Department for Business, Energy & Industrial Strategy

# Net Zero and the Power Sector Scenarios

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# Summary


- This report accompanies the Energy and Emissions Projections interim update[i] and shows illustrative, net zero-consistent electricity demand and generation scenarios for Great Britain. The 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 are the power sector scenarios used in the Net Zero Strategy[ii] and show technically feasible pathways for the power sector that are consistent with achieving the Nationally Determined Contribution (NDC) in 2030, the Carbon Budget 6 (CB6) in 2033-37, and net zero in 2050.
- The scenarios are indicative of what a future energy generation mix may look like rather than prescriptive forecasts. There remains much uncertainty, including for example 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.
- Two sets of scenarios are presented here, one set that includes Hydrogen-based power generation from 2030 and one set without. This reflects the significant uncertainty around Hydrogen use in power, but also, it's potential within the sector.
- The scenarios do not indicate a preferred outcome nor are they an expression of government policy.


# 1. Methodology

The net zero power sector scenarios reported here were generated by BEIS' model of the electricity supply sector, the Dynamic Dispatch Model (DDM)[iii], and were used to inform the Government's Net Zero Strategy. The scenarios are broadly consistent with the whole energy sector modelling for the Net Zero Strategy. Most underlying assumptions are the same as the Net Zero Strategy Baseline[iv], with changes made to make the scenarios net zero consistent.

Based on whole system modelling for the Net Zero Strategy, power sector emissions may need to drop 71 – 76% by 2030 (NDC), 80 – 85% by 2035 (CB6), and 95 – 98% by 2050 (Net Zero) relative to 2019 levels. This would result in total emissions of 1-3 $MtCO_2e$ by 2050. The scenarios have been constructed such that emissions are within these ranges for each of these years whilst ensuring that security of supply is met.

[i] Energy and emissions projections: Net Zero Strategy baseline (partial interim update December 2021) - https://www.gov.uk/government/publications/energy-and-emissions-projections-net-zero-strategy-baseline-partial-interim-update-december-2021
[ii] https://www.gov.uk/government/publications/net-zero-strategy
[iii] Further info on the DDM: https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm
[iv] For details of assumptions in the Net Zero Strategy, see the technical annex of the Net Zero strategy.

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

| Scenario | 2050 electricity demand (TWh) | Narrative |
|---|---|---|
| Net Zero Lower demand | **575** | Based on the UKTM High Resource scenario for the NZ strategy. Road transport mostly electrified with some Hydrogen HGVs and LGVs but demand less due to less traffic on the road. Higher levels of Hydrogen for heating |
| Net Zero Higher demand | **765** | Based on UKTM High electrification scenario for the NZ strategy. Road transport nearly all electrified with higher overall traffic levels. Higher electrification of heat in homes and businesses. |

*Table 1 – Power sector demand levels consistent with meeting net zero across the whole economy.*

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[vii] 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[viii] published alongside the Energy White Paper[ix].

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[x]), and have total system costs within 10% of the minimum modelled. This was done for scenarios with and without Hydrogen. A defined amount of Biomass CCUS was also included to ensure consistency with 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.

In the modelling, it is assumed most low carbon capacity is supported in some way; renewables are deployed through the Contract for Difference (CfD) mechanism[xi], Nuclear is deployed through a Regulated Asset Base (RAB)[xii] and Gas CCUS through

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[v] 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

[vi] 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 presented here are at GB level

[vii] Using a running mode whereby the DDM can explore a large number of capacity mixes in the year 2050

[viii] https://www.gov.uk/government/publications/modelling-2050-electricity-system-analysis

[ix] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

[x] 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 are anticipated to make up the bulk of future GB electricity generation to 2050

[xi] The Contracts for Difference (CfD) scheme is the a government scheme for supporting low-carbon electricity generation - https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference

[xii] A RAB model is used to incentivise private investment into public projects by providing a regulated return on investment for developers - https://www.gov.uk/government/consultations/regulated-asset-base-rab-model-for-Nuclear. Within the modelling RAB is modelled in the same way as CfD but with hurdle rates for technologies adjusted.

a Dispatchable Power Agreement (DPA) type mechanism[xiii]. This does not indicate that these are BEIS' preferred method to deploy these technologies, more that this is a way to reflect that many technologies currently may require some support to deploy.

| Scenario | Nuclear | Gas CCUS | Solar | Onshore Wind | Offshore Wind | Hydrogen† |
|---|---|---|---|---|---|---|
| Net Zero Lower Demand with Hydrogen | 11 | 11 | 58 | 24 | 73 | 20 |
| Net Zero Higher Demand with Hydrogen | 22 | 19 | 81 | 43 | 92 | 25 |
| Net Zero Lower Demand without Hydrogen | 11 | 13 | 60 | 30 | 80 | 0 |
| Net Zero Higher Demand without Hydrogen | 24 | 21 | 90 | 50 | 100 | 0 |

*Table 2 – 2050 Capacities in GW used in the scenarios. † Hydrogen usage was limited by assumed fuel availability (up to 60 TWh fuel in 2050), with capacity aligned to this.*

For the Hydrogen scenarios, the Hydrogen price was adjusted so that Hydrogen power plants were lower in the merit order than unabated Gas by the early 2030s with all Hydrogen plants assumed to be CCGTs. Interconnectors, Batteries, and some Onshore Wind and Solar are assumed to deploy through the market on a merchant basis. All other technologies (except existing and planned plants) are built by the model's investment algorithm[xiv].

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 evolves. 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 so 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. 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).

[xiii] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/984402/dpa-update-may-2021.pdf

[xiv] Unabated technologies are mostly deployed through the capacity market in the model

# 2. Summary of Projections

There are significant differences between these scenarios and the Net Zero Strategy Baseline (Baseline hereafter)[xv]; the Net Zero Higher and Net Zero Lower demand scenarios have emissions at around 3 $MtCO_2e$ by 2050 compared to 12 $MtCO_2e$ in the Baseline despite demand being 50-100% higher. This is a result of the much higher levels of low carbon and renewable generation in these scenarios.

Figures 1 to 4 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 Baseline is required to meet additional demand and ensure low emissions. This includes 7-21 GW more Nuclear (beyond Hinkley Point C), 36-65 GW more Offshore Wind, 12-38 GW more Onshore Wind and 11-21 GW Gas CCUS in 2050. Solar capacity in the Net Zero Scenarios is similar or less than in the baseline due to higher levels of merchant build in the baseline. In the Net Zero Scenarios the average capture prices[xvi] are lower than in the baseline due to increased low carbon deployment, meaning it is more challenging for large scale Solar to deploy on a merchant basis and it therefore may need some support to deploy.
- **Hydrogen** is utilised in the Net Zero Scenarios with Hydrogen assumed to be 20-25 GW by 2050 and generating 25-30 TWh of electricity. Hydrogen tends to act as a peaking technology in the scenarios reducing the Unabated Gas generation in 2050 and thus lower emissions. Having Hydrogen on the system also means less other low carbon technologies are needed as Hydrogen generation replaces these without increasing emissions. In these illustrative scenarios, there is 0-1.6 GW less Nuclear, 2 GW less Gas CCS, 8 GW less Offshore Wind, 5-7 GW less Onshore Wind and 5-9 GW less Solar in 2050 in the Net Zero Scenarios with Hydrogen compared to without Hydrogen.
- Over time, **low carbon generation** increases. In all four scenarios, from 2035 onwards low carbon generation makes up more than 99% of domestic generation. In 2030, low carbon generation is 90-93% of domestic generation compared with 86% in the Baseline.
- Generation from **renewables** rises significantly. By 2050, total renewable generation reaches 480 TWh and 580 TWh in Net Zero Scenarios without Hydrogen and 450 TWh and 570 TWh in the Net Zero Scenarios with Hydrogen - around double the 290 TWh in the Baseline in all scenarios. From 2030 onwards renewable generation makes up around 70-80% of domestic generation in all four scenarios.

[xv] The Net Zero Strategy baseline is the "baseline" projections against which the indicative "delivery pathways" outlined in the Net Zero strategy were assessed. The baseline projections are projections of what we would expect to happen in the absence of the additional measures set out in the Net Zero Strategy

[xvi] "Capture price" refers to the price an asset or technology achieves in the market – for example, because Offshore Wind generation is correlated across the country it can create periods of additional supply in the wholesale market. This depresses prices at that point and means average capture prices through the year may be below the average wholesale price

- **Unabated Natural Gas** generation falls throughout the modelled period. Natural Gas generates less than 1% of total generation by 2050 with fleet average unabated Gas load factors below 1% in all scenarios from 2035. Gas capacity increases from 35 GW in 2020 to 70-100 GW in 2050 in the Net Zero Scenarios without Hydrogen. Unabated Gas capacity is lower in the Hydrogen Net Zero Scenarios at 50-90 GW in 2050 as there is 20-25 GW of Hydrogen on the system. Increases in Gas capacity ensure that the system can still meet security of supply constraints. This suggests that ‘peaking capacity’ in some form (whether gas or hydrogen fuelled) will likely be needed to provide infrequent short-term dispatchable generation to ensure reliable supply in peak demand periods.
- **Nuclear** generation increases from 2020 to 2050 in these scenarios. By 2050, Nuclear generation reaches 85 TWh in both Net Zero lower demand scenarios and 175-190 TWh in the Net Zero higher demand scenarios; a 50-150 TWh increase on the Baseline.
- From 2030 onwards, in all scenarios GB becomes a **net exporter to Europe** rather than a net importer. Net exports range from 40 to 70 TWh in 2050. This is because the high level of renewables on the system allows GB to export cheaper energy to Europe more regularly.
- **Gas CCUS** generation increases significantly compared to the Baseline, reaching between 40 and 70 TWh by 2050. It is assumed that CCUS’ load factors will fall over time as the deployment of other low carbon capacity reduces the need for gas-based generation. However, analysis shows that its role in responding to periods of lower Solar/wind output is crucial to meet security of supply.
- **Short term Battery** use increases in all scenarios, rising from 1 GW in 2020 to 17-20 GW in 2050.

**Figure 1: Electricity generation by fuel source in GB, TWh – Net Zero Lower Demand Scenario without Hydrogen**

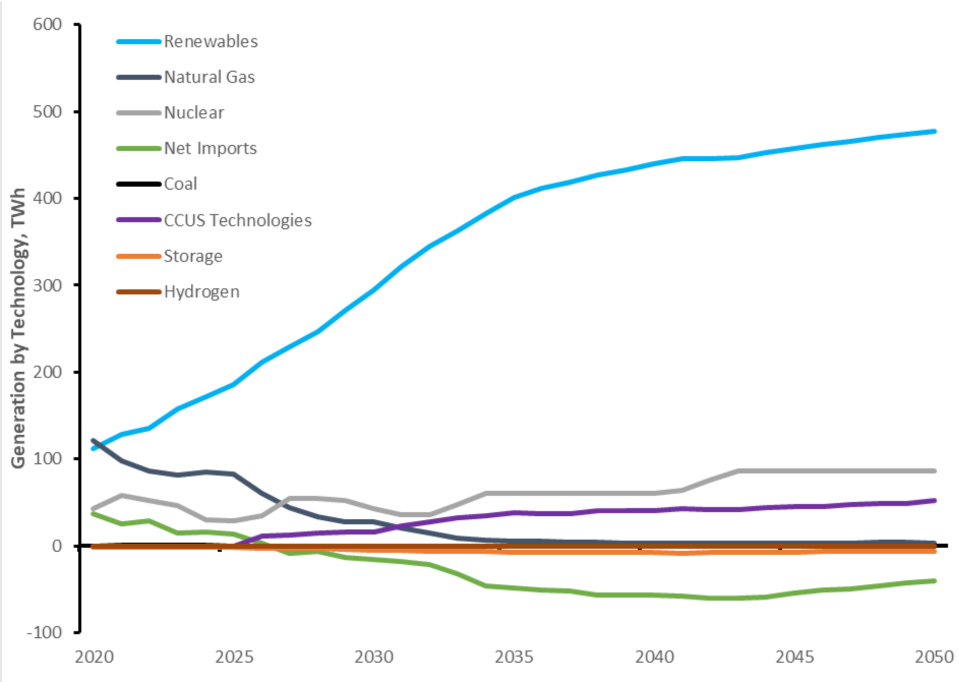



**Figure 2: Electricity generation by fuel source in GB, TWh – Net Zero Higher Demand Scenario without Hydrogen**

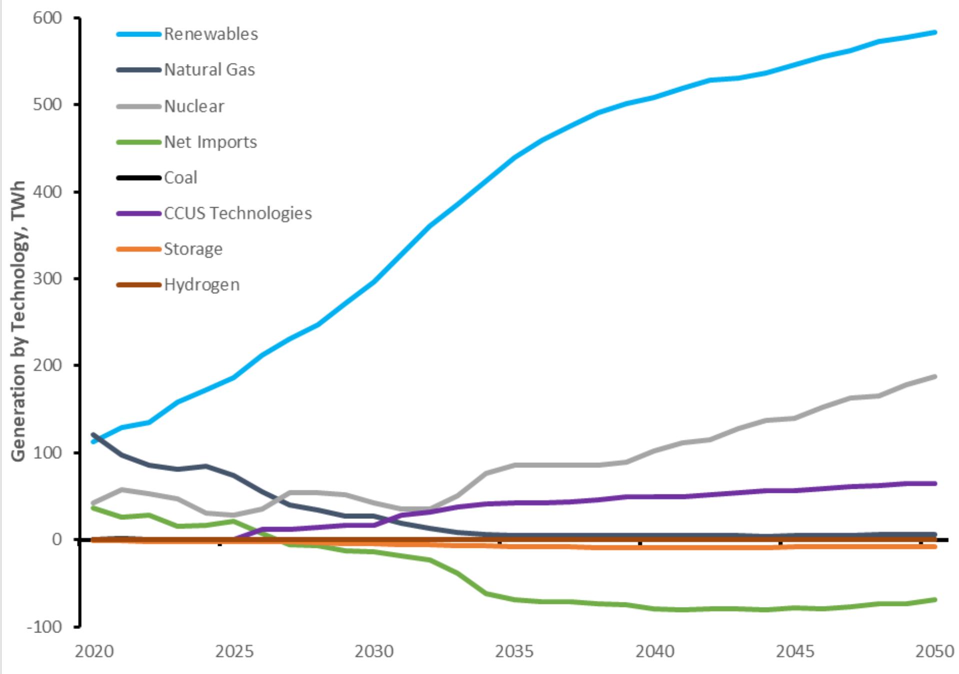


**Figure 3: Electricity generation by fuel source in GB, TWh – Net Zero Lower Demand Scenario with Hydrogen**

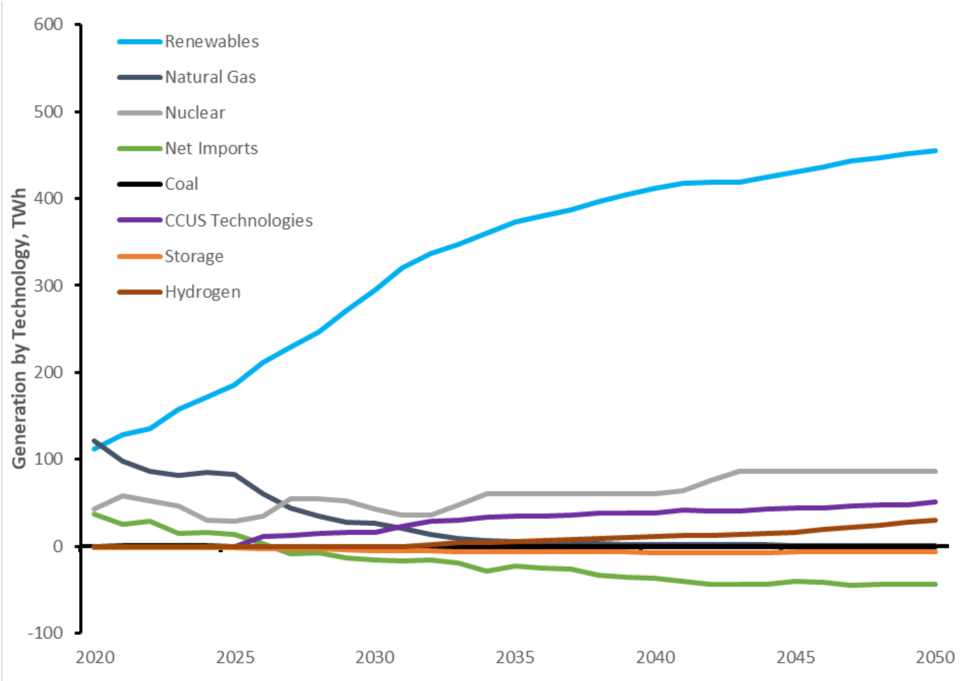
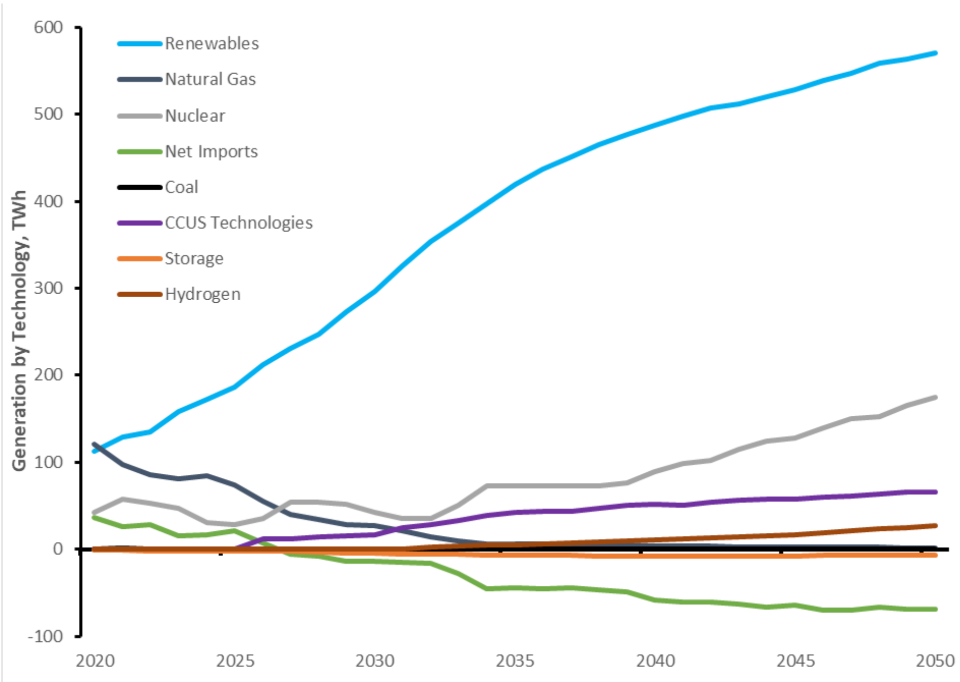



**Figure 4: Electricity generation by fuel source in GB, TWh – Net Zero Higher Demand Scenario with Hydrogen**



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