Department for
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& Industrial Strategy

UPDATED ENERGY AND EMISSIONS PROJECTIONS 2017

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Any enquiries regarding this publication should be sent to us at emissionsprojections@beis.gov.uk.

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Executive summary

Achieving clean growth, while ensuring an affordable energy supply for businesses and consumers, is at the heart of the UK's Industrial Strategy.

The UK has been among the most successful countries in the developed world in growing our economy while reducing emissions, and the recently published Clean Growth Strategy[1] sets out ambitious policies and proposals to meet our carbon reduction targets while seizing the opportunities of clean growth.

To support our work on clean growth, BEIS produces projections of UK energy demand and greenhouse gas emissions, currently up to 2035.

The analysis set out in this report shows that the UK's projected performance against our carbon budgets has improved. BEIS's current estimated projection for the fourth and fifth carbon budgets suggests that we could deliver 97 per cent and 95 per cent of our required performance against 1990 levels – for carbon budgets which will end in ten and fifteen years' time respectively.

The central projections[2] detailed in this report include policies which are categorised as implemented, adopted or planned. Further detail of these categories is given in Chapter 1. The projections are based on policy analysis from July 2017 and power sector modelling from September 2017. Potential savings from a subset of policies in the Clean Growth Strategy are included in Table 2.1 on page 19, and the full impact of new policies and proposals from the Clean Growth Strategy will be included in future EEP editions when they are developed more fully[3].

Other key projections in the report are that:

- trends in total primary energy demand are similar to the 2016 projections, falling 11% between 2016 and 2025, from 201 to 179 million tonnes of oil equivalent (Mtoe), before rising again to 193 Mtoe in 2035.
- in the power sector, the central projection shows greenhouse gas emissions falling by 53% between 2015 and 2020.

[1] Clean Growth Strategy: published in October 2017. https://www.gov.uk/government/publications/clean-growth-strategy
[2] The report and annexes contain outputs from projections under a number of different macro-economic assumptions. All of these include implemented, adopted and planned policies except the "baseline" projection which projects energy and emissions in the absence of policies, and the "existing policies" projection which excludes planned policies.
[3] The Clean Growth Strategy quoted the latest available projections at the time of publication (EEP 2016).

The changes to our projections are due to updates to a range of data and assumptions – these include updates to 2016 actual data on energy demand and temperature, and the higher assumptions for fossil fuel price projections as compared to those used in EEP 2016.

As set out in the Clean Growth Strategy, we will in future also track our progress through annual publication of our Emissions Intensity Ratio.

1 Introduction

- This report contains projections of performance against UK greenhouse gas (GHG) targets under existing policies.
- Legally binding carbon budgets are set for five year periods and are aimed at reducing emissions by at least 80% by 2050.
- Performance against carbon budgets is measured by the net carbon account (see Box 1 in Chapter 2) and primarily depends on the level of non-traded emissions. These are emissions not covered by the European Union Emissions Trading System (EU ETS).
- The carbon budgets periods are: 2008 to 2012 (CB1); 2013 to 2017 (CB2); 2018 to 2022 (CB3); 2023 to 2027 (CB4); and 2028 to 2032 (CB5).
- The fifth carbon budget (CB5) was approved by Parliament in summer 2016.
- The Government published its Clean Growth Strategy in October 2017.

About this document

Since the late 1970s, the Government has published projections of UK energy demand and supply, and in the 1990s these were extended to include projected carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions as well. The Department for Business, Energy & Industrial Strategy (BEIS) is responsible for publishing these projections annually. This is the latest report in a series, providing up-to-date projections to 2035.

The main projection is the 'reference case', which is one view of how the UK energy and emissions system could evolve if implemented, adopted and agreed[4] Government policies were implemented but no new policies or changes to existing policies were introduced.

This report sets out the 2017 projections, with a comparison against the projections published for 2016 (EEP 2016, published in March 2017) and explanations of differences between these (mainly focusing on changes in the fourth and fifth carbon

[4] By agreed policies, we mean policies which are at the point that policy-specific analysis has been published with sufficient detail for inclusion in the Energy and Emissions Projections (EEP).

budget periods). The projections bring together statistical and modelled information from a wide variety of different sources[5]:

- The main source of energy consumption data is the annual Digest of UK Energy Statistics (often referred to as DUKES). The most recent full year of data is 2016 (published July 2017), so all DUKES figures in this report are quoted against a comparison year of 2016.
- The main source of emissions statistics is the Greenhouse Gas Inventory, updated each February. The most recent full year of data is 2015, so all Inventory figures in this report are quoted against a comparison year of 2015.
- To produce these projections, these data sets are combined with economic data (for example, GDP projections from the Office for Budget Responsibility) to update equations that project forward energy demand and emissions in the absence of policy.

The main model used is the Energy Demand Model (EDM), which is a mixed (top down/bottom up) econometric model of energy demand and combustion related greenhouse gas (GHG) emissions for the UK economy. It is run in combination with other BEIS models which model retail electricity prices and the electricity supply sector.

This generates projections of primary and final energy demand by year, economic sector and fuel. The following 'non-energy-related' GHG emissions are projected by other Government departments and external bodies and then added to the EDM projections:

- Emissions from agriculture and waste;
- Emissions from Land Use, Land Use Change and Forestry (LULUCF).

This report helps to assess the UK's progress towards its own targets for GHG emissions. The targets were introduced by the 2008 Climate Change Act, which established a long-term target for the UK to reduce its net emissions in 2050 by at least 80% compared to 1990[6]. The Act also established a system of legally binding limits on the net amount of GHGs that can be emitted. These are called carbon budgets[7]. Each carbon budget spans five years and is set with a view to keeping the UK on track to its 2050 target. The UK Parliament approved the level of the fifth carbon budget[8] in summer 2016. Chapter 2 assesses the UK's progress towards

[5] Energy and emissions projections: https://www.gov.uk/government/collections/energy-and-emissions-projections
[6] Compared with a base year of 1990 for CO_2, CH_4 and N_2O, and 1995 for fluorinated gases: https://www.legislation.gov.uk/ukpga/2008/27/contents
[7] See page 142 of the Clean Growth Strategy for more background on carbon budgets: https://www.gov.uk/government/publications/clean-growth-strategy
[8] Fifth carbon budget order: http://www.legislation.gov.uk/uksi/2016/785/made

these carbon budget obligations and gives an overview of emissions by different economic sectors.

The UK Government develops and implements policies with the aim of reducing GHG emissions in line with the carbon budgets and current international commitments. These projections indicate the broad scale of action that may be needed to keep emissions within the carbon budgets. This is the subject of Chapter 3. These projections include policies mentioned in the Clean Growth Strategy if they were classed as implemented, adopted or agreed at the cut-off point of July 2017. In addition, table 2.1 shows projected performance against carbon budget targets, and provides an updated version of the Clean Growth Strategy's summary of performance against carbon budgets with the initial estimates of new early stage policies and proposals included. As the range of other policies and proposals are developed, their impacts will be included as appropriate in future projections.

Emission estimates are underpinned by projections of the future demand for energy. Chapter 4 sets out final and primary energy use projections to 2035 and includes a discussion of trends within the key consuming sectors.

Chapter 5 sets out the projections for the electricity sector, and briefly reviews the influence of this sector's activity on wider emissions.

Finally, Chapter 6 summarises some of the sources of uncertainty in these projections. It explains the methodology which was used to estimate the lower and upper confidence interval for the 2017 Energy and Emissions Projections.

The reference case and other scenarios

The main projection presented in this report is the BEIS 'reference case' or central projection. The reference case is based on central projections for the key drivers of energy and emissions, such as fossil fuel prices, Gross Domestic Product (GDP) and population. Projections of emissions outside of the power sector are based on applying standard statistical techniques to project forward energy demand and emissions based on trends and relationships identified in past data. These are adjusted to take account of the estimated impact of implemented, adopted and agreed (as at July 2017) Government policies.

Electricity demand is also projected forward using statistical techniques and adjusted for the impact of existing policies that impact on electricity demand. However, the projection of electricity generation is based on a model of supplier behaviour rather than statistical analysis of past trends. It also only reflects current policy up to 2020. Beyond 2020, the electricity generation scenario includes assumptions that go beyond current Government policy, and is therefore illustrative. The reference electricity generation scenario therefore represents one particular view of how the system could evolve and is not a forecast or preferred scenario.

Chapter 3 discusses policy impacts on emissions, and for this the 'reference' scenario is compared against a 'baseline' scenario which excludes the impact of all climate change policies brought in since the 2009 Low Carbon Transition Plan[9] (LCTP).

Besides the reference and baseline scenarios, the annexes to this report also set out the following additional scenarios:

- low and high fossil fuel price scenarios;
- low and high economic growth scenarios;
- an 'existing policies' scenario which only includes policies that have been implemented or adopted (but not planned policies).

For all these scenarios, other views of the future are possible and there are significant uncertainties in these projections. Some of this uncertainty is captured in our projections modelling and presented in this report, but not all of it (see Chapter 6).

Details of changes to the projections methodology

Since the EEP 2016 projections (published in March 2017), the BEIS modelling team have concentrated on updates to the projections methodology and quality assurance. In particular, improvements were made to Combined Heat and Power (CHP) modelling and the calculation of traded shares. As in all years, the model was updated to use the most recent actual emissions data (2015 inventory[10]), energy statistics (DUKES) and the macro-economic projections available at the time the projections were calculated.

The methodological and reporting changes in the 2017 projections are:

[9] The Low Carbon Transition Plan publication is available at: https://www.gov.uk/government/publications/the-uk-low-carbon-transition-plan-national-strategy-for-climate-and-energy

[10] EEP 2017 uses historic (inventory) GHG emissions data to 2015 and projected emissions from 2016.

- Modelling of Combined Heat and Power (CHP) plants has been incorporated within BEIS's "Dynamic Dispatch Model" of the wider power supply sector[11]. CHP had previously been projected using a separate model. The new approach enables projections to be made in the context of the whole electricity market and facilitates projections beyond 2030. It also ensures that interactions between CHP and the wider power sector are taken into account.

- Final energy demand (Annex F) no longer includes fuel used to make heat which is sold as steam or hot water (for example, by CHP plants).[12] Primary energy demand (Annex E) continues to include fuel used for heat generation. This contributes around 1.4% of primary energy in 2020.

- The methodology for calculating the proportion of UK emissions traded under the EU Emissions Trading System (EU ETS) has been modified so that a consistent approach is used across all policies. Previously the method used bespoke estimates of the 'traded share' of future emissions savings for individual policies. Under this approach it had not been possible for all policy teams to calculate impacts in a way consistent between policies and with the EEP reporting methodology. Direct traded and non-traded emissions savings for all policies are now estimated jointly as part of the EEP production process, and are projected forward in each industrial subsector assuming a constant split between the traded and non-traded sectors, using latest evidence on current proportions. This means they are now consistent with EU ETS verified emissions.

- In previous years' EEPs all power station emissions were projected as traded under the EU ETS. This year, projections of emissions from 'Energy from Waste' power plants (which burn municipal waste) are accounted for as 'non-traded'.

- The EU ETS carbon price has now been included in the industry sector of the model and the equations of the minerals and chemicals sectors have been improved. This was undertaken with the help of the analytical experts at University College London (UCL) who carried out the improvements in early 2017[13].

We are continually working to improve our projections. In 2018 we intend to share more details of the methodology.

[11] For detail on the DDM see:
https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

[12] This aligns with the treatment of heat in DUKES classification (table 1.1) which lists 'heat generation' under 'Transformation' rather than 'Final consumption'.

[13] The paper is available online at :
http://www.sciencedirect.com/science/article/pii/S0140988317302943?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y

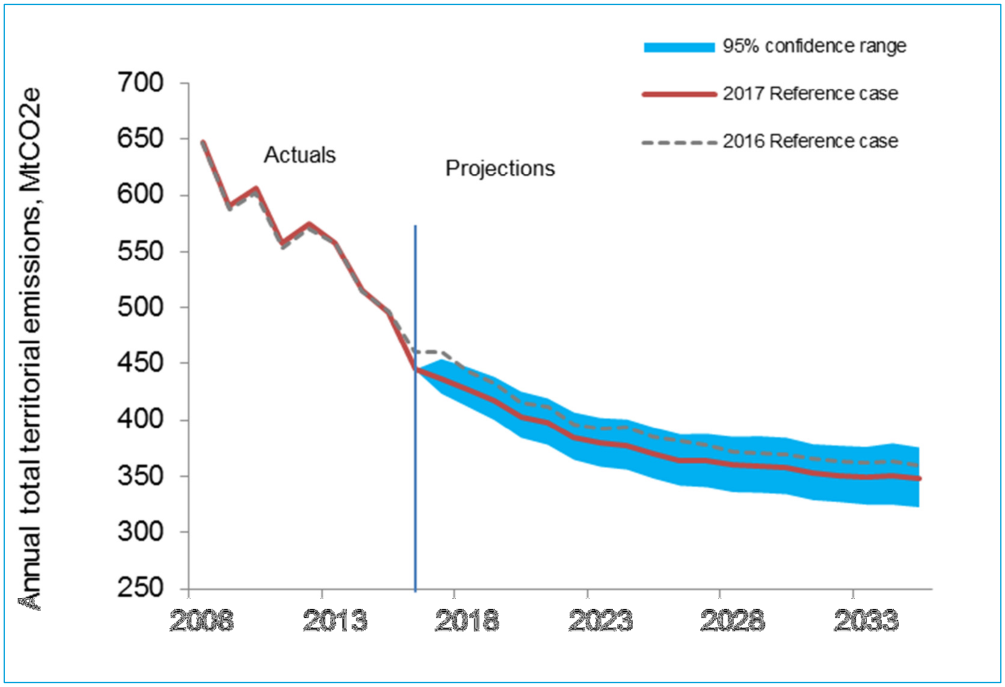
2 UK emissions projections

- By 2020, emissions are projected to be 50% below 1990 levels in the reference case (assuming implemented, adopted and agreed policies).
- The UK met the first carbon budget with headroom of 36 $MtCO_2e$, and is projected to meet the second and third carbon budgets with headroom of 125 and 143 $MtCO_2e$, respectively.
- There are projected shortfalls against the fourth and fifth carbon budgets. As policies and proposals in the Clean Growth Strategy are developed more fully, their impacts will be included as appropriate in future EEP editions.
- In EEP 2017, emissions are projected to be 3.6% lower in total over the period 2017 to 2035, compared to EEP 2016 projections. The main reason for this is the updated data for key inputs such as energy demand and temperature and fossil fuel price projections.

Figure 2.1 shows actual and projected UK territorial emissions. These projections are very uncertain. For example, societal and behavioural trends and breakthrough technologies could have profound impacts on our energy mix and emissions, but are impossible to fully anticipate.

Some of this uncertainty is captured in our projections modelling, but not all of it. The uncertainty we have been able to model is shown as a fan chart around the central reference case projections, and is higher for the later years. Chapter 6 discusses different sources of uncertainty, how this is captured in the projections modelling, and the methodology used for uncertainty analysis.

Figure 2.1: Uncertainty in projected overall territorial emissions



Comparison to the 2016 projections

Overall, projected emissions are lower in the 2017 projections than 2016[14]. For example, over the fourth carbon budget period (2023-27 inclusive), projected territorial emissions are 78 MtCO_2e (4%) lower than in the 2016 projections. There are a number of reasons that, together, explain most of this difference.

Key drivers reducing projected emissions for the fourth and fifth carbon budget periods:

- **Updated data for key inputs:** The projections are dependent on inputs such as GDP assumptions, temperature and fossil fuel prices, and can therefore fluctuate considerably from year to year.
    - **Winter degree days:** The inclusion of 2016 actual data on energy demand and temperature (winter degree days[15]) caused the projections of

[14] Energy and emissions projections 2016: published in March 2017 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016

[15] Winter degree days are the number of degrees the external temperature is below 15.5 degrees Celsius on any one particular day summed over all the days in a season. Cold weather in winter has a big impact on energy use, particularly in the residential and service sectors. This is why estimates of Winter degree days are included in the modelling.

future heating requirements to be revised downward for domestic and services energy demand.

- **Fossil fuel prices:** For the residential and industry sectors, emissions have reduced due to the higher assumptions for fossil fuel prices compared to those used in EEP 2016. Higher fossil fuel prices generally have an effect of dampening energy demand.

Some less significant drivers which slightly increase projected emissions for the fourth and fifth carbon budget periods:

- **Iron and Steel**: Compared to EEP 2016, emissions in the Iron and Steel sector are projected to rise by 8 $MtCO_2e$ in the fourth carbon budget period. This is due to improved projections processes, which corrected a potential misalignment affecting this sector in EEP 2016.
- **Land Use, Land Use Change and Forestry (LULUCF)**: Compared to EEP 2016 there is a slight decrease in the projected removals of greenhouse gases due to LULUCF. This is due to updated modelling of forest carbon stocks in soils and litter and new data on settlement expansion which have been used to revise the model. This also affects historical years.

Key drivers which shifted the classification of some emissions include:

- **Energy from waste:** In previous editions of EEP, all power station emissions were projected as traded under the EU ETS. This year, projections of emissions from 'Energy from Waste' power plants are now accounted for as 'non-traded', bringing this into line with the ETS directive[16]. This resulted in a shift of 11 $MtCO_2e$ of power sector emissions from the traded to non-traded sector for the fourth carbon budget period.

- **Allocation of policy savings to traded sector:** To produce projections of the net carbon account and hence progress against carbon budgets, the EEP apportions industry and services emissions into traded and non-traded for reporting purposes. An improvement in the methodology this year[17] led, in general, to a higher allocation of policy savings to the traded sector than to the non-traded sector. The new methodology aims to provide improved aggregated policy savings and is now based on historic EU ETS data[18]. However since it is

[16] See annex I of the ETS directive, available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02003L0087-20140430&from=EN.
[17] Traded share estimates for policies had previously been provided by policy experts, however, the average traded share of the sector, based on historic verified EU ETS data, is now used.
[18] Traded share estimates for policies had previously been provided by policy experts, however, the average traded share of the sector, based on historic verified EU ETS data, is now used.

not tailored to each specific policy, sector splits may not match those presented in individual policy impact assessments.

Progress towards the carbon budgets

The Energy and Emissions Projections are one measure of the UK's progress towards future targets for GHG emissions. The 2008 Climate Change Act established a long-term target for the UK to reduce its net emissions in 2050 by at least 80% compared to 1990[19]. The Act also established a system of legally-binding carbon budgets which limit the net amount of GHGs that can be emitted in successive five-year periods, starting in 2008[20].

The first carbon budget covered the period 2008 to 2012 and the UK met this budget with headroom of 36 $MtCO_2e$. Budget levels have been set for four further periods: 2013 to 2017 inclusive, 2018 to 2022, 2023 to 2027, and 2028 to 2032.

In 2016, the Government set the level of the fifth carbon budget (2028-32) in agreement with advice from the Committee on Climate Change, at a level of 1,725 $MtCO_2e$, equivalent to an average 57% reduction on 1990 emissions.

In October 2017, the Government published its Clean Growth Strategy, setting out policies and proposals for meeting future carbon budgets and illustrative pathways for the 2050 target[21]. Table 2.1 shows projected performance against carbon budget targets, and provides an updated version of the Clean Growth Strategy's summary of performance against carbon budgets[22] with the initial estimates of new early stage policies and proposals included.

[19] Compared with a base year of 1990 for CO_2, CH_4 and N_2O, and 1995 for fluorinated gases: https://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/

[20] For more details on the UK's climate change targets, including the carbon budgets, see: https://www.gov.uk/guidance/carbon-budgets

[21] Clean Growth Strategy: published in October 2017. https://www.gov.uk/government/publications/clean-growth-strategy

[22] The Clean Growth Strategy quoted the latest available projections at the time of publication (EEP 2016). Emissions projections from the Clean Growth Strategy are therefore not directly comparable to the projections within this report.

Box 1: The UK net carbon account

Compliance with the budgets is assessed by comparing the UK "net carbon account"[1] (NCA) against the carbon budget level. The NCA is currently defined as the sum of three components: 1) emissions allowances allocated to the UK under the EU Emissions Trading System (EU ETS), 2) UK emissions not covered by the EU ETS; 3) credits/debits from other international crediting systems.

1. Emissions covered by the EU ETS, or "traded sector emissions" generally include those from power generation and from large energy-intensive industrial plants. For the net carbon account, traded sector emissions are measured as the UK's allocation of allowances under the EU ETS. To project future carbon budget performance the level of allocation must be estimated. The levels used are based on the assumed shares at the time of setting the respective carbon budgets, as the UK's actual future shares are not fully known at this stage. Projections for the actual level of allocation covered by the EU ETS can be found in the web tables.
2. "Non-traded emissions" include all UK GHG emissions which are not covered by the emissions trading system (EU ETS). For example, this includes road transport, heating in buildings, agriculture, waste and some industry. For EEP 2017, projections of emissions from 'Energy from Waste' power plants are now accounted for as 'non-traded', bringing this into line with the ETS directive[1].The UK net carbon account reflects the actual emissions from the UK in those sectors.
3. Credits/debits are also included from other international credit systems.

On 23 June 2016, the EU referendum took place and the people of the United Kingdom voted to leave the European Union. Until the date of exit, the UK remains a full member of the European Union and all the rights and obligations of EU membership remain in force. While exit negotiations remain in progress, the Energy and Emissions Projections are produced on that basis.

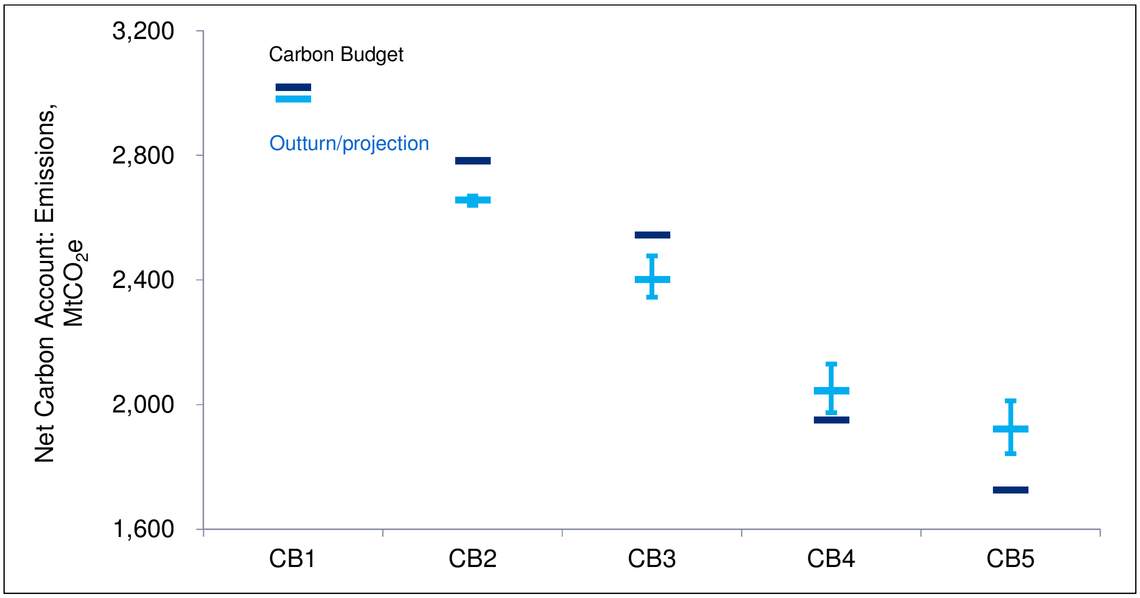
Performance against carbon budgets is measured by the UK net carbon account – described in Box 1. Figure 2.2 and Table 2.1 show the actual and projected performance against legislated carbon budgets. The range presented in the projected net carbon account is the 95% confidence interval for uncertainties that have been modelled. Chapter 6 gives more details on how this uncertainty analysis was carried out, and Table 6.1 summarises the variables considered in this uncertainty analysis. This does not capture all sources of uncertainty or the full range in uncertainty (discussed in Chapter 6).

The UK met the first carbon budget with headroom of 36 $MtCO_2e$, and is projected to meet the second carbon budget with headroom of 125 $MtCO_2e$ (range: 112 to 142 $MtCO_2e$)[23] and the third carbon budget by 143 $MtCO_2e$ (range: 66 to 200 $MtCO_2e$).

There are projected shortfalls for the fourth carbon budget. These projections are highly uncertain and only some of this uncertainty is captured in modelling and presented in the ranges here (see Chapter 6).

The chart below (Fig 2.2) shows cumulative values over five year periods from 2008 to 2027.

Figure 2.2: Actual and projected performance against carbon budgets, $MtCO_2e$



Vertical bars show uncertainty in the projections and indicate 95% confidence intervals for the central reference scenario.

Progress against future carbon budgets is projected to be as follows:

- The 2017 projections show that the second and third carbon budgets, covering 2013 to 2022, are likely to be achieved. Uncertainty analysis indicates that even the highest emission scenario (based on the upper 95% confidence interval) would be within these carbon budgets. The reference case projection would meet the second carbon budget with a margin of 125 $MtCO_2e$ and the third carbon budget with a margin of 143 $MtCO_2e$.

[23] For the CB2 period (2013-2017) and beyond, the UK net carbon account is based on estimates of the proportion of emissions which are traded within the EU ETS.

- For the fourth carbon budget (2023 to 2027), the UK's emissions are currently projected to be greater than the cap set by the budget, so a shortfall remains against this target. Taking into account the uncertainty around the projections, this shortfall could be as low as 23 $MtCO_2e$ or as high as 180 $MtCO_2e$[24]. However the size of this shortfall has reduced since the 2016 projections: in the 2016 projections, the reference case shortfall was 146 $MtCO_2e$, but this has fallen to 94 $MtCO_2e$.

- Many policies which will affect the 2020s and beyond have not yet been developed to the point at which they can be included in these projections[25].

In October 2017, the Government published its Clean Growth Strategy, setting out policies and proposals for meeting future carbon budgets and illustrative pathways for the 2050 target[26]. Table 2.1 provides an updated version of the Clean Growth Strategy's summary of performance against carbon budgets[27] with the initial estimates of a subset of new early stage policies and proposals included.

The Clean Growth Strategy used the latest available projections at the time of publication (EEP 2016). Projected performance against carbon budgets has improved compared to the EEP 2016 projections. The gap between projected performance and targets (before Clean Growth Strategy policies and proposals) has narrowed by 52, 53 and 51 $MtCO_2e$ in the third, fourth and fifth carbon budgets respectively, before new policies from the Clean Growth Strategy are taken into account.

The updated projections for the fourth and fifth carbon budgets (including estimates of emission reductions from a subset of Clean Growth Strategy policies and proposals) suggests that we could deliver 97 per cent and 95 per cent of our required performance against 1990 levels – for carbon budgets which will end in ten and fifteen years' time respectively. As policies and proposals in the Clean Growth Strategy are developed more fully, their impacts will be included as appropriate in future EEP editions.

[24] In the 2016 projections this fourth carbon budget period shortfall was projected to be between 103 and 236 $MtCO_2e$.
[25] Within the main EEP projections, policies are included if they are either currently implemented or firmly planned in the future i.e. policies which are still under development are not included.
[26] Clean Growth Strategy: published in October 2017. https://www.gov.uk/government/publications/clean-growth-strategy
[27] The Clean Growth Strategy quoted the latest available projections at the time of publication (EEP 2016). Emissions projections from the Clean Growth Strategy are therefore not directly comparable to the projections within this report.

Table 2.1 shows performance against the carbon budgets, after inclusion of the initial estimates of potential reductions from a subset of policies and proposals in the Clean Growth Strategy[28]. These projections are based on the EEP reference case (central assumption) as defined in chapter 1.

Table 2.1: Performance against carbon budgets, $MtCO_2e$

		Carbon budget:	1 (2008-12)	2 (2013-17)	3 (2018-22)	4 (2023-27)	5 (2028-32)
			Actual	**Projection**	**Projection**	**Projection**	**Projection**
Carbon Budget level, cumulative emissions			3,018	2,782	2,544	1,950	1,725
Average required reduction vs 1990 emissions, %			-25%	-31%	-37%	-51%	-57%
2016	**Existing policies**	Projected emissions, Mt	2,982	2,650	2,453	2,096	1,972
	Existing and new policies and proposals[28]	Projected emissions, Mt	2,982	2,650	2,453	2,066	1,892
2017	**Existing policies**	Projected emissions, Mt	2,982	2,657	2,401	2,044	1,921
	Existing and new policies and proposals[28]	Projected emissions, Mt	*2,982*	2,657	2,401	2,014	1,841
		Result vs. Budget, emissions, Mt	*-36*	*-125*	*-143*	*64*	*116*
		Result vs. Budget, %	-1.2%	-4.5%	-5.6%	3.3%	6.7%
		Cumulative surplus (+) or deficit (-), Mt		*+125*	*+268*	*+204*	*+88*

Non-traded emissions projections by sector

Non-traded emissions for all years are based on estimates of the proportion of emissions which are not traded within the EU ETS. All figures are total greenhouse gas emissions (CO_2e).

Overall, non-traded emissions are projected to fall from 319 $MtCO_2e$ in 2015 to 268 $MtCO_2e$ in 2035 (a fall of 16%). The projections show how different sectors of the economy[29] contribute to the total.

Figure 2.3 depicts the projected trends in sector emissions. Note that the categories here are different to those for reporting to international organisations. Annex C,

[28] Includes emissions reduction estimates of a subset of new early stage policies and proposals from the Clean Growth Strategy showing an additional potential reduction of up to 30Mt and 80Mt over the fourth and fifth carbon budget periods respectively.
[29] These are as defined in the Digest of UK Energy Statistics (DUKES), see: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

"Carbon dioxide emissions by IPCC category", contains values and definitions for these.

Industry[30]**, commercial services** and **public administration, agriculture** and **waste** contributed around 38% of non-traded emissions in 2015. This is projected to fall to around 31% by 2035.

Land Use, Land Use Change and Forestry (LULUCF) emissions are accounted for in carbon budgets. They include both sources and sinks[31] of greenhouse gases from forest land, cropland, grassland, human settlements and due to changes of land use between any of these categories[32]. LULUCF is currently a sink for atmospheric CO_2 but a source of other greenhouse gases – notably nitrous oxide caused by changes in soil decomposition following the disturbance of soil in land conversion. In 2015, this sector removed around 1.5% of total greenhouse gas emissions. This figure is projected to remain at 1.5% in 2035. Further information on non-CO_2 emissions from LULUCF can be found in Annex N of this report.

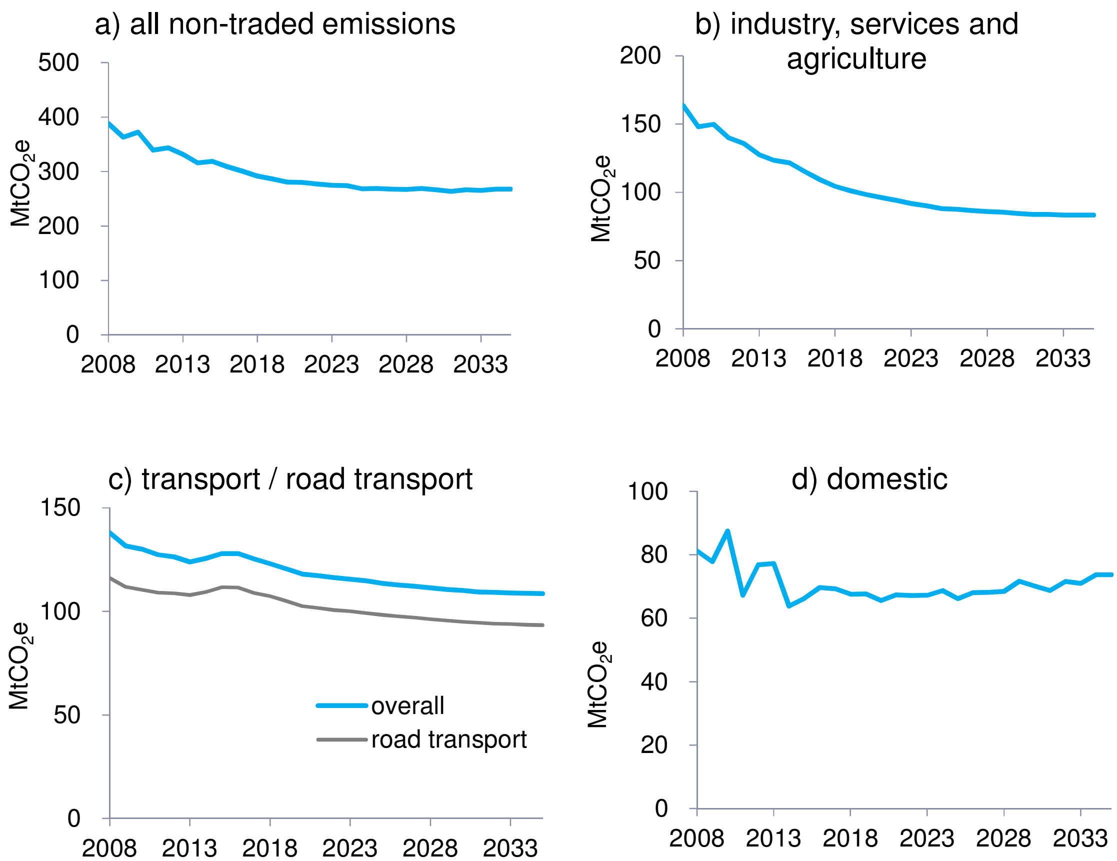
Transport, mostly road transport, contributed around 40% of UK non-traded emissions in 2015 (Figure 1.2c). The projections show a decline to 2035 (emissions are projected to fall by 15% from 2016 levels).

The **domestic** residential sector (Figure 1.2d) was responsible for 21% of non-traded emissions in 2015. All emissions from this sector are non-traded. In comparison to 2015 levels, they are projected to rise by 8 $MtCO_2e$ (11%) by 2035, and will then account for 28% of non-traded emissions.

In past editions of the EEP all **power sector** emissions were considered traded but for EEP 2017 emissions from 'Energy from Waste' (municipal waste) were excluded from the traded sector in line with ETS directive 2003/87/EC. These are projected to account for 2.4 $MtCO_2e$ (0.9% of total non-traded emissions) in 2035.

[30] This includes CO_2 emissions from agriculture due to the burning of fuels and fertiliser use.
[31] Carbon sinks are elements of the carbon system that absorb or store carbon dioxide, for example the forests and oceans.
[32] A detailed discussion of the components of LULUCF is available here: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

Figure 2.3: Non-traded emissions in the economy, $MtCO_2e$



Non-traded emissions by consumer sector, 2008 to 2035. a) All non-traded emissions, b) Industry, services and agriculture, c) Transport (road transport in grey), d) Domestic.

Annexes A and B contain detailed emission projections by sector and type of greenhouse gas. Section 4 discusses the projections of energy demand which lead to these emissions.

3 Effect of policies on emissions

- Government policies are projected to reduce non-traded GHG emissions. The projected reduction in the fourth carbon budget period is 290 $MtCO_2e$ (or about 21% of non-traded emissions in that period).
- About four fifths (81%) of the reduction in non-traded GHG emissions during the fourth carbon budget period comes from policies adopted after the Low Carbon Transition Plan (LCTP) of 2009. The remainder is from policies adopted before the LCTP.
- Overall projected policy savings in the non-traded sector are 7 $MtCO_2e$ higher than in EEP 2016 during the fourth carbon budget period due to changes in evidence, assumptions and policies. For the fifth carbon budget period, non-traded policy savings are 16 $MtCO_2e$ higher than in EEP 2016.

Policies for emissions reduction

This chapter looks at the impact of Government policies that directly influence energy use and emissions. Government estimates individual policy impacts by comparing modelled emissions from scenarios which contain a policy, against scenarios which do not. The savings from some policies cannot currently be explicitly identified, particularly in the agriculture and waste management sectors. Although not separately identifiable, these policy savings are included in the baseline, and are therefore captured in the projections. Descriptions of some policies for which GHG savings have not been quantified are given in Annex D.

These projections include policies mentioned in the Clean Growth Strategy only if they were classed as implemented, adopted or agreed at the cut-off point of July 2017. In addition the Clean Growth Strategy included an initial estimate of the savings from a further subset of planned policies showing savings of 30 $MtCO_2e$ during the fourth carbon budget period and 80 $MtCO_2e$ during the fifth carbon budget period. As the policies and proposals in the Clean Growth Strategy are further developed, their impacts will be included as appropriate in future EEP editions.

This chapter focuses on policies that produce savings in the non-traded sector since they contribute to meeting the carbon budgets (see Chapter 2, Box 1). It also includes a discussion of the Government policies which reduce emissions from electricity generation. The coverage for both traded and non-traded sectors includes all policies consistent with UNFCCC definitions, as explained on the notes tab of Annex D[33].

For this analysis, policies are grouped according to whether they were adopted before or after the Low Carbon Transition Plan (LCTP) of 2009. This was the UK's first comprehensive plan for moving to a low carbon economy.

Within this chapter, the savings refer only to policies adopted after the LCTP unless otherwise stated; estimates for these are more robust than for policies adopted before the LCTP.

Modelling of policy effects is updated regularly and any changes to assumptions will be incorporated in due course.

Table 3.1 shows that Government policies are estimated to reduce non-traded emissions by 950 $MtCO_2e$ over carbon budgets 2 to 5.

Table 3.1: Non-traded GHG emissions savings from policies, $MtCO_2e$

Carbon budget:	2 (2013 - 2017)	3 (2018 - 2022)	4 (2023 - 2027)	5 (2028 - 2032)
Savings from pre-LCTP policies	65	63	54	44
Savings from LCTP policies	48	155	235	287
Savings from all policies	112	218	290	330

The reference projection includes all *expired, implemented, adopted* and *planned* policies[34].

The following categories are used to describe the implementation status of policies, which are consistent with UNFCCC definitions:

a. Expired are closed policies that still provide legacy carbon savings;
b. 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;

[33] Annex D also displays the savings for only those policies which are beyond the planned stage. This is also known as the "with existing measures" scenario.
[34] In UNFCCC reporting standards this is known as a '*with additional measures'* (WAM) projection. In the annexes of this report, energy and emissions projections are also given without *planned* policies, a '*with existing measures'* (WEM) projection. The baseline projection excludes policies adopted since the Low Carbon Transition Plan (LCTP) of 2009.

iv. human resources have been mobilised.

c. 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.

d. Planned policies and measures are options under discussion and having a realistic chance of being adopted and implemented in future.

Changes to emissions savings since EEP 2016

Non-traded GHG savings from Government policies are projected to be slightly higher in the 2017 projections (in comparison to EEP 2016) for all years after 2020. In the third carbon budget, policy savings reduced slightly from 219 to 218 $MtCO_2e$, but in the fourth carbon budget, savings increased from 283 to 290 $MtCO_2e$ (in comparison to EEP 2016), and for the fifth carbon budget, savings rose from 314 to 330 $MtCO_2e$.

There are a number of reasons that together explain most of this change.

Key drivers increasing projected non-traded emissions savings from policies:

Transport efficiency policies: The reported savings provided by car fuel efficiency and electrification policies are higher in these projections than in EEP 2016. Non-traded savings from car efficiency policies are 58 $MtCO_2e$ in the fourth carbon budget period compared to 42 $MtCO_2e$ in EEP 2016. The main reason for this change is the removal of electric cars from the baseline to simplify analysis and align with the approach taken by the Committee on Climate Change. There is a further relatively small increase in savings resulting from higher projections of electric car usage compared to EEP 2016.

Products policy: More energy-efficient products lead to significant electricity savings but also result in a Heat Replacement Effect (HRE), requiring an increase in heating and gas consumption in order to maintain the same level of temperature. Compared to EEP 2016, the increase in non-traded emissions attributed to products policy is 4 $MtCO_2e$ lower in the fourth carbon budget period and traded emission savings are 9 $MtCO_2e$ lower over the same period. The update reflects improved evidence and updated assumptions, including to the modelling of the Heat Replacement Effect (HRE).

Key drivers reducing projected emissions savings from policies:

Traded share methodology change: To produce projections of the net carbon account and hence progress against carbon budgets, the EEP apportions industry and services emissions into traded and non-traded for reporting purposes. Traded share estimates for policy savings had previously been provided by policy experts while in EEP 2017 we have used the average traded share of the sector, based on historic verified EU ETS data. The new methodology aims to provide improved aggregated policy savings. However since it is not tailored to each specific policy, sector splits may not match those presented in individual policy impact assessments.

This has led, in general, to a higher allocation of policy savings to the traded sector than to the non-traded sector compared to EEP 2016. This means that savings estimated in the EEP may differ slightly from the individual policy appraisals.

Renewable Heat Incentive (RHI): As a consequence of using industry average traded shares rather than policy-specific traded shares of emissions, while the total projected policy savings from the Renewable Heat Incentive remain constant compared to EEP 2016, the traded savings are now 7 $MtCO_2e$ higher with the non-traded savings lower by the same amount.

As in EEP 2016, only downstream emissions savings from RHI, those from the combustion of renewable fuels instead of fossil fuels, are quantified in Annex D of the projection. Although the impacts of RHI upstream savings are included in the projection for the waste management sector, assumptions differ between modelling of RHI savings and modelling of the waste management sector as a whole, which means that the figures are not directly comparable. Upstream emissions attributable to biomethane are set out in the RHI impact assessment. Harmonisation of assumptions is on-going and will be incorporated into future projections.

Renewable Transport Fuel Obligation (RTFO): Under the implemented RTFO scenario, non-traded emissions savings from the RTFO in the fourth carbon budget period have reduced from 42 $MtCO_2e$ in EEP 2016 to 39 $MtCO_2e$ in these projections, due to updated evidence which reduced the proportion of biofuel projected in future years under the implemented RTFO. Assumptions in the reference case remain unchanged from EEP 2016. A consultation on amendments to the Renewable Transport Fuel Obligation (RTFO) has concluded. The outcome of the consultation includes amendments that will impact savings estimated for the planned RTFO. Analysis had not yet been completed (at July 2017) to incorporate planned changes into the EEP. The percentage share of biofuels in transport will be updated in future projections.

F-gas Regulation: Non-traded emissions savings due to F-gas regulation are 2 $MtCO_2e$ lower during the fourth carbon budget period than in the EEP 2016 projections. This is due to an updated assumption about the rate of decrease of hydrofluorocarbons emissions (the rate of decrease is now assumed to be slower than it was in EEP 2016).

Agricultural Action Plan: Compared to EEP 2016, policy savings for the Agricultural Action Plan only include England, because agricultural policies in the devolved administrations have not yet been finalised. As a result, non-traded savings are projected to be 2 $MtCO_2e$ lower in the fourth carbon budget period than in EEP 2016.

Forestry policies: Non-traded savings from forestry policies in the fourth carbon budget period are projected to be 2 $MtCO_2e$ lower than EEP 2016, primarily due to a change of the scope of what is considered forestry policy. In EEP 2016 all the savings coming from policies affecting land use were included, while for these projections, only policies with impact on forests and harvested wood are in scope.

Emissions savings from policies by consumer sector

In the **domestic residential sector**, Part L of the Building Regulations continues to provide the largest share of the sector's total policy savings, approximately 50% in the fourth carbon budget period. Carbon Emissions Reduction Target (CERT), F-gas, smart metering and the RHI together provide non-traded savings of 22 $MtCO_2e$ in the fourth carbon budget period.

In **commercial services** the largest savings come from F-gas regulation which aims to displace fluorinated gas with gases of lower global warming potentials. In the fourth carbon budget period the F-gas regulation is projected to save 38 $MtCO_2e$, increasing to 57 $MtCO_2e$ of non-traded savings in the fifth carbon budget period.

Public services contribute approximately 2% of total emissions in the fourth carbon budget period. Over this period, emissions savings in the public services sector account for 4% of total emissions savings from policies, with the largest savings coming from Building Regulations.

In **industry**, for all projected years between 75% and 85% of emissions are within the traded-sector, where GHG reductions are incentivised by the EU Emissions Trading System (EU ETS). Non-traded savings in industry are 4 $MtCO_2e$ during the fourth carbon budget period, compared to 12 $MtCO_2e$ in EEP 2016. The difference is mostly due to the new methodology used to allocate savings between traded and non-traded sectors.

The **transport sector** accounts for 41% of non-traded policy savings in the fourth carbon budget period. Non-traded savings from car, Light goods vehicle (LGV) and heavy goods vehicle (HGV) efficiency improvements are projected to be 58, 12 and 5 $MtCO_2e$ respectively in the fourth carbon budget period.

Agriculture contributes more than 10% of total emissions in all years between 2016 and 2035, most of which do not relate to energy use. In the fourth carbon budget period the Agricultural Action Plan is projected to save 16 $MtCO_2e$ in non-traded emissions.

Details of the emissions savings from all policies, grouped by economic sector, can be found in Annex D along with descriptions of policies and measures.

Emissions savings from policies in electricity supply

Most emissions from electricity supply fall under the EU Emissions Trading System and therefore do not affect the UK's "net carbon account" (see Chapter 2, Box 1). However since the 2009 Low Carbon Transition Plan, new Government policies have resulted in significant emissions savings from the Electricity Supply Industry (ESI).

Supply side policies comprise:

- Large Combustion Plant Directive
- Industrial Emissions Directive
- EU ETS
- UK Carbon Price Support
- Feed-in-Tariffs (for small scale generation)
- Renewables Obligation and Contracts for Difference (for large-scale generation).

We are unable to provide a breakdown of the individual effect of these policies on greenhouse gas emissions due to the highly interrelated nature of power supply markets. However, it is estimated that in total these policies reduced emissions from the power sector by 38 $MtCO_2e$ (33%) in 2016 alone.

ESI policy savings are projected to be 231 $MtCO_2e$ during the fourth carbon budget period (2023 to 2027) as compared to 264 $MtCO_2e$ as projected in EEP 2016. However, beyond 2020 policy savings are illustrative and future market and policy developments could lead to different outcomes. Aggregated emissions savings from power supply policies are reported in the "All, by sector" section of Annex D.

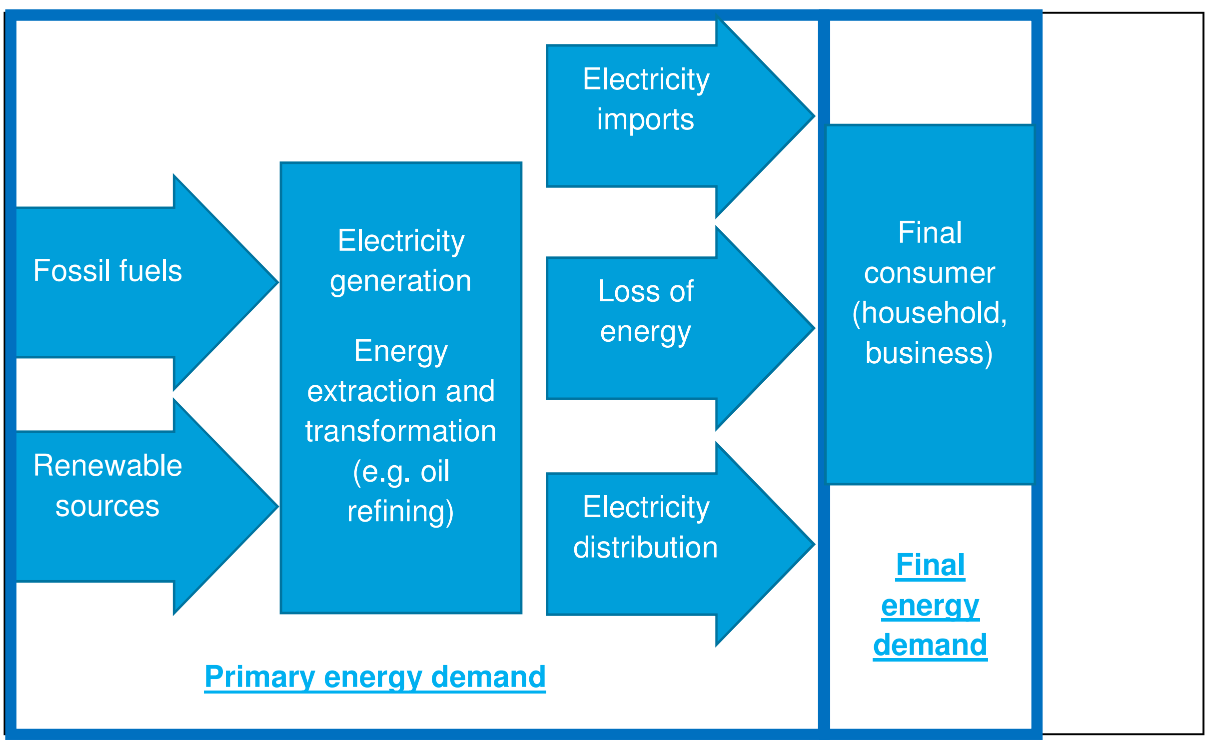
4 Demand for energy

- Final energy demand is projected to fall 3% between 2016 and 2025, from 139 Mtoe (million tonnes of oil equivalent) in 2016 to 134 Mtoe in 2025.
- It is then projected to increase to 141 Mtoe in 2035, an overall increase of 2%.

Introduction

There are two ways of presenting demand for energy: by final or primary demand. Figure 4.1 shows this distinction.

Figure 4.1: Primary and final energy demand



Energy required by the final consumer is known as *final* energy demand. Energy is used by various consumers, for example households, industrial sites, offices and agricultural installations. They are known as the “final” consumers, as opposed to intermediaries such as electricity generators, and these consumers use a range of different fuels. Electricity is usually generated off-site and distributed to consumers. Fuels such as gas, biomass, oil and coal can also be burnt directly by the consumer.

Energy demand can also be described in terms of *primary* demand. In this case electricity used by the final consumer is categorised by the fuel used to generate the electricity. For example, fossil fuels, biomass or uranium used in power stations, or the use of renewable energy such as from wind and solar. Primary energy demand also includes loss of energy in the generation and distribution of electricity, net imports of electricity from overseas, and energy used to extract and transform to other energy forms e.g. in the oil refining industry.

Methodology for demand projections

For the Energy and Emissions Projections, final energy demand from 2017 to 2035 is projected by using statistical methods to estimate the historic relationship between the underlying final energy consumption and key drivers of demand such as economic growth, fuel prices and ambient temperature[35]. "Underlying consumption" excludes the effect of policies which alter energy consumption[36].

Specific relationships are estimated for demand for each fuel in each consumer sector, e.g. electricity demand in the industrial sector. The projections of the demand drivers are obtained from official sources[37] and, together with the estimated relationships, are used to produce projections of the underlying final energy demand. A fundamental assumption of this approach is that the historic relationship is valid for the duration of the projections.

To obtain projections of demand *with* the effect of policies included, the process described in the last paragraph is "reversed", i.e. an estimate of the change in future energy consumption due to policies is *subtracted* from the projected underlying energy demand.

In previous projections DUKES final energy demand statistics were adjusted to add fuel used for heat sold to the demand figures for the sector buying the heat. This adjustment was done using DUKES Annex J: Heat Sold Reallocation. Removing this adjustment reduces 2016 final energy consumption by 1 Mtoe, mostly natural gas. The change means that final fuel consumption statistics in the EEP are now aligned with DUKES.

[35] Data on historic (pre-2017) energy consumption is taken from the Digest of UK Energy Statistics (DUKES) 2017 edition:
https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[36] To remove the effect of policies, the change in historic energy consumption due to policies is modelled separately and then added to the actual final energy consumption.

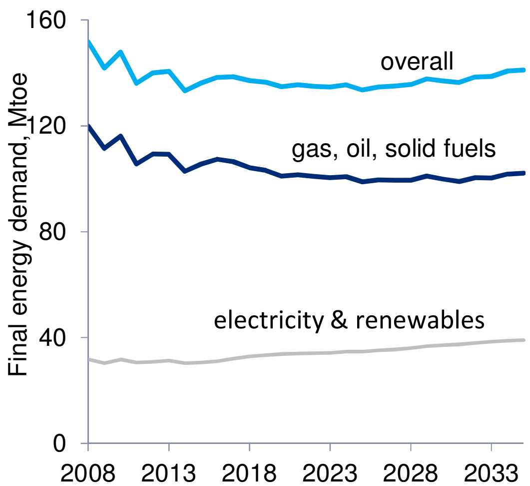
[37] See Annex M for details of the data sources for the drivers of demand.

Final energy demand

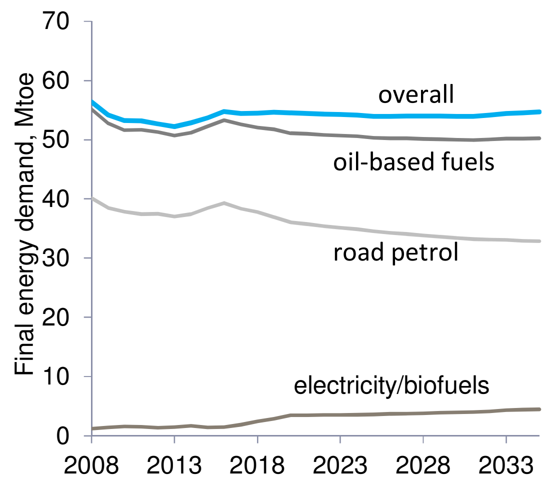
Final energy demand is up to 4% per year lower in the 2017 projection than in the 2016 projection. This is due to the inclusion of 2016 actual data on energy demand and temperature, the removal of the adjustment for fuels for heat sold and the increased fuel price assumptions.

Figure 4.2: Final energy demand by fuel and consumer sector 2008 to 2035, Mtoe

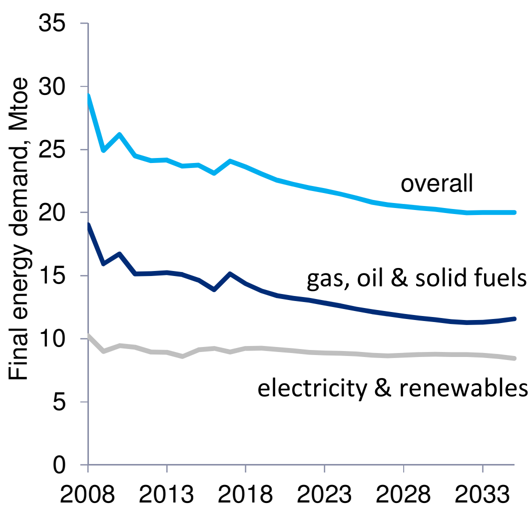
a) Total demand, broken down by fuel



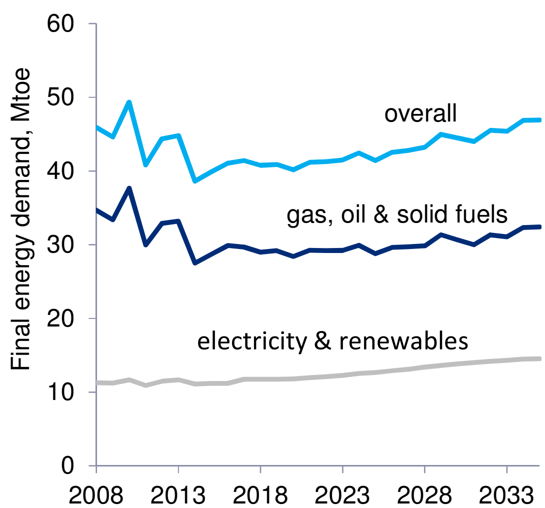
b) Demand by transport



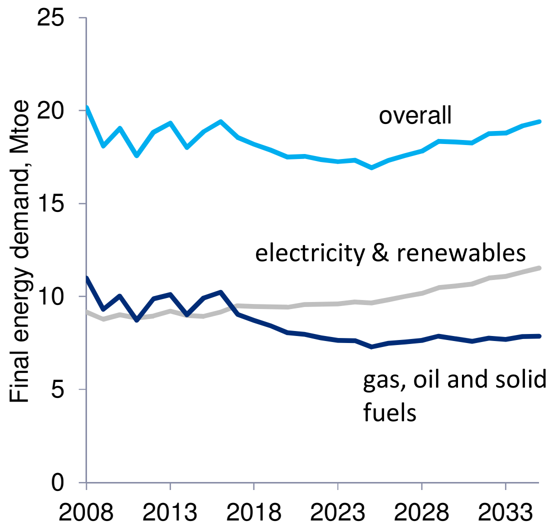
c) Demand by industry



d) Demand by domestic sector (households)



e) Final energy demand by the services sector (including agriculture)



Final energy demand is projected to be 134 Mtoe in 2025, 3% lower than in 2016. It is then projected to increase again after 2025, as the effects of included policies diminish and macroeconomic drivers continue to increase demand. Projected final energy demand is projected to increase by 2% in 2035 compared to 2016.

The shape of this trend reflects the combined demand across the four major energy consuming sectors: transport (Figure 4.2b), domestic (Figure 4.2d), industry (Figure 4.2c) and services (Figure 4.2e). However, the trends in demand by sector are different.

Transport is the largest consumer on a final energy basis, accounting for 40% of final energy demand in 2016 when international aviation is included. This share is projected to stay almost constant to 2035. Around 97% of 2016 final energy consumption in transport was from oil-based fossil fuels but by 2035 this is projected to fall to 92% due to uptake of electric vehicles and increased use of biofuels (Figure 4.2b).

The **domestic sector** accounted for 30% final energy consumption in 2016, rising to 33% in 2035. Projected energy demand in the **domestic sector** is determined by projections of numbers of households, retail fuel prices and weather. Electricity and renewables accounted for 28% of domestic final energy consumption in 2016 and are projected to rise to 31% in 2035. The projected trends in demand by fuel for this sector are displayed in Figure 4.2d.

Energy demand in the **domestic sector** is lower than in the 2016 projection by 5% on average between 2017 and 2035, mostly due to a higher gas price assumption and the removal of the adjustment for fuels for heat sold.

The **industrial sector** accounted for 17% of total final energy in 2016. Demand is projected to be around 6% per year lower than in the 2016 projections due to the removal of the adjustment for fuels used for heat sold and higher fossil fuel prices.

In these projections, industrial energy demand is projected to fall by 13% overall between 2016 and 2035. Renewables are projected to meet 10% of industrial energy demand in 2030 compared to 6% in 2016. Projected trends in demand by fuels for the industrial sector are displayed in Figure 4.2c.

The **services sector** accounted for 13% of final energy demand in 2016 and this share remains almost constant through to 2035. The share of demand met by electricity and renewables is projected to increase to 59% in 2035 from 47% in 2016 due to increasing electricity demand.

Final energy demand in the services sector in 2035 is 8% lower than in EEP 2016, due to the update of winter degree days referred to in chapter 2 and higher fossil fuel prices.

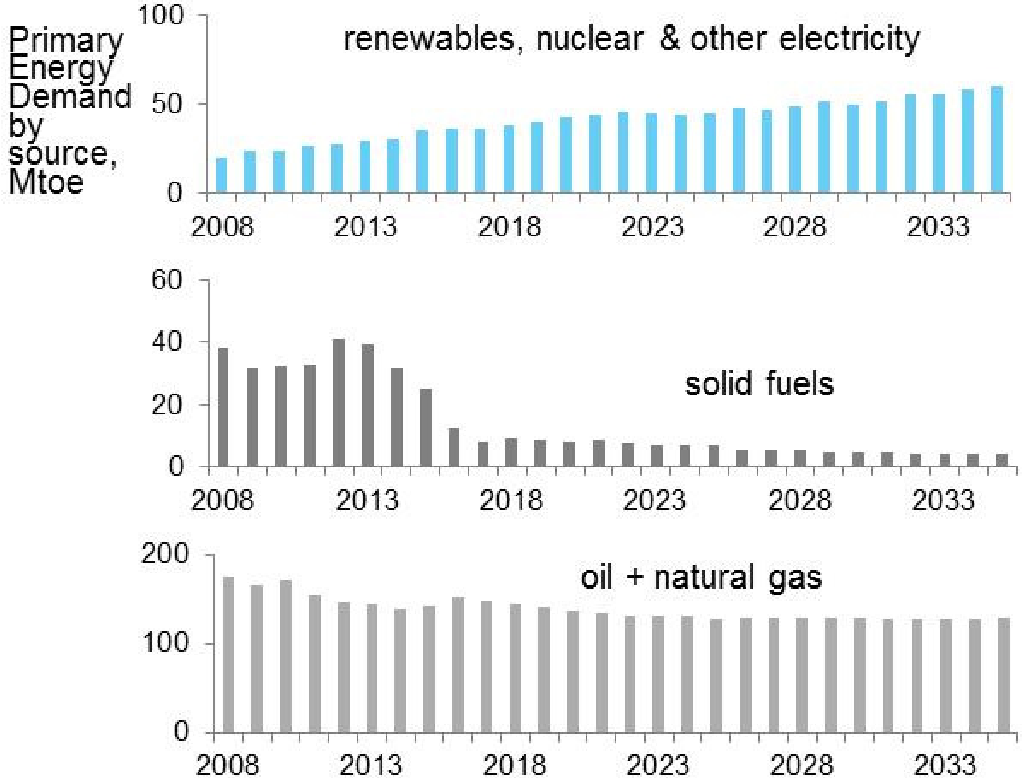
Primary energy demand

Trends in total primary energy demand are similar to EEP 2016, falling 11% between 2016 and 2025, from 201 to 179 Mtoe. After 2025, primary energy demand rises again to 193 Mtoe in 2035.

Coal use has fallen rapidly since 2013 as electricity generation has switched to using more renewables, waste and gas. By 2035, only 4 Mtoe of primary energy demand is projected to be met by coal (from a total of 193 Mtoe). Oil use is projected to decline by 8% in 2035 compared to 2016 levels as biofuels and electricity meet an increasing proportion of road fuel demand.

In 2035 primary energy demand in the latest projection is 3% lower than in EEP 2016, but there are more significant changes in the mix of fuels meeting this demand. Use of gas as a primary fuel is 17% lower in 2025 than in EEP 2016 because of the reduced final consumption of gas described previously and lower gas consumption for electricity generation. However demand met by renewables and waste is 26% higher in 2025 compared to EEP 2016. Use of nuclear fuel is reduced in all years after 2025 compared to EEP 2016 (see chapter 5).

Figure 4.3: Primary energy demand by fuel, Mtoe



5 Electricity supply

- CO_2 emissions from major power producers are projected to fall by nearly 70% between 2010 and 2020.
- The low carbon share of UK electricity generation (renewables and nuclear generation, as a proportion of all power producers)[38] is projected to rise from 22% in 2010 to 58% in 2020.
- Beyond 2020, the scenario presented here is illustrative and includes assumptions that may go beyond current Government policy.

This section covers projections of electricity supply, the full results of which can be found in Annexes G to L.

The electricity supply sector modelling was undertaken in September 2017 using BEIS's "Dynamic Dispatch Model" (DDM)[39]. The DDM models the impact of all relevant policies including small scale Feed-in Tariffs, the Renewables Obligation, Contracts for Difference, Carbon Price Support, the Capacity Market and Industrial Emissions Directive.

Since EEP 2016, the DDM reference case assumptions have been updated with new fossil fuel price assumptions, a revised carbon price floor trajectory and the latest Contracts for Difference (CfD) auction results. There are also some changes to the assumptions for future nuclear build[40] (one less new plant by 2030) and Li-ion battery storage capacity (slightly increased). Changes have also been made to the electricity demand profiles of key electricity using technologies, and how this demand may be shifted, and assumed system operability requirements.

In past EEP editions, all power station emissions were projected as traded under the EUETS. This year, projections of emissions from 'Energy from Waste' power plants are accounted for as 'non-traded'.

[38] Please note that statistics quoted in this chapter pertain to 'All Power Producers'. In EEP 2016, most graphs were based on the less comprehensive category of 'Major Power Producers'.
[39] For detail on the DDM see:
https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm
[40] These projections are not based on developers' proposed pipeline of nuclear projects. Instead we have made a simplifying assumption of steady frequency of deployment of new nuclear plants. Whilst there are several projects in the pipeline, it would be improper for Government to pre-empt which of them will come forward and on what timelines.

Up to 2020, the reference scenario reflects current power sector policies. Beyond 2020, the reference scenario includes some assumptions that go beyond current Government policy, and is therefore illustrative. The results do not indicate a preferred outcome and should also be treated as illustrative.

Results are presented separately for 'Major Power Producers' (MPPs) and 'All Power Producers' (which includes 'autogenerators') in the report annexes. As of 2016, MPPs accounted for around 95% of the UK's electricity generation.

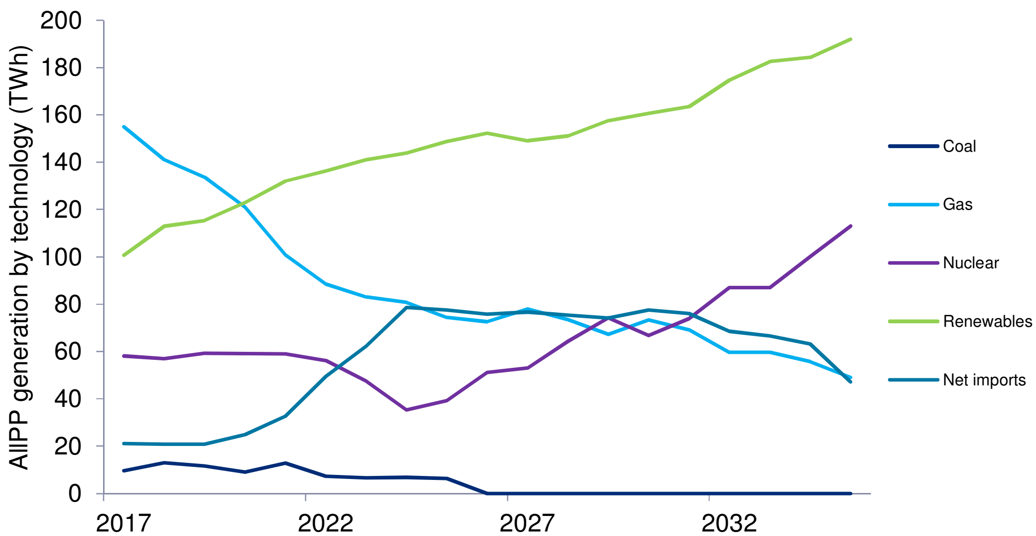
The definition of MPPs in EEP 2017 has been brought closer to the DUKES convention[41]. Thermal renewables based CHP plants are no longer counted as MPPs but as autogenerators, in accordance with DUKES convention[42].

Summary of projections

Total electricity generation and generating capacity projections are very similar to those in EEP 2016 and can be found in Annexes J and L of this report.

Figure 5.1, below, shows the projections of generation by technology for all power producers to 2035. Source data can be found in Annex J.

Figure 5.1: Generation and net imports, TWh



[41] The DUKES definition of MPPs is defined and discussed in paragraph 5.62 and following of DUKES 2017 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/643414/DUKES_2017.pdf

[42] A remaining exception to the DUKES convention is a small number of CHP plants which are situated on MPP sites. These are still modelled and reported as MPP.

Following a sharp fall in coal fired generation in 2016, the DDM projects a further gradual decline in fossil fuel based generation out to 2035. This is displaced by more renewables and eventually nuclear based generation with increased imports (via interconnectors) until new nuclear capacity reduces the need for this in the 2030s.

Emissions from electricity production are projected to fall steadily over the full period. The vast majority of these emissions are covered by the EU Emissions Trading System and therefore emissions savings have minimal direct impact on progress towards meeting UK Carbon Budgets (see Box 1). However reducing power sector emissions is important to meet our 2050 greenhouse gas emissions target.

In the reference case, CO_2 emissions from electricity generation by major power producers are projected to fall from 60 Mt in 2017 to 48 Mt by 2020. Under the illustrative scenario presented for beyond 2020, emissions are projected to fall to 28 Mt in 2030. Further details of these projections can be seen in annexes B and C.

Figure 5.2: Emissions intensity (vs EEP 2016), gCO_2e/kWh[43]

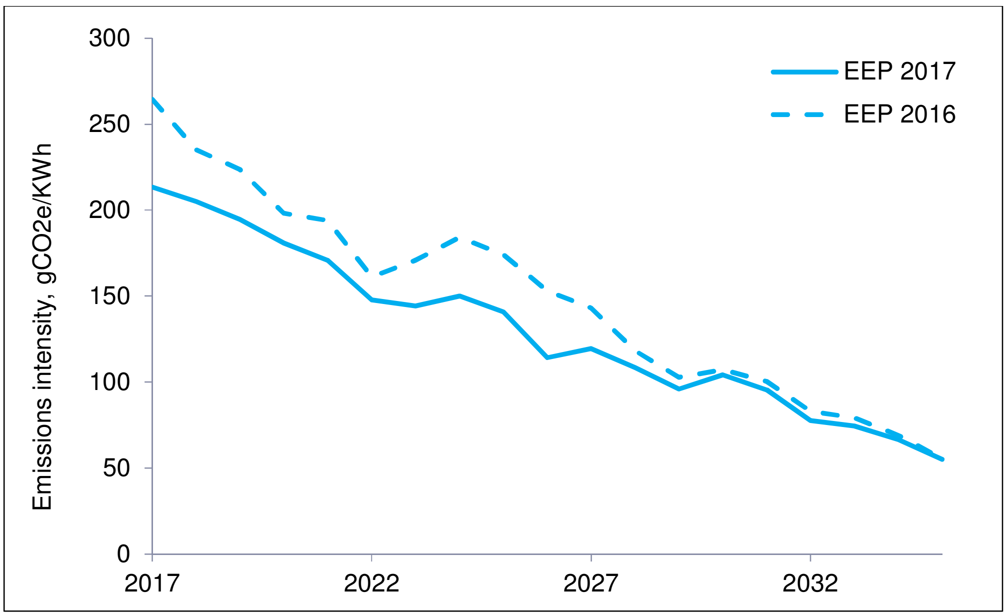


Figure 5.2 shows a lower trajectory of power sector emissions intensity between 2017 and 2030 in EEP 2017 (in comparison to EEP 2016). This is predominantly because some coal generation is replaced by gas in the projections up to 2020 whilst there is less curtailment of wind generation after 2020, compared to EEP 2016. As shown above, the projected emissions intensity in 2030 (104 gCO_2e/kWh) is similar to that in EEP 2016 (107 gCO_2e/kWh).

[43] Figure 5.2 includes both CO_2 and non-CO_2 greenhouse gases

Revised system operability requirements from National Grid allow greater penetration of renewables in this year's EEP[44].

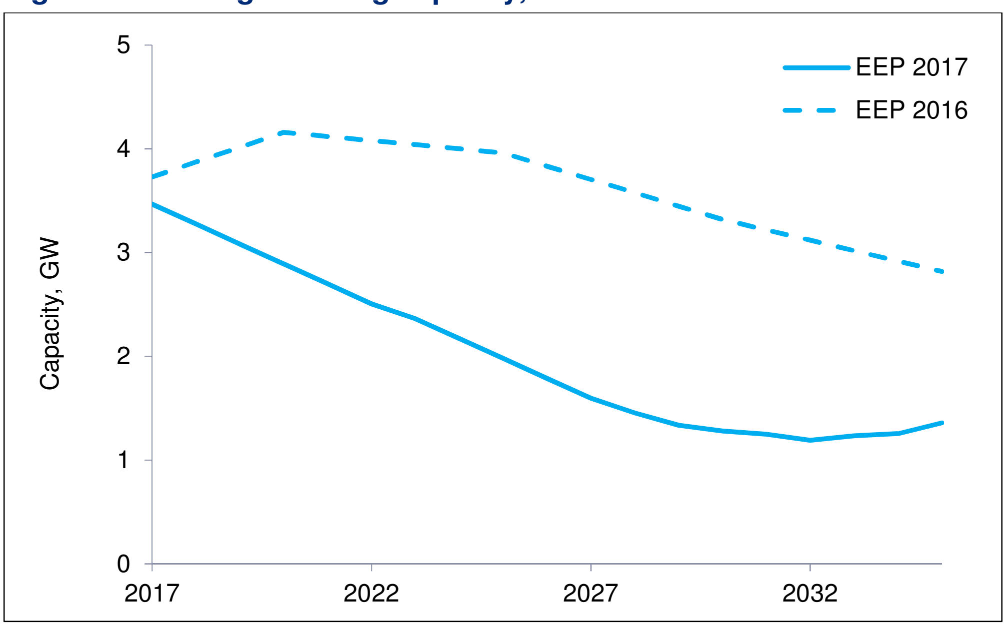
Autogenerators

Autogenerators are electricity plants owned by businesses whose main activity is not electricity generation. They are mostly comprised of 'Good Quality' CHP (Combined Heat and Power) schemes that have been certified by the UK's CHP Quality Assurance (CHPQA) programme. There is also some CHP capacity which does not qualify as 'Good Quality' under the CHPQA programme, as well as a small amount of pure autogeneration (with no exported heat). The latter is projected independently and is estimated to comprise less than 0.5 GW total capacity in all years.

For EEP 2017, the DDM (BEIS's model for electricity supply modelling) has been improved to incorporate all Combined Heat and Power (CHP) plants amongst its modelling of the wider electricity market. Previously most CHP had been modelled separately.

The CHP capacities projected using the DDM are generally lower than with the previous model. This can be seen in Figure 5.3 which compares the outputs against EEP 2016 on a like for like basis (excluding CHP powered by thermal renewables and that on MPP sites).

Figure 5.3: CHP generating capacity, GW



[44] 2016 System Operability Framework http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

EEP 2017 projections show a gradual decline in CHP capacity until the early 2030s, continuing the declining trend of Good Quality CHP since 2010, observed in DUKES historical data. The change in the projections since EEP 2016 is purely a result of the different modelling methodology this year and is not due to any change in Government policy.

6 Uncertainty in emissions projections

- Uncertainty analysis for 2017 considers more variables than EEP 2016, and additionally includes analysis of uncertainty within model equations and of structural breaks.
- Within this chapter, we report uncertainty based on four categories: policy savings, evidence base inputs, state of the world (which includes factors such as GDP, population and fossil fuel prices) and model equations.
- By the fourth carbon budget period, the greatest uncertainty comes from the state of the world category (approximately +/- 5%). Evidence base showed +/- 2% variability, while policies and industry equation uncertainty both showed about 1.5% for this carbon budget period.

Since EEP 2016, BEIS has improved the approach used to estimate the uncertainty of the Energy and Emissions Projections. This chapter sets out different sources of uncertainty and the extent to which they are reflected in these projections. As with last year, it should be noted that uncertainty analysis excludes the electricity supply industry, and so does not capture uncertainty on the effects of policies in this sector.

It is helpful to understand the significant scale of uncertainty, the scope for the future to turn out differently and what influences this. This is important context in our efforts to reduce emissions, highlighting the value of a flexible and responsive approach.

Different sources of uncertainty

As with any other projections, our energy and emissions projections are subject to a degree of uncertainty. This uncertainty comes from different sources: there are four broad steps to producing our projections, and each has uncertainty surround it.

Step 1 – estimate historic drivers of energy use: Using historic data, we estimate the relationships between key drivers and energy use. For example, we estimate the historic impact of fossil fuel prices, population and GDP on energy use.

Uncertainty: we cannot be certain of the relationships between drivers of energy use and emissions because of limits in available historical data and because we cannot assess all possible drivers. For the 2017 projections, we have partly captured this uncertainty by estimating the error in the model equations in the industry sector.

Step 2 – forecast key drivers which shape the 'state of the world': We use forecasts of key drivers as a starting point for the projections (alongside the current energy mix). For example, we use projections of future coal, oil and gas prices, and of future population and GDP growth.

Uncertainty: For many of the drivers it is not possible to forecast with high accuracy, particularly over periods of more than 15 years. We have captured some of this uncertainty in our projections analysis by testing a range of different forecasts for the most influential key drivers. These are summarised in Table 6.1.

Step 3 – apply historic relationships to forecast of key drivers: We assume that the historic relationship between key drivers and energy use (estimated in step 1) will continue into the future.

Uncertainty: we assume that estimated historic relationships will continue unchanged in the future, however relationships could change. Historic trends may break down, for example, with structural breaks such as high-impact innovations or changes in behaviour. In summer 2017, we undertook a pilot project to identify possible structural break scenarios with a significant impact on the energy sector and to estimate their impact. The work has not been included in the main uncertainty analysis, but is discussed later in this chapter.

Step 4 – estimate impact of policies on energy use: Steps 1-3 produce the baseline projections scenario. We then adjust this with estimates of recent policy impacts on energy use. For example, we estimate the recent fuel savings from efficiency policies and switching between fuels driven by clean energy policies.

Uncertainty: we cannot be sure of the exact impact our policies will have, and so we also estimate a range of uncertainty around our central projections of policy impacts. These uncertainty ranges are reflected in this report (see Table 6.1). Uncertainty analysis excludes the electricity supply industry, and so does not capture uncertainty on the effects of policies in this sector.

Parameters considered for uncertainty analysis

The uncertainty described in steps 1, 2 and 4 is modelled through Monte Carlo analysis. This analysis was based on 36 of the most influential drivers of energy use[45], compared to the 19 considered in EEP 2016, and all the policy savings estimates[46]. We also considered the uncertainty in the relationship between key drivers and energy use by considering the regression residuals[47] of the 38 main equations in the industry sector.

Parameters used for uncertainty analysis fall into the following categories:

Table 6.1: Categorisation of parameters and variables considered

Category of parameters	Variables within this group which were evaluated	Unevaluated variables
State of the world: Macroeconomic, demographic and temperature	Gross domestic product (GDP), public employment, household income Gas price, oil price, coal price, carbon price dollar / sterling exchange rate population, household numbers, temperature[48], basic oxygen steelmaking (BOS) output etc.	Interest rates Electricity price
Estimated policy impact and innovation[49]	Policy energy savings (electricity, gas, oil, solid fuel and renewables in domestic, commercial services, public services, industry and agriculture) Transport policies: car fuel efficiencies Light Goods Vehicle (LGV) fuel efficiencies, Heavy Goods Vehicle (HGV)	Supply side policies Policy savings from non-energy policies (e.g. fluorinated gas regulation, Agricultural Action

[45] These parameters were identified through sensitivity analysis as the variables having the highest impact on the model outputs.
[46] These are based around 5 fuels (electricity, gas, oil, solid fuel and renewables) across 5 of the modelled sectors (domestic, commercial services, public services, industry and agriculture).
[47] In statistical terms, the residual of an observed value is the difference between the observed value and the estimated value of the quantity of interest. For this analysis we considered the difference between the output of the regression equations and the historical actual values and included it in the future uncertainty
[48] The impact of temperature is measured by two variables related to Winter Degree Days, i.e. over the winter, the number of cold days multiplied by the number of degrees each day is below a given temperature.
[49] These Projections only consider implemented, adopted and planned policies. New policies or changes to existing policies which have not yet reached the planned stage are not considered in uncertainty analysis.

	fuels efficiencies etc.	Plan)
Evidence base	Land Use, Land Use Change and Forestry (LULUCF)	Emissions factors Global warming potentials
Regression residuals of equations in industry sector	(Industry sector only) Regression residuals of equations for future industrial Gross Value Added (GVA), demand and fuel shares	Regression residuals for sectors apart from Industry

To explore the impact of uncertainty in the model on emissions, a Monte Carlo simulation was carried out using these categories of parameters. The process involved analysis to derive historical distributions of the input values. Then the emissions projections model was run using samples from these distributions and the resulting projections recorded over a large number of simulations[50].

This method underpins the 95% Confidence Interval (CI) estimates in all tables and figures on uncertainty within this report. The upper and lower boundaries represent the projected emissions corresponding to the lower 2.5% and upper 97.5% percentiles of the simulations respectively.

To understand the size of the impact on total GHG emissions from each of the categories of parameters, Figure 6.1 shows the uncertainty range.

[50] This method of uncertainty analysis is called Monte Carlo analysis: https://en.wikipedia.org/wiki/Monte_Carlo_method. Historical data and expert elicitation was used to estimate probability distributions and cross-correlation for the selected variables. Multiple runs of the model were then carried out, randomly extracting the variables based on these probability distributions.

Figure 6.1: Total GHG emissions: uncertainty range for each category separately

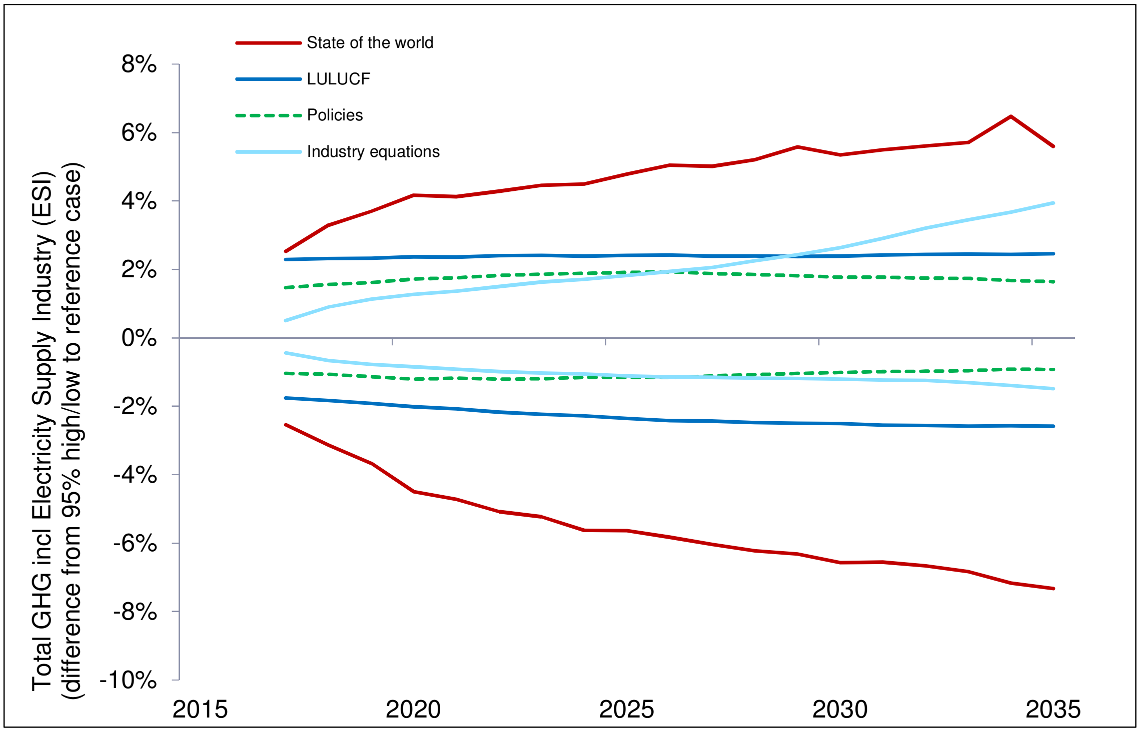


Figure 6.1 shows that each set of parameters have different trends over time in the way that they affect uncertainty:

- Uncertainty on policy has a relatively small impact on projected GHG emissions. This uncertainty impact peaks in the mid-2020s: this is because policies are only included if they are either currently implemented or firmly planned in the future (therefore policies which are still under development are excluded).

- The main uncertainty impact on projected emissions comes from the category of parameters classified in Table 6.1 as state of the world. This uncertainty is projected to grow over time, as the effects tend to compound.

- The uncertainty from the evidence base (LULUCF) is relatively constant over time, due to the potential for methodological improvements which may lead to both future and retrospective revisions.

- The uncertainty in the equations in the industrial sector is asymmetrical, with higher probability of resulting in higher emissions than in the reference case. This is because exponential functions are used in some of the equations considered, leading to a skewed uncertainty range

The main analysis within this report is based on all variables (the combination of all 4 categories together).

Table 6.2: Net carbon account for the fourth carbon budget period: uncertainty ranges by category, $MtCO_2e$

Categories included	Upper 95% confidence range	Reference case	Lower 95% confidence range
All (State of the world, LULUCF, policies and industrial equations)	2,154	2,044	1,951
1) State of the world	2,127	2,044	1,957
2) LULUCF	2,088	2,044	2,001
3) Policies	2,078	2,044	2,023
4) Industrial equations	2,065	2,044	2,030

Structural break uncertainty

During 2017, BEIS carried out a pilot project with Forum for the Future[51], a non-profit organisation with expertise in futures techniques and sustainability, to explore the potential impact that structural breaks could have on the Energy and Emissions Projections, and to test horizon scanning applications to uncertainty analysis for energy modelling.

As mentioned earlier in step 3, our standard uncertainty analysis assumes that estimated historic relationships will continue unchanged in the future. Structural breaks are defined as significant changes in demographics, technology, behaviour or the economy, meaning future trends could be very different to the past.

[51] Forum for the Future is an independent, international non-profit organization. This page provides more detail on their futures expertise: https://www.forumforthefuture.org/project/futures-techniques/overview

This analysis focused on externally driven changes which are not primarily led by Government policy[52], but would still have a significant impact on energy use and greenhouse gas emissions and the success of policies relating to energy and climate change.

To do this, BEIS selected a subset of key variables used for modelling these Projections, including energy demand for households, services, and various industrial sectors. Forum for the Future then researched potential structural breaks which could widen the uncertainty range already considered for these variables. Forum for the Future created two exploratory scenarios based on their existing collection of scenarios (and the research and interviews that informed those), and further desk research and conversations. This gave an indication of how quickly and how significantly the scenarios might impact on emissions.

1. Scenario A explored changes which would primarily affect buildings and housing, and could lead to a sharp reduction in emissions compared to the EEP reference case. The scenario considered structural breaks related to technological innovation in new materials and societal preferences for low-carbon buildings and infrastructure. In this scenario, innovation in business models could enhance the appeal of retrofitting, and smart grid/internet of things could help informed consumers to reduce energy used in existing buildings.
2. Scenario B explored changes in manufacturing, where emerging digital trends in automation, 3D printing and robotics could combine with societal trends for localisation and personalisation, leading to increased UK manufacturing. This could lead to an increase in UK GDP and higher emissions compared to the reference case, as production and transport emissions would shift to the UK. Additionally, small-scale production and local transportation could be more carbon-intensive than mass production.

As this work was only a pilot, the challenge was in identifying the scale of change plausible. Given this, results need to be treated as ‘informed guesstimates’ so graphs are not presented here. However this analysis showed that this approach has strong potential in helping to identify additional factors for uncertainty analysis, and we hope to continue this further in future editions of the Energy and Emissions Projections.

[52] For the central scenario of this analysis we considered the status of the world as projected in the EEP reference case, which includes only implemented, adopted and planned policies.

Uncertainties not covered in this analysis

The results presented in this chapter are likely to be an underestimate of the actual uncertainty in the projections. The main sources of residual uncertainty are:

- The analysis assumed that all policy inputs varied independently;
- For EEP 2017, we added a new category of uncertainty (regression residuals for the industry sector), however we do not yet include this analysis for other sectors;
- As in previous years, uncertainty analysis excludes the electricity supply industry. This is because it is currently not possible to run the electricity supply model with all combinations of the different inputs. Therefore this analysis does not capture uncertainty on the effects of policies in the electricity supply sector;
- Given the very high number of variables used in the model, it was not possible to consider all of them in the Monte Carlo simulation. However, we increased the number of variables considered (compared to EEP 2016) and we ranked all variables in order of their impact on the outputs and included those estimated to be most influential on emissions;
- The distributions and correlations used in the Monte Carlo simulation are approximations, sometimes based on limited historical data that often require a level of subjectivity to interpret;
- The methodology used assumes that the future variability in the key parameters will be similar to the historical variability. This approach is not able to take into account the possibility of structural changes in the system, which may arise due to innovation or changes in behaviour. The pilot project we described in the section above is an attempt to reduce the impact of this modelling limitation and we are planning to do more work on this next year;
- The methodology focuses on future uncertainty, rather than analysis of how uncertain inputs or outputs may have been historically, i.e. before 2017.

Conclusions

Understanding the scale and sources of uncertainty is important context for interpreting these projections.

It is clear that as we look further into the future, uncertainty grows. Whilst the analysis above can give us these insights, it is far from exhaustive and we know there are other sources of uncertainty not fully captured. Further work is underway to better understand the scope for innovation and changing societal behaviours to reshape future energy and emissions. These insights underline the value of flexibility and responsiveness in policy design, particularly in areas with a long-term outlook, such as the transition to a low carbon economy.

7 Lists of supporting material

Annexes

Annex A: Greenhouse gas emissions by source

Annex B: Carbon dioxide emissions by source

Annex C: Carbon dioxide emissions by IPCC category

Annex D: Policy savings in the projections

Annex E: Primary energy demand

Annex F: Final energy demand

Annex G: Major power producers' generation by source

Annex H: Major power producers' cumulative new electricity generating capacity

Annex I: Major power producers' total electricity generating capacity

Annex J: Total electricity generation by source

Annex K: Total cumulative new electricity generating capacity

Annex L: Total electricity generating capacity

Annex M: Growth assumptions and prices

Annex N: 2017 non-CO_2 GHG emissions projections report

Web tables and charts

Web tables and charts have been uploaded alongside this report. Some of these replicate tables and figures within this report, others are supplementary.

Appendix A: List of abbreviations

BEIS	Department for Business, Energy & Industrial Strategy
CB	Carbon budget
CGS	Clean Growth Strategy (published by BEIS in October 2017)
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DUKES	Digest of UK Energy Statistics
EEP	Energy and Emissions Projections (also sometimes called UEP)
ETS	Emissions Trading System
EU	European Union
F-gas	Fluorinated (greenhouse) gases
g	Grams
GDP	Gross Domestic Product
GHG	Greenhouse gas
GVA	Gross Value Added
GW	Gigawatt
IED	Industrial Emissions Directive
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt-hours
LULUCF	Land Use, Land-Use Change, and Forestry
MPP	Major Power Producer
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
NCA	Net Carbon Account
RHI	Renewable Heat Incentive
UK	United Kingdom