Department for
Business, Energy
& Industrial Strategy

# ENERGY AND EMISSIONS PROJECTIONS

## Methodology overview

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

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# 1 The Energy and Emissions Projections: overview

The Energy and Emissions Projections (EEP) model suite is BEIS's set of tools for projecting future energy demand and greenhouse gas emissions for the UK.

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 published outputs of the EEP are a report, data underpinning the tables and figures within the report and a range of annexes. These are all available online[1], including past editions back to 2008.

The EEP projects energy demand and emissions, based on economic, demographic and other drivers—projections of which are inputs to the modelling suite. The projections account for the expected impact of current and planned Government policies. They provide assumptions for modelling climate change and energy policies, for monitoring progress against emissions reduction targets and for reporting internationally (e.g. under the EU Monitoring Mechanism as well as National Communications to the UNFCCC).

The core EEP model suite comprises three related models. The Energy Demand Model (EDM) projects demand for energy sources including electricity and renewable fuels. The Dynamic Dispatch Model (DDM) projects the electricity generation mix and electricity wholesale price and the Prices & Bills (P&B) model projects retail energy prices. To produce the EEP, we combine the outputs from the three models (EDM, DDM and P&B) and aggregate them for reporting purposes.

Since there are interactions between electricity demand and electricity prices, we produce the EEP by "cycling" these three models together until they converge on a single answer for electricity demand, electricity supply and retail electricity prices (to within a small degree of variance).

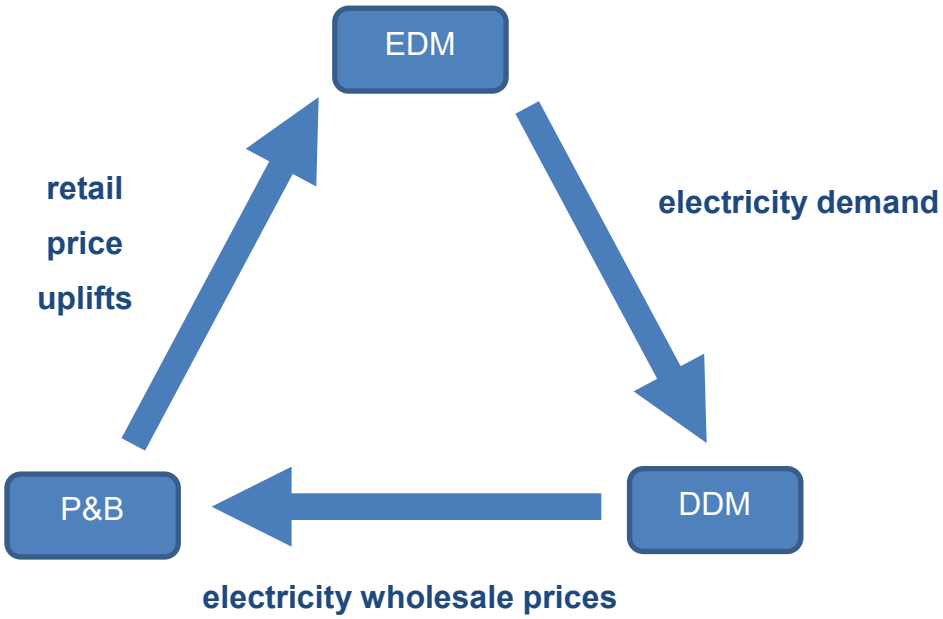
[1] Energy and emissions projections: https://www.gov.uk/government/collections/energy-and-emissions-projections

This process of model cycling is coordinated by a centralised spreadsheet called the EEP Control Module which:

- supplies common assumptions to all three models;
- runs each model in turn, passing key output data from one model to the next;
- checks for convergence of key outputs;
- and exports all data once this is achieved.

The following diagram illustrates the links between the components of the EEP core modelling suite:

**Figure 1: EEP data transfer between models**




We then project energy-related emissions by multiplying the amount of fossil fuels consumed by emissions factors. The EDM also produces projections of emissions from industrial processes. Emissions from other sources such as those from livestock or from changes in land use come from separate projections which we add to the emissions from the core modelling suite (see next section).[2]

[2] We publish details of the modelling methodology for non-energy and non-CO2 emissions each year as an annex to the EEP.

# 2 The core model suite

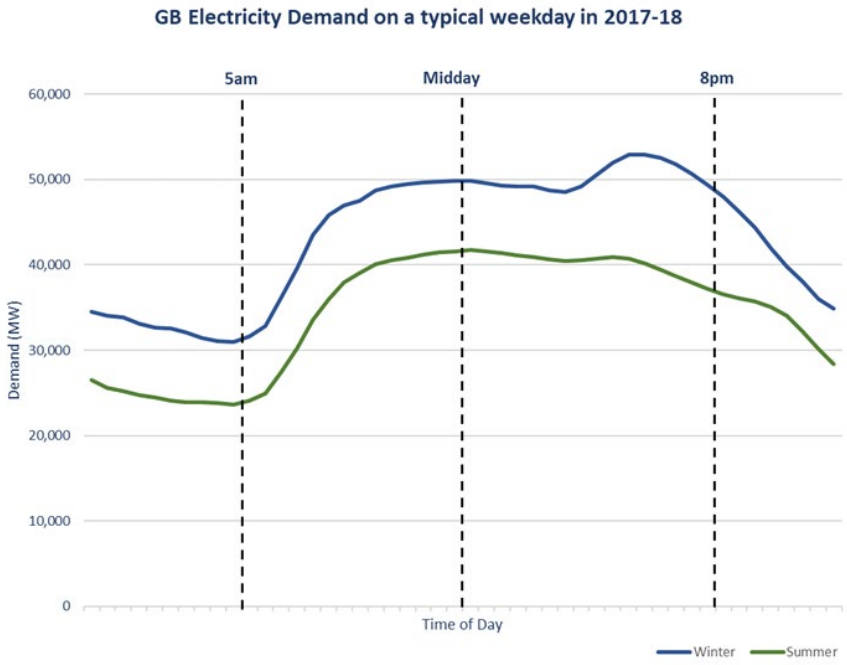
## *Energy Demand Model (EDM)*

The core of the EDM is an Excel model containing a set of equations that project energy demand and emissions by sector as named entities or variables. The EDM has over 2,500 of these variables representing all sectors of the UK economy. Most of the core equations are based on econometric analysis[3] of past data. The core model and associated input / output-processing workbooks also contain transformations to convert raw inputs to the format required for the core model and to translate model outputs into the published numbers.

## *Dynamic Dispatch Model (DDM)*

The DDM simulates the operation of the electricity generation market and the investment decisions of market participants in response to a given demand profile, power sector policies and other market conditions. The DDM transforms the projections of annual electricity demand it receives from the EDM into daily and seasonal load curves (see figure 2).

**Figure 2: Typical daily load curve in the DDM**




[3] Econometrics is the quantitative application of statistical/mathematical models using data to develop theories or test existing hypotheses in economics, or for forecasting future trends from historical data.

It is a profit-maximisation model and projects total generating capacity, plants built and the economics of their operations. A model run may typically project 25 years into the future in half-hourly demand segments[4]. For every half-hour it determines which plants will be generating, the amount of greenhouse gas emissions they will produce, the wholesale electricity price and other economic metrics.

The DDM only models electricity supply in Great Britain. We augment the DDM outputs with a simple projection of generation and generating capacity in Northern Ireland to provide UK-wide power sector projections for the EEP.

### *Average Prices & Bills Model (P&B)*

The Average Prices & Bills Model estimates the average impact of energy and climate change policies on energy prices and bills for households and businesses, along with the price impacts of network costs and supplier costs. These costs to consumers are known as “price uplifts” and they are added back onto the wholesale energy prices in the EDM. This price increase suppresses projected energy demand.

The modelling only includes those policies already in place or that have been planned in a sufficient degree of detail (i.e. with quantified estimates of costs and benefits). We discuss this further in the section on scenarios.

[4] For background information on the DDM please see: https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

# 3 EEP model inputs and assumptions

Data from BEIS sources updated annually:

- Fossil fuel prices[5];
- Digest of UK Energy Statistics[6] (DUKES: historic energy statistics);
- EU ETS carbon price projections[7];
- BEIS policy savings (fuel use savings from low carbon policies)[8];
- The DDM[9] uses electricity market assumptions.

Other data come from outside BEIS:

- Forecasts of demand for aviation and rail, as well as assumptions about road vehicle types (Department for Transport);
- EU ETS verified emissions (European Union registry)[10];
- Household number projections[11] (Ministry of Housing, Communities and Local Government);
- Winter Degree Days[12] (Met Office);
- Greenhouse gas Inventory[13] (currently produced by Ricardo);
- Economic growth projections[14] (Office for Budget Responsibility);
- Some non-$CO_2$ greenhouse gas projections are derived from external sources (e.g. agriculture projections are provided by Defra).

All model input data are available in the public domain, except the assumptions for the Dynamic Dispatch Model as some of these are commercially confidential.

# 4 Energy demand projections

The Energy Demand Model generates projections of UK energy use by year, economic sector and fuel. We project energy demand on two different bases:

[5] https://www.gov.uk/government/collections/fossil-fuel-price-assumptions
[6] https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes
[7] https://www.gov.uk/government/collections/carbon-valuation--2
[8] See Annex D at https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017
[9] For background information on the DDM please see: https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm
[10] https://ec.europa.eu/clima/policies/ets/registry_en#tab-0-1
[11] https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections
[12] https://www.metoffice.gov.uk/climate/uk/data/ukcp09/datasets
[13] https://www.gov.uk/government/collections/uk-annual-national-Inventory-report
[14] https://obr.uk/

- **Final energy demand** (consumption) is the end user consumption of energy in its final form. This does not include fuel demand within the energy industry e.g. oil refining. It includes electricity consumption as a distinct energy source.

- **Primary energy demand** includes all UK energy usage including within the energy industry. Transformed fuels such as electricity and sold heat are categorised by the fuel used to generate them (e.g. fossil fuels, biomass, wind and solar energy). Primary energy demand also includes energy loss in the generation and distribution of electricity as well as net imports of electricity from overseas.[15]

As far as possible, we ensure the EDM energy demand and electricity supply projections match the definitions the Digest of UK Energy Statistics (DUKES) uses. This gives energy and emissions projections on a consistent basis with other BEIS modelling and historic data.[16]

### *Demand projection methodology*

The EDM contains variables representing energy use and emissions across different fuels and economic sectors. Each variable has a technical name and comprises a time series of annual values, some of which may hold historical data. The variable may also have an econometric equation for calculating future years' values from other variables.

As an example, the variable COMMERCE__TOTAL_TOT_DEM represents total useful energy demand[17] across all fuels in the commercial services sector.

[15] We classify Imported electricity as a primary fuel. The model does not estimate the fuel used to produce it.
[16] One exception is the EEP definition of "Major Power Producers": this includes some large Combined Heat and Power (CHP) plants which DUKES regards as "Autogenerators".
[17] This is energy available after being converted from its source fuel. To convert useful energy into the calorific value of source fuel, it must be divided by a "useful energy factor".

We project it for future years using the equation:

$$\frac{CTD(y)}{CTD(y-1)} = 0.994\left(\frac{WDD(y)}{WDD(y-1)}\right)^{0.256}\left(\frac{GVA(y)}{GVA(y-1)}\right)^{0.611}\left(\frac{AFP(y)}{AFP(y-1)}\right)^{-0.136}$$

Where:

- *y* is the current year, *y – 1* is the year before;
- *CTD(y)* is COMMERCE__TOTAL_TOT_DEM for this year;
- *WDD(y)* stands for Winter Degree Days and represents forecast winter heating requirements;
- *GVA(y)* represents forecast UK economic growth (Gross Value Added of the commercial sector[18]);
- *AFP(y)* is an average of fuel prices (including electricity) weighted by usage volume.

The above equation projects the change in energy consumption each year. The first year's projected consumption is projected by adding the projected change in consumption to latest actual. Subsequent years are projected in the same way but adding the projected change to the previous year's projected level. The equation estimates the future change in demand between two years using the projected change in Winter Degree Days, commerce GVA and average fuel prices for those two years.

We review and re-estimate model equations regularly. This work is sometimes done in-house by the EEP team and sometimes by contracted experts[19]. We regularly assess the performance of the equations against known historic outputs and prioritise the re-estimation of any which predict these actuals poorly.

Each economic sector has a bespoke set of equations for projecting fuel demand. However, in many cases we adopt a broadly similar approach for the projections:

- We project total useful energy demand for the sector using an econometric equation with key drivers such as economic growth.

[18] Gross Value Added is a similar measure to Gross Domestic Product but excludes the additional tax revenue generated for Government and includes any corporate subsidies. At an industry level, GVA is total output (roughly equivalent to turnover or sales) minus intermediate consumption (the value of goods and services purchased to produce that output and realise those sales); in a sense it is literally the value added by the industry.

[19] For example, in 2016 we commissioned University College of London to re-develop the econometric equations in the industrial subsectors:
http://www.sciencedirect.com/science/article/pii/S0140988317302943?_rdoc=1&_fmt=high&_origin=gateway&_docanchor=&md5=b8429449ccfc9c30159a5f9aeaa92ffb&ccp=y

- In each sector, the DDM projects the heat bought by consumers through heat networks. This feeds back into the EDM during the cycling process.
- We subtract this heat bought from the overall sectoral energy demand and split the remainder between major fuel groups – solid fuels, oil-derived fuels, gas, electricity and renewables.
- We calculate the shares for each fuel with a logistic regression equation[20]. They can vary over time.
- Within major fuel categories we assign a share of demand to individual fuel sub-types (e.g. burning oil). These equations are generally quite simple and in some cases are a fixed proportion for all years.

Different fuels deliver energy services with different levels of efficiency. Useful energy factors" are applied as an adjustment for these differences.

Some sectors (notably the Energy Industry and Iron & Steel) have a more complex set of projection equations modelling key processes.

### *Sectors and fuels*

Demand projections by sector are produced for the following broad energy categories:

- Electricity
- Natural gas
- Petroleum products
- Solid and manufacture fuels (e.g. coal and coke)

Some sector models include other, additional fuels:

- Iron and Steel industry sub-sector model includes fuels like benzole, blast furnace gas.
- Transport includes fuels like DERV, motor spirit, aviation turbine fuel.
- Energy Industry Sector model includes fuels like refinery gas, and colliery methane. We do not publish this (latter) fuel use in the annual EEP report but aggregate it with all primary energy in Annex E.

The "renewables" category is broad. In line with the DUKES definition it includes:

[20] A logistic regression equation involves a transformation to ensure the output is always between 0 and 1

- Wood;
- Plant biomass;
- Waste (used for combustion and landfill gas);
- Gas from anaerobic digestion;
- Liquid biofuels;
- Ground/air source pumped heat;
- Geothermal and solar heat.

The EDM projects the direct "final consumption" use of these fuels as an aggregated calorific value in ktoe (kilotonnes of oil equivalent).

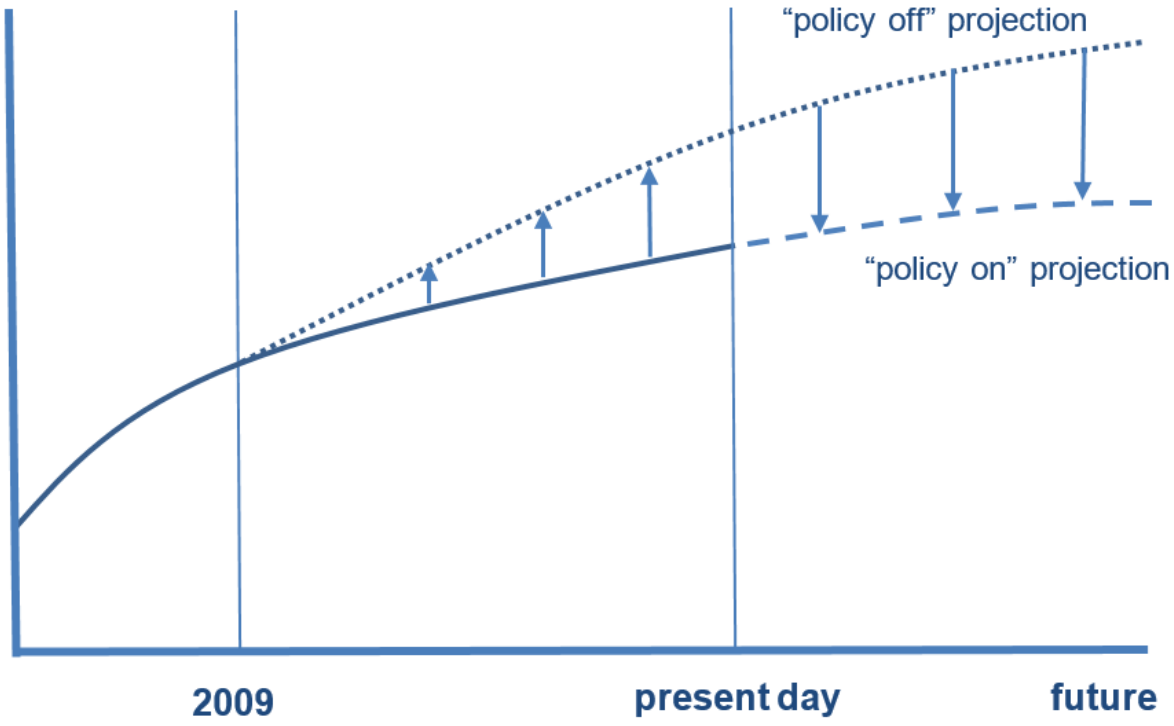
The Dynamic Dispatch Model calculates electricity derived from renewable sources. This is listed as "electricity" demand in the final consumption output but as source fuel (renewables) in the primary energy output.

### *Policy savings*

Policy teams within BEIS and other Government Departments provide the EEP team with historic and future estimates of annual fuel use (or sometimes emissions) savings[21] from the policies they oversee. The EDM econometric equations project fuel demand in each economic sector excluding the impact of the climate change policies. i.e. a "policy off" projection. We then subtract the policy fuel savings to give "policy on" projections (see Figure 3). We publish the latest policy savings projections in Annex D.

[21] Renewables savings are usually included here as negative values (i.e. policies increase the consumption of renewables).

**Figure 2: Inclusion of Government policy in projections**



# 5 Emissions projections

The EEP produces emission projections which match several different taxonomies including the National Communication Classification used by the UK Greenhouse Gas Inventory[22]. In the EDM, we calculate $CO_2$ combustion-related emissions by multiplying the fuel use projections by emission factors consistent with the Inventory. These factors represent the emissions released per unit of fuel burnt.

We also model some non-energy $CO_2$ emissions from industrial processes in the EDM. For example, we project process emissions from aluminium production by taking the last year of historic emissions data and projecting this forward in proportion to growth in the non-ferrous metals sector.

The DDM projects $CO_2$ emissions from the generation of electricity, including emissions from combined heat and power installations.

Projections of non-CO2 emissions and $CO_2$ emissions from LULUCF (land use land change and forestry). Non-CO2 projections are produced within BEIS using a separate model, which for some process emissions takes drivers from the EDM. LULUCF is produced by an external partner. These are added to energy related and non-energy related industrial process $CO_2$ emissions to produce published projections for all GHG emissions.

The following non-$CO_2$ greenhouse gases covered under the Kyoto Protocol are projected:

- methane ($CH_4$)
- nitrous oxide ($N_2O$)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)
- sulphur hexafluoride ($SF_6$)

[22] For further information about the National Atmospheric Emissions Inventory see http://naei.beis.gov.uk/

### *Traded shares*

The net carbon account measures the UK's performance against legislated targets [23]. To project it, we estimate how many emissions will be traded in the EU Emissions Trading System and (hence) what proportion will be "non-traded" emissions. To do this, we use verified emissions data from the EU registry to estimate the proportion of UK emissions in industry subsectors, services and refineries which are EU-ETS traded. We assume that these "traded shares" remain constant in each sector in future years: this means that as projected future emissions in these sectors vary, the traded emissions vary proportionately.

### *Fuel use reallocations*

The Greenhouse Gas Emissions Inventory[24] is produced under contract. It is based largely on DUKES energy data, although there are some fuel use reallocations to different categories according to information from other data sources.

The EDM mimics the most significant fuel reallocations to align the projected emissions as closely as possible with Inventory historic values.

[23] The Climate Change Act, passed in 2008, committed the UK to reducing greenhouse gas emissions by at least 80% by 2050 when compared with 1990 levels: https://www.legislation.gov.uk/ukpga/2008/27
[24] Greenhouse Gas Emissions Inventory

# 6 Scenarios

We can set the EEP model suite up to produce projections under different Government policy and economic scenarios. Each year, we publish projections for the following:

- Central Reference case – Includes all *expired, implemented, adopted* and *planned* policies[25]. This is the main projection under current and expected Government policies which we discuss in detail in the EEP report.
- High / Low Fossil Fuel prices – This has higher or lower fossil fuel prices than the reference case but is the same otherwise.
- High / Low GDP – With higher or lower annual economic growth than the reference case but otherwise equivalent.
- With Existing Measures – Includes all *expired, implemented* and *adopted* policies but not *planned* policies. This projection is required for international reporting.
- Baseline – This includes only policies implemented before the Low Carbon Transition Plan (LCTP) of 2009. It provides a basis for assessing the effectiveness of post-LCTP policies.

[25] 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.

# 7 Uncertainty

As with all projections, the Energy and Emissions Projections are uncertain. It is helpful for users to have an estimate of how accurate they are likely to be and the most significant potential causes of errors.

We perform a Monte Carlo analysis[26] to estimate the uncertainty associated with the EEP reference case. This is a mathematical technique where repeated random sampling simulates a wide range of possible future outcomes. We run the model 10,000 times without cycling, each time taking randomly from a distribution of values for each key input. We also simulate the "structural uncertainty" of some model formulae by adding random error terms to each one. Table 6.1 in the EEP report presents a list of the main variables included in the uncertainty analysis.

[26] More details can be found here: https://en.wikipedia.org/wiki/Monte_Carlo_method

# 8 Frequently Asked Questions

### Q: What fuel emissions factors are used?

We use the same fuel emissions factors as those used to produce the UK National Inventory, with some additional adjustment to take account of energy uses not captured in DUKES. We calibrate industry process emissions by relating Inventory emissions to production.

### Q: What sector definitions does EEP use?

The EDM's main projections are aligned with DUKES energy-use sectors rather than the emissions sectors defined for National Communications or the Inventory's IPCC categories. As we describe above, we present outputs from the model according to various different taxonomies.

### Q: What is the geographic coverage of the projections?

The EEP covers fuel use and emissions for the UK including Crown Dependencies (Isle of Man and the Channel Islands) but excluding Overseas Territories[27]. This is the same geographical basis as DUKES.

However, geographical coverage varies slightly by report type:

- The carbon budgets only include territorial UK emissions.
- Gibraltar is included for EU reporting purposes (such as the Effort Share Decision).
- UNFCCC reporting includes the Crown dependencies and UK Overseas Territories.

In practice, the difference between these is small.

[27] The geographical coverage of DUKES is the United Kingdom. However, within UK trade statistics, shipments to the Channel Islands and the Isle of Man from the United Kingdom are not classed as exports. Supplies of solid fuel and petroleum to these islands, from the UK, are therefore included as part of United Kingdom inland consumption or deliveries.

### Q: How does weather affect the projections?

Cold weather in winter has a big impact on energy use, especially in the residential and service sectors. This is why we include estimates of Winter Degree Days (WDDs) in the modelling. We employ two slightly different WDD seasons:

- January-March with December of the same year for electric and solid fuel heating;
- January-April with November-December of the same year for gas and oil heating.

### Q: Do the projections include CCGT plants with consent?

The projections do not take into account any announcements that energy companies make about planned future investment in new plant. However, they do include plants whose construction has already begun.