Department for
Business, Energy
& Industrial Strategy

PROJECTED EMISSIONS OF NON-CO_2 GREENHOUSE GASES

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Contents

Executive summary

This report presents the methodology used in the non-CO_2 projections. The non-CO_2 gases are methane (CH_4), nitrous oxide (N_2O) and the fluorinated gases (HFCs, PFCs, SF_6 and NF_3). The projections are a best estimate of future emissions, accounting for expected technological developments, key drivers such as population and known policy commitments. It is important to note that policies affecting these projected emissions are still being developed and will be incorporated in future updates.

1. Introduction

1.1 Overview

The UK government has set a target for a reduction in greenhouse gas emissions of at least 80% below 1990 baselines by 2050 (**BEIS, 2017a**). Emissions projections are used as a way of monitoring progress towards this target and to identify emission sources which would need additional measures. The UK is also required to submit projected emissions of greenhouse gases biennially under the European Union Monitoring Mechanism Regulation, and periodically in the form of National Communications and Biennial Reports to the UN Framework Convention on Climate Change (UNFCCC).

Process changes and improvements to note in this year's publication are:

- The assumptions and models used in forming emission projections are updated annually where required.
- The historical GHG emissions (**BEIS, 2017b**) which form the baseline for these projections undergo annual updates to comply with Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines (**IPCC, 2006**). Any annual changes are incorporated into these projections to remain consistent with the latest inventory.

1.2 Scope

Non-CO_2 emission sources covered by this publication

The projections cover **non-CO_2** component of the Kyoto Protocol's basket of greenhouse gases, which we refer to as the 'non-CO_2 GHGs'. These gases are:

- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)
- Nitrous Trifluoride (NF_3)

* The HFCs, PFCs,SF_6 and NF_3 are also collectively known as the fluorinated gases, or "F-Gases".

Geographical scope, time horizon and units

- The geographical scope of these projections is the UK only
- Emissions are projected up to 2050.

- Emissions are presented in CO_2 equivalent (CO_2e), according to GWPs set out in the IPCC 4AR (IPCC, 2007) Sector assignment

For the purposes of reporting, greenhouse gas emissions are allocated into National Communication (NC) sectors. These are a small number of broad, high-level sectors, and are as follows: energy supply, business, transport, public, residential, agriculture, industrial processes, land use land use change and forestry (LULUCF), and waste management.

These high-level sectors are made up of a number of more detailed sectors that follow the definitions set out by the IPCC for GHG emissions reporting, and are used in international reporting tables submitted to the UNFCCC every year. The sectoral assignments are based on the source of the emissions as opposed to where the end user activity occurred. A complete mapping of IPCC sectors to National Communication sectors is available on the BEIS website (**BEIS, 2017b**). These are the sectoral assignments used in this report.

1.3 Current UK GHG emissions and targets

As part of the UK's commitments for reporting its GHG emissions, a national inventory is produced each year containing estimates for the UK's GHG emissions from all anthropogenic sources. This is referred to as the GHG Inventory (GHGI) and is annually submitted to the UNFCCC, previous GHGI reports are available (**BEIS, 2017c**).

The GHGI forms the baseline for the projections, although the geographical scope is slightly different between the UNFCCC submission and these projections. The UNFCCC submission covers the UK plus Crown Dependencies and Overseas Territories, whereas only the UK component is covered by this report. All reference to the GHGI in this report refers to this UK only scope.

- **Methane (CH_4)** – CH_4 represents the majority of non-CO_2 GHG emissions at 57%. The agriculture sector as a whole accounts for 53% of all CH_4 emissions, while the waste management sector accounts for around 32%. The remaining CH_4 emissions are largely attributed to fugitive energy emissions.

- **Nitrous oxide (N_2O)** – N_2O representsa quarter of non-CO_2 GHG emissions. The majority of N_2O emissions (71%) are attributed to the agriculture sector. Waste, transport, energy supply, business and LULUCF make up the rest with minor contributions from the industrial processes and the residential sectors.

- **F-Gases (HFCs, PFCs, SF_6 and NF_3)** – HFCs represent 17% of non-CO_2 GHG emissions, while PFCs, SF_6 and NF_3 represent less than 1% between them. Refrigeration and air conditioning account for the majority of HFC emissions, with the dominant source being commercial refrigeration. Other significant HFC emissions sources include aerosols and metered dose inhalers (e.g. asthma inhalers). The major sources of PFC emissions are halocarbon production and the

electronics industry. SF_6 emissions are largely attributable to electrical insulation. NF_3 emissions are all attributable to electronics.

Further details on breakdown of each of these gases to specific activities over the period 1990 - 2015 can be found in the latest National Statistics release (**BEIS, 2017b**).

The UK has both international and domestic targets for reducing greenhouse gas emissions. These targets encompass all GHG emissions, not just the non-CO_2 component projected in this report. BEIS's Updated Energy and Emissions Projections report (**BEIS, 2017d**) provides more information on the UK's complete GHG emissions projections in comparison to targets.

2. Projections methodology

2.1 Overview of methodology

Baseline

Emissions statistics based on the 2017 GHG Inventory Submission (GHGI), the estimate of the UK's historical GHG emissions from all anthropogenic sources, are used as the baseline for projections (**BEIS, 2017d**). The GHGI calculates emissions by combining activity data (e.g. fuel use, livestock numbers) and emission factors (e.g. kg pollutant / tonne fuel used, / head livestock). A new GHGI is produced each year (x) detailing emissions from each source from 1990 to year $x - 2$ (e.g. the GHGI produced in 2017 provides emissions from 1990 - 2015). This means that the base year for these projections is 2015.

The historical emissions estimates are revised each year to account for new information that becomes available, and methodological improvements. The data and compilation methods used in the GHGI are reviewed annually (**BEIS, 2017c**). The most notable specific changes to this year's GHGI are:

- Changes to estimates of emissions from harvested wood products
- Changes to ammonia and methanol feedstocks
- Changes to estimates of emissions from grassland
- New data for commercial and industrial waste in landfill and change of decay rates
- Changes to estimates of emissions from forest land
- The time series for estimates of emissions from fluorinated gas use in aerosols have been revised in the Business sector to reflect new data from the British Aerosol Manufacturers' Association
- Activity data for non-agricultural anaerobic digestion has been updated and rationalised between the greenhouse gas and ammonia inventories

Overall impact on emissions

In total, the changes made to the methods and data for the 2017 inventory submission have led to an increase in total 2014 emissions(the latest year for which a comparison can be made) of around 0.1 %.

All projections have been updated to account for these changes to the baseline, and the most impactful changes are described in the relevant chapters of this report.

Projections

The GHGI emissions from each source within scope of this report are projected from the latest GHGI year (currently 2015) up to 2050 (previously up to 2035) to form the BEIS non-CO_2 GHG projections. Given the disparate nature of the emission sources in scope, the methodologies used to define the projections are wide ranging. The drivers on emissions and methodologies used to model this are discussed in the relevant sector chapters. These drivers range from simple assumptions to complex analytical models, depending on data availability and emissions magnitude.

As noted above, the baseline GHGI is defined by activity data and emission factors. The emission projections can similarly be thought of as the combination of:

- Projections of the change in activity data, e.g. changes to livestock numbers or changes in behaviour affecting the waste sector.
- Projections of the change in emission factors, e.g. improvements to technology for the abatement of emissions.

We have moved to a system whereby annual updates to projections involve one of the three following methods:

- If there are apparent major changes to the drivers then we undergo a formal update of the projections from that source.
- If there are no apparent major changes to the drivers or the historical emissions, then the projections are left unchanged.
- If there are no apparent major changes to the drivers, but the historical emissions have changed due to a methodology change then the projections model is rerun.

Changes in projections for each source are discussed in the relevant sector chapter.

Policies

The non-CO_2 projections include the effects of a number of government policies which mitigate GHG emissions. The standard EU/UNFCCC definitions used to categorise policies are:

- **'Expired'** are closed policies that still provide legacy carbon savings;
- **'Implemented'** are policies that are being applied;
- **'Adopted'** are policies that have been agreed and where the process of implementation is well advanced but not yet complete.
- **'Planned'** are policies at an earlier stage towards implementation, e.g. where the government's intentions have been announced or are still being consulted on.

An 'existing policies' scenario includes all currently expired, implemented and adopted policies. A 'reference' scenario includes all the above policies, plus planned policies. As there are no planned policies within the non-CO_2 projections then they are both an 'existing policies' scenario and a 'reference' scenario.

The policies that we have explicitly included in projections are:

- F-gas regulation (2006, 2015 and Mobile Air-Conditioning Directive) (**EU 2006a, 2006b, 2014**).
- Solid waste policies (including those that support commitments to the Waste Framework Directive and Landfill Directive) such as, Landfill Tax etc all contribute to the waste activity projections provided by Defra) (**Defra, 2014**)
- Transport policies (Local Sustainable Transport Fund, road biofuels, road vehicle efficiencies and road investment strategy are included in the DfT activity projections) (**DfT, 2015a**)
- LULUCF afforestation policies (**Defra 2015, Welsh Gov 2015, Scottish gov 2015, DARDNI 2015**)
- English GHG Agriculture Action Plan (**NFU, 2011**)

2.2 Quality Assurance / Quality Control procedures

The business as usual QA/QC process involves the following measures:

- A wide range of data is used in the projections and each source is quality assured. Many of the new data sources are publicly available (see references) and where possible data are subject to peer review.
- Sector experts providing QC on the assumptions used.
- Significant verification and error checking by the production team. These include but are not limited to the following: consistency checks when transferring data; independent checks of every calculation; verification of workbook structure through mapping; comparison of absolute/percentage changes from the previous publication and checking final projections against source projections.
- The changes incorporated into this update have also been checked, and overseen by the non-CO_2 GHG emissions projections Steering Group.

The main benefit of the QA/QC is that the processes aim to find any errors at any point in the methodology, rather than focusing on changes made in the last year.

3. Industrial Processes, Residential & Business (F-gases)

Background

All F-gas emissions are in the industrial processes, residential and business sectors. The F-gases are HFCs, PFCs, SF_6 and NF_3.

Since 1990, emissions of HFCs have increased by 10% due to their use as replacement gases in the phasing out of Chlorofluorocarbons (CFCs) as a result of the Montreal Protocol.This is particularly evident in a growing refrigeration and air conditioning sector. There was however a significant fall in emissions between 1997 – 2000 to a timeseries low of 9.8 $MtCO_2e$, when abatement equipment was applied to plants that produce halocarbons. In 1990 F-gases emissions largely arose as by-products from halocarbon manufacture, while in 2015 refrigeration and air conditioning is the dominant source.

How we project emissions

- **Primary aluminium production** – We now know the effect of all the recent abatement measures applied and we expect no further abatement so project constant emissions from aluminium production.
- **Magnesium cover gas** – We project magnesium emissions based on (i) sector expert knowledge on short term replacement of F-gases and (ii) long term replacement of F-gases due to the 2014 EU F-gas regulation.
- **Production of Halocarbons** - We project HFC emissions based on (i) short term company planning information and (ii) long term replacement of F-gases due to the 2014 EU F-gas regulation. We project PFC emissions to be constant, equal to the 10 year average as there is no discernible trend.
- **Metered Dose Inhalers** – Emissions are exempt from the 2014 EU F-gas regulation and we project emissions using population growth (**ONS, 2015)** as the driver.
- **Aerosols** – We project sector growth to be zero, in line with the trend in recent years, and model the gas bans and phase down resulting from the 2014 EU F-gas regulation.
- **Refrigeration & Air-conditioning** - We use the same model as used for the historical emissions calculation. Then assumptions are applied from the 2014 F-Gas regulation, most important of which is the HFC phase down which caps the amount of HFC's placed on the market each year. This model was reviewed and updated in 2015 by F-gas sector experts.
- **Foams** –We extend the mapping of activity and emissions to 2035 from the historical inventory model. This model was reviewed and updated in 2017 in line with the updated model produced for the 2016 GHGI submission. Then we model the gas bans and phase down resulting from the 2014 EU F-gas regulation.

- **Firefighting** – We extrapolate the latest GHGI model out to 2050 using emissions factors based on UNFCCC sectoral guidance and Article 5 of the 2014 F-gas regulations.
- **Solvents** - We project sector growth to be zero, in line with the trend in recent years, and model the phase down resulting from the 2014 EU F-gas regulation.
- **High voltage switch-gear (SF_6)** – We project sector growth based on expert advice which is in line with **Schwarz et al (2011)**, assuming continuing decreasing leakage due to the 2006 EU F-gas regulation.
- **Electronic manufacture (HFCs / PFCs / SF_6 / NF_3)** - Project constant emissions due to limitations in the historical data.
- **AWACS (SF_6)** – Project constant emissions in line with historical data.
- **Training shoes (PFCs / SF_6)** – Emissions from this source have ceased and are not expected to resume, therefore we assume no emissions from this source in future years.
- **Particle accelerators (SF_6)** - Emissions are very small and are projected to be constant.
- **Tracer gas (SF_6)** – Project constant emissions based on last two years in the GHGI.

4. Industrial Processes, Residential & Business (CH_4 / N_2O)

Background

Nitrous oxide emissions from nitric acid and adipic acid production have historically been a significant contributor to emissions. However, following plant closures (no adipic acid production facilities remain) and the adoption of improved abatement technology, these emissions have decreased significantly compared to 1990 levels..

In recent years, N_2O emissions from industrial off-road machinery and anaesthetic use have been the dominant CH_4/N_2O emission source in the industrial processes, business & residential sectors.

There are a number of other small sources of emissions in these sectors:

- Fletton brick manufacture CH_4 emissions are very small and have been relatively well correlated with the number of manufacturing plants in operation over the period. The closure of the last plant to burn coal in 2008 was the most notable event.
- Household composting CH_4 / N_2O emissions have risen continually since 2004, though emissions are still very small.
- Accidental fires CH_4 emissions are very small and have decreased since 1990, though they have levelled out more in recent years.
- House & garden machinery CH_4 / N_2O emissions have decreased due to a reduction in the CH_4 emission factor which dominates over the increase in machinery usage.

How we project emissions

- **Industrial machinery (CH_4 / N_2O)** - Activity data is projected using EEP industrial economic drivers and emission factors are projected by a simple vehicle turnover model.
- **House & garden machinery (CH_4 / N_2O)** - Activity data is projected using projected household numbers from DCLG **(DCLG, 2014)** and emission factors are projected by a simple vehicle turnover model.
- **Nitric acid production (N_2O)** – We project nitric acid emissions using the Chemistry Growth Strategy Group baseline scenario for chemical sector growth, an annual 1.7% increase (**CIA, 2013**). This was following consultation with the Environment Agency chemicals sector leads who also expect a growth in overall chemical production.
- **Fletton brick manufacture (CH_4)** – We now project Fletton brick emissions using a simple 1:1 scaling with the 'Construction' economic index from the 2016 EEP.
- **Household composting / Accidental fires / Anaesthetic use (CH_4 / N_2O)** - We project these emissions source as constant from the latest GHGI year. Anaesthetic

use emissions have increased across the time series due to corrections of a conversion error in the GHGI.

5. Energy

Background

The energy sector emissions covered in this report are fugitive emissions, i.e. due to leakage, and they are all methane. These emissions result from natural gas leakage, operational and closed coal mines, and solid fuel transformation.

Leakage from the gas distribution network is the largest CH_4 source in the GHGI outside of the agriculture and waste sectors, comprising approximately 7% of all CH_4 emissions. Methane emissions from deep mined coal also make a significant contribution of around 2%. Both sources combined comprise around 89% of non-CO_2 emissions from the energy sector. Closed coal mine CH_4 emissions are the third most significant source in this sector. Historically, energy sector non-CO_2 emissions have decreased by approximately 26 $MtCO_2e$ since 1990 with this being predominantly as a result of a programme to fix leaks in the gas distribution network, and decreasing coal mining activity.

A small percentage of combustion related non-CO_2 emissions are underpinned by economic demand. Further details about this can be found in BEIS's Updated Energy and Emissions Projections report (**BEIS, 2017d**)

How we project emissions

- **Closed coal mines (CH_4)** – A model developed by WSP in 2011 (**WSP, 2011**) is used to project closed coal mine emissions. The model catalogues mines and estimates methane gas reserves and emission rates to construct a profile of emissions up to 2050. The model was updated in 2016 to reflect more recent information on the closure dates of some mines and changes to the inventory calculation for these emissions.
- **Coal mining (CH_4)** – We project coal mining emissions based on internal BEIS UK coal production projections. We expect the overall projected downward trend to be reliable, although the exact shape of this decline is subject to significant uncertainty.
- **Charcoal/coke/solid-smokeless fuel production (CH_4)** – These are very small sources of emission. Emissions from charcoal and solid-smokeless fuel production are projected to be constant in line with last year's projections. Coke production is projected using a driver from the EEP representing coal consumed by the iron and steel industry. The historical fit is very good.
- **Gas supply leakage (CH_4)** – Emissions reduction is driven by a 30 year programme to replace the gas distribution network (**HSE, 2011**). In 2013, OFGEM set gas distribution network leakage targets as part of the roll-out of a new price control period (Apr 2013 - Mar 2021) (**OFGEM, 2012**). This equated to an emissions reduction of approximately 20%. These targets were linearly extrapolated out to 2032 and then set as constant post 2032. These targets form the long term emission projections. In the short term the projections are revised downwards to reflect the faster progress than stipulated by targets. The same reductions were assumed to apply to gas transmission leakage.

6. Waste

Background

The major source of emissions from this sector is CH_4 from landfill sites, which contribute 13% of all non-CO2 emissions. CH_4 and N_2O emissions from wastewater treatment make up most of the remaining waste emissions. There are also small contributions from Biological Waste Treatment (BWT) processes and waste incineration plants without energy recovery. The latter burn waste outside of the normal waste stream, such as clinical and chemical waste.

Landfill emissions have decreasedby approximately 79% since the Landfill Directive was introduced in 2000, which had the aim of reducing the amount of waste going to landfill and improving the collection of methane from landfill sites. Emissions from wastewater treatment have been largely constant historically. Emissions from BWT processes - composting, anaerobic digestion and mechanical biological treatment – have been rising since 1990 and composting is the biggest emission source of the three.

How we project emissions

- **Landfill (CH_4)** – Tonnages of waste to landfill projections are provided by Defra (municipal waste) and HMRC (commercial & industrial waste). We project composition from the changes to BWT processes and Defra projections of waste arisings. These projections of waste to landfill are then run through MELMod (**Eunomia, 2010**), the landfill emissions calculation model. MELMod is based on the first-order decay Intergovernmental Panel on Climate Change (IPCC) methodology, and is summarised in the 2014 GHGI report (**BEIS, 2017c**).
- **Wastewater treatment (CH_4 / N_2O)** – Domestic wastewater emission projections are driven by ONS population projections (**ONS, 2015**), although note that work is being done to better project the emission factor. Industrial wastewater emissions are projected to be constant due to lack of data.
- **BWT (CH_4 / N_2O)** – We linearly extrapolate the previous 5 year trend in the time series out to 2020 using linear regression. We then assume constant emissions post 2020 as there is no policy in place post 2020.
- **Incineration without energy recovery (CH_4 / N_2O)** – We project constant emissions using the 5 year historical average.
- **Sewage and sludge decomposition (CH_4 / N_2O)** – Emissions projections are driven by ONS population projections (**ONS, 2015**). Private systems CH_4 emissions remain constant from the latest GHGI due to Biological Oxygen Demand per person being assumed to be constant in future years.

7. Agriculture

Background

Agriculture emissions result from (i) enteric fermentation from livestock, (ii) manure management and (iii) agricultural soils. The two biggest sources are enteric fermentation in cattle and fertiliser use for CH_4 and N_2O respectively. CH_4 and N_2O from manure management also represent a significant source of emissions. Agriculture emissions were roughly constant in the mid-1990s, but then decreased in all sources from the late 1990s.

How we project emissions

Activity data projections (livestock numbers, crop production, fertiliser N use) to 2030 (note that we flat line post 2030), were provided by Defra using the Food and Agricultural Policy Research Institute (FAPRI) methodology (**FAPRI, 2010**). The FAPRI projections are based on an economic model assuming a specific set of international prices for agricultural commodities and a particular path for the sterling exchange rate. Together these factors are important determinants of the returns to farmers and hence total agricultural production. The FAPRI activity projections are converted to agriculture emissions projections using the latest agriculture GHGI model.

Since the UK agricultural inventory model does not currently capture mitigation it was necessary to adjust the GHG estimates for the impacts of existing mitigation policies. In particular the English agricultural industry's GHG Action Plan (**NFU, 2011**), which aims to reduce English agricultural emissions by 3MtCO_2e by 2022, has been included. Monitoring by Defra suggests that by 2015 the Action Plan had reduced emissions from English agriculture by 1MtCO_2e since its implementation.

8. Transport

Background

Non-CO_2 emissions are a very small fraction of all transport emissions at around 1%.

- The major contributor is road transport N_2O emissions, representing 92% of non-CO_2 transport emissions. These emissions had been falling since the mid-1990s, though have started to increase since 2010. This is due to the upward trend in diesel emissions just beginning to take over from the downward trend in petrol emissions.
- CH_4 road transport emissions have been decreasing since 1990 due to increasing European standards on emissions from new road transport vehicles.
- Aircraft support vehicles, which represent 5% of non-CO_2 transport emissions, have been on an upward trend with the exception of a dip after the recession and are now more than double the emissions seen in 1990.
- The remaining transport emissions are from domestic aviation and military vehicles.

How we project emissions

Road transport emissions projections follow a bottom up calculation methodology in line with that used to calculate the historical time-series of emissions. The activity data - vehicle distance travelled - is projected using 2015 DfT traffic forecasts (**DfT, 2015b**).

Aircraft support vehicle projections are based on forecasts of the number of UK airport terminal passengers and the driver for domestic aircraft activity is DfT's air traffic movement projections (**DfT, 2013**). Military transport emissions are projected to be constant.

9. LULUCF

Background

It should first be noted that when considering all emissions (CO_2 and non-CO_2), the Land Use, Land Use Change and Forestry (LULUCF) sector is an emissions sink. However, the non-CO_2 component is a source of emissions. The major contributor is direct N_2O emissions from changes in soil decomposition following the disturbance of soil in land conversion. Other N_2O emissions are the result of drainage of organic soils, biomass burning and the application of nitrogen based fertiliser to forested land.

Methane is a comparatively small contributor to overall emissions from LULUCF contributing only 2% of non-CO_2 LULUCF emissions. Emissions of CH_4 are driven by wildfires and deforestation through controlled burning, both of which have large inter-annual variability.

How we project emissions

LULUCF emissions projections are produced by the Centre for Ecology & Hydrology (CEH) and Forest Research on the basis of assumptions applied to the current inventory methodology. Four scenarios (Baseline, Central, High and Low) are produced and the assumptions regard afforestation, wildfires, peat extraction, land use change and deforestation. The scenarios were developed by a policy maker stakeholder group and have been updated in 2016 following discussions with all of the UK devolved administrations. Broadly, the Central scenario is a continuation of current policies and activity rates and is the scenario used in generating emissions projections for the purpose of this report.

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