Department for
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& Industrial Strategy

UPDATED ENERGY AND EMISSIONS PROJECTIONS 2016

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

This publication is available for download at www.gov.uk/government/publications.

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Executive summary

This report presents the 2016 projections of the UK's energy demand and greenhouse gas (GHG) emissions up to 2035. The main projection is the 'reference case', which is one view of how the UK energy and emissions system could evolve if existing and agreed government policies were implemented but no new policies or changes to existing policies were introduced. Other views of the future are possible and there are significant uncertainties in these projections.

The energy and emissions projections are one way in which we monitor progress towards our carbon budgets – this is discussed in Chapter 2, which sets out projections of emissions and estimated future performance against carbon budgets.

Compared to the 2015 Energy and Emissions Projections[1], total projected emissions are lower.

A key reason for this reduction is new evidence in the Land Use, Land Use Change and Forestry (LULUCF) sector. Emissions for LULUCF over the fourth carbon budget period in these projections are 45 $MtCO_2e$ lower than in the 2015 projections.

There are also reductions in projected agricultural and industrial emissions over this period. To some extent, these are offset by increased projected emissions in other sectors, particularly the domestic sector and road transport.

The UK's primary energy demand is projected to fall by a total of 6% over the next 10 years, before rising to 2% above current levels by the end of 2035.

Up to 2020, the reference scenario reflects current power sector policy. Under this central projection, emissions from the power sector fall by 52% from 113 $MtCO_2e$ in 2015 to 54 $MtCO_2e$ in 2020. Low carbon generation is projected to increase from 47% of the generation mix in 2015 to 61% in 2020, whilst final electricity demand falls by 1% from 322 TWh in 2015 to 318 TWh in 2020. Beyond 2020, the power sector reference scenario includes assumptions that go beyond current Government policy, and is therefore illustrative.

[1] Energy and emissions projections 2015: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015

1 Introduction

- Between 1990 and 2015, UK GHG emissions fell 38%[2] (provisional statistic) whilst the economy grew by 64%[3]. Emissions are projected to continue falling against the backdrop of a growing economy.
- 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 (emissions not covered by the 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 was approved by parliament in summer 2016.

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. Before BEIS was formed, projections were published by the Department of Energy and Climate Change (DECC). This is the latest report in a series, providing up-to-date projections to 2035.

This report sets out the 2016 projections, with a comparison against the projections published in 2015 and explanations of differences between these (mainly focusing on changes in the fourth carbon budget period, to assist comparison with EEP 2015). The projections bring together statistical and modelled information from a wide variety of different sources. Further details of the sources and methods have been published in the methodology sections of previous publications[4].

[2] Emissions data sourced from: https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2015
[3] GDP data sourced from: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/pn2
[4] Energy and emissions projections: https://www.gov.uk/government/collections/energy-and-emissions-projections

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 80% compared to 1990[5]. The Act also established a system of legally binding limits on the net volume of GHGs that can be emitted. These are called carbon budgets[6], each one spanning five years and 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[7] in summer 2016. Chapter 2 assesses the UK's progress towards 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.

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 2016 Energy and Emissions Projections.

The reference case and other scenarios

The main projection presented in this report is the BEIS 'reference case'. This is not a forecast or preferred scenario: it represents one particular view of how the UK energy and emissions system could evolve with existing and agreed government policies implemented but no new policies introduced. For the electricity generation sector however, the reference scenario only reflects current policy up to 2020. Beyond 2020, the electricity generation scenario includes assumptions that go beyond current Government policy, and is therefore

[5] 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/

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

[7] Fifth carbon budget order: http://www.legislation.gov.uk/uksi/2016/785/made

illustrative. The central reference case is based on central projections for key drivers of energy and emissions, such as fossil fuel prices, GDP and population.

Chapter 3 discusses policy impacts on emissions, and for this the 'reference' scenario is compared against a 'baseline' scenario which excludes the impact of Climate Change policies brought in since the 2009 Low Carbon Transition Plan[8] (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 excludes 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 2015 projections, the BEIS modelling team concentrated on updates to the projections methodology, quality assurance, reviewing assumptions in the models of the larger energy sources, updating to the 1990 to 2014 inventory[9] and updating source data for the largest sources.

The methodological changes in the 2016 projections are:

- Improving the model of industrial energy demand which is used in the energy and emissions projections by recalibrating this based on the most recent data. This involved work from independent analytical experts at University College London (UCL) to carry out a major revision of the relationships used to project industrial energy demand and economic activity[10] and a stronger relationship with fuel price. A detailed description of this work can be found in forthcoming academic publications from UCL.

[8] 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
[9] EEP 2016 uses historic (inventory) GHG emissions data to 2014 and projected emissions from 2015
[10] Economic activity, as represented by the gross value added (GVA) of industry, is a key driver of energy demand. Projections of industrial GVA, based on UK GDP projections issued by the OBR, are produced specifically for the Energy and Emissions Projections.

Some changed methodologies for key model inputs are:

- Road transport projections have been updated to include new assumptions on road vehicle efficiencies and a change in the allocation of fuel consumption from Heavy Goods Vehicles (HGVs) to other vehicle types. Section 3 also explains the effect of revised assumptions on the efficiencies of cars and Light Goods Vehicles (LGVs) on projected policy savings.

- Changes in projections methodology for non-CO_2 emissions are described in Annex N.

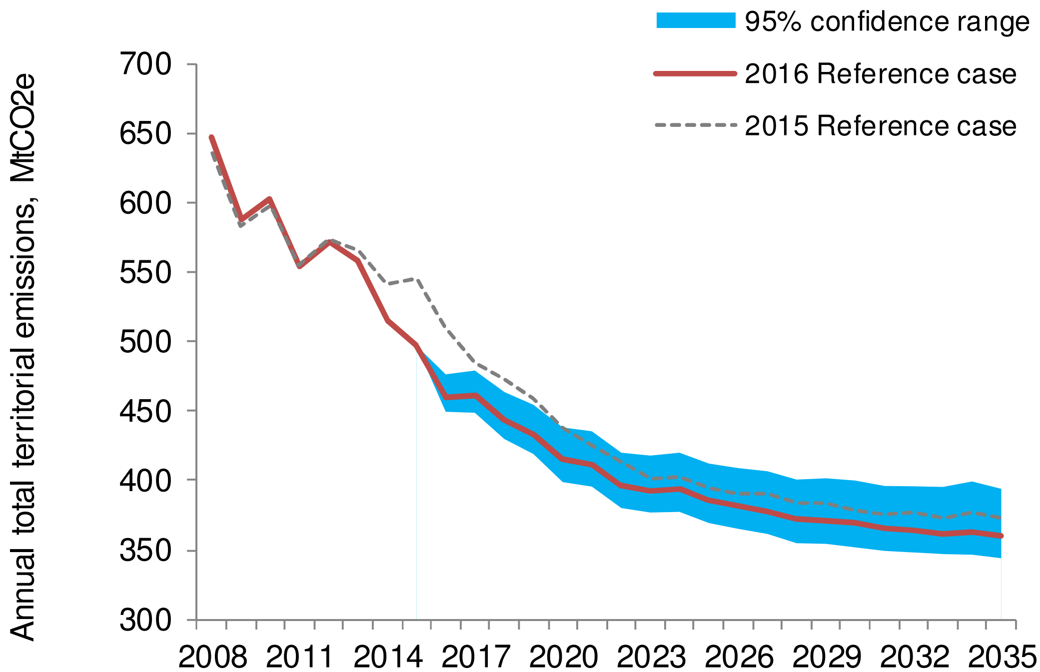
2 UK emissions projections

- Between 1990 and 2015, UK emissions fell 38%[11] (provisional statistic) whilst the economy grew by 64%[12]. By 2020, emissions are projected to be 48% below 1990 levels.
- The UK met the first carbon budget by 36 $MtCO_2e$, and is projected to meet the second and third carbon budgets by 132 and 91 $MtCO_2e$, respectively.
- There are projected shortfalls against the fourth and fifth carbon budgets of 146 $MtCO_2e$ and 247 $MtCO_2e$, respectively. The government will be publishing its emissions reduction plan, setting out plans for decarbonising in the 2020s.
- In EEP 2016, emissions are projected to be lower over the period to 2035 than in EEP 2015.

Figure 2.1 shows actual and projected UK territorial emissions. These projections are very uncertain. For example, economic and social trends and breakthrough technologies can 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.

[11] Emissions data sourced from: https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2015
[12] GDP data sourced from: https://www.ons.gov.uk/economy/grossdomesticproductgdp/timeseries/abmi/pn2

Figure 2.1: Uncertainty in projected overall territorial emissions



Comparison to last year's projections

Overall, projected emissions are lower in the 2016 projections than 2015 (EEP 2015[13]). For example, over the fourth carbon budget period (2023-27 inclusive), projected territorial emissions are 47 $MtCO_2e$ (2%) lower than in the 2015 projections. There are a number of reasons, that together, explain most of this difference.

Key drivers reducing projected emissions:

- **Land Use Change and Forestry**: There have been a number of improvements to the evidence base for net emissions from Land Use, Land Use Change and Forestry (LULUCF). The LULUCF sector includes both sources and sinks[14] of CO_2. Projected emissions have decreased by 45 $MtCO_2e$ over the fourth carbon budget

[13] Energy and emissions projections 2015: https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015
[14] Carbon sinks are elements of the carbon system that absorb or store carbon dioxide, for example the forests and oceans.

period compared to 2015 projections (from -10 $MtCO_2e$ to -54 $MtCO_2e$ in the 2016 projections). Improvements to the evidence base include[15]:

- A new dataset for forests is being used which has a larger estimate of the forested area of the UK;
- Improved estimates of carbon stocks in private forest areas;
- A change in emissions factor in the grasslands category for calculating emissions due to drainage of organic soils;
- A small difference in the 1990 to 2014 inventory and the projections based on it for Cropland, Grassland and Settlements due to correction of an error in the use of the emission factor for N_2O emissions.

- **Agriculture**: Projected agricultural emissions for the fourth carbon budget have also decreased by 29 $MtCO_2e$[16] (12%) compared to 2015 projections.
  The main reason for this reduction is the removal of the Dairy Growth Plan which increased the growth rate of the dairy industry. This has been removed in the 2016 projection to bring the projection methodology inline with other sectors where historic trends are used to project future growth. Removing the Dairy Growth Plan reduces emissions by 18 $MtCO_2e$ in the fourth carbon budget period.

- **Industry**: Improvements to BEIS's industrial energy demand modelling have contributed to a reduction in projected emissions of 36 $MtCO_2e$ (9%) over the fourth carbon budget, compared to 2015 projections.

Key drivers increasing projected emissions:

- **Transport**: Road transport emissions are projected to rise by 28 $MtCO_2e$ (6%) over the fourth carbon budget period, compared to 2015 projections, reflecting improved evidence on real world vehicle efficiencies. Historic emissions are based on direct estimates from total fuel consumption data, rather than indirectly estimated based on vehicle stocks, mileage, and assumed efficiencies. This means the calculation of historic emissions is unaffected.
- **Estimated policy impacts**: Due to some improved policy assumptions for Products Policy and some policy changes to the Renewables Heat Incentive (RHI), emissions savings from these policies are forecast to be lower than in the 2015 projections.

[15] This will be published in a document entitled: Projections of emissions and removals from the LULUCF sector to 2050.
[16] These improvements were part of the regular cycle of development for models used to produce the Energy and Emissions Projections. Each year, policy projections are updated based on any changes since the previous year, and past projections are compared against historic data so that recalibrations can be made for any sectors where this is necessary.

- **Fossil fuel prices**: Across all sectors, the lower assumptions for fossil fuel prices (compared to assumptions in 2015) are projected to lead to an increase in emissions, although changes in modelling of the industry sector lead to an overall net decrease.

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 80% compared to 1990[17]. The Act also established a system of legally-binding carbon budgets which limit the net volume of GHGs that can be emitted in successive five-year periods, starting in 2008[18].

The first carbon budget covered the period 2008 to 2012 and the UK met this budget with a 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. Further details on this are within the October 2016 government response to the CCC's 2016 progress report[19]. The government will be publishing its emissions reduction plan, setting out plans for decarbonising in the 2020s.

[17] 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/

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

[19] Government response to the 2016 progress report: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/559954/57204_Unnumbered_Gov_Response_Web_Accessible.pdf

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) 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 currently known. Projections for the actual level of emissions covered by the EU ETS can be found in the web tables.
2. "Non-traded emissions" include all 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. 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.

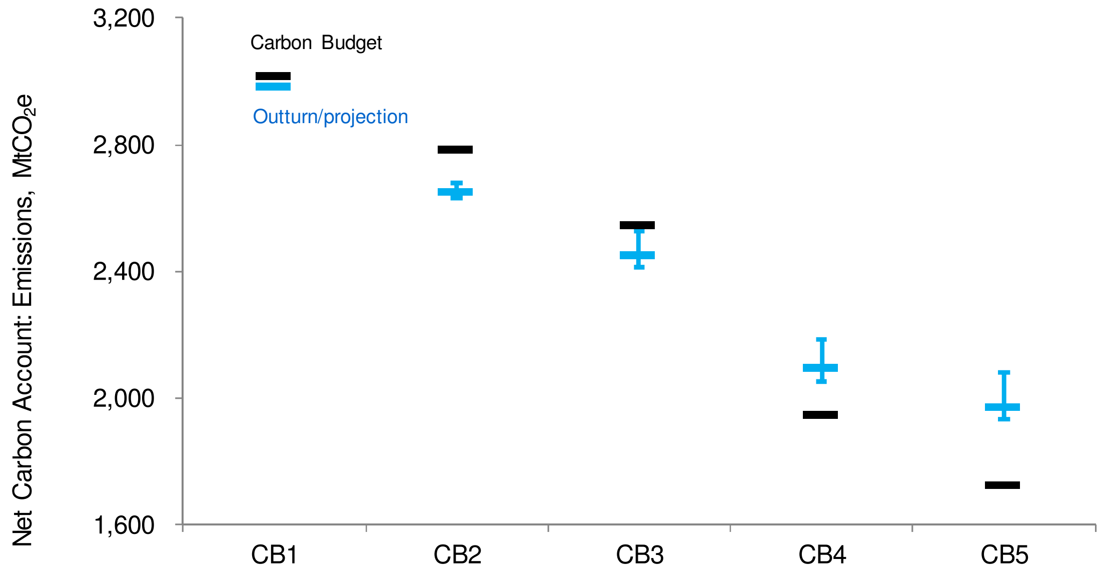
Performance against carbon budgets is measured by the UK net carbon account – described in Box 1. Figure 2.2 and Table 2.1 show the actual and projected performance against legislated carbon budgets. The range presented in the projected net carbon account is the 95% confidence internal for uncertainties that have been modelled. 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 a headroom of 36 MtCO_2e, and is projected to meet the second carbon budget by 132 MtCO_2e (range: 104-149 MtCO_2e)[20] and the third carbon budget by 91 MtCO_2e (range: 16-129 MtCO_2e). There are projected shortfalls for the fourth carbon budget of 146 MtCO_2e (range: 103-236 MtCO_2e) and for the fifth carbon budget of 247 MtCO_2e (range: 207-354 MtCO_2e). These projections are highly uncertain and only some of this uncertainty is captured in modelling and presented in the ranges here (see Chapter 6).

[20] 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.

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.

In Table 2.1 below, the projected net carbon account is shown for each Carbon Budget period, with the uncertainty range for these projections.

Table 2.1: Actual and projected performance against carbon budgets, $MtCO_2e$

					$MtCO_2e$
	Carbon budget: 1 (2008-12)	2 (2013-17)	3 (2018-22)	4 (2023-27)	5 (2028-32)
Carbon budget	3,018	2,782	2,544	1,950	1,725
Net UK carbon account:					
Lower 95% confidence interval		2,633	2,415	2,053	1,932
Reference case	2,982 (actual)	2,650	2,453	2,096	1,972
Upper 95% confidence interval		2,678	2,528	2,186	2,079
Performance against carbon budget					
Lower 95% confidence interval		-149	-129	103	207
Reference case	*-36 (actual)*	*-132*	*-91*	*146*	*247*
Upper 95% confidence interval		*-104*	*-16*	*236*	*354*

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

- The 2016 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 central case projection would meet the second carbon budget with a margin of 132 $MtCO_2e$ and the third carbon budget with a margin of 91 $MtCO_2e$.

- 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 103 $MtCO_2e$ or as high as 236 $MtCO_2e$[21]. However the size of this shortfall has reduced since the 2015 projections: in the 2015 projections, the central reference case shortfall was 187 $MtCO_2e$, but this has fallen to 146 $MtCO_2e$.

- This is the first year that projections of the net carbon account have been made for the fifth carbon budget period[22]. 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[23]. The government will be publishing its emissions reduction plan, setting out plans for decarbonising in the 2020s.

Non-traded emissions projections by sector

Overall, non-traded emissions are projected to fall from 312 $MtCO_2e$ in 2016 to 278 $MtCO_2e$ in 2035 (a fall of 11%). The projections show how different sectors of the economy[24] 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, "Carbon dioxide emissions by IPCC category", contains values and definitions for these.

[21] In the 2015 projections this fourth carbon budget period shortfall was projected to be between 122 and 256 $MtCO_2e$.
[22] The value used for the traded sector share for the fifth carbon budget period is 590 $MtCO_2e$. This is consistent with the recommendation of the Committee on Climate Change (CCC).
[23] 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.
[24] 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

Non-traded emissions for all years are based on estimates of the proportion of emissions which are traded within the EU ETS.

Industry[25]**, commercial services** and **public administration, agriculture** and **waste** currently contribute around 38% of non-traded emissions. This is projected to fall to around 32% by 2035.

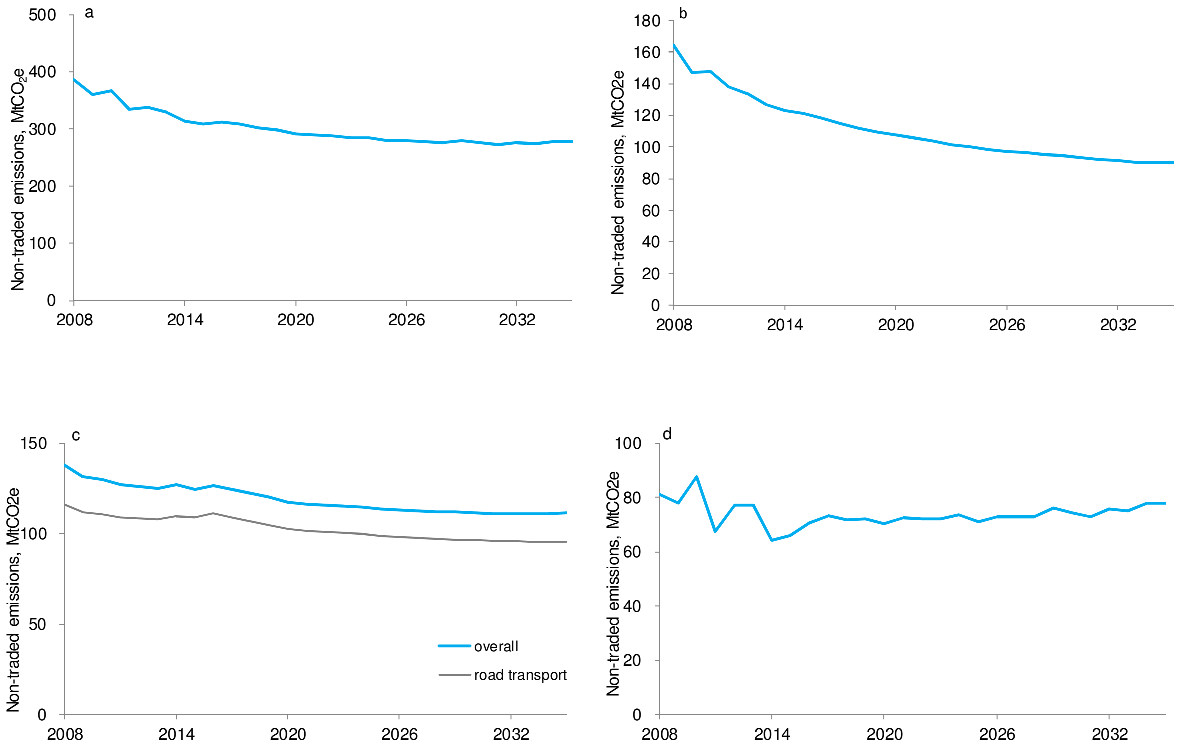
Land Use, Land Use Change and Forestry are accounted for in carbon budgets although its emissions do not result from use of energy. It includes emissions from forest land, cropland, grassland, human settlements, and due to a change of land use between any of these categories[26]. It differs from other sectors in that it contains both sources and sinks[27] of CO_2. Overall, this sector currently removes around 2.5% of total emissions. This level of removal is projected to fall slightly to 1.8% by 2035.

Transport, mostly road transport, contributed around 41% of UK non-traded emissions in 2016 (Figure 1.2c). The projections show a decline to 2035 (emissions projected to fall by 12%) due to improvements in road vehicle fuel efficiencies and, to a lesser extent, the inclusion of biofuels in road transport fuels and increased use of electric vehicles.

The **domestic** residential sector (Figure 1.2d) is responsible for 23% of non-traded emissions in 2016. Emissions are projected to rise by 7 $MtCO_2e$ (10%) by 2035, and to account for 28% of non-traded emissions by 2035.

[25] This includes CO_2 emissions from agriculture due to the burning of fuels and fertiliser use.
[26] 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
[27] Carbon sinks are elements of the carbon system that absorb or store carbon dioxide, for example the forests and oceans.

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 lead to a large reduction in non-traded GHG emissions, 284 $MtCO_2e$ or about 20% of total non-traded emissions in the fourth carbon budget period.
- Over 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.
- Overall projected policy savings in the non-traded sector are 44 $MtCO_2e$ lower than in EEP 2015 during the fourth carbon budget period due to changes in evidence, assumptions and policies.

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 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.

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[28].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:

- Policies adopted before the LCTP are known as “earlier policies”;
- Policies adopted after the LCTP are known as “later policies”.

[28] 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.

Within this chapter, the savings refer only to the later policies unless otherwise stated; estimates for these are more robust than for earlier policies.

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 929 $MtCO_2e$ 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	63	61	53	42
Savings from LCTP policies	48	158	231	274
Savings from all policies	111	219	284	316

The reference projection includes all *expired, implemented, adopted* and *planned* policies[29].

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;
    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.

[29] 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.

Changes to emissions savings since EEP 2015

As well as overall projected emissions being lower in the 2016 projections, so too are projected non-traded emission savings from government policies.

Non-traded GHG savings from government policies are projected to be lower in the 2016 projection than in the 2015. In the third carbon budget savings are down from 252 to 219 $MtCO_2e$ and in the fourth carbon budget savings are down from 328 to 284 $MtCO_2e$.

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

Key drivers reducing projected emissions savings from policies:

Road vehicle efficiencies: Non-traded emissions savings in transport during the fourth carbon budget period are 15 $MtCO_2$ less than in last year's projections due to improved evidence on the difference between fuel efficiencies of road vehicles in the real world compared to under lab conditions. This evidence update means that car efficiencies are estimated to be 18% lower for the year 2016 than had been projected in EEP 2015. Policy savings from fuel efficiencies are projected to rise by 21 $MtCO_2$ from 2016 to 2035 – a comparable increase to that seen in EEP 2015 projections[30].

Renewable Heat Incentive: Projections for 2016 have been updated based on RHI funding announcements in the November 2015 Spending Review and revised assumptions on the expected uptake of renewable heat measures. 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. BEIS has published an impact assessment including the GHG savings from RHI as a whole[31]. Downstream, non-traded emissions savings from the RHI are projected to be 22 Mt over the fourth carbon budget, lower than illustrative savings presented in the 2015 projections. Upstream emissions savings from the RHI are estimated to have increased since the 2015 projections.

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

[30] To model emissions reduction from road vehicle efficiency policies, the overall energy demand model is used to produce demand and emissions projections based on different vehicle efficiency scenarios. This allows for the calculation of GHG savings attributable to car fuel efficiency policies, the Renewable Transport Fuel Obligation (RTFO) and the Local Sustainable Transport Fund (LSTF).

[31] Impact assessment available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/577026/RHI_Reform_Govt_Response_Impact_Assessment_FINAL.pdf

comparable. Harmonisation of assumptions is on-going and will be incorporated into future projections.

Products policy: Energy and emissions savings attributed to products policy are lower in this year's projections compared to last year's. Improved evidence indicates that the efficiency of ventilation equipment in the absence of products policy is better than previously thought. This has led to a reduction in projected non-traded emissions savings from products policy of 9 $MtCO_2e$ during the fourth carbon budget period compared to last year's projections.

Key drivers increasing projected emissions savings from policies:

Climate Change Levy (CCL): The 2016 Budget announced some changes to the Climate Change Levy (CCL). Within this report, these changes have been modelled as a separate policy. In 2019 the CCL on electricity will increase from 0.58 p/kWh to 0.85 p/kWh for electricity and from 0.20 p/kWh to 0.34 p/kWh on gas. The Budget 2016 changes are projected to decrease non-traded emissions during the fourth carbon budget period by 3.5 $MtCO_2e$.The effects of pre-existing CCL are included in the baseline scenario (but have not been isolated and quantified).

Forestry policies: Savings from forestry policies, previously included in the baseline, have now been separately identified and are included in just the reference case scenario. During the fourth carbon budget period, forestry policies are projected to reduce non-traded emissions by 1 $MtCO_2e$.

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 policy savings, approximately 50% in the fourth carbon budget period. Carbon Emission Reduction Target (CERT), F-gas, smart metering and the RHI together provide non-traded savings of 19 $MtCO_2$ in the fourth carbon budget period.

In **commercial services** the largest savings come from the 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 37 $MtCO_2e$, increasing to 56 $MtCO_2e$ of non-traded savings in the fifth carbon budget period, unchanged since EEP 2015.

Public services contribute approximately 2% of total emissions in the fourth carbon budget period. Emissions savings are 4% of total emissions savings from policies with the largest savings coming from Building Regulations and the RHI.

In **industry**, for all projected years over 70% of emissions are within the traded-sector, where GHG reductions are incentivised by the EU-Emissions Trading System (EU ETS). The effect of the EU ETS on industry has not been modelled for EEP 2016. Non-traded savings in industry are 12 $MtCO_2e$ during the fourth carbon budget period; 8.7 $MtCO_2e$ comes from the RHI.

The **transport sector** accounts for 37% of non-traded policy savings in the fourth carbon budget period. Savings from car, Light goods vehicle (LGV) and heavy goods vehicle (HGV) efficiency improvement are projected to be 42, 10 and 5 $MtCO_2e$ respectively in the fourth carbon budget period. The planned component of the Renewable Transport Fuel Obligation (RTFO) is currently under review and may be revised in the next projection.

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 18 $MtCO_2e$ 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

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). New Government policies are estimated to reduce power sector emissions compared to the baseline scenario by 16 $MtCO_2e$ (12%) in the year 2015 and 38 $MtCO_2e$ (42%) in the year 2020.

ESI policy savings are projected to be 208 $MtCO_2e$ during the fourth carbon budget period (2023 to 2027), however beyond 2020, policy savings are illustrative and future market and policy developments could lead to different outcomes. Aggregated emissions emissions savings from power supply policies in this scenario are reported in the "Traded, by sector" section of Annex D.

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.

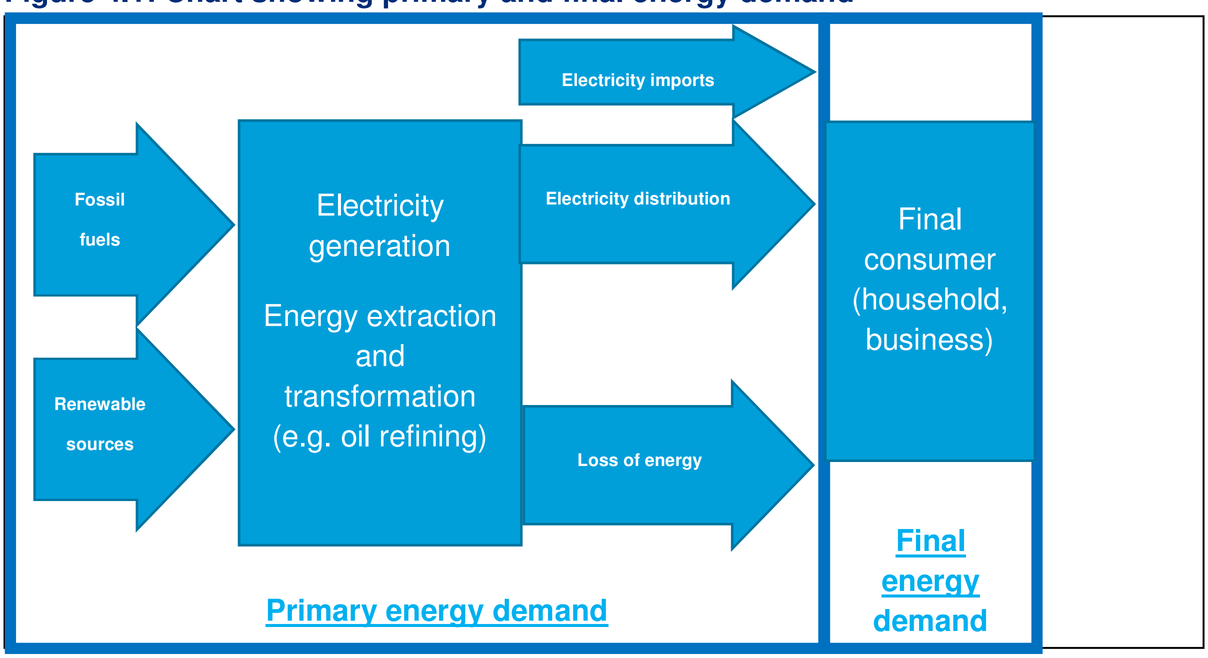
4 Demand for energy

- Final energy demand is projected to fall by 2% from 2016 to the mid-2020s. It is then projected to rise, with final energy demand in 2035 projected to be 6 Mtoe (million tonnes of oil equivalent) higher than 2016 levels (a 4% increase).
- Transport energy demand is higher than the 2015 projections due to a revision of the estimated fuel efficiency of road vehicles.

Introduction

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

Figure 4.1: Chart showing 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.

The following sections describe the drivers of energy demand in the projections, together with a comparison against the 2015 projections: firstly on a final energy basis, then by a primary energy basis. Energy demand as referred to in this section includes the effect of policies, details of which can be found in Section 3.

Methodology for demand projections

For the Energy and Emissions Projections, final energy demand from 2016 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[32]. “Underlying consumption” means consumption with the effect of policies which alter energy consumption removed from the total[33].

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[34] 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.

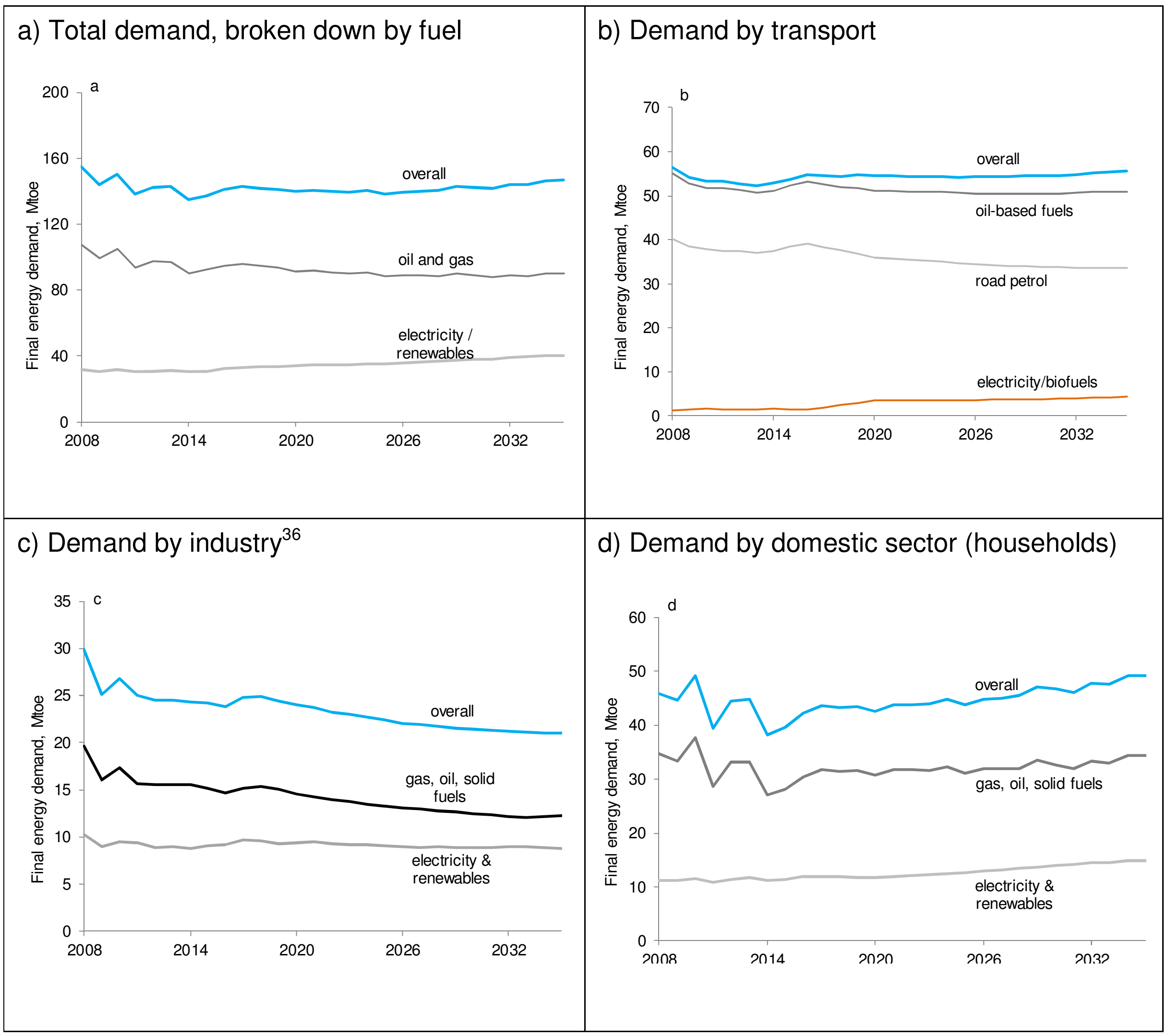
In order to obtain projections of demand *with* the effect of policies included, the process described in the last paragraph is “reversed”, i.e. an estimate of the change in future energy consumption due to policies is *subtracted* from the projected underlying energy demand.

[32] Data on historic (pre-2016) energy consumption is taken from the Digest of UK Energy Statistics (DUKES) 2016 edition: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes
[33] In order 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.
[34] See Annex M for details of the data sources for the drivers of demand.

Final energy demand

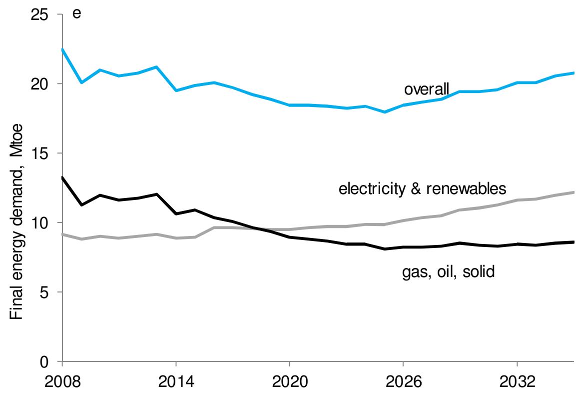
Final energy demand is higher in all years compared to the 2015 projections, by between 1 and 4% depending on the year. The majority of this increase is due to the transport and domestic sectors[35].

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



[35] In all years, at least 75% of the change from 2015 to 2016 projections increase comes from the transport and domestic sectors.
[36] The DUKES 2016 edition contained a substantial downwards revision of historical industrial energy demand for 2013 and 2014.

e) Demand by the services sector (including agriculture)



The overall trends are unchanged since the last projections. Demand is projected to fall by 2% from 2016 to the mid-2020s, returns to 2016 levels by 2028 and is 4% higher by 2035, see Figure 4a. The shape of this trend reflects the combined demand across the four major energy consuming sectors[37]: transport (Figure 4.2b), domestic (Figure 4.2c), industry (Figure 4.2d) and services (Figure 4.2e). However, the trends in demand by sector are rather different. Throughout the period 2016 – 2035, projections show a 16% growth in demand in the domestic sector whereas demand in industry is projected to fall by 12%. Total demand in transport and services shows a slight increase (2%). The reasons for the sectoral trends are discussed in detail below.

Transport is the largest consumer on a final energy basis, accounting for 39% of final energy demand in 2015. This share is projected to stay almost constant to 2035. Most (97%) of the 2015 consumption was due to oil-based fuels (Figure 4b), although their share of demand is projected to fall to 92% by 2035. As in the 2015 projections, this is due to the uptake of electric vehicles and the renewable transport fuel obligation which mandates suppliers of road transport fuels to include a set proportion of biofuel.

Transport energy demand is substantially higher in this edition compared to the 2015 projections: 3% higher on average between 2016 and 2035. This is primarily due to a revision of the estimated fuel efficiency of road vehicles. The revised efficiencies are more representative of "real world" conditions rather than those in laboratory testing.

[37] Definitions of sectoral final energy demand as referred to in this section are as follows. For transport, demand includes international aviation, i.e. international flights departing from UK airports. Fuel used for inbound flights is not included. See Annex F for energy demand specifically due to international aviation. For industry, demand due to the iron and steel sector is included. For services, demand from commercial services, public administration and agricultural installations is combined.

The **domestic sector** also accounts for a large share of total final energy demand: almost 30% in 2015, rising to 34% by 2035. The increase in demand is suppressed to some extent by rising energy prices, driven by rising fossil fuel prices.

Electricity and renewables accounted for 29% of total domestic demand in 2015, with the rest supplied by fossil fuels. The electricity and renewables share is projected to be very similar in 2035, at 30%. The projected trends in demand by fuel for this sector are displayed in Figure 4.2c.

Domestic energy demand is higher than in the 2015 projections: 5% higher on average between 2016 and 2035. To the early 2020s, this is primarily due to lower gas and electricity price assumptions whereas after this point an upwards revision in average household income is responsible. A reduction in the projected energy savings due to policies has resulted in a small increase in demand: less than 1% on average for each year between 2016 and 2035 (see Section 3 for details).

The **industrial sector** accounted for almost one fifth of total final energy demand in 2015. Demand is projected to be lower than in the 2015 projections in most years: 4% lower in 2016 and 7% lower in 2035. The majority[38] of this reduction is due to a major revision of the relationships used to project industrial energy demand and economic activity[39,]

In these projections, energy demand is projected to fall by 12% between 2016 and 2035. This is despite a projected 3% rise in total industrial economic activity over the same period. The share of demand supplied by electricity and renewables in this sector is higher than the economy-wide average, at 37% in 2015. This is projected to rise to 42% in 2035. The projected trends in demand by fuel for this sector are displayed in Figure 4.2d.

The **services sector** accounts for 14% of final energy demand in 2015 and this share remains almost constant through to 2035. However, the growth in the share of electricity and renewables consumption, from 44% in 2015 to 58% in 2035, is the strongest of any sector[40]. This is mainly due to a large projected increase in the share of total *commercial services* energy demand which is electricity, from 49% in 2015 to 70% in 2035[41].

[38] Revisions to UK economic growth released by the Office of Budget Responsibility (OBR) in 2016, had the effect of reducing projected industrial energy demand for each year from 2016 to 2035 inclusive. The fall in tonnage of steel produced by UK plants during 2016 reduces projected total industrial energy demand by only 0.1% on average for each year over the same period.

[39] Economic activity, as represented by the gross value added (GVA) of industry, is a key driver of energy demand. Projections of industrial GVA, based on UK GDP projections issued by the OBR, are produced specifically for the Energy and Emissions Projections.

[40] The change in this share between 2015 and 2035 in transport is +5%, in domestic is +2% and in industry is +3%.

[41] An increase in the share for electricity of commercial services energy consumption has been observed since at least 1970, when it was only 26%. The increase in the *projected* share reported here relies on the assumption that historic rates of increase of the share will continue in the future.

Final energy demand across all fuels in this sector is 8% higher, on average between 2016 and 2035, in this year’s projections. This is mainly due to revised projections for the key energy demand drivers of ambient temperature and energy prices.

Primary energy demand

The projection and trend for primary energy demand looks similar to the 2015 edition of these projections: demand is projected to decline steadily to 2025 and then increase as the impact of existing policies declines.

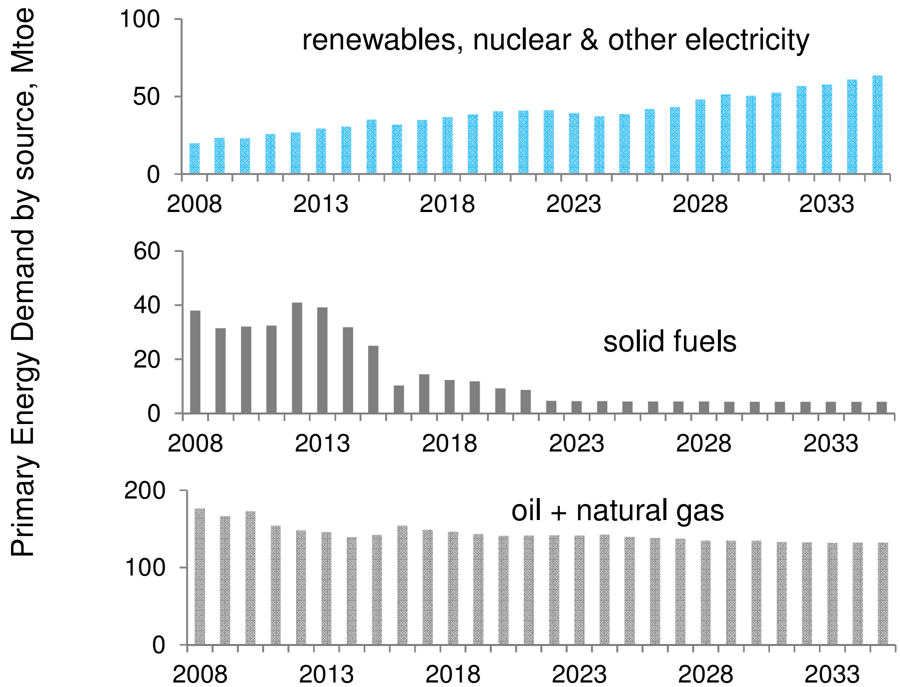
Primary energy demand is projected to fall to 182 Mtoe (million tonnes of oil equivalent) in 2025 from 196 Mtoe in 2016 before rising back to 2% above current levels in 2035.

Figure 4.3 shows a 59% decline in solid fuel use between 2016 and 2035. This is mainly due to a decreasing reliance on coal for electricity generation.

In comparison, natural gas use is projected to fall by 24% between 2016 and 2035. Currently, the amount of natural gas used for electricity generation approximately equals that used for cooking and heating in households. However, the amount of gas used for electricity generation is projected to decrease by 70% whereas the amount used by households is projected to increase by around 17% over this period.

Oil use is projected to decline by 4% to 2025, reflecting declining use in road transport, before increasing slightly to 2035 due to increasing use in air transport. In contrast, the use of renewables and nuclear fuels for electricity generation is projected to increase strongly with new nuclear generating capacity scheduled to come online in the mid-2020s.

Figure 4.3: Primary energy demand by fuel, Mtoe



5 Electricity generation

- Emissions from power stations have halved since 1990, including a 35% fall between 2010 and 2015[42] (provisional statistics).
- Strong progress is set to continue with the low carbon share of UK electricity generation projected to increase from 24% in 2010 and 47% in 2015 to 61% in 2020.
- Beyond 2020, the scenario presented here is illustrative and includes assumptions that may go beyond current Government policy.

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

The power supply sector is projected using BEIS's "Dynamic Dispatch Model" (DDM)[43]. This chapter considers projections of Major Power Producers (MPPs) and autogeneration. The definition of Major Power Producers in EEP differs from that in DUKES and includes all renewable generators[44]. MPPs account for around 94% of the United Kingdom's electricity generation, the remainder coming from autogeneration as described below.

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. Up to 2020, the reference scenario reflects current power sector policies[45]. Beyond 2020, the reference scenario includes assumptions that go beyond current Government policy, and is therefore illustrative. The modelling was undertaken in December 2016. The results do not indicate a preferred outcome and should be treated as illustrative.

The DDM projects a continued decline in fossil fuel based generation to 2020. In the projections beyond 2020, this trend continues with increased renewable, nuclear and imported electricity.

[42] Provisional UK GHG emissions statistics available from here: https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2015
[43] For detail on the DDM see https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm
[44] The coverage of the MPP category is defined and discussed in paragraph 5.67 and following of DUKES. However, within the EEP, all renewables are included in the MPP category whereas in DUKES some renewables are included as autogeneration: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/552060/DUKES_2016_FINAL.pdf
[45] The Renewables Obligation (RO) assumptions in the baseline scenario have been updated for this year's Energy and Emissions Projections, and are consistent with the reference case.

Figure 5.1 shows the projections of generation by technology group to 2035. Detailed projections are in Annex G of this report.

Figure 5.1: Generation and net imports, TWh

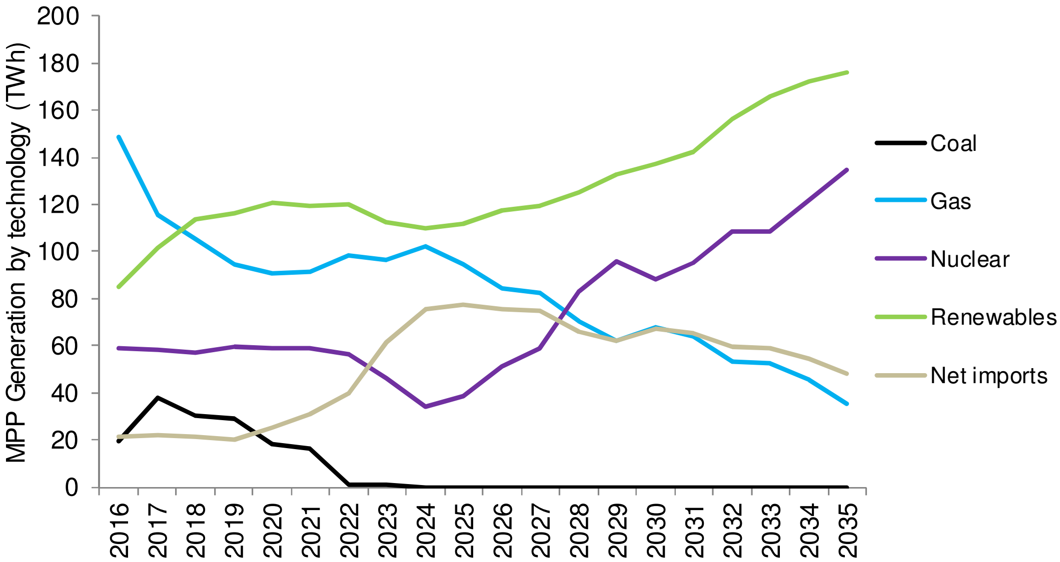
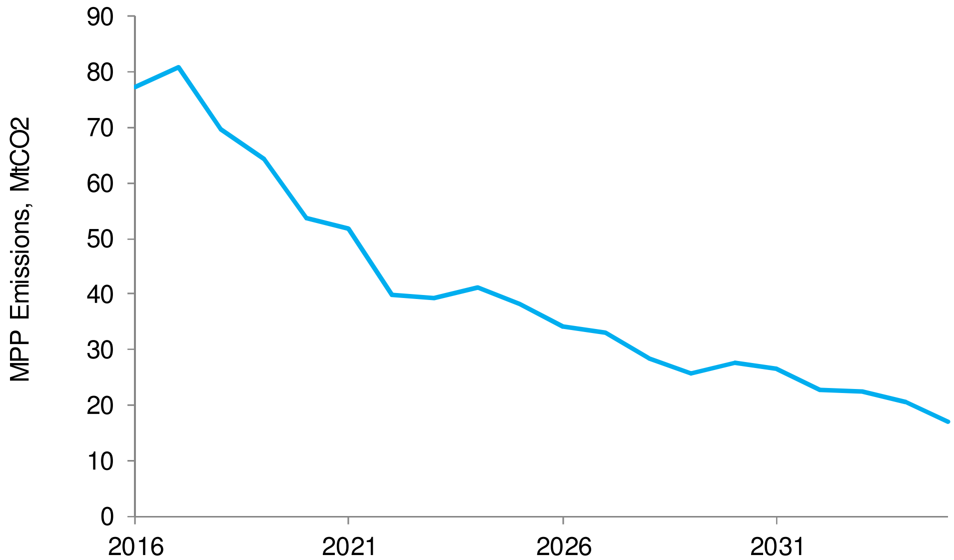


Figure 5.1 shows a phasing out of coal-fired generation with unabated gas-fired generation gradually being displaced in the longer term by more renewables and nuclear based generation as well as increasing net imports via interconnectors. Current model outputs show a small temporary reduction in renewable electricity generation in the early 2020s. This is due to a number of factors, including the temporary increase in gas generation to maintain system flexibility. There is significant uncertainty over how the tools available for system management would adapt to changes in generation mix, and these outputs should be viewed as illustrative. Volatility in fossil fuel prices makes it difficult to accurately project the decline in coal fired generation.

Emissions from major generators

In the reference case, the amount of CO_2 emissions from electricity generation by major power producers falls from 77Mt in 2016 to around 54Mt by 2020. Under the illustrative scenario presented for beyond 2020, emissions are projected to fall to 28Mt in 2030. Further detail can be seen in the annexes to this report.

Figure 5.2: CO_2 emissions from electricity supply sector, Mt



Emissions from MPPs fall under the EU Emissions Trading System and therefore emissions savings do not count directly towards meeting carbon budgets. Reducing power sector emissions is however important to meet our 2050 greenhouse gas emissions target.

Autogeneration

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.

This year there have been some revisions to the assumptions concerning CHP and autogeneration capacity and generation. To align the projections with the latest historic DUKES data, capacity and generation from qualifying Good Quality CHP have been revised downwards by about 20% from EEP 2015.

Table 5.1, below, gives the projections of Good Quality CHP generating capacity from recent EEP editions. They show a consistent pattern with greatest capacity at around 2020 followed by a slow decline through to 2035.

Table 5.1: Projections of total installed Good Quality CHP capacity[a], GW

	2010	2015	2020	2025	2030	2035
EEP 2014	6.2	7.3	9.2	8.1	7.1	6.9
EEP 2015	6.2	7.4	9.9	9.4	8.3	7.7
EEP 2016	5.9	5.7	7.6	7.2	6.4	6.0

a. These are the projections of total CHP capacity including CHP MPPs and renewable plant. CHP MPPs and renewable CHP are excluded from the autogenerator category elsewhere but are included in the MPP tables.

There is also an amount of CHP which does not qualify as 'Good Quality' under the CHPQA, as well as pure autogeneration (with no heat sold). The combined total capacity of these installations is estimated to be less than 1 GW in all years.

Differences from EEP 2015 projections

Key changes in the reference case compared to 2015 projections include:

- In 2016, emissions from the power sector are around 33Mt lower than projected in EEP 2015. This is largely due to changed assumptions around fossil fuel prices: lower gas and coal prices tend to favour gas generation. A number of coal plants also closed in 2016, including Longannet and Rugeley. The projections also show higher electricity imports than last year. These changes to the DDM input assumptions also lead to the emissions intensity being 20-50 gCO_2e/kWh lower between 2017 and 2022 than in EEP 2015.
- Carbon Capture and Storage (CCS) is not assumed to come on in any significant capacity over the period of this modelling. In the 2015 projections, CCS generation had been assumed from 2025. The Government's approach to CCS will be set out in due course.
- Assumptions about the Carbon Price Floor trajectory have been revised[46]. Therefore the modelling for these projections now assumes fossil fuel based generation is less expensive during the 2020s in comparison to costs in the 2015 projections. The change to the Carbon Price Floor trajectory is to be considered a BEIS modelling assumption and not indication of wider

[46] Details of the revised assumptions can be found on p10 of the Electricity Generation Costs report at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566567/BEIS_Electricity_Generation_Cost_Report.pdf

government policy. The government will continue to consider the appropriate mechanism for determining the carbon price in the 2020s.

- Fossil fuel prices – Fossil fuel prices have been updated using the assumptions published in November 2016[47]. The 2016 price assumptions are lower than the 2015 assumptions, due to market developments in the short term and new evidence on the long run marginal cost of oil, gas and coal supply.
- Battery based storage capacity (around 3 gigawatts) is assumed to come on-stream by 2030.
- The Renewables Obligation (RO) assumptions in the baseline scenario have been updated for the 2016 Energy and Emissions Projections, and are consistent with the reference case.
- The DDM has improved modelling of electricity dispatch and the 'whole system' impacts of generators on the public distribution system.
- Electricity demand in the late 2020s is slightly lower (by around 3%) than projected in last year's EEP.
- The Contract for Difference (CfD) agreed with EDF Energy in connection with the Hinkley Point C nuclear plant has not required any change to EEP modelling assumptions.

[47] Fossil fuel price assumptions are available from here: https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2016

6 Uncertainty in emissions projections

- Since the 2015 report, the analysis of uncertainty has been expanded. For these projections, a wider range of input parameters have considered, and all statistical distributions on input variables have been reviewed and updated.
- In addition to the analysis involving all parameters considered (quoted throughout this report), analysis was also carried out by 3 specific categories of inputs to the model: policies, evidence base and state of the world (including factors such as GDP, population and fossil fuels).
- By the fourth carbon budget period, the greatest uncertainty comes from the state of the world category (approximately +/- 4%). Both policies and evidence base led to +/- 1% variability for this carbon budget period.

Since the 2015 projections, 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. 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. We will set out further details in our emissions reduction plan.

From this work it is clear that there is scope for innovations and changes in behaviour to influence energy and emissions in ways that are not fully captured in these projections. A project is underway to identify possible examples of such disruptions and assessment their potential impact.

Different sources of uncertainty

There are four broad steps to producing our projections, and each has uncertainty surround it:

1. **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. The impacts of this uncertainty are not reflected in the uncertainty ranges presented in this report.

2. **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 range of different forecasts for the most influential key drivers. These are summarised in Table 6.1.

3. **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. This uncertainty is not reflected in these projections; however a project is under way to explore these types of uncertainty.

4. **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 step 2 and 4 is modelled through Monte Carlo analysis. This analysis was based on 19 of the most influential drivers of energy use[48] and 25 policy savings estimates[49].

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 dollar / sterling exchange rate population, household numbers temperature[50], basic oxygen steelmaking (BOS) output	Interest rates Carbon price Electricity price
Estimated policy impact and innovation[51]	Policy energy savings (electricity, gas, oil, solid fuel and renewables in domestic, commercial services, public services, industry and agriculture) Car fuel efficiencies Light Goods Vehicle (LGV) fuel efficiencies and Heavy Goods Vehicle (HGV) fuels efficiencies	Supply side policies Policy savings from non-energy policies (e.g. fluorinated gas regulation, Agricultural Action Plan)
Evidence base	Land Use, Land Use Change and Forestry (LULUCF)	Emissions factors Global warming potentials

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

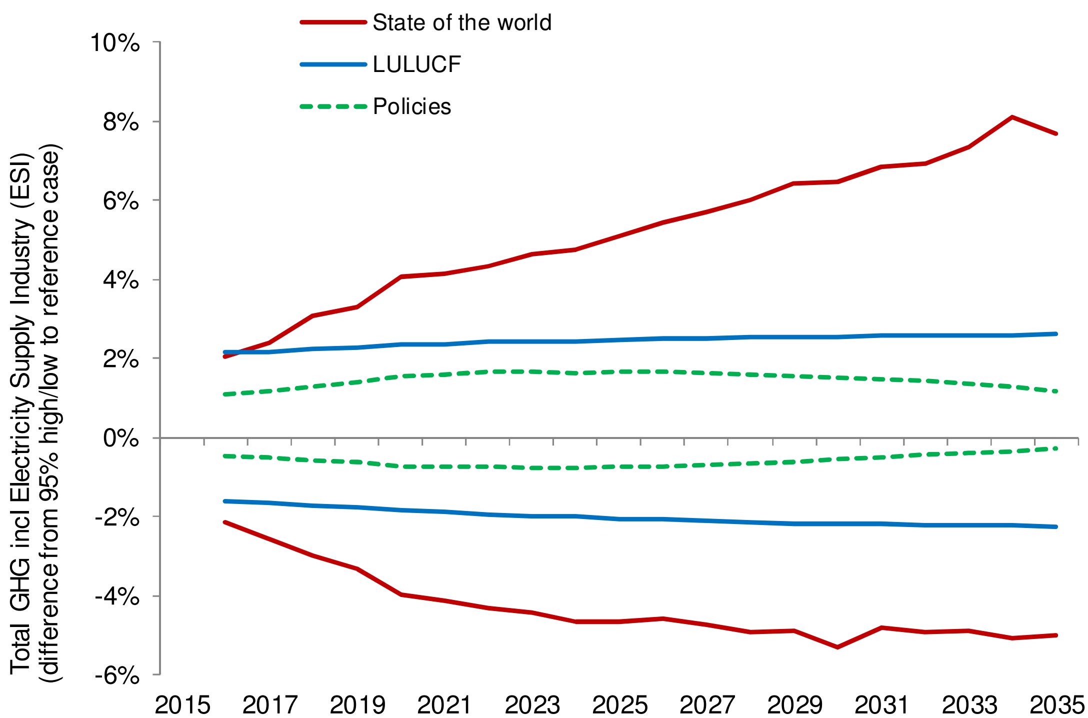
[48] These parameters were identified through sensitivity analysis as the variables having the highest impact on the model outputs.
[49] These are based around the 5 fuels (electricity, gas, oil, solid fuel and renewables) across 5 of the modelled sectors (domestic, commercial services, public services, industry and agriculture).
[50] The impact of temperature is measured by 2 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.
[51] These Projections only consider current and *planned* policies. New policies or changes to existing policies which have not yet reached the planned stage are not considered in uncertainty analysis.

was run using samples from these distributions and the resulting projections recorded over a large number of simulations[52].

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.

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



As can be seen in Figure 6.1, the different categories of parameters have different trends over time in the way that they impact total GHG emissions:

- 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

[52] 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.

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 main analysis within this report is based on all variables (the combination of all 3 categories together).

Table 6.2 shows the net carbon account total over the fourth carbon budget period. It can be seen that the combination of all variables is only slightly higher than the state of the world categories by itself.

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, policies and LULUCF)	2,186	2,096	2,053
1) State of the world	2,155	2,096	2,041
2) Policies	2,127	2,096	2,083
3) LULUCF	2,120	2,096	2,080

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:

- Model structural uncertainty (the first type of uncertainty described above, relating to a model not being a perfect representation of the real world);
- The analysis assumed that all policy inputs varied independently;
- Uncertainty analysis excludes the electricity supply industry due to the inability to run the electricity supply model with many different inputs within the available time. Therefore this analysis does not capture uncertainty on the effects of policies in the electricity supply sector;
- Not all variables were considered in the Monte Carlo simulation so there is a possibility other variables would also have been significant. However, the variables

that were included were selected as 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 methodology focuses on future uncertainty, rather than analysis of how uncertain inputs or outputs may have been historically, i.e. before 2016.

Conclusions

Understanding the scale and sources of uncertainty is important context for interpreting these projections. Looking at the different sources of uncertainty set out here, it is clear that some of the most significant drivers of uncertainty are also drivers over which Government has limited influence. For example, uncertainty from Government policies is less than uncertainty relating to the future state of the world.

It is also 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:	2016 Non-CO_2 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 and Industrial Strategy
CB	Carbon budget
CfD	Contracts for Difference
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
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