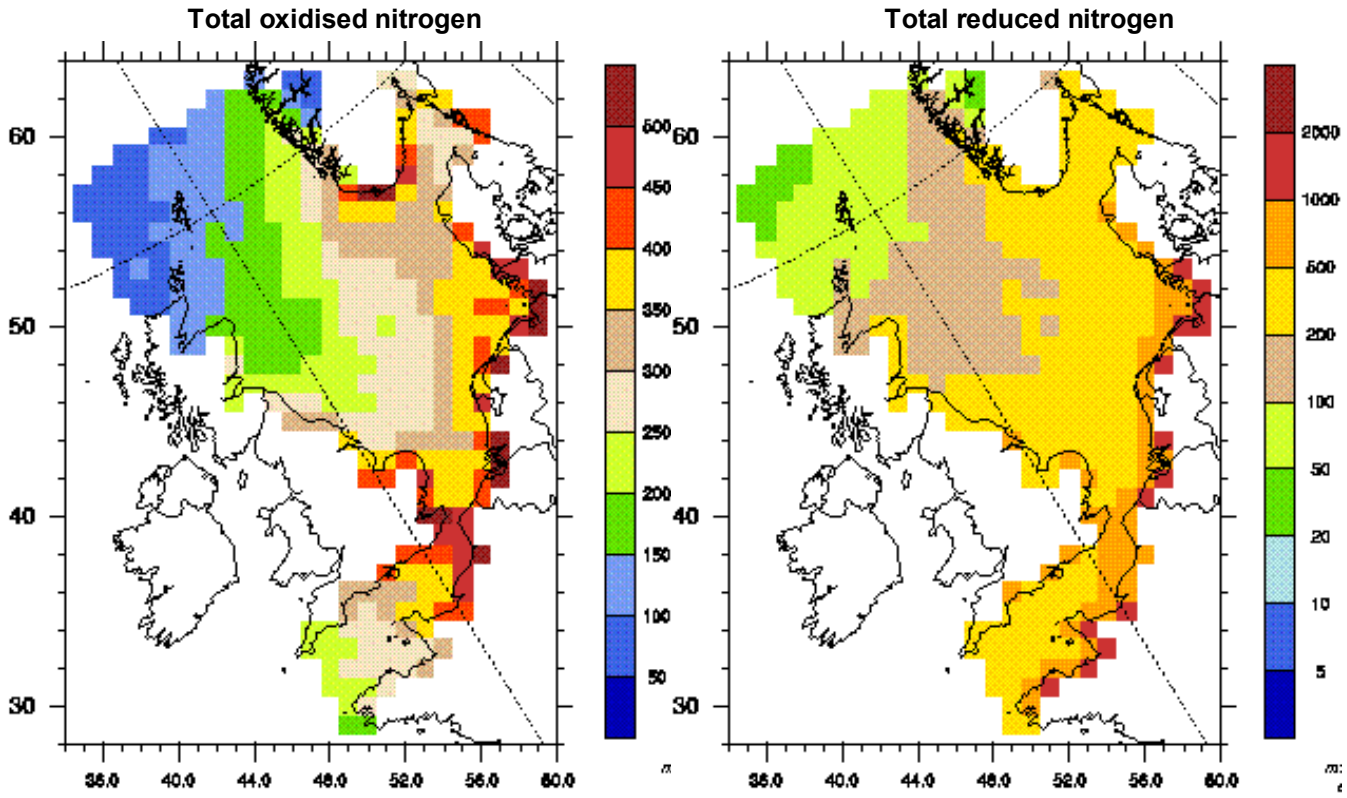
[2] Using the EMEP/MSC-W model, a chemical transport model developed at the Meteorological Synthesizing Centre - West (MSC-W) at the Norwegian Meteorological Institute (met.no). The EMEP model is designed to calculate air concentrations and deposition fields for major acidifying and eutrophying pollutants, photo-oxidants and particulate matter. Source: https://wiki.met.no/emep/page1/emepmscw_opensource

[3] The European Monitoring and Evaluation Programme (EMEP) is a programme under the Convention on Long-range Transboundary Air Pollution (CLRTAP), with the objective of providing governments and subsidiary bodies under the LRTAP Convention with qualified scientific information to support the development and further evaluation of the international protocols on emission reductions negotiated within the Convention.

[4] http://msceast.org/index.php/msce-hm

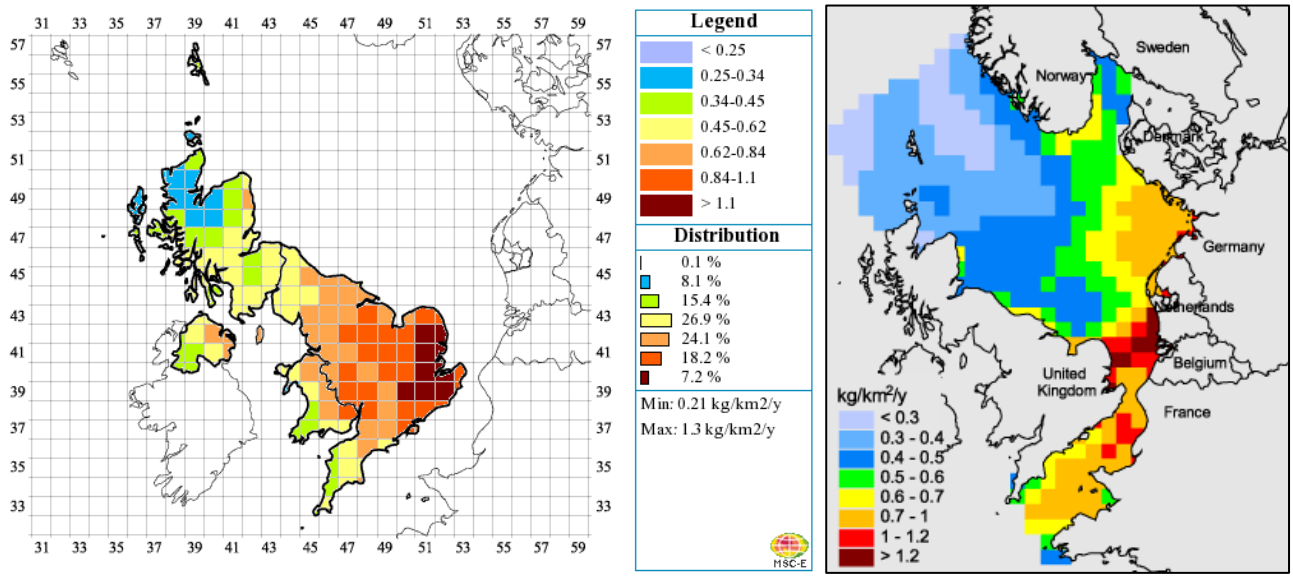
(OSPAR 2000). The UK contributed approximately 20% (12 tonnes) of the total deposition of lead to the North Sea in 2013 (http://msceast.org/index.php/marginal-seas#north).

Figure A1e.10: Atmospheric deposition of nitrogen (mg/m^2) to the North Sea in 2013



Source: EMEP MSC-W modelled air concentrations and depositions website - http://emep.int/mscw/index_mscw.html

Figure A1e.11: Atmospheric deposition of lead (kg/km^2/y) to UK and North Sea in 2013



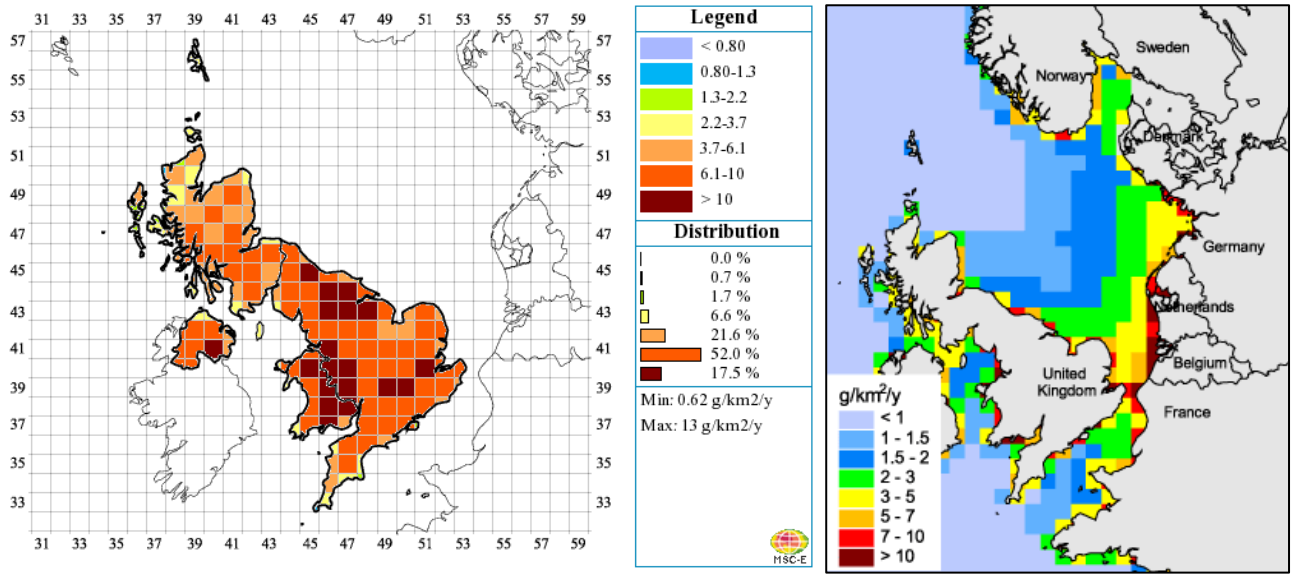
Source: http://msceast.org/index.php/united-kingdom, http://msceast.org/index.php/marginal-seas#north

A1e.4.3 Persistent Organic Pollutants (POPs)

For almost 70% of the countries in the EMEP region, the deposition of the polycyclic aromatic hydrocarbon B[a]P from transboundary transport, exceeds the deposition from national emission sources. However, the UK is less affected by transboundary transport of pollution due to its geographical location and levels of pollution are determined mostly by national emissions (Gusev *et al.* 2014). Between 1990 and 2012, UK emissions of B[a]P decreased by 94%.

The long range transport and deposition of a range of POPs across Europe has been modelled using the EMEP/Meteorological Synthesizing Centre-East POP transport model (MSCE-POP)[5]. This provides information on the spatial distribution of deposition fluxes of a number of POPs with Figure A1e.12 is an example of the modelled distribution of B[a]P deposition to both the UK and North Sea in 2013.

Figure A1e.12: Atmospheric deposition of B[a]P (g/km^2/y) to UK and North Sea in 2013



Source: http://msceast.org/index.php/united-kingdom, http://msceast.org/index.php/marginal-seas#north

Between 1990 and 2012 deposition of B[a]P to the North Sea has decreased by over 70%, primarily due to the reduction of emissions in the surrounding countries (Gusev *et al.* 2014). In 2013, it was estimated that the UK contributed 9% (160kg) of the total annual deposition to the North Sea[6].

A1e.5 Evolution of the baseline

As part of the National Atmospheric Emissions Inventory, projections of UK emissions of key air quality pollutants are compiled to inform policy development and to enable comparisons to be made with international commitments. The latest set of projections provides emissions of the pollutants NO_X, SO_2, NMVOCs, ammonia (NH_3), $PM_{2.5}$ and PM_{10} for 2015, 2020, 2025 and 2030 (Misra *et al.* 2012). Whilst the projections are based on a range of activity statistics and emission factors from between 2009 and 2011 (see Misra *et al.* 2012), they provide relevant information on the potential evolution of the baseline. To reflect the inherent uncertainties in

[5] http://msceast.org/index.php/msc-pop
[6] http://msceast.org/index.php/marginal-seas#north

predicting future emissions activity over a twenty year time horizon, a number of alternative emission projection scenarios were developed using a range of assumptions. The inputs that were varied were the growth in UK Gross Domestic Product (GDP), fossil fuel price determined energy demand and alternative scenarios for agricultural activity. Misra *et al.* (2012) used Scenario 3[7], a mid-range scenario, to exemplify the projected emission trends by pollutant out to 2030 and these are compared to the latest emission estimates for 2012 provided by NAEI in Table A1e.1, along with relevant emission ceilings under the National Emission Ceilings Directive (for 2010) and the revised Gothenburg Protocol (for 2020). The latest UK Informative Inventory Report (1990 to 2013, Misra *et al.* 2015) which accompanied the UK's 2015 data submission under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) also provided projected emissions for 2020 which are also included.

Table A1e.1: Projected emissions for Scenario 3 by pollutant and year (kilotonnes)

Year	NH_3	PM_{10}	NO_X	SO_2	NMVOCs
NECD ceiling for 2010[1]	**297**	**-**	**1,167**	**585**	**1,200**
2012[2]	**274**	**113**	**1,062**	**427**	**757**
2015	272	111	910	371	715
2020	284	106	708	287	705
2020[3]	277	-	711	197	721
Gothenburg ceiling for 2020[4]	**279**	**-**	**714**	**291**	**773**
2025	289	105	612	250	712
2030	294	108	589	242	725

Note:

1. *The National Emission Ceilings Directive (Directive 2001/81/EC, NECD) set limits for each Member State for the total emissions of NOx, SOx, NMVOC and NH_3 in 2010 and subsequent years. A proposal to amend the Directive to set ceilings for 2020 and 2030 is currently under negotiation - http://ec.europa.eu/environment/air/pollutants/rev_nec_dir.htm*
2. *Total emission figures reported for 2012 (NAEI website)*
3. *Projected emissions for 2020 based on the 2012 inventory (from Misra et al. 2015)*
4. *The Gothenburg Protocol under the UNECE Convention on Long-range Transboundary Air Pollution was revised in 2012 to set new emission ceilings to apply from 2020.*

Source: NAEI website - http://naei.defra.gov.uk/overview/ap-overview, Misra et al. (2012)

The results show that during the period up to 2025 in which current measures on climate and air quality continue to be implemented then emissions will reduce. Hence emissions in 2020 are below 2012 levels for all pollutants. However for ammonia, PM_{10} and NMVOCs the longer term projections are driven by economic growth. Hence as a result of the absence of currently firm and funded further measures, emissions are currently projected to be greater in 2030 than 2020. Emissions of nitrogen oxides and sulphur oxides are predicted to continue to decline as energy efficiency measures reduce energy demand and renewable sources of energy replace coal and natural gas combustion (Misra *et al.* 2012).

[7] Scenario 3 was a realistically ambitious scenario with higher economic growth, fossil fuel prices, and transport activity, and increases in livestock numbers and urea use.

A1e.6 Environmental issues

Air pollutant emissions reductions do not always produce a corresponding drop in atmospheric concentrations in the UK. For example, emissions of the pollutants that lead to ozone formation have reduced substantially, but this is not reflected in the long-term trend in ozone concentrations. This is partly explained by a proportion of the ozone experienced in the UK originating from air pollutant emissions from mainland Europe and beyond. Whilst mainland Europe has also been reducing emissions of pollutants that lead to ozone formation, emissions from outside Europe have increased leading to higher concentrations overall. The long-term trend in ozone concentrations are also partly influenced by the chemistry of ozone formation and destruction. Levels of ozone have historically been higher in rural areas compared to urban areas due to lower local emissions of nitric oxide. However, as a result of measures to control NO_X there have been increased concentrations of ozone in urban air as levels of ozone approach rural levels (DEFRA 2014).

NO_X are emitted by road vehicles, shipping, power generation, industry and households and are a key component in increased levels of ground-level ozone, which is harmful to human health. As described in Section A1e.2, the most recent compliance report for 2013 (Bush *et al*. 2014) indicated that 38 out of the 43 UK zones were assessed to be exceeding the maximum annual limit[8] for NO_2, together with one zone exceeding the hourly limit. The European Commission launched legal proceedings against the UK in 2014 for being in breach of its obligations under the 2008 ambient air quality directive with respect to levels of NO_2 (http://europa.eu/rapid/press-release_IP-14-154_en.htm). In September 2015, DEFRA opened a consultation on draft plans to improve air quality in England, Wales and Northern Ireland. These set out the action taken, being implemented and planned at local, regional and national levels to meet the annual and hourly EU NO_2 limit values in the shortest possible time, including draft plans to improve air quality in each of the 38 zones exceeding the annual mean limit value for NO_2 (https://consult.defra.gov.uk/airquality/draft-aq-plans).

Particulate matter is of concern in urban areas where it is generated by vehicles (accounting for 20% of PM_{10} emissions in 2012) and by combustion for industrial, commercial and residential purposes (accounting for 33% of emissions in 2012). There may be significant health implications to humans from particulate emissions which are not yet well understood, though levels have been generally declining since the 1980s due to stricter regulation and the adoption of improved technology (Maggs *et al*. 2008). Metal and persistent organic pollutant emissions, and by association deposition, have been declining over the past 20 years and it can be expected that this will continue. Both can pose a range of contamination problems in the natural environment when they interact with soil, groundwater and runoff, and in turn may be incorporated into the food chain and may result in ecotoxicity.

[8] In 2013, 7 of the zones which exceeded the 40µg/m had a valid time extension. The UK had been granted a time extension for compliance with the NO_2 annual mean limit values in 12 zones and agglomerations. Where a time extension applies the UK is required to provide the Commission with data indicating that the annual mean NO_2 concentrations in these zones have remained below the annual limit value plus the maximum margin of tolerance of 60µg/m.

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