Department for
Energy Security
& Net Zero

Net Zero and the power sector scenarios

Annex O

May 2023

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

Contents

Acronym glossary

BECCS	Bioenergy with Carbon Capture and Storage
CB6	Carbon Budget 6
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture Usage and Storage
DACCS	Direct Air Carbon Capture and Storage
DDM	Dynamic Dispatch Model
EEP	Energy and Emissions Projections
EfW	Energy from Waste
GHG	Greenhous Gas
GW	Gigawatt
GWh	Gigawatt-hour
HGV	Heavy Goods Vehicle
kW	Kilowatt
kWh	Kilowatt-hour
LGV	Large Goods Vehicle
MtCO2e	Metric ton of carbon dioxide equivalent
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally Determined Contribution
TW	Terawatt
TWh	Terawatt-hour

Summary

This report accompanies the Energy and Emissions Projections: 2021 to 2040[1] publication and shows two illustrative, net zero-consistent electricity demand and generation scenarios for UK and GB. These scenarios will be used as counterfactuals in power sector analysis to assess the impact of policies against a counterfactual consistent with reaching emissions targets.

These scenarios show two technically feasible pathways for the power sector that are consistent with achieving the Nationally Determined Contribution (NDC) in 2030, the sixth carbon budget (CB6) in 2033-37, and Net Zero in 2050. These scenarios are also consistent with the British energy security strategy[2].

The scenarios are indicative of what a future energy generation mix may look like rather than prescriptive forecasts. There remains much uncertainty, including uncertainty about the pace of innovation in the market, demand levels, the technical feasibility of some technologies, and the investment decisions of electricity generators. While they should not be considered forecasts given this uncertainty, these scenarios do illustrate the mix of properties required for a NDC, CB6 and Net Zero consistent power system. The scenarios vary the electricity demand and generation mix depending on what happens in other parts of the energy sector.

The scenarios do not indicate a preferred outcome or expression of government policy.

Methodology

The Net Zero power sector scenarios reported here were generated by the department's model of the electricity supply sector, the Dynamic Dispatch Model (DDM)[3]. Most assumptions were kept the same as in the EEP Reference 2021-2040 scenario ('Reference' hereafter), with the primary changes being in electricity demand, technology mix, and carbon price.

For both scenarios, two electricity demand profiles were generated using data from the UKTIMES model (UKTM)[4] and other sectoral information (Table 1). This was done to illustrate the range of possible outcomes for UK[5] demand; these are indicative and do not define the upper and lower bounds of what is possible.

[1] https://www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040
[2] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy
[3] Further info on the DDM: https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm
[4] The UK TIMES Model (UKTM) is a least-cost, optimisation model covering all UK emissions (including land use) and the UK energy system over the period 2010 to 2060. For more information, see UCL, 'UK TIMES', https://www.ucl.ac.uk/energy-models/models/uk-times
[5] Note that UKTM models at a UK level whilst the DDM models at GB level. Demand outputs from UKTM were adjusted to be for GB only before being used in the DDM. All power sector results are adjusted to be presented at UK level unless specified otherwise.

Based on whole system modelling, power sector emissions may need to drop by 72 – 75% by 2030 (NDC), 83% by 2035 (CB6), and 98% by 2050 (Net Zero) relative to 2021 levels. In addition, the UK has an existing additional ambition to decarbonise the power sector by 2035, subject to security of supply[6]. This would result in total emissions of around 1 MtCO2e by 2050. These scenarios have been constructed such that emissions are within these ranges for each of these years whilst ensuring that security of supply is met.

Table 1 - Power sector demand levels consistent with meeting net zero across the whole economy

Scenario	2040 electricity demand (TWh)	2050 electricity demand (TWh)	Narrative
Net Zero low electrification	**495**	**596**	Based on the UKTM 'High Resource' scenario completed for the CB6 Impact Assessment[7]. Road transport mostly electrified with some hydrogen HGVs and LGVs but demand is lower due to less traffic on the road. Higher levels of hydrogen for heating in the buildings sector.
Net Zero high electrification	**578**	**792**	Based on UKTM 'Core' scenario completed for the CB6 Impact Assessment[8]. Road transport nearly all electrified with higher overall traffic levels. Higher electrification of heat in homes and businesses.

As there are a range of technology mixes that could achieve the emissions reductions required while meeting the above parameters, the single-year version of the DDM[9] was used to model thousands of different technology deployment mixes for the electricity system in 2030, 2035 and 2050. More detail on this method and results from it can be seen in the Modelling 2050: Electricity System Analysis report[10] published alongside the Energy White Paper[11].

Based on this modelling, the technology mixes reported in the scenarios here (Table 2) were chosen as they contain a balanced mix of low carbon and flexibility technologies (Nuclear, Gas with Carbon Capture, Utilisation and Storage (CCUS), Wind, Solar, Interconnectors and Batteries/Demand Side Response[12]), and have total system costs within 10% of the minimum modelled. A defined amount of Biomass CCUS was also included to ensure consistency with

[6] https://www.gov.uk/government/publications/powering-up-britain/powering-up-britain
[7] https://www.legislation.gov.uk/ukia/2021/18/pdfs/ukia_20210018_en.pdf
[8] ibid
[9] Using a running mode whereby the DDM can explore a large number of capacity mixes in the year 2050.
[10] https://www.gov.uk/government/publications/modelling-2050-electricity-system-analysis
[11] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[12] Other technologies that can produce low carbon electricity may have a future role to play in the UK. We have focused on those technologies that are currently cost competitive and have significant growth potential in the UK. This does not mean other technologies will not be needed but that these are the primary technologies that will make up the bulk of future GB electricity generation.

scenarios for the Greenhouse Gas Removals Sector. The capacities used here are illustrative and are just some of many different possible pathways for the power sector.

This was supported with further modelling in 2021 and 2022 using updated market and technology information. In addition, this modelling supported and is consistent with the policy ambitions contained in the British energy security strategy.

This means that in the modelling, renewables and low carbon deployment are optimised according to the above, with other unabated technologies deploying through the capacity market or on a merchant basis through the model's investment algorithm.

In both scenarios a limited amount of subsidised hydrogen is available from 2025 onwards to reflect the availability of hydrogen supported by the Hydrogen Production Business Model[13]. Up to 100 TWh of unsubsidised hydrogen is available in 2050. The price of unsubsidised hydrogen is based on levelised cost of hydrogen production analysis. All hydrogen plants are assumed to be 100% hydrogen-fired CCGTs.

Table 2 - 2050 capacities in GW used in the scenarios. ****Hydrogen usage was limited by fuel availability, with capacity aligned to this.*

Scenario	Nuclear	CCUS	Solar	Wind	Hydro-gen*	Storage	Inter-connectors
Net Zero low electrification	13	10	73	109	35	15	26
Net Zero high electrification	24	20	90	151	45	15	26

Deployment profiles for each technology are illustrative pathways of how the power sector could contribute to meeting emissions targets. The transition to Net Zero will involve considerable technological innovation and investment; how the market responds to these changes and challenges will play a considerable part in determining future capacity mixes. Scenarios are likely to change over time as knowledge and understanding of this transition evolved.

Uncertainties over the timing and characteristics of long-term storage and energy from waste with CCUS meant that these were not included in these scenarios – although both may have a role to play in the power sector in future. Long-term storage will likely play a similar role to hydrogen in the system and hydrogen may have to be stored before being used in power plants. Therefore hydrogen modelling can be assumed to be a proxy for long-term storage.

Understanding of the role of power in the wider system, what the sector will look like, and the level of demand it will need to meet, will evolve over time. There is significant interconnectedness between the power and other sectors; for instance, the extent to which hydrogen is used for heat vs. electrification, the ability to reduce overall electricity demand (e.g.

[13] https://www.gov.uk/government/publications/hydrogen-production-business-model

through energy efficiency), and the availability and cost of Greenhouse Gas (GHG) removal technologies, such as bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS).

Summary of Projections

There are significant differences between these scenarios and the Reference. The Net Zero high electrification and Net Zero low electrification scenarios have emissions at around 4 MtCO2e by 2040 compared to 22 MtCO2e in the Reference despite GB demand being 34-79% higher. This is a result of the much higher levels of low carbon and renewable generation in these scenarios.

Figure 1 and Figure 2 show the annual electricity generation by each technology out to 2050 for both sets of Net Zero Scenarios. The scenarios show that:

- Substantial **additional deployment** of most technologies compared to the Reference in 2040 is required to meet additional demand and ensure low emissions. In comparison to capacity levels in the Reference in 2040, the Net Zero scenarios include, in total:
  - 9 – 14 GW nuclear.
  - 98 – 124 GW wind (offshore and onshore).
  - 9 – 14 GW CCUS.
  - 62 – 77 GW solar.
- **Hydrogen** is utilised in the Net Zero scenarios with hydrogen CCGT capacity assumed to be 16 - 18 GW by 2040 and generating 11 TWh of electricity. Hydrogen tends to act as a peaking technology in the scenarios reducing the unabated peaking generation in 2040 and 2050, leading to lower emissions.
- Over time, **low carbon generation** increases. In both Net Zero scenarios, after 2035 UK low carbon generation makes up 99% of domestic generation compared to 88% in the Reference. This is in line with our GB deployment assumptions in the Net Zero Strategy[14]. Low carbon generation in GB in 2021[15] was 31 – 35% of the amount of low carbon generation needed in GB in 2035 (473 – 534 TWh) as modelled in the Net Zero scenarios presented here. This is an update from the statistic presented in 'Powering Up Britain'[16].
- Generation from **renewables** rises significantly. By 2040, total renewable generation reaches 427 TWh and 494 TWh in Net Zero low and high electrification scenarios – compared to 282 TWh in the Reference. By 2050, renewable generation increases to 483 – 591 TWh in the Net Zero scenarios.

[14] Table 10, https://www.gov.uk/government/publications/net-zero-strategy
[15] DUKES 5.1 and 5.8, https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes
[16] Table 2, Technical Annex, https://www.gov.uk/government/publications/powering-up-britain/powering-up-britain

- **Peaking plant** generation excluding hydrogen (for example, from unabated natural gas) falls throughout the modelled period. These plants generate less than 1% of total generation by 2040 in our modelling. Non-hydrogen, peaking plant capacity increases from roughly 42 GW in 2025 to 49-78 GW in 2040 in the Net Zero scenarios. Modelling suggests that there is likely to still be a need for some peaking capacity to provide infrequent short-term dispatchable generation to ensure reliable supply in peak demand periods. This peaking capacity could be provided by low carbon peaking generation such as CCUS or Hydrogen, over and above the levels presented in this report, or by unabated gas generation.
- **Nuclear** generation increases from 2020 to 2040 in these Net Zero scenarios. By 2040, nuclear generation reaches 65 – 94 TWh in the Net Zero scenarios, in comparison to 53 TWh in the Reference. By 2050, nuclear generation increases to 91 – 180 TWh.
- From 2029 in the Net Zero high electrification scenario, and 2034 in the low electrification scenario onwards, **GB becomes a net electricity exporter to Europe** rather than a net importer. Net exports range from 41 to 60 TWh in 2040 in the Net Zero scenarios. This is because the high level of renewables on the system allows GB to export cheaper energy to Europe more regularly. For the UK as a whole this ranges from 37 - 55 TWh in 2040.
- **CCUS** generation increases significantly compared to the Reference in our modelling, reaching 30 - 36 TWh by 2040, and 33 – 47 TWh by 2050. Gas CCUS load factors are assumed to fall over time, as other low carbon capacity is deployed. However, analysis shows that its role in responding to periods of lower solar/wind output is crucial to meet security of supply. Biomass with CCUS is assumed to operate at baseload and has a constant load factor.
- **Short term battery use** increases in both Net Zero scenarios, rising from 1 GW in 2020 to 12 GW in 2040 and 2050.

Figure 1 - Electricity generation by fuel source in UK - Net Zero low electrification scenario

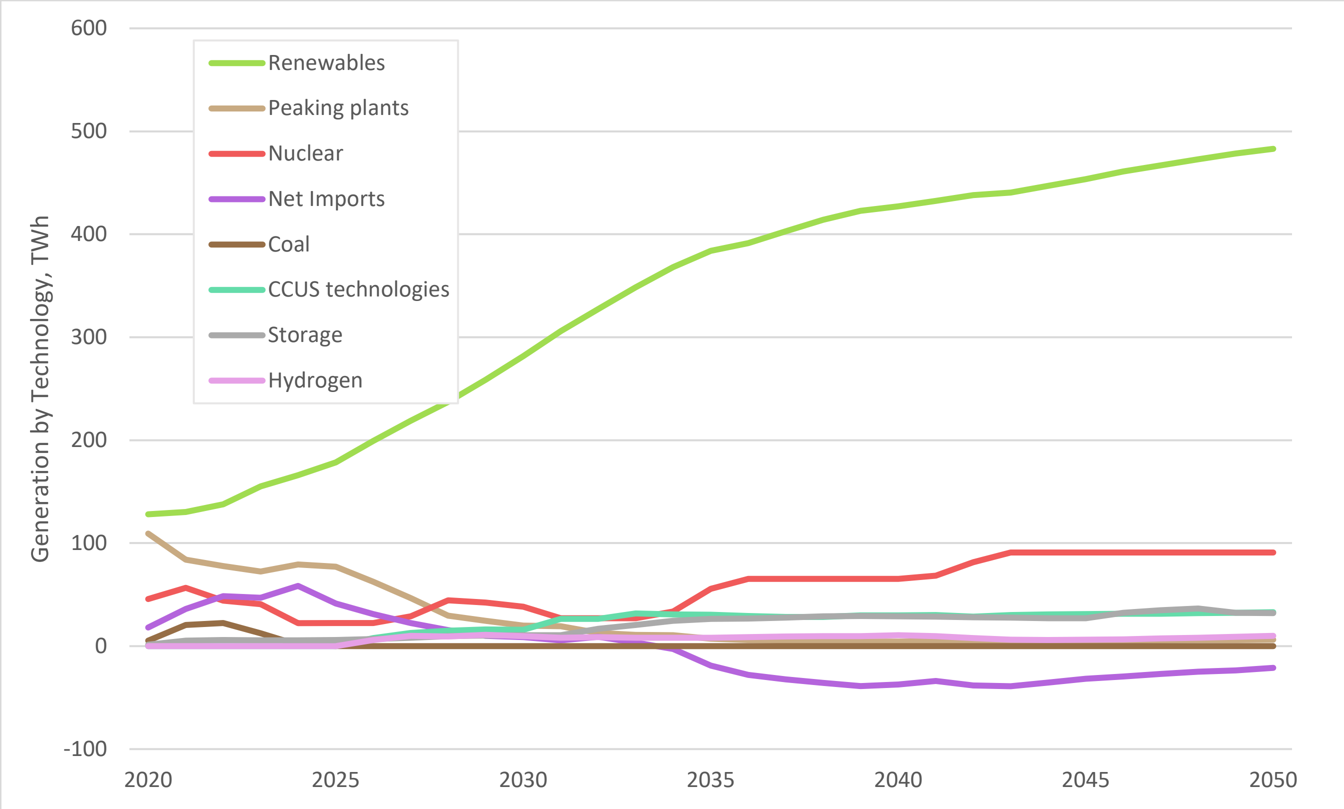
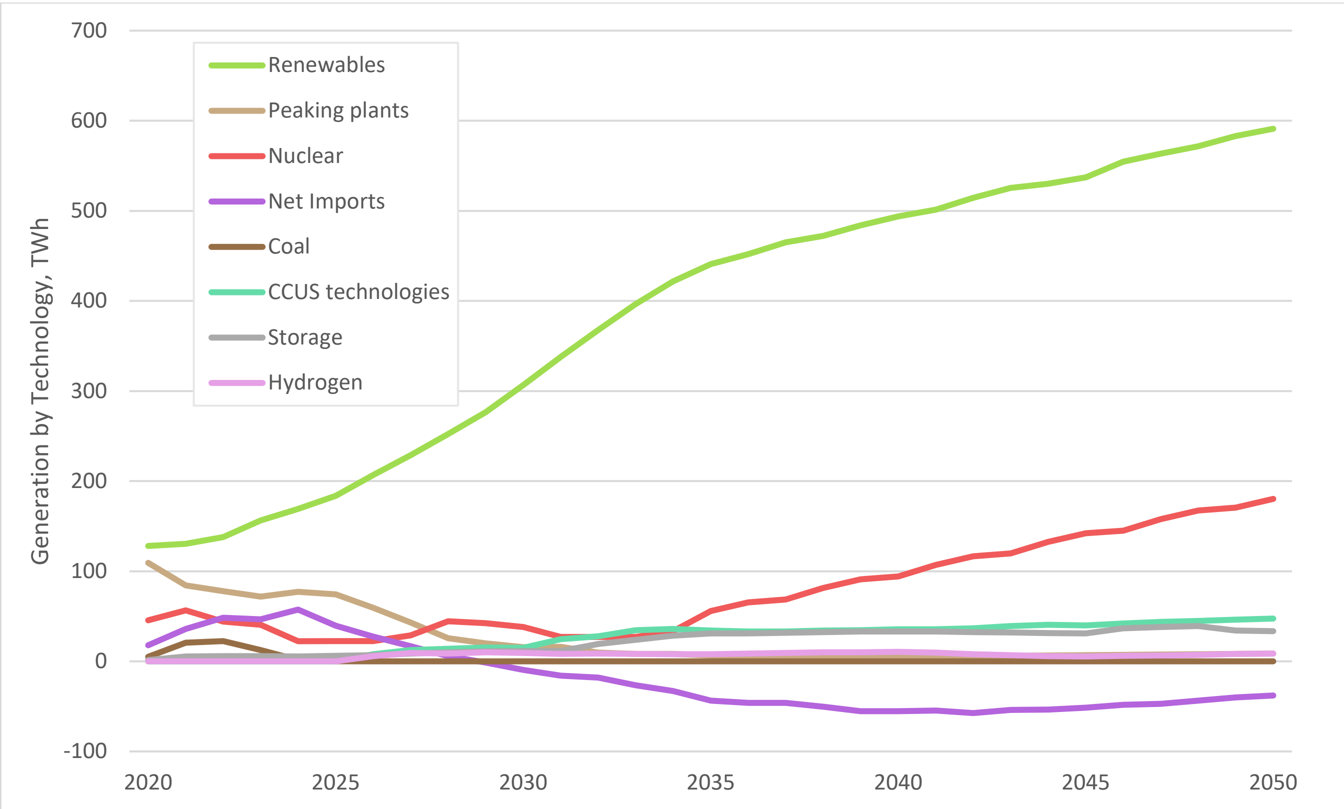


Figure 2 - Electricity generation by fuel source in UK - Net Zero high electrification scenario



This publication is available from: www.gov.uk/government/publications/energy-and-emissions-projections-2021-to-2040

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