



Department for
Business, Energy
& Industrial Strategy

PROJECTED EMISSIONS OF NON-CO₂ GREENHOUSE GASES

April 2019



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Executive summary

This report presents the methodology used in the non-CO₂ projections. The non-CO₂ gases are methane (CH₄), nitrous oxide (N₂O) and the fluorinated gases (HFCs, PFCs, SF₆ and NF₃). 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, 2018a) which form the baseline for these projections undergo annual updates to comply with the 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-CO₂ emission sources covered by this publication

The projections cover the **non-CO₂** component of the Kyoto Protocol's basket of greenhouse gases, which we refer to as the 'non-CO₂ GHGs'. These gases are:

- Methane (CH₄)
- Nitrous oxide (N₂O)
- Hydrofluorocarbons (HFCs) *
- Perfluorocarbons (PFCs) *
- Sulphur hexafluoride (SF₆) *
- Nitrous trifluoride (NF₃) *

* The HFCs, PFCs, SF₆ and NF₃ are also collectively known as 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 and published up to 2035.
- Emissions are presented in CO₂ equivalent (CO₂e), according to Global Warming Potentials 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, 2018a). 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, 2018b). At the time of modelling, the most recent full year of data was 2016 (published February 2018).

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 (CH₄)** – CH₄ represents the majority of non-CO₂ GHG emissions, at 58% in 2016¹. The agriculture sector as a whole accounted for 51% of all CH₄ emissions that year, while the waste management sector accounted for around 35%. The remaining CH₄ emissions are largely attributed to fugitive energy emissions.
- **Nitrous oxide (N₂O)** – N₂O represented 24% of non-CO₂ GHG emissions in 2016. The majority of N₂O emissions (68%) were attributed to the agriculture sector. Waste, transport, energy supply, business and LULUCF sectors make up the rest with minor contributions from the industrial processes and the residential sectors.
- **F-Gases (HFCs, PFCs, SF₆ and NF₃)** – HFCs represented 17% of non-CO₂ GHG emissions in 2016, while PFCs, SF₆ and NF₃ represented about 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. SF₆ emissions are largely attributable to electrical insulation. NF₃ emissions are all attributable to electronics.

¹ All inventory figures within the body of this report and used for modelling are from the inventory data published in February 2018, which was the most recently published at the time of modelling.

The latest data and further details on the breakdown of each of these gases to specific activities over the period 1990-2017 can be found in the latest National Statistics release (BEIS, 2019).

The UK has both international and domestic targets for reducing greenhouse gas emissions. These targets encompass all GHG emissions, not just the non-CO₂ component projected in this report. BEIS's Updated Energy and Emissions Projections report (BEIS, 2018c) provides more information on the UK's complete GHG emissions projections in comparison with targets.

2. Projections methodology

2.1 Overview of methodology

Baseline

Emissions statistics based on the 2018 GHG Inventory Submission (GHGI), the estimate of the UK's historical GHG emissions from all anthropogenic sources, are used as the baseline for these projections (BEIS, 2018c). 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 (t) detailing emissions from each source from 1990 to year $t - 2$ (e.g. the GHGI produced in 2018 provides emissions from 1990-2016). This means that the base year for these projections is 2016, as that was the most recent full year of data available at the time of modelling.

The historical emissions estimates are revised each year to account for new information that becomes available, and for methodological improvements. The data and compilation methods used in the GHGI are reviewed annually (BEIS, 2018b). The most notable specific changes to this year's GHGI are (BEIS, 2018d):

- Implementation of a new shipping model;
- Development of devolved administration specific models for residual waste;
- Updated proportion of harvested wood products allocated to semi finished wood products;
- Agriculture emissions updated to more accurately reflect the UK agriculture sector as part of the Defra Smart Inventory Programme;
- Changes to emissions from forest land mainly as a result of updated CARBINE modelling.

Overall impact on emissions

In total, the changes made to the methods and data for the 2018 inventory submission have led to a decrease in total 2015 emissions (the latest year for which a comparison can be made) by 3.4 MtCO_{2e}.

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 (2016 at the time of modelling) up to 2050 to form the BEIS non-CO₂ GHG projections. Given the disparate nature of the emission sources in scope, the methodologies used to define the projections are wide-ranging. The drivers of 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 two 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, 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-CO₂ 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** policies and measures are closed policies that still provide legacy carbon savings;
- **Implemented** policies and measures are those for which one or more of the following applies:
 - (i). national legislation is in force;
 - (ii). one or more voluntary agreements have been established;
 - (iii). financial resources have been allocated;
 - (iv). human resources have been mobilised.
- **Adopted** policies and measures are those for which an official Government decision has been made and there is a clear commitment to proceed with implementation;
- **Planned** policies and measures are options under discussion with a realistic chance of being adopted and implemented in future.

An 'existing policies' scenario includes all currently expired, implemented and adopted policies. A 'reference' scenario includes all the above policies, plus planned policies. As no planned policies are included in the non-CO₂ projections they are both an 'existing policies' scenario and a 'reference' scenario.

The policies that we have explicitly included in the projections are:

- F-gas regulations (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)
- The Climate Change Plan (Scottish Gov, 2018)
- Climate Change Strategy for Wales (Welsh Gov, 2016)

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-CO₂ 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, SF₆ and NF₃.

Compared to 1990, emissions of HFCs were 5% higher in 2016 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 time series low of 9.8 MtCO_{2e}, when abatement equipment was applied to plants that produce halocarbons. In 1990, F-gas 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 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 for the historical emissions calculation. Then we apply the assumptions from the 2014 F-Gas regulation, the most important of which is the HFC phase down which caps the amount of HFCs 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.

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- **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 (SF₆)** — 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 / SF₆ / NF₃)** — We project constant emissions due to limitations of the historical data.
 - **AWACS (SF₆)** — We project constant emissions in line with historical data.
 - **Training shoes (PFCs / SF₆)** — 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 (SF₆)** — Emissions are very small and are projected to be constant.
 - **Tracer gas (SF₆)** — We project constant emissions based on the last two years in the GHGI.

4. Industrial Processes, Residential & Business (CH₄ / N₂O)

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 with 1990 levels.

In recent years, N₂O emissions from industrial off-road machinery and anaesthetic use have been the dominant CH₄ / N₂O emission source in the industrial processes, business and residential sectors.

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

- **Fletton brick manufacture** CH₄ 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** CH₄ / N₂O emissions have risen continually since 2004, though emissions are still very small.
- **Accidental fires** CH₄ emissions are very small and have decreased since 1990, though they have levelled out more in recent years.
- **House & garden machinery** CH₄ / N₂O emissions have decreased due to a reduction in the CH₄ emission factor which dominates over the increase in machinery usage.

How we project emissions

- **Industrial machinery (CH₄ / N₂O)** – Activity data are projected using EEP industrial economic drivers, and emission factors are projected by a simple vehicle turnover model.
- **House & garden machinery (CH₄ / N₂O)** – Activity data are projected using projected household numbers from DCLG (DCLG, 2014) and emission factors are projected by a simple vehicle turnover model.
- **Nitric acid production (N₂O)** – 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 (CH₄)** – We now project Fletton brick emissions using a simple 1:1 scaling with an index for CO₂ emissions from total brick manufacturing in the UK from the 2016 EEP.

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- **Household composting / Accidental fires** – We project these emissions sources as constant from the latest GHGI year.
 - **Anaesthetic use (CH₄ / N₂O)** – We project this using the EEP's Population driver, based on the methods used in GHG Inventory (BEIS, 2018b). Anaesthetic use estimates 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 CH₄ source in the GHGI outside of the agriculture and waste sectors, comprising approximately 7% of all CH₄ emissions in 2016. Methane emissions from coal mining and handling also made a substantial contribution of around 1%. Methane emissions from leakage from the gas distribution network and methane emissions from coal mining and handling comprised around 66% of non-CO₂ emissions from the energy sector. Energy sector non-CO₂ emissions were approximately 29 MtCO₂e lower in 2016 than in 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-CO₂ emissions are underpinned by economic demand. Further details about this can be found in BEIS's Updated Energy and Emissions Projections report (BEIS, 2018c).

How we project emissions

- **Closed coal mines (CH₄)** — We use a model developed by WSP in 2011 (WSP, 2011) 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 about the closure dates of some mines and changes to the inventory calculation for these emissions.
- **Coal mining (CH₄)** — We project coal mining emissions to be constant based on expert advice from the Oil & Gas Authority. Deep-mined coal production virtually ceased in 2017 while surface mining could continue almost indefinitely, given no policy input.
- **Charcoal/coke/solid-smokeless fuel production (CH₄)** — These are very small sources of emissions. 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 (CH₄)** — Here, reduction in emissions 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, when the 30-year programme ends, and then set as constant post 2032 for gas leakage from natural gas supply and transmission. 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. Gas leakage at point of use is now projected using EEP index for 'CO₂ emissions from Domestic gas use' following consultation with GHG inventory experts.

6. Waste

Background

The major source of emissions from this sector is CH₄ from landfill sites, which contributed 16% of all non-CO₂ emissions in 2016. CH₄ and N₂O emissions from wastewater treatment and non-household composting 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 in 2016 were approximately 76% lower than when 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 since 2000. Emissions from BWT processes —composting (excluding household 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 (CH₄)** — Tonnes 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 2018 GHGI report (BEIS, 2018b).
- **Wastewater treatment (CH₄ / N₂O)** — 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 (CH₄ / N₂O)** — A projection model was created in 2018 to improve projections from this sector. The model includes extension of existing anaerobic digestion ammonia projections to cover GHG emissions up to 2050 and utilises expert knowledge from Defra waste experts. The model includes the impact of relevant policies, such as the Circular Economy Package recycling targets and evidence base for composting and mechanical biological treatment projections.
- **Incineration without energy recovery (CH₄ / N₂O)** — We project constant emissions using the 5-year historical average.
- **Sewage and sludge decomposition (CH₄ / N₂O)** — Emissions projections are driven by ONS population projections (ONS, 2015). Private systems CH₄ 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 CH₄ and N₂O respectively. CH₄ and N₂O 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 2030², 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. The FAPRI projections for 2018 were not available at the time of modelling, so we have used the same outputs as last year. This means that the projections do not currently incorporate the updates from the Defra Smart Inventory programme. This is a temporary change and will be rectified in the next update to these projections.

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 3 MtCO_{2e} by 2022, has been included. Monitoring by Defra suggests that from its implementation to 2015, the Action Plan had reduced emissions from English agriculture by 1 MtCO_{2e}. Additionally this year we have also included policies from Climate Change Strategy for Wales (reduce emissions 0.2 MtCO_{2e} by 2020) and the Climate Change Plan from Scotland (reduce emissions by 0.8 MtCO_{2e} by 2032 with savings starting in 2021).

² Note that we flat line post 2030 in the absence of activity data projections.

8. Transport

Background

Non-CO₂ emissions are a very small fraction of all transport emissions, at around 1% in 2016.

- The major contributor is road transport N₂O emissions, representing 84% of non-CO₂ 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.
- CH₄ road transport emissions have been decreasing since 1990 due to increasing European standards on emissions from new road transport vehicles.
- The remaining transport emissions are from aircraft support vehicles, 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 (CO₂ and non-CO₂), the Land Use, Land Use Change and Forestry (LULUCF) sector is an emissions sink. However, the non-CO₂ component is a source of emissions, albeit a relatively small source (approximately 1.5 MtCO₂e in 2016). The major contributor is direct N₂O emissions from changes in soil decomposition following the disturbance of soil in land conversion. Other N₂O 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-CO₂ LULUCF emissions in 2016. Emissions of CH₄ 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. Five scenarios (Two Baseline scenarios, 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 2018 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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