Department for
Business, Energy
& Industrial Strategy

ELECTRICITY GENERATION COSTS 2020

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Contents

Acronym Glossary

ACT	Advanced Conversion Technologies
AD	Anaerobic Digestion
ASP	Administrative Strike Price
BEIS	Department for Business, Energy and Industrial Strategy
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture Usage and Storage
CfD	Contract for Difference
CHP	Combined Heat and Power
CPF	Carbon Price Floor
CPS	Carbon Price Support
DSR	Demand-Side Response
EEP	Energy and Emissions Projections
EfW	Energy from Waste
EU ETS	European Union Emissions Trading System
FiT	Feed-in Tariff

FOAK	First of a Kind
HHV	Higher Heating Value
kW	Kilowatt
kWh	Kilowatt-hour
LCOE	Levelised Cost of Electricity
LHV	Lower Heating Value
MW	Megawatt
MWh	Megawatt-hour
NOAK	Nth of a Kind
NPV	Net Present Value
OCGT	Open Cycle Gas Turbine
O&M	Operations and Maintenance
PPA	Power Purchase Agreement
PV	Photovoltaic
WRAP	Waste and Resources Action Programme

Introduction

Electricity generation costs are a fundamental part of energy market analysis, and a good understanding of these costs is important when analysing and designing policy to make progress towards net zero.

This report, produced by the Department for Business, Energy and Industrial Strategy (BEIS), presents estimates of the costs and technical specifications for different generation technologies.

Since our last report in 2016, we have updated key assumptions that underlie our analysis.

The Department has:

- commissioned an external provider to update financing cost assumptions for a range of generation technologies (2018).
- commissioned an external provider to produce a full set of new costs and technical assumptions for gas plants with carbon capture, usage and storage (gas CCUS) (2018).
- commissioned an external provider to produce a full set of costs and assumptions for Bioenergy with Carbon Capture and Storage (BECCS) (2019).
- applied evidence from published reports and internal BEIS expertise to update key assumptions for offshore wind, onshore wind and solar photovoltaics (PV) (2018-19).
- collected new evidence on small scale solar PV using published information (2019).
- made smaller changes to specific assumptions for some technologies, including combined cycle gas turbines (CCGT), anaerobic digestion (AD) and tidal stream (2017-19).

Unless otherwise stated, other assumptions remain the same as in the 2016 report[1].

In this report we consider the costs of planning, construction, operation and carbon emissions, reflecting the cost of building, operating and decommissioning a generic plant for each technology. Potential revenue streams are not considered. The majority of costs in this

[1] BEIS Electricity Generation Costs (2016) https://www.gov.uk/government/publications/beis-electricity-generation-costs-november-2016

report are presented as **levelised costs**, which is a measure of the average cost per MWh generated over the full lifetime of a plant. All estimates are in 2018 real values unless otherwise stated.

Levelised costs provide a straightforward way of consistently comparing the costs of different generating technologies with different characteristics, focusing on the costs incurred by the generator over the lifetime of the plant. However, the simplicity of the measure means that there are factors which are not considered, including a technology's impact on the wider system given the timing, location and other characteristics of its generation. For example, a plant built a long distance from centres of high demand will increase transmission network costs, while a 'dispatchable' plant (one which can increase or decrease generation rapidly) will reduce the costs associated with grid balancing by providing extra power at times of peak demand. For the first time, we present enhanced levelised costs which capture some of the wider system impacts of adding a marginal unit of a technology to a range of generation mixes. The enhanced levelised costs provide an indication of the relative marginal impacts of different technologies to the system in different scenarios – the full system costs of different pathways are considered in BEIS's power sector modelling.

Generation costs are used as inputs to BEIS analysis, including the setting of Administrative Strike Price setting for Contracts for Difference allocation rounds[2]. However, it is important to note that levelised costs are not the same as strike prices. Strike prices include additional considerations, such as market conditions, revenues for generators, and policy factors, which are not considered in levelised costs. To date, they have also typically been expressed in 2012 prices, whereas the levelised costs reported here are in 2018 prices. For further details on the differences between strike prices and levelised costs, please see Section 3.

This report is structured as follows:

- **Section 1** provides an overview of how levelised costs are calculated, as well as some of the uncertainties around projecting the costs of future generation.
- **Section 2** outlines the changes to cost assumptions that we have made in our most recent review.
- **Section 3** outlines how BEIS uses generation cost data in its modelling, including the links between generation costs and strike prices.
- **Section 4** presents selected levelised cost estimates generated using the BEIS Levelised Cost Model and technology-specific hurdle rates.
- **Section 5** presents sensitivity analysis showing the impact of various uncertainties on the levelised costs presented in Section 4.

[2] https://www.gov.uk/government/publications/contracts-for-difference-an-explanation-of-the-methodology-used-to-set-administrative-cfd-strike-prices-for-the-next-cfd-allocation-round

- **Section 6** discusses peaking technologies, presenting an alternative metric to levelised costs on a £/kW basis.
- **Section 7** presents scenarios of the effect of including wider system impacts in the cost of generation.
- **Annex 1** presents estimated levelised costs for a full range of technologies for 2025, 2030, 2035 and 2040.

Further detail on the data and assumptions used can be found in the Key Data and Assumptions spreadsheet published alongside this report.[3]

Uncertainty

As with any projection, there is inherent uncertainty when estimating current and future costs of electricity generation. While we consider that the ranges of levelised cost estimates presented in this report are robust for BEIS analysis, these estimates should also be used with a level of care given the uncertainties around the future cost of generation. These uncertainties include the potential for unanticipated cost reductions in less mature technologies, greater uncertainty for technologies where we have access to less detailed evidence, and uncertainty around fossil fuel prices and carbon values. To illustrate the potential effects of these uncertainties, the report presents ranges and sensitivity analysis on the effects of changes in parameters.

Covid-19

The analysis in this report was completed by the end of January 2020, and so this report does not account for potential effects of the Covid-19 pandemic on electricity generation costs.

[3] https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020

Section 1: How levelised costs are calculated

The Levelised Cost of Electricity (LCOE) is the discounted lifetime cost of building and operating a generation asset, expressed as a cost per unit of electricity generated (£/MWh). It covers all relevant costs faced by the generator, including pre-development, capital, operating, fuel and financing costs. This is sometimes called a life-cycle cost, which emphasises the “cradle to grave” aspect of the definition.

The levelised cost of a generation technology is the ratio of the total costs of a generic plant to the total amount of electricity expected to be generated over the plant’s lifetime. Both are expressed in net present value terms. This means that future costs and outputs are discounted, when compared to costs and outputs today. Because the financing cost is applied as the discount rate, this means it is not possible to express it as a £/MWh component of the cost directly.

The main intention of a levelised cost metric is to provide a simple “rule of thumb” comparison between different types of generating technologies. However, the simplicity of this metric means some relevant issues are not considered. Further details on the considerations included and excluded from levelised costs can be found in Section 3.

Chart 1.1 demonstrates at a high level how Levelised Costs are calculated and what is included. For further information on how levelised costs are calculated and BEIS’s Levelised Cost Model please refer to section 4.2 of Mott MacDonald (2010). [4]

[4] Mott MacDonald, 2010, *UK Generation Costs Update*. https://www.gov.uk/government/publications/uk-electricity-generation-costs-mott-macdonald-update-2010

Chart 1.1: Levelised costs[5]

Step 1: Gather Plant Data and Assumptions

Capital Expenditure (Capex) Costs:	**Operating Expenditure (Opex) Costs:**	Expected Generation Data:
• Pre-development costs • Construction costs* • Infrastructure costs* *adjusted over time for learning	• Fixed opex* • Variable opex • Insurance • Connection costs • Carbon transport and storage costs • Decommissioning fund costs • Heat revenues • Fuel prices • Carbon costs	• Capacity of plant • Expected availability • Expected efficiency • Expected Load Factor* (all assume baseload generation with no curtailment)

Step 2: Sum the net present value of total expected costs for each year

$$\text{NPV of Total Costs} = \Sigma_n \frac{\text{total capex and opex costs}_n}{(1+\text{discount rate})^n}$$

n = time period

Step 3: Sum the net present value of expected generation for each year

$$\text{NPV of Electricity Generation} = \Sigma \frac{\text{net electricity generation}_n}{(1+\text{discount rate})^n}$$

n = time period

Step 4: Divide total costs by net generation

$$\text{Levelised Cost of Electricity Generation Estimate} = \frac{\text{NPV of Total Costs}}{\text{NPV of Electricity Generation}}$$

[5] Note that in this table, net electricity generation refers to gross generation minus any internal plant losses/use before electricity is exported to the electricity network.

Section 2: Changes to generation cost assumptions

The first half of this section covers technology-specific changes to our assumptions. For offshore wind, onshore wind, solar PV, and Carbon Capture Usage and Storage technologies (CCUS), there have been significant updates, which we discuss below. We have also made minor changes to CCGT, tidal stream and AD assumptions. Finally, we discuss those technologies for which we have not updated the generic assumptions, including nuclear and small-scale technologies (except small-scale solar PV).

The second half of this section covers changes which apply across technologies – primarily new financing cost assumptions which apply across technologies. The section also discusses capital cost ranges, decommissioning costs, fuel costs, gate fees, carbon prices, load factors and heat revenues.

We present costs for 2025, 2030, 2035 and 2040 here, though for power sector modelling the trajectory between these years is also considered.

Significant updates: Renewable technologies

For onshore wind, offshore wind and solar PV, we have conducted a review of the assumptions presented in the 2016 Generation Costs report using external published sources from industry and consultancies, informal engagement with developers and industry stakeholders, and internal technology expertise.

This new information has been used to update key assumptions on capital costs, as well as operating lifetime, operating costs and load factors. The updated assumptions for 2025, 2030, 2035 and 2040 are detailed below in tables 2.1, 2.2 and 2.4.

For **onshore wind and large-scale solar PV**, we have reviewed capital costs and developed an updated learning rate – the rate at which capital costs decrease as more plants are built, resulting from greater technical and construction experience – to reflect the projected decreases in capital costs over time. We have also reviewed technical assumptions for small-scale solar PV (<4kW, 4-10kW, 10-50kW) – updated assumptions are available in the accompanying Key Data and Assumptions file.

These projections were made prior to the proposal in the CfD Allocation Round 4 Consultation for the inclusion of Pot 1 technologies. The potential impact of a competitive auction on onshore wind and large-scale solar PV costs will be reflected in future reports.

Table 2.1: Key technical assumptions for large-scale (>5MW) solar PV (by commissioning year) [6]

	2025	2030	2035	2040
Pre-development (£/kW)	50	50	50	50
Construction (£/kW)	400	400	300	300
Fixed O&M (£/MW/year)	6,700	6,400	6,000	5,700
Variable O&M (£/MWh)	-	-	-	-
Load factor (net of availability)	11%			
Operating period	35 years			

Table 2.2: Key technical assumptions for onshore wind (by commissioning year)

	2025	2030	2035	2040
Pre-development (£/kW)	120	120	120	120
Construction (£/kW)	1,000	1,000	900	900
Fixed O&M (£/MW/year)	23,500	23,500	23,500	23,500
Variable O&M (£/MWh)	6	6	6	6
Load factor (net of availability)	34%			
Operating period	25 years			

For **offshore wind**, in keeping with the rapid pace of developments in offshore wind technology, we have assumed that the £/MW capital and operating costs decrease over time with the size of the turbine due to economies of scale. Updates to plant lifetimes and learning rates were also made.

There are significant differences of opinion over future turbine sizes; some stakeholders are predicting 20MW turbines as early as 2030, while others doubt the feasibility of such large turbines. Our estimates (shown in table 2.3) represent a balanced consideration of multiple internal and external views.

Load factors (expected annual generation as a percentage of theoretical maximum generation) were also modelled to increase with turbine size. Larger turbines are expected to produce higher load factors for several reasons, most importantly that larger turbines can access higher winds due to their increased height, and that a wind farm with fewer, larger

[6] Note that in all tables construction costs are rounded to the nearest £100/kW, pre-development costs to the nearest £10/kW, Fixed O&M to the nearest £100/MW/yr, Variable O&M to the nearest £1/MWh, and load factor to the nearest 1%.

turbines has increased efficiency. Detailed discussion of these relationships is found in a recent report for BEIS by DNV GL Energy[7]. Future load factors were calculated by combining a theoretical turbine power curve (power output as a function of wind speed, modelled using turbine specifications provided by manufacturers) with hourly wind speed data from existing offshore wind sites. Load factor assumptions are also shown in table 2.3.

Updated cost assumptions for offshore wind are shown in table 2.4.

Table 2.3: 2019 Offshore wind turbine size and load factor projections (by commissioning year)

	2020	2025	2030	2035	2040
Projected Turbine Size / MW	9	12	15	17.5	20
Projected load factor (net of availability)	47%	51%	57%	60%	63%

Table 2.4: Key technical assumptions for offshore wind (by commissioning year)

	2025	2030	2035	2040
Pre-development (£/kW)	130	130	130	130
Construction (£/kW)	1,500	1,300	1,100	1,100
Fixed O&M (£/MW/year)	36,300	28,000	24,500	22,500
Variable O&M (£/MWh)	4	4	4	4
Load factor (net of availability)	51%	57%	60%	63%
Operating period	30 years			

We have also adjusted our approach to decommissioning costs for offshore wind – for further details, please see the “Other cross-cutting assumptions” section below.

Contracts for Difference Allocation Round 3 (CfD AR3)

Levelised costs are not equivalent to CfD strike prices. Section 3 contains more detail on the relationship between these costs and the CfD AR3 auction which took place in 2019.

[7] https://www.gov.uk/government/publications/potential-to-improve-load-factor-of-offshore-wind-farms-in-the-uk-to-2035

Technology updates: Gas with Carbon Capture Usage and Storage (CCUS)

For gas CCUS technologies, BEIS commissioned an evidence review by Uniper, which was published alongside the CCUS Action Plan[8] in November 2018.

While gas CCUS technologies could be deployed in the UK in the 2020s, there remains some uncertainty around exact deployment timeframes, and the technology remains at the first of a kind (FOAK) stage of development. We therefore present FOAK costs for 2025 and 2030 in this report, and Nth of a kind (NOAK) costs for 2035 and 2040.

The evidence base for oxy-fuel combustion with CCUS and hydrogen generation with CCUS (both covered in the Uniper report) is limited, as the technologies are at an earlier stage of development relative to post-combustion. As a result, we are only presenting costs for CCGT + CCUS Post Combustion, which is based on a wider and more robust range of evidence.

The technical assumptions for CCGT + CCUS are presented in table 2.5 below. Further details on how these costs were reached can be found in the Uniper report.[9]

Table 2.5: Key technical assumptions for CCGT + CCUS Post Combustion by commissioning year

	FOAK		**NOAK**	
	2025	**2030**	**2035**	**2040**
Pre-development (£/kW)	10	10	10	10
Construction (£/kW)	1,500	1,400	1,300	1,300
Fixed O&M (£/MW/year)	25,800	25,800	22,300	22,300
Variable O&M (£/MWh)	5	5	5	5
Average fuel efficiency (HHV)	47%			
Load factor (net of availability)	87%		92%	
Operating period	25 years			

[8] https://www.gov.uk/government/publications/the-uk-carbon-capture-usage-and-storage-ccus-deployment-pathway-an-action-plan

[9] https://www.gov.uk/government/publications/power-carbon-capture-usage-and-storage-ccus-technologies-technical-and-cost-assumptions

Technology updates: Bioenergy with Carbon Capture and Storage (BECCS)

In 2019, BEIS commissioned a report from Ricardo Energy and Environment on the development of Bioenergy with Carbon Capture and Storage (BECCS) in the UK. Alongside the report, Ricardo also provided updated technical and cost assumptions for BEIS's modelling of levelised costs of electricity. While the report covers various BECCS technologies, costs in this report are only for biomass with post-combustion carbon capture and storage. Although various BECCS technologies for electricity generation were analysed by Ricardo, BEIS had greatest confidence in the post-combustion capture benchmark as it was based on more comprehensive work done for BEIS by Wood[10].

Table 2.6: Key technical assumptions for Biomass with post-combustion carbon capture and storage

	FOAK		NOAK	
	2025	**2030**	**2035**	**2040**
Pre-development (£/kW)	100	100	90	90
Construction (£/kW)	3,400	3,400	3,100	3,100
Fixed O&M (£/MW/year)	160,400	160,400	146,200	146,200
Variable O&M (£/MWh)	4	4	4	4
Average fuel efficiency (HHV)	30%			
Load factor (net of availability)	89%			
Operating period	25 years			

Since the technology is in an early stage of development, BECCS plants commissioning before 2035 are considered First of a Kind. It should be noted that Ricardo have their own models for calculating levelised costs so while the technical and cost assumptions may be the same, BEIS's and Ricardo's levelised costs may differ.

Technologies with minor updates

For some other technologies, minor changes have been made to the underlying technical assumptions. These are detailed below.

[10] Assessing the Cost Reduction Potential and Competitiveness of Novel (Next Generation) UK Carbon Capture Technology – Benchmarking State-of-the-art and Next Generation Technologies, Revision 4A, Wood, October 2018 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/864688/BEIS_Final_Benchmarks_Report_Rev_4A.pdf

CCGT H Class: We have assumed a higher level of efficiency for CCGT plants than in the 2016 report, increasing this from 59.8% to 62.4% on a lower heat value (LHV) basis, and from 54% to 56.2% on a higher heat value (HHV) basis. This is in line with the benchmarking exercise conducted for BEIS in 2018 by Wood.

Tidal stream: We have assumed a higher load factor for tidal stream plants, increasing this from 31% to 35%. This is based on an internal review of tidal stream assumptions.

Anaerobic digestion (AD): We have reduced our assumptions around digestate disposal cost in line with stakeholder responses to the 2017 review of support for AD under the Feed in Tariff scheme[11]. Digestate disposal costs are part of variable O&M, which we have reduced from £87/MWh to £58/MWh as a result.

Technologies which we have not updated

For **nuclear**, we continue to use the assumptions from the 2016 Generation Costs Report. Our assumptions refer to large-scale nuclear plants.

The Government's ambition is for the nuclear sector to deliver a 30 per cent reduction in the cost of new build nuclear projects by 2030, as set out in the Nuclear Sector Deal published in 2018.

Nuclear costs are revealed through bilateral negotiations which relate to specific projects. Project-specific analysis is used to inform the Government's approach to these negotiations. Because the information and analysis used in these negotiations is commercially confidential, it is not available to be used to update our generic cost assumptions. Our previously published generic costs can be found in the 2016 Generation Costs Report.

We have not updated small-scale technologies other than small-scale solar PV since 2016. For our most recent analysis on these technologies, please see the 2016 Generation Costs Report. We have also reduced the number of CCUS technologies from the previous report.

Financing costs/hurdle rates

Hurdle rates are defined as the minimum financial return that a project developer would require over a project's lifetime on a pre-tax real basis. This acts as the rate at which both

[11] BEIS (2017), Review of support for Anaerobic Digestion and micro-Combined Heat and Power under the Feed-in Tariffs scheme: https://www.gov.uk/government/consultations/review-of-support-for-anaerobic-digestion-and-micro-combined-heat-and-power-under-the-feed-in-tariffs-scheme

costs and generation revenues are discounted across time in producing the levelised cost measure.

BEIS commissioned a report from Europe Economics (EE), updating the Department's hurdle rate assumptions for projects starting development from 2018 in a range of technologies.

The Europe Economics (EE) report is published alongside this document[12], along with a peer review by Cambridge Economic Policy Associates (CEPA).

Europe Economics analysed developments in bond markets, the energy market and the electricity sector, as well as changing risk drivers, to understand how hurdle rates have changed since our 2015 update. They found the hurdle rates to have fallen across all technologies due to falls in market-wide parameters (the risk-free rate and the equity risk premium) and in debt premia, convergence in risks in the sector and falls in effective tax rates. This was despite rises in systematic risk across energy markets in general and the electricity generation sector in particular.

The CEPA peer review found that Europe Economics "broadly applied a reasonable methodology given the challenges of the study" and stated that the updated figures were "more likely to represent current hurdle rates" than those used in the 2016 Generation Costs Report.

The hurdle rates presented are pre-tax and in real terms. They represent the weighted average cost of capital (WACC), incorporating the cost of debt, equity and technology-specific debt-to-equity ratios. For technologies which compete as part of the Contracts for Difference (CfD) allocation framework, we assume that they receive a CfD and therefore are not exposed to merchant risk during the period of that CfD.

BEIS has applied these hurdle rates across the following technologies:

[12] https://www.gov.uk/government/publications/cost-of-capital-update-for-electricity-generation-storage-and-dsr-technologies

Table 2.7: Technology-specific hurdle rates provided by Europe Economics

Technology	2018 Hurdle Rate
Solar PV	5.0%
Onshore wind	5.2%
Offshore wind	6.3%
CCGT	7.5%
Hydro	5.4%
Hydro Large Storage	5.4%
Wave	8.6%
Tidal stream	9.4%
Geothermal CHP	18.8%
Dedicated Biomass >100MW	8.1%
Dedicated Biomass 5-100MW	7.9%
Biomass CHP	9.9%
Biomass Conversion	9.2%
ACT standard	7.2%
ACT advanced	8.1%
ACT CHP	8.9%
AD CHP	9.9%
AD	8.3%
EfW CHP	7.6%
EfW	6.5%
Landfill	6.1%
Sewage Gas	7.1%
CCUS Gas First of a Kind	9.0%
CCUS Gas Nth of a Kind	7.3%
Gas/Diesel Reciprocating engine	7.1%
OCGT	7.1%
CCGT CHP	9.0%
CCUS Biomass	9.1%

The hurdle rates applied are based on investor expectations at the time the work was undertaken. For investments to be made in future years, the hurdle rates may change. However, such changes are difficult to project and therefore we assume a flat trajectory for hurdle rates applied to investments to be made in future years in our modelling – sensitivities to changes in hurdle rate are shown in section 5.

Small-scale solar

Small-scale solar technologies were not covered as part of the Europe Economics review. We have drawn on evidence from the 2015 consultation on a review of the Feed-In Tariff scheme[13] to estimate hurdle rates, using the EE large-scale solar (>5MW) as an updated reference point and assuming the relative differences between size categories remain the same.

Table 2.7: Small-scale solar hurdle rates[14]

Solar Technology Output	Average 2015 hurdle rates following consultation	Revised 2018 hurdle rate assumptions
>5MW	5.6%	5.0% (Europe Economics)
10-50kW	6.2%	5.6%
<10kW	5.7%	5.1%
<4kW	5.7%	5.1%

Other cross-cutting assumptions

Approach to capital cost ranges

To generate high and low capital cost ranges, we have varied the central capital cost figure by the same percentages used in the 2016 BEIS Generation Costs report.

Further detail can be found in the Key Data and Assumptions file which accompanies this publication.

Balancing Services Use of System (BSUoS) charges

BSUoS charges are levied by National Grid on generators to cover the cost of day-to-day balancing of the electricity system. These charges have been updated using 2018 data from National Grid[15].

[13] Impact Assessment: Government response to consultation on a review of the Feed-in Tariff scheme (2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/487300/FITs_Review_Govt__response_Final.pdf

[14] We have reviewed solar costs by size rather than by type of developer. The review of small-scale solar costs did not include projects between 50kW and 5MW.

[15] https://www.nationalgrideso.com/charging/balancing-services-use-system-bsuos-charges

Gate fees and other fuel costs

We have adjusted the 2016 BEIS assumptions, informed by data from the WRAP (Waste and Resources Action Programme) gate fee report[16]. Our new assumptions are listed in the table below.

Table 2.8: Gate fee and fuel cost assumptions (£/MWh)

£/MWh	2016 report	2020 report
Biomass 5-50MW	£10	£10
EfW	-£32	-£32
AD	-£5	-£4
ACT	-£13	-£13
Conversions and BECCS	£30	£30

Decommissioning costs

For offshore wind, we have also made an allowance for decommissioning costs in line with the approach outlined in Arup (2018)[17]. This assumes that developers must provide a financial security to cover the costs of decommissioning the project. Developers incur a financing cost of providing that security as well as the final cost when the project is decommissioned. The effect on the LCOE of decommissioning costs is less than £1/MWh.

For all other technologies, the approach remains the same as in the 2016 Generation Costs report. In line with previous reports, we take the simplifying assumption for other technologies that decommissioning costs are equal to the scrap value of the plant (and therefore that the net cost is zero).[18]

Fossil fuel prices

Fossil fuel price assumptions have been updated in line with the figures used in the 2019 Fossil Fuel Price Projections[19].

Fuel emissions factors

Fuel emissions factors (mass of CO_2 released per relevant quantity of fuel burned) were updated from the UK Greenhouse Gas Emissions Inventory[20].

[16] WRAP Gate Fees Report 2019: comparing the costs of waste treatment options http://www.wrap.org.uk/gatefees2019
[17] Cost estimation and liabilities in decommissioning offshore wind installations: https://www.gov.uk/government/publications/decommissioning-offshore-wind-installations-cost-estimation

[18] See Mott McDonald (2010), page 4.
[19] https://www.gov.uk/government/publications/fossil-fuel-price-assumptions-2019
[20] https://naei.beis.gov.uk/

Carbon prices

For gas and coal plants, the total carbon price up until 2030/31 is given by the sum of the 2018 EU ETS carbon price projections and the rate of Carbon Price Support (CPS). At Budget 2018 it was announced that the CPS rate was capped at £18/tCO_2 until the end of year 2020/21.

From 2021/22 onwards, we assume that the total carbon price for the electricity sector remains fixed in real terms at the 2021/22 level until the price of the EU ETS rises above this; after this the carbon price for the electricity sector coincides with the EU ETS price. Beyond 2030, the total carbon price increases linearly to reach the appraisal value of carbon in 2050[21].

Heat revenues

A simplified methodology based on the avoided boiler cost approach has been used to estimate the heat revenue per MWh of electricity generated. This approach estimates the cost that would have been incurred by the heat offtaker (the buyer of heat produced by the CHP plant) if they were to produce the same amount of heat using a boiler, assuming that 100% of the heat is purchased. This would incur fuel costs at the retail gas price, which are avoided by buying heat from the CHP plant.

Load factors

Where changes are not specified above, load factor assumptions remain the same as in the 2016 Generation Costs report. For flexible technologies such as CCGTs and CCUS plants, the load factor assumptions represent the maximum potential generation (net of availability), i.e. baseload of a plant. Where flexible technologies operate at lower load factors, their levelised costs will be higher than those presented here. This sensitivity is illustrated in Section 5.

Peaking technologies such as OCGTs and reciprocating engines are assumed to run for a specified number of hours a year. Wind, solar PV and marine technologies operate as intermittent electricity generation technologies, and therefore have lower load factors..

Further details on key assumptions

The accompanying Key Data and Assumptions file covers other key assumptions used to calculate levelised costs for technologies in this report. This includes data on:

[21] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

- Reference plant sizes.
- Average load factor (net of availability) and plant efficiency.
- Duration of pre-development, construction and operating periods.
- Main cost categories used in BEIS levelised cost modelling.

Section 3: How BEIS uses generation cost data in modelling

The estimates outlined in this report are intended to provide a high-level view on the costs of different generating technologies. Because levelised costs are a simplified metric, this means that not all relevant issues are considered.

In practice, BEIS's electricity market modelling, including BEIS's Dynamic Dispatch Model (DDM), does not use levelised cost estimates directly. Instead it models private investment decisions using the same capital expenditure (capex) and operating expenditure (opex/O&M) assumptions incorporated in the levelised cost estimates reported above. The DDM also includes assumptions on investors' expectations over fossil fuel, carbon and wholesale electricity prices, as well as the financial incentives from policies such as Contracts for Difference (CfDs) and the Capacity Market.

To model the investment decision, the internal rate of return of a potential plant is compared to a technology-specific hurdle rate. As noted above, this report focuses on these technology-specific hurdle rates. The technology-specific hurdle rates reflect different financing costs for different technologies.

Levelised cost estimates do not consider revenue streams available to generators (e.g. from sale of electricity or revenues from other sources). One exception to this is heat revenues for Combined Heat and Power (CHP) plants. As the cost of the owning and operating the CHP technology is included in the capital and operating costs of the plant, heat revenues are also included so that the estimates reflect the net cost of electricity generation only.

As levelised costs relate only to those costs accruing to the owner/operator of the generation asset, the metric does not cover wider costs to the electricity system. Further information on Wider System Impacts, including illustrative scenarios, can be found in Section 7.

Levelised costs are less suitable for peaking technologies where the most relevant consideration is the cost of capacity rather than the cost per MWh. A £/kW measure covering fixed costs for peaking technologies is presented in Section 6.

Levelised Costs are sensitive to the assumptions used

Levelised cost estimates are highly sensitive to the underlying data and assumptions used. Within this, different technologies are sensitive to different input assumptions.

This report captures some of these uncertainties through ranges presented around key estimates. A range of costs is presented for capex and fuel, depending on the estimates, and the tornado graphs illustrate sensitivity to other assumptions. However, not all uncertainties are captured in these ranges and estimates should be viewed in this context. It is often more appropriate to consider a range of costs rather than point estimates.

It should also be noted that levelised costs are generic, rather than site-specific. Land costs are not included and use of system charges are calculated on an average rather than a site-specific basis.

Levelised Costs are not Strike Prices

The levelised cost estimates in this report do not provide an indication of potential future Administrative Strike Prices (ASPs) for technologies under Contracts for Difference (CfDs) allocation rounds.

Generation cost assumptions, such as that summarised here in the form of levelised costs, are one set of inputs into setting administrative strike prices – the maximum strike price applicable to a technology in a Contracts for Difference (CfD) allocation round.

Other inputs, including market conditions and policy considerations, may include:

- Revenue assumptions;
- Other costs not included in our definition of levelised cost (for example the generator's share of transmission losses, route to market costs reflected in Power Purchase Agreement (PPA) discounts, and technology-specific estimates for decommissioning costs and scrappage values);
- CfD contract terms including length, risk allocation, and eligibility requirements within technologies;
- Other relevant information such as studies or data published by industry;
- Developments within industry; and
- Wider policy considerations.

The generation costs data used here may be different from that used as part of the administrative strike price-setting process. This is particularly where information relevant to potential bidders in a particular allocation round is used to inform cost assumptions for pipeline projects. Further, ASPs are normally set so as to bring forward the most cost-effective projects, which may not be the same as the estimates of typical project costs estimated in this report.

For all these reasons, the levelised costs presented here may be significantly different from the administrative strike prices that are set for CfDs and therefore should not be seen as a guide to potential future administrative strike prices.

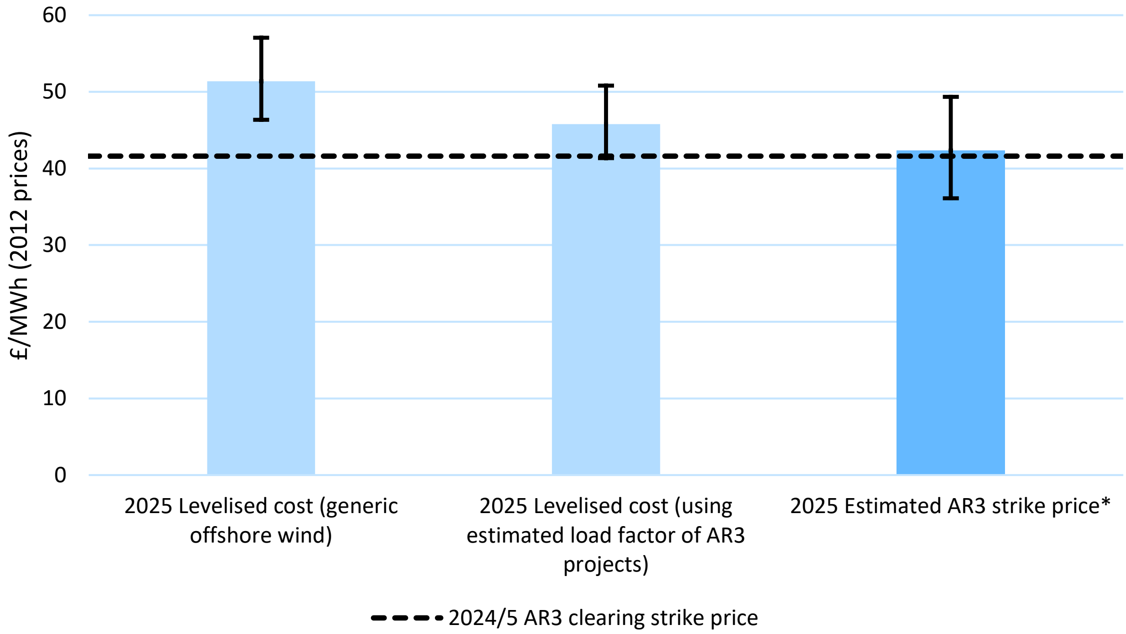
Offshore Wind costs and CfD Allocation Round 3

In September 2019, the CfD AR3 Pot 2 auction cleared at £39.65/MWh and £41.61/MWh for offshore wind projects commissioning in 2023/4 and 2024/5 respectively (2012 prices). These prices are lower than would be expected from our generic levelised costs - various factors are considered to have contributed to the low strike price:

- The Dogger Bank projects (which accounted for 5.0GW out of the 5.5GW of offshore wind capacity awarded in CfD AR3) are significantly larger than our reference plant size assumption, likely leading to savings due to economies of scale;
- The Dogger Bank projects, situated far from shore, benefit from good wind resource as well as relatively shallow water depth, leading to expected load factors significantly higher than average, without significantly higher construction costs;
- Other project-specific factors listed in the previous section.

Chart 3.1 is an illustration of how our offshore wind levelised costs align with the results of the AR3 auction once the higher estimated load factors of AR3 projects are accounted for (noting that the larger turbines expected to be used in AR3 projects are already taken into account in our generic costs). Values are expressed in **2012 prices**, in line with conventional presentation of CfD strike prices.

Chart 3.1: Comparison of generic levelised costs for offshore wind with CfD AR3 strike prices (2012 prices)



Error bars show sensitivites of LCOEs and strike prices to high/low capex assumptions. This plot is illustrative, and should not be taken as a precise indicator of the levelised costs of individual offshore wind projects.

**This column shows the approximate equivalent strike price to the LCOE shown in the middle column. This estimate uses assumptions appropriate for AR3, and should not be taken as an indication of the relationship between levelised costs and strike prices in future CfD allocation rounds.*

Levelised costs depend on timing

Levelised cost estimates can be reported for different milestones associated with a project including the project start, the financial close and the commissioning year. In this publication, we report levelised cost estimates for projects commissioning in the same year.

Pre-development and construction timings will vary by technology and therefore estimates reported for 'project start' or 'financial close'[22] for different technologies may not be commissioning in the same year as each other. Central estimates for pre-development and construction timings are presented for key technologies in the accompanying spreadsheet to this publication.

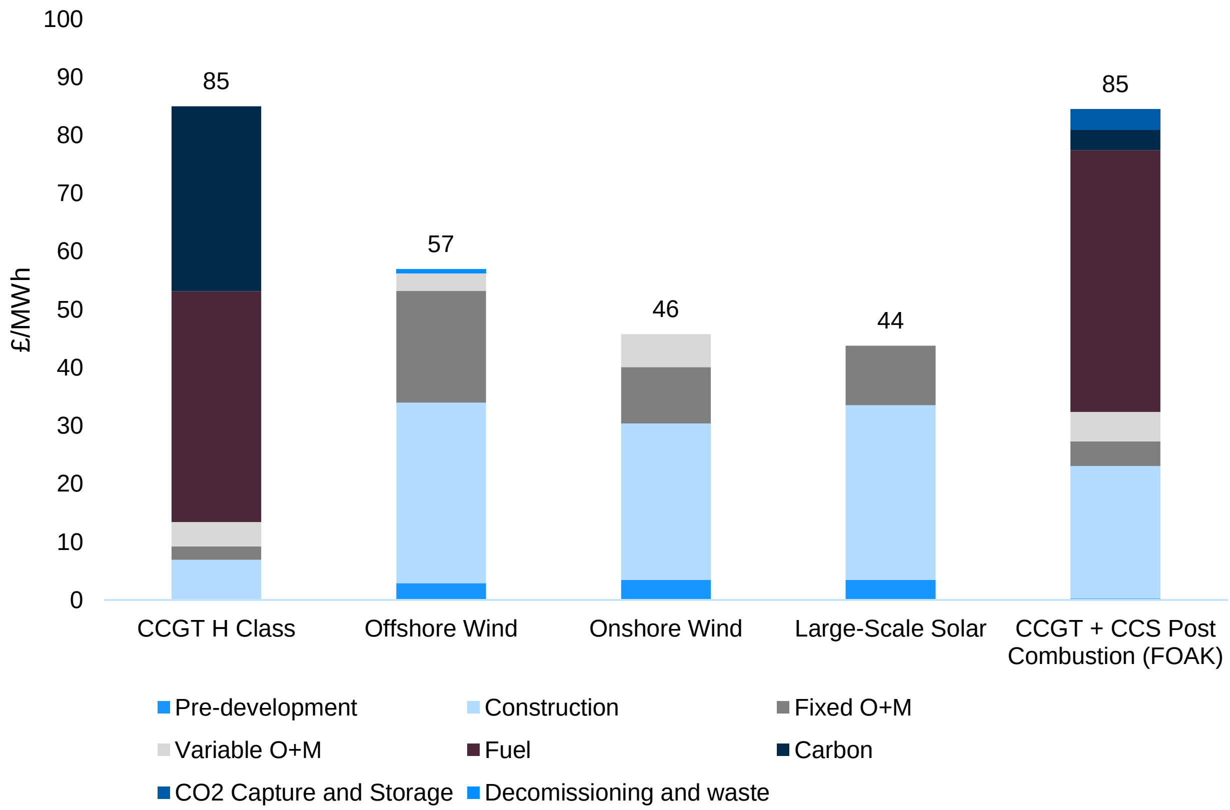
[22] Financial close can also be known as the point of Final Investment Decision or FID.

Section 4: Generation cost estimates

This section summarises the analysis of the levelised cost of electricity generation at technology-specific hurdle rate for a selection of technologies. All values presented are in 2018 real prices.

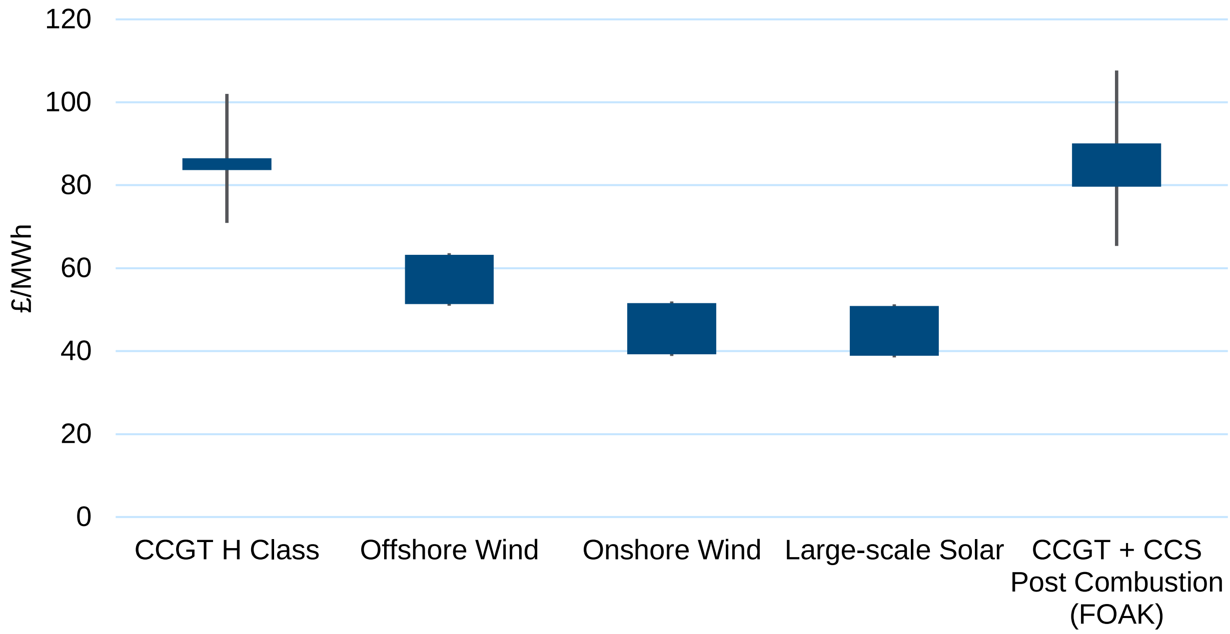
Projects commissioning in 2025

Chart 4.1: NOAK Projects commissioning in 2025, in real 2018 prices[23]



[23] Please note these estimates should be viewed in the context of the sensitivities and uncertainties highlighted in the text of this report.

Chart 4.2: Levelised Cost Estimates for NOAK Projects Commissioning in 2025, Sensitivities, £/MWh, in real 2018 prices



Boxes represent capital expenditure variation, and whiskers represent operating expenditure variation.

Table 4.3: Levelised Cost Estimates for NOAK Projects Commissioning in 2025, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-Scale Solar	CCGT + CCS Post Combustion (FOAK)
Pre-Development Costs	<1	3	3	3	<1
Construction Costs	7	31	27	30	23
Fixed O&M	2	19	10	10	4
Variable O&M	4	3	6	0	5
Fuel Costs	40	0	0	0	45
Carbon Costs	32	0	0	0	3
CO2 Transport and Storage	0	0	0	0	4
Decommissioning and waste	0	1	0	0	0
Total	**85**	**57**	**46**	**44**	**85**

Table 4.4: Levelised Cost Estimates for NOAK Projects Commissioning in 2025, Sensitivities, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-Scale Solar	CCGT + CCS Post Combustion (FOAK)
High capex	87	63	52	51	90
Central	85	57	46	44	85
Low capex	84	51	39	39	80
High capex, high fuel	102				107
Low capex, low fuel	71				66

Projects commissioning in 2030

Chart 4.5: Levelised Cost Estimates for Projects Commissioning in 2030, £/MWh, in real 2018 prices

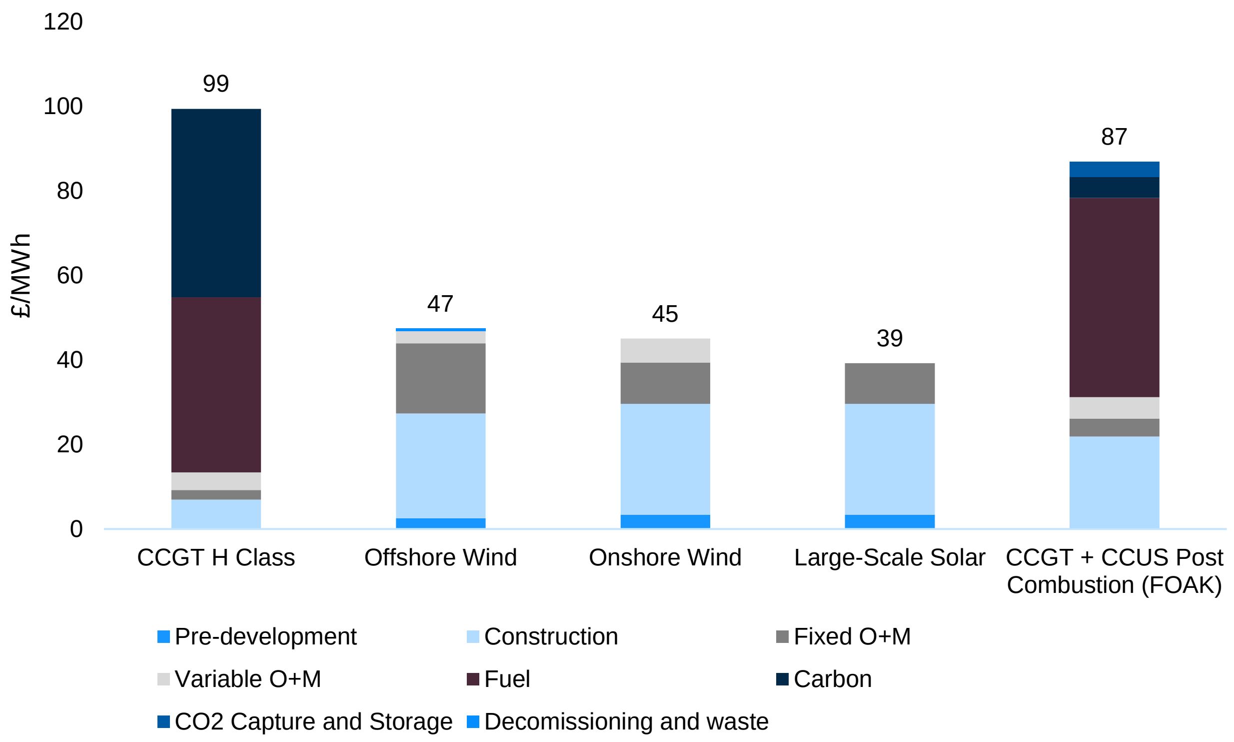
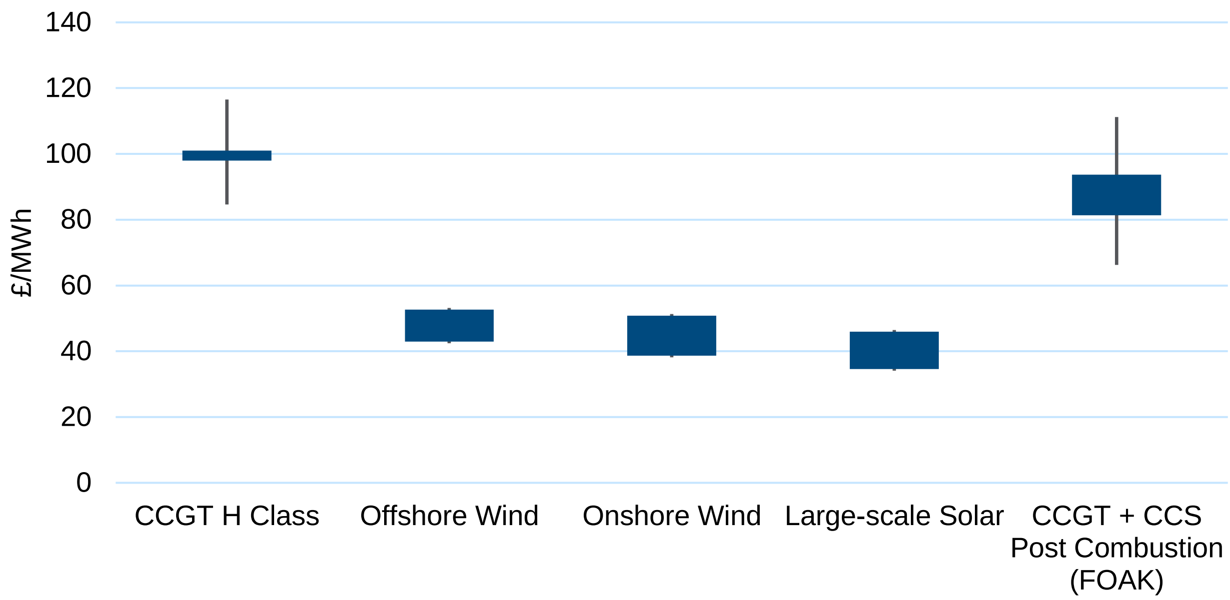


Chart 4.6: Levelised Cost Estimates for Projects Commissioning in 2030, Sensitivities, £/MWh, in real 2018 prices



Boxes represent capital expenditure variation, and whiskers represent fuel expenditure variation.

Table 4.7: Levelised Cost Estimates for Projects Commissioning in 2030, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-Scale Solar	CCGT + CCUS Post Combustion (FOAK)
Pre-Development Costs	<1	3	3	3	<1
Construction Costs	7	25	26	26	22
Fixed O&M	2	17	10	10	4
Variable O&M	4	3	6	0	5
Fuel Costs	41	0	0	0	47
Carbon Costs	45	0	0	0	5
CO2 Transport and Storage	0	0	0	0	4
Decommissioning and waste	0	1	0	0	0
Total	**99**	**47**	**45**	**39**	**87**

Table 4.8: Levelised Cost Estimates for Projects Commissioning in 2030, Sensitivities, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-Scale Solar	CCGT + CCUS Post Combustion (FOAK)
High capex	101	53	51	46	94
Central	99	47	45	39	87
Low capex	98	43	39	35	81
High capex, high fuel	116				111
Low capex, low fuel	85				67

Projects commissioning in 2035

As discussed in section 2, CCGT + CCS plants commissioning in 2035 are assumed to be Nth of a kind, compared with First of a kind for plants commissioning earlier

Chart 4.9: Levelised Cost Estimates for Projects Commissioning in 2035, £/MWh, in real 2018 prices

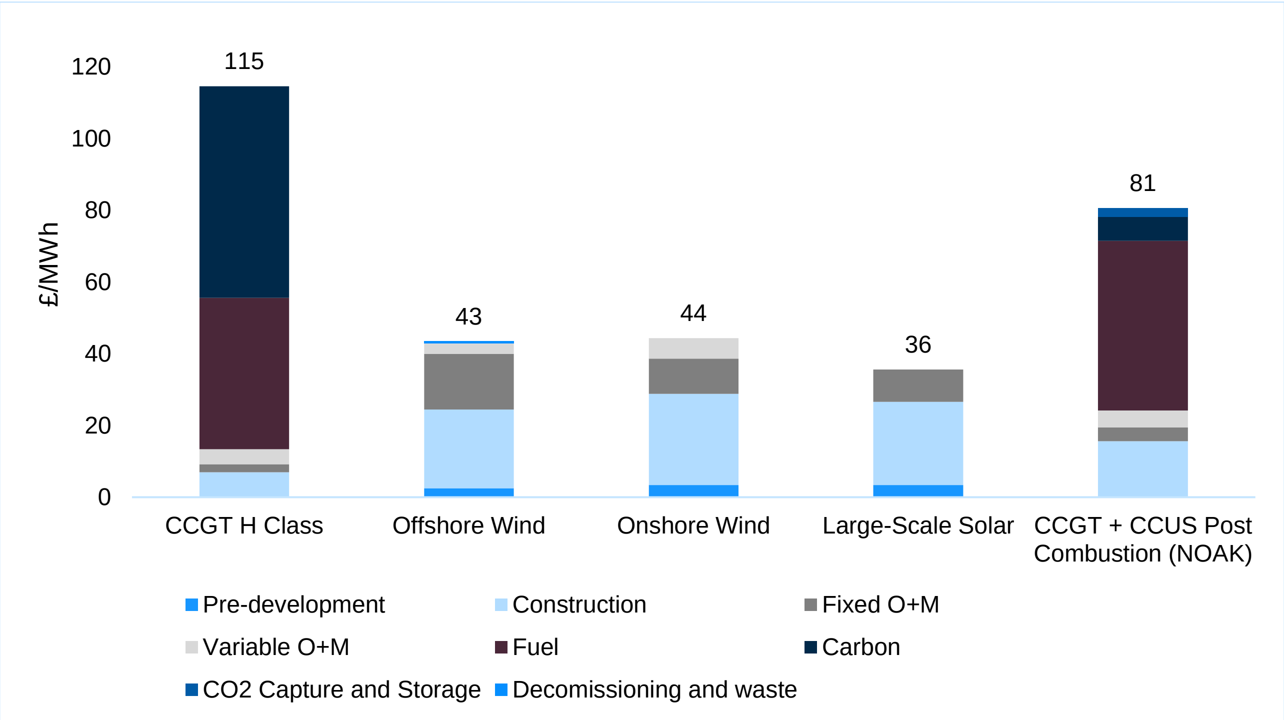
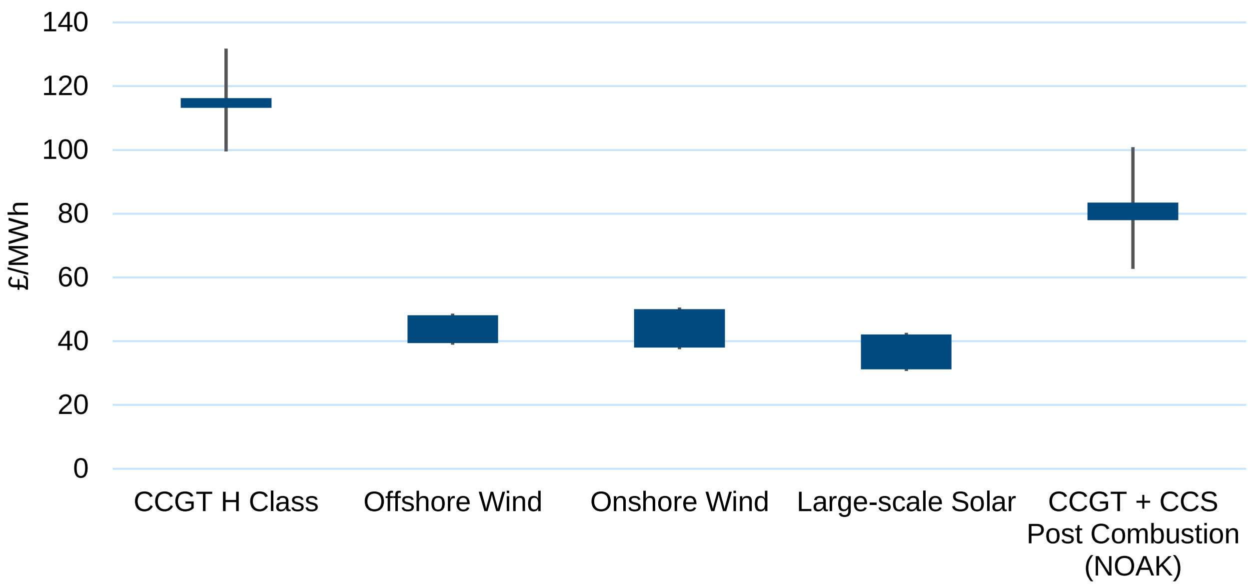


Chart 4.10: Levelised Cost Estimates for Projects Commissioning in 2035, Sensitivities, £/MWh, in real 2018 prices



Boxes represent capital expenditure variation, and whiskers represent fuel expenditure variation.

Table 4.11: Levelised Cost Estimates for Projects Commissioning in 2035, £/MWh, in real 2018 prices

	CCGT H Class	**Offshore Wind**	**Onshore Wind**	**Large-Scale Solar**	**CCGT + CCUS Post Combustion (NOAK)**
Pre-Development Costs	<1	2	3	3	<1
Construction Costs	7	22	25	23	15
Fixed O&M	2	16	10	9	4
Variable O&M	4	3	6	0	5
Fuel Costs	42	0	0	0	47
Carbon Costs	59	0	0	0	7
CO2 Transport and Storage	0	0	0	0	2
Decommissioning and waste	0	1	0	0	0
Total	**115**	**43**	**44**	**36**	**81**

Table 4.12: Levelised Cost Estimates for Projects Commissioning in 2035, Sensitivities, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-scale Solar	CCGT + CCS Post Combustion (NOAK)
High capex	116	48	50	42	83
Central	115	43	44	36	81
Low capex	113	39	38	31	78
High capex, high fuel	131				100
Low capex, low fuel	100				63

Projects commissioning in 2040

Chart 4.13: Levelised Cost Estimates for Projects Commissioning in 2040, £/MWh, in real 2018 prices

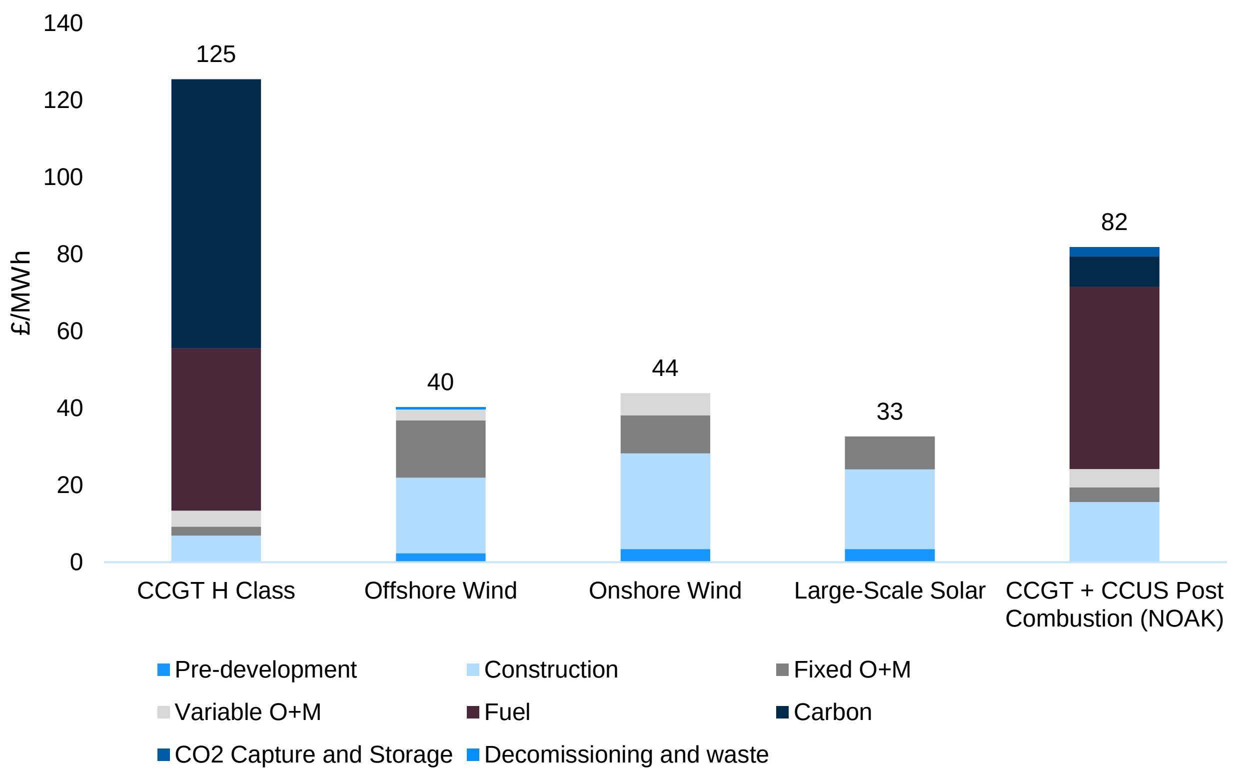
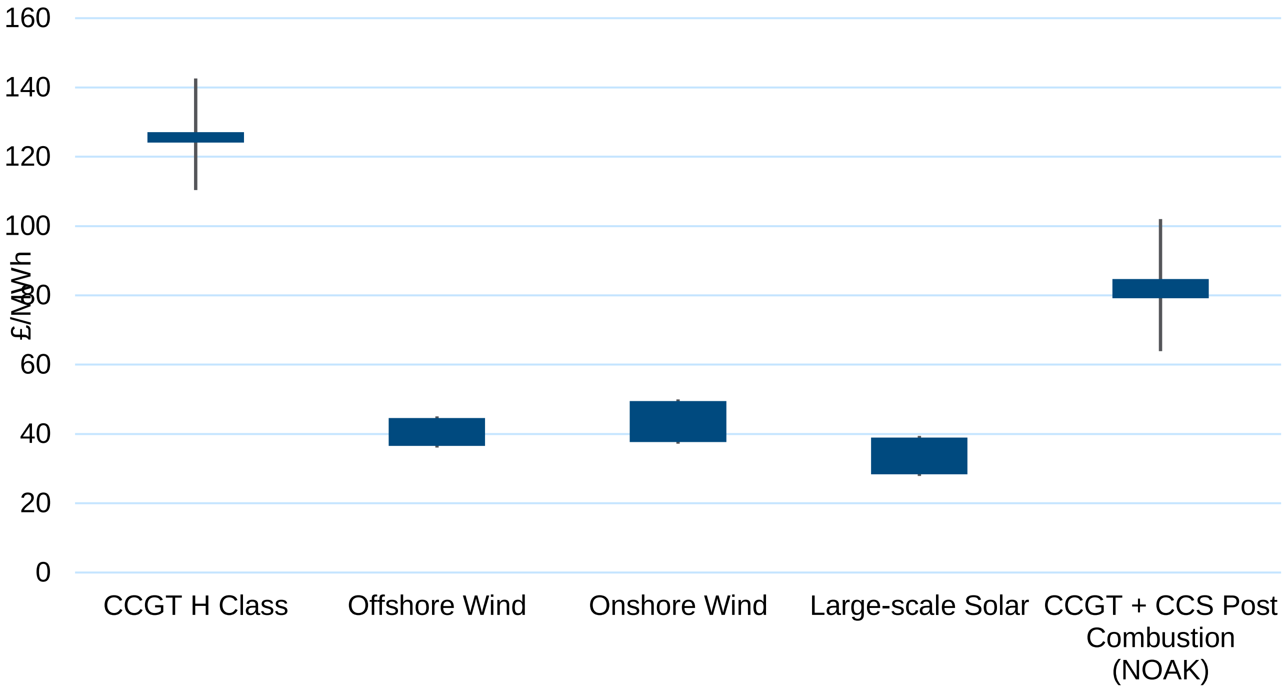


Chart 4.14: Levelised Cost Estimates for Projects Commissioning in 2040, Sensitivities, £/MWh, in real 2018 prices



Boxes represent capital expenditure variation, and whiskers represent fuel expenditure variation.

Table 4.15: Levelised Cost Estimates for Projects Commissioning in 2040, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-Scale Solar	CCGT + CCUS Post Combustion (NOAK)
Pre-Development Costs	<1	2	3	3	<1
Construction Costs	7	20	25	21	15
Fixed O&M	2	15	10	9	4
Variable O&M	4	3	6	0	5
Fuel Costs	42	0	0	0	47
Carbon Costs	70	0	0	0	8
CO2 Transport and Storage	0	0	0	0	2
Decommissioning and waste	0	1	0	0	0
Total	**125**	**40**	**44**	**33**	**82**

Table 4.16: Levelised Cost Estimates for Projects Commissioning in 2040, Sensitivities, £/MWh, in real 2018 prices

	CCGT H Class	Offshore Wind	Onshore Wind	Large-scale Solar	CCGT + CCS Post Combustion (NOAK)
High capex	127	44	50	39	85
Central	125	40	44	33	82
Low capex	124	36	38	28	79
High capex, high fuel	142				102
Low capex, low fuel	111				64

Comparison between technologies over time

Table 4.17: Levelised Cost Estimates for Projects Commissioning in 2025, 2030, 2035 and 2040, £/MWh, highs and lows reflect high and low capital and pre-development cost estimates, in real 2018 prices

Commissioning		2025	2030	2035	2040
CCGT H Class	High	87	101	116	127
	Central	85	99	115	125
	Low	84	98	113	124
Offshore Wind	High	63	53	48	44
	Central	57	47	43	40
	Low	51	43	39	36
Onshore Wind	High	52	51	50	50
	Central	46	45	44	44
	Low	39	39	38	38
Large-Scale Solar	High	51	46	42	39
	Central	44	39	36	33
	Low	39	35	31	28
CCGT + CCS Post Combustion	High	90	94	83	85
	Central	85	87	81	82
	Low	80	81	78	79

Comparison to previous BEIS Levelised Cost estimates

The below table summarises the changes made to the previous BEIS estimates (BEIS 2016)[24] with the revised BEIS estimates in this report for 2025, 2030, 2035 and 2040 commissioning. All values below are in 2018 prices.

Since 2016, renewables costs have declined compared to gas, particularly steeply in the case of offshore wind. Across the renewable technologies, increased deployment has led to decreased costs via learning, which has then incentivised further deployment, and so on. For offshore wind, significant technological improvements (for example, large increases in individual turbine capacity) have driven down costs faster than other renewable technologies (and will continue to do so). Lower hurdle rates have also contributed to the decline in renewables costs.

Projected CCGT + CCUS costs have fallen for a number of reasons. The CCUS efficiency penalty is lower than in 2016, while the associated CCGT efficiency is higher. A shorter construction period also reduces financing costs, and estimates of both the construction cost and variable operating cost of Transport & Storage are lower. Finally, lower hurdle rates also contribute to the lower LCOEs.

Table 4.18: Change in Levelised Cost Estimates for Projects Commissioning in 2025, 2030, 2035 and 2040, £/MWh, highs and lows reflect high and low capital and pre-development cost estimates

Commissioning		2025		2030		2035		2040	
		BEIS 2016	This Report	BEIS 2016	This Report	BEIS 2016	This Report	BEIS 2016	This Report
CCGT H Class	High	89	87	107	101	-	116	-	127
	Central	87	85	105	99	-	115	-	125
	Low	86	84	104	98	-	113	-	124
Offshore Wind	High	120	63	116	53	-	48	-	44
	Central	106	57	103	47	-	43	-	40
	Low	94	51	91	43	-	39	-	36
Onshore Wind	High	79	52	77	51	-	50	-	50
	Central	65	46	64	45	-	44	-	44
	Low	49	39	48	39	-	38	-	38
Large-Scale Solar	High	81	51	77	46	-	42	-	39
	Central	68	44	64	39	-	36	-	33
	Low	58	39	56	35	-	31	-	28
CCGT + CCS Post Combustion	High	132	90	129	94	-	83	-	85
	Central	117	85	118	87	-	81	-	82
	Low	109	80	112	81	-	78	-	79

[24] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/566567/BEIS_Electricity_Generation_Cost_Report.pdf

Section 5: Sensitivity analysis

To illustrate the uncertainties around our levelised cost estimates, we present tornado graphs below for selected technologies to show the effects of:

- Increasing or decreasing parameters by 10% from the central estimate while holding all others constant.
- Applying the high or low cost estimates for individual parameters while holding all others constant.

These graphs show which underlying assumptions have the largest effect on the costs of each technology. The blue bars show the impact of a reduction in assumptions, and the orange bars show the impact of an increase in assumptions. Key findings are shown below.

Chart 5.1: Offshore Wind, Commissioning 2025 LCOE Tornado Chart, £/MWh

For offshore wind, total O&M and capex have the largest effects in the high/low range scenarios. In the ±10% scenario, the load factor is most significant but total O&M and capex remain significant.

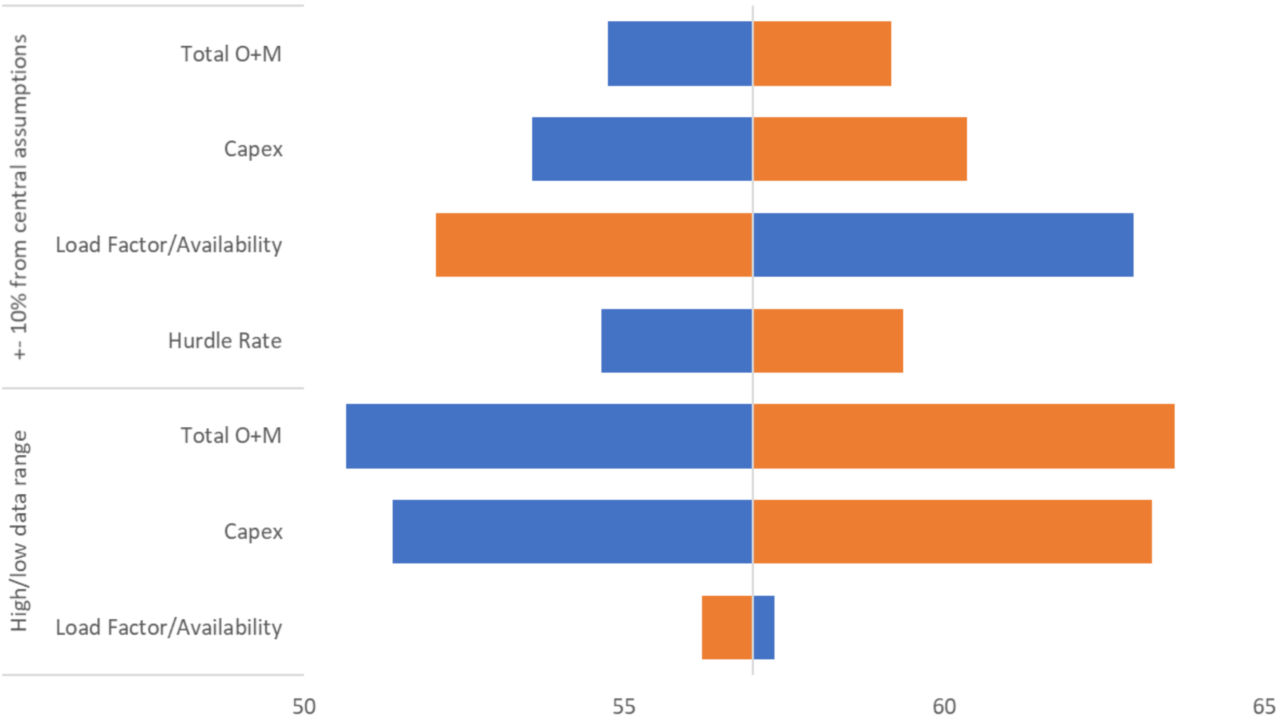


Chart 5.2: CCGT, Commissioning 2025 LCOE Tornado Chart, £/MWh

For CCGTs, fuel price variation is the most significant sensitivity in both the ±10% variation and high/low range scenarios.

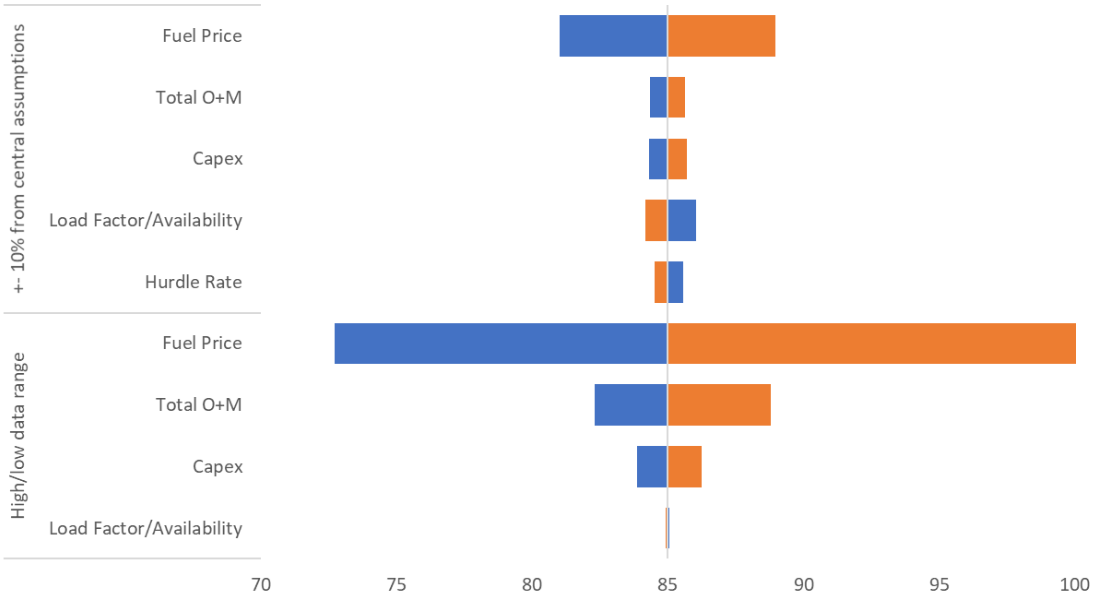


Chart 5.3: Onshore Wind, Commissioning 2025 LCOE Tornado Chart, £/MWh

For onshore wind, the capex and load factor assumptions are most significant in the ±10% scenario. For the high/low range scenario, total O&M, capex and load factor assumptions are all important determinants.

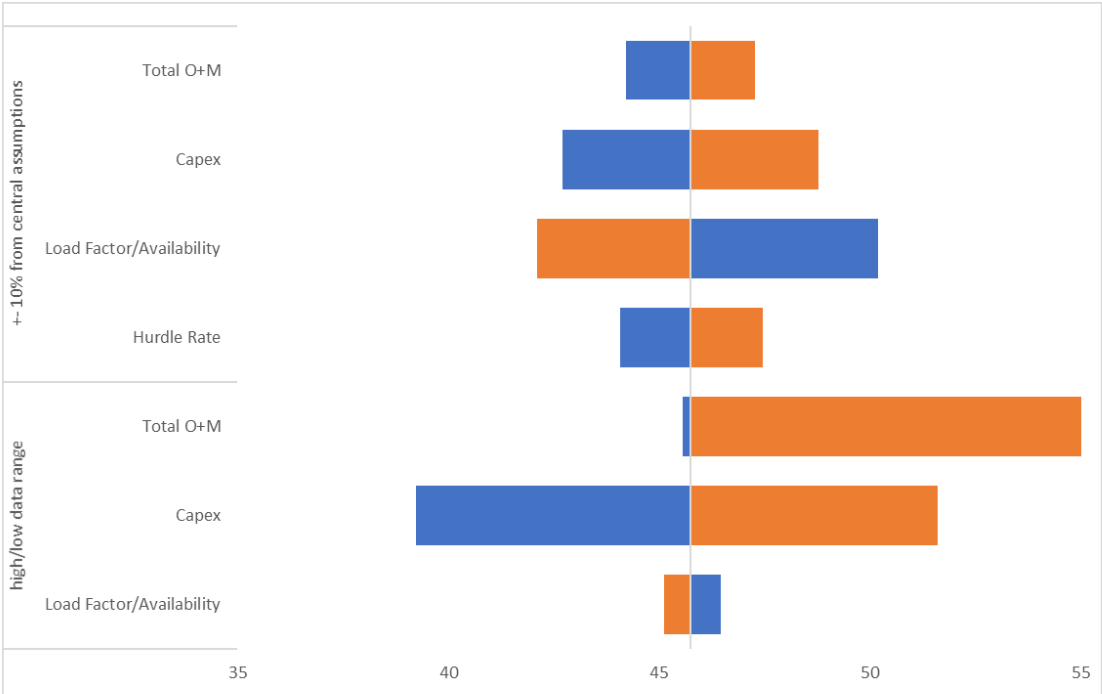


Chart 5.4: Gas CCUS (FOAK), Commissioning 2025 LCOE Tornado Chart, £/MWh

For gas CCUS, the fuel price is most significant in both scenarios, though capex, O&M and load factors also have material effects.

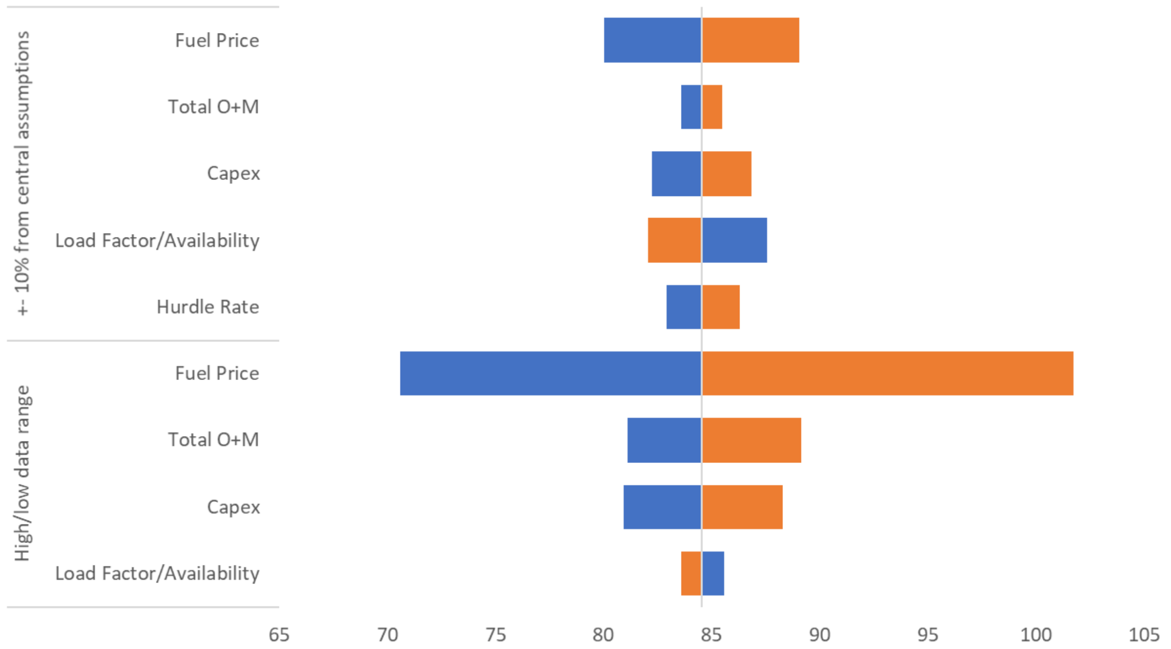
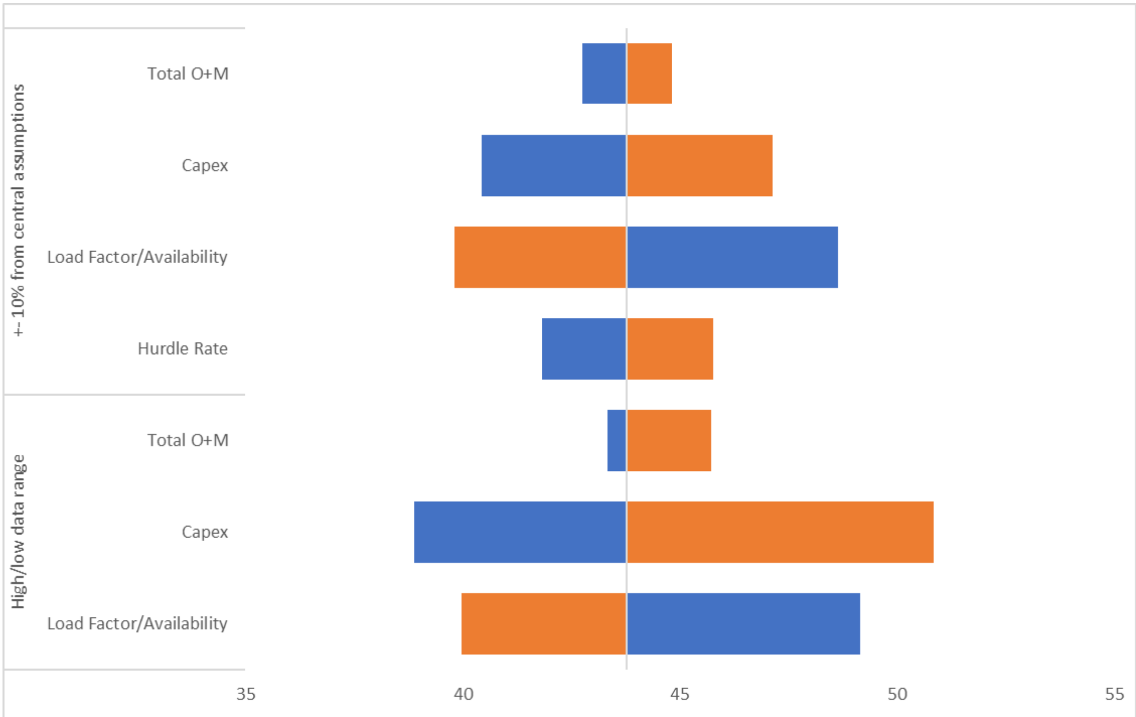


Chart 5.5: Large Scale Solar PV, Commissioning 2025 LCOE Tornado Chart, £/MWh

For solar, the capex and load factor assumptions are most significant in both scenarios.



Section 6: Peaking technologies and storage

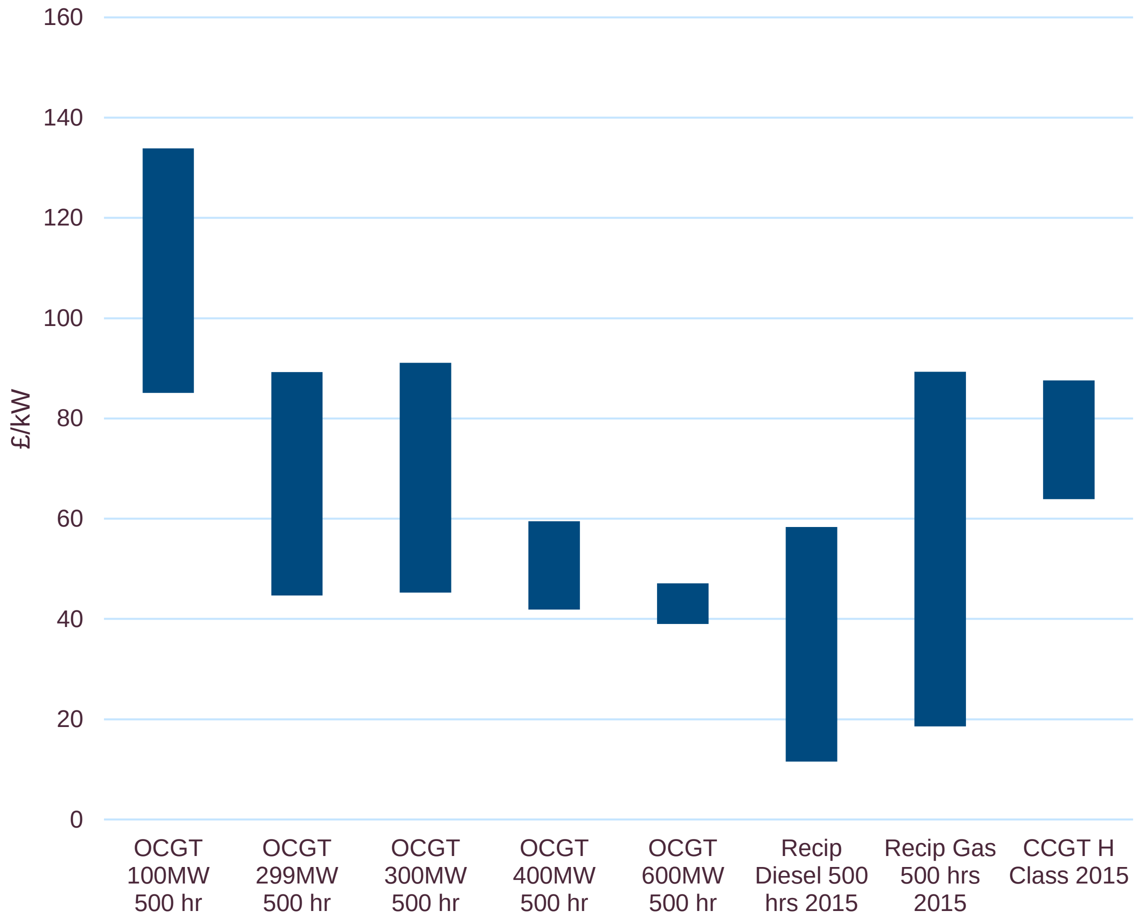
This section presents a £/kW measure for peaking technologies (OCGT and reciprocating engines), as well as a CCGT H Class for comparison. This measures the cost of capacity rather than the cost of generation – it therefore ignores fuel costs, carbon costs and other variable costs. This measure is more suitable for comparing technologies where generation varies with demand.

Chart 6.1 represents the annual cashflows required to finance the pre-development, construction and fixed costs for a generic plant. These cashflows are assumed to be paid over the operating lifetime of the plant. The range of costs is created by varying capital expenditure to the high and low values.

All technologies except CCGT are assumed to run for a fixed 500 hours per year. CCGT is assumed to run at baseload.

This metric is not meant to illustrate likely capacity market outcomes, which reflect a range of other factors, including different contract lengths, load factor and wholesale price expectations and other sources of revenue.

Chart 6.1: Peaking technologies (reciprocating diesel and gas and OCGT at 500 hours per year) and CCGT (at normal load factors), £/kW per annum for construction and fixed operating costs, technology-specific discount rates



Storage technologies

As the UK decarbonises, the demand for flexible technologies such as storage, demand-side-response and interconnectors is expected to increase.

In 2018 BEIS appointed Mott MacDonald to deliver a project on storage cost and technical assumptions, to inform future policy development in this area.

From this project, BEIS procured a robust and consistent set of cost and technical information for a range of storage technologies that could be deployed between now and 2050. The assumptions procured include the key technical attributes for the various storage technologies such as efficiency rates, plant lifetime and duration as well as the key cost information for these technologies such as pre-development, construction and operational costs. These assumptions have not been presented in the main body of the report because they are not comparable with levelised costs, however detailed information on these assumptions can be found in the following report: 'Storage cost and technical assumptions for BEIS'[25].

BEIS intends to keep these new storage assumptions under review given that storage technologies are not yet mature and there is considerable uncertainty regarding the future costs.

[25] Mott MacDonald, 2018, *Storage cost and technical assumptions for BEIS.* https://www.gov.uk/government/publications/storage-cost-and-technical-assumptions-for-electricity-storage-technologies

Section 7: Wider system impacts

The levelised cost estimates presented in this report do not take into account wider positive or negative impacts that an electricity generation plant may have on the electricity system due to timing of its generation, its location and other characteristics. In 2017 BEIS published its analytical framework for how to consider these wider system impacts in the electricity system.[26] Note, the work did not consider impacts beyond the electricity system, such as impacts on the wider economy, international trade or technological innovation.

The qualitative framework

The analytical framework sets out that wider impacts in the electricity system occur in addition to technology own costs, which are captured in levelised cost estimates. Wider impacts fall into the following categories:

- **Impacts in the wholesale market**: This category considers how timely or valuable each MWh generated by a technology is. This will differ by technology type. For example, a CCGT plant is dispatchable and will be able to focus its generation on valuable/useful time periods, while renewable technologies' generation is determined more by availability of resource.

- **Impacts in the capacity market**: This category considers how firm or reliable each MW of capacity provided by a technology is at moments of peak demand. This will differ by technology type. For example, an OCGT plant is very reliable at moments of peak demand (e.g. on a winter's evening), while other technologies' available capacity in those moments is less reliable (e.g. solar).

- **Impacts in balancing and ancillary service markets**: This category considers how helpful or unhelpful a technology's generation is for the balancing and operability of the system. This will differ by technology type. For example, a technology whose output is more difficult to forecast is likely to increase the need for balancing in the system, while flexible, dispatchable technologies will potentially be able to solve balancing issues more cost-effectively. Regarding operability, technologies that, for example, provide additional inertia (which helps to slow a drop in frequency following a system loss, e.g. a large generator coming off the system unexpectedly) will help to reduce costs, while plants that currently cannot or are not incentivised to provide inertia will increase the system's need to procure additional inertia from other plants. The model also considers technologies' ability to provide reserve.

[26] https://www.gov.uk/government/publications/whole-power-system-impacts-of-electricity-generation-technologies

- **Impacts on networks**: This category considers how conveniently located a technology is, i.e. its proximity to demand centres. This will differ by technology type and location. This category is highly subjective as it depends on where a technology is assumed to be located.

As noted above, all generating technologies impose wider impacts on the electricity system to varying degrees. Current market arrangements to allocate these impacts are rooted in the principles of cost-reflectivity, but Ofgem, as the independent energy regulator, keeps these arrangements under review. For example, Ofgem has recently concluded a charging review and a second one is ongoing to ensure charges are fair, proportionate and cost-reflective.

Enhanced levelised costs

The wider system impacts listed above, together with levelised costs, form a technology's enhanced levelised cost. Enhanced levelised costs serve the same purpose as levelised costs - they provide a straightforward way of consistently comparing the costs of different generating technologies with different characteristics. However, unlike levelised costs, they also account for different wider system impacts between technologies due to differences in the timing of their generation, their location and other characteristics. This results in a fairer comparison between technologies. Importantly, enhanced levelised costs do not show the full system cost of different pathways but provide an indication of the relative marginal impacts of different technologies to the system in different scenarios.

The quantitative analysis

The below sets out the calculation method and main caveats of wider system impacts.

- **Calculation Method**: Wider system impacts represent a technology's discounted impact on the wholesale market, capacity market, balancing and ancillary service markets, and networks to 2050.[27] They are converted into an equivalent unit of wider system impact in £/MWh by dividing the impact by the total amount of electricity expected to be generated over the same timeframe. Both the wider system impact and generation are expressed in net present value terms. This means that future costs and outputs are discounted, when compared to costs and outputs today.

  Unlike in the levelised cost assumptions, which assume that all technologies run at their maximum load factor, wider system impacts use projections of a plant's load factor from the BEIS Dynamic Dispatch Model. If this load factor differs from the maximum load factor in level and/or profile, this will change a technology's levelised cost. For example, while it might increase £/MWh fixed costs (such as construction costs) of a plant, it might lower its £/MWh carbon and fuel costs, if generation is more

[27] These impacts are modelled within BEIS's Dynamic Dispatch Model, which models electricity dispatch and investment decisions from 2010 through to 2050. Note that the modelling does not consider all balancing and ancillary services but focuses on the Balancing Mechanism, reserve for frequency response and inertia.

frontloaded when carbon and fuel prices are lower. These effects are captured in the enhanced levelised cost ‘dots’ set out in Chart 7.1. In addition, levelised costs presented in this report do not include the costs of unpriced carbon, which however represents a system cost. These additional costs are therefore also included in the enhanced levelised cost ‘dots’. Table 7.1 shows these ‘other impacts’ separately.

- **System dependency**: Wider system impacts are entirely system dependent and there is no one ‘right’ estimate. Therefore, any estimates of wider system impacts should be treated with caution; they are only valid for one state of the world. The estimates presented in this report only reflect six[28] possible scenarios and do not cover the whole range of possibilities. The scenarios assume differing uptakes of various low-carbon technologies, and differing projections of long-term electricity demand. While these scenarios have been designed to illustrate the impact of different generation mixes, different assumptions could lead to wider system impacts outside the range illustrated.

  The estimates show the wider system impact that a hypothetical small increment of a technology, e.g. of offshore wind, onshore wind or solar, would have at the margin of the different market segments (i.e. the wholesale market, capacity market, balancing and ancillary service markets) when added into these different generation mixes. While the estimates reflect the characteristics of the technology added, most importantly they reflect the state of the background scenario, i.e. a more flexible or diverse scenario is better able to absorb new inflexible or variable plants compared to a less flexible or diverse system.

- **Subjective nature of plant location**: The wider system impacts presented in this report include impacts on transmission networks by considering a range of possible locations for a generic plant; distribution network impacts are not included. However, results are still to a large extent driven by the subjective choice of the range of locations used and should be interpreted with caution. It is important to note that network costs and charges are likely to change going forward; this is not captured in the estimates presented.

- **Presentation**: In line with other literature, wider system impacts in this report are presented relative to the wider system impacts of a nuclear plant. Alternatively, wider system impacts can be presented as absolute estimates or relative to any other technology type.

[28] The scenarios consist of three different generation mixes (higher renewables, higher nuclear, and a balanced mix), each taken for two different projections of demand levels. All are high-decarbonisation scenarios consistent with the UK’s commitment to net zero emissions by 2050.

- **Results of three scenarios**: Chart 7.1 and Table 7.1 show the levelised costs presented elsewhere in this report, assuming maximum load factors but with balancing charges stripped out to avoid double counting with the balancing and ancillary service costs included in the wider system impact. On the other hand, transmission network impacts exclude the average network charges faced by different technologies that are already included in the levelised costs. The 'dots' represent a technology's enhanced levelised cost, made up of the original levelised cost 'bar', the technology's wider system impact and its 'other' impacts, including unpriced carbon and lower than maximum load factors, with the latter being particularly important for dispatchable technologies or those that get curtailed.

  While dispatchable technologies like CCGTs and CCUS generally help to reduce system costs, they run at less than maximum load factors and therefore their levelised costs increase. In these six scenarios, generally (but not always) the system savings outweigh the load factor impacts, resulting in an overall cost reduction. Intermittent technologies (e.g. wind and solar) generally impose a wider system cost, which is more severe in scenarios with lower flexibility or a less diverse generation mix.

  The results from the six assessed scenarios highlight that considering wider system impacts changes our cost perception of different technologies. Across some of the scenarios assessed, the ranking of technologies changes.

  The enhanced levelised cost range is particularly large for CCGTs commissioning in 2035. The value of additional CCGT capacity to the system is greater in scenarios where demand increases faster or there is a higher proportion of intermittent renewable capacity. It should be noted that for a technology that operates at increasingly low load factors as the system decarbonises, a £/MWh metric may not be appropriate (see Section 6).

Chart 7.1: Enhanced levelised cost for plants commissioning in 2025, 2030 and 2035 across three scenarios with varying amounts of low-carbon, £/MWh

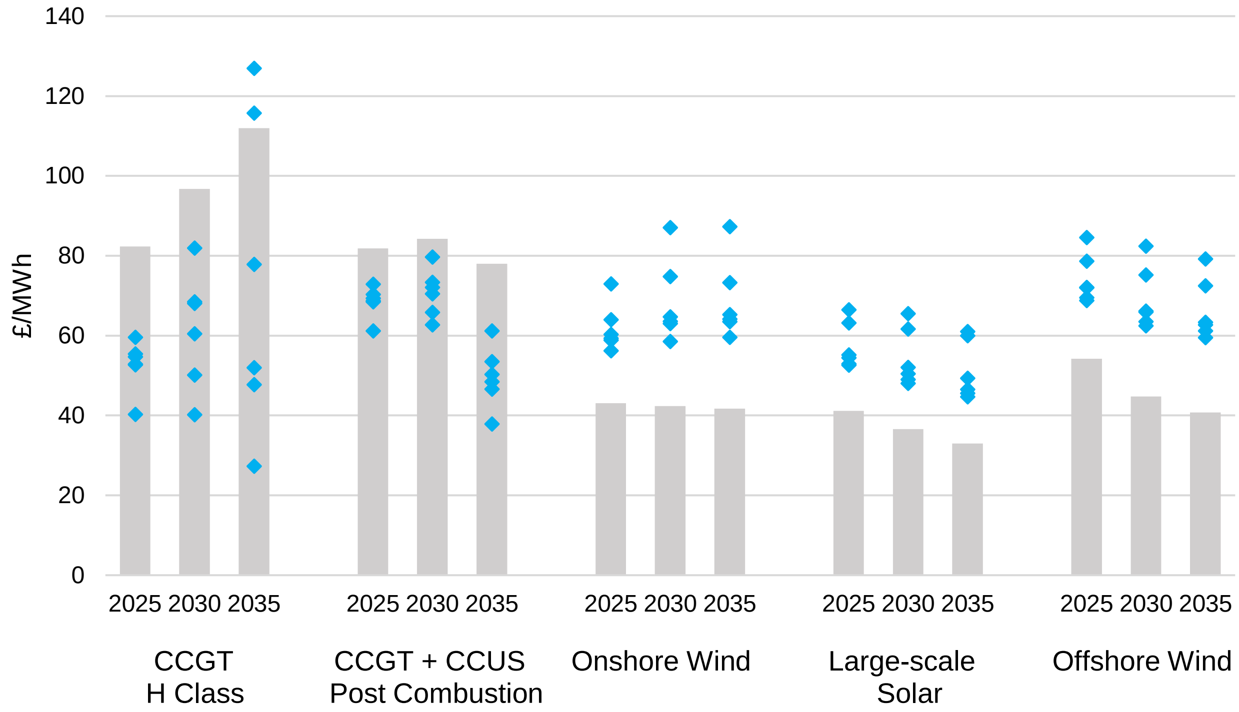


Table 7.1: Enhanced levelised cost ranges for plants commissioning in 2025 across six low-carbon generation scenarios, £/MWh

	Original Levelised Cost (A)	Wider System Impact (excl. transmission network and other impacts) (B)	Other Impacts (C)	Transmission Network Impacts (D)	Enhanced Levelised Cost (A+B+C+D)
CCGT H Class	82	-46 to -24	2 to 5	-2 to 0	40 to 60
CCGT+CCUS Post Combustion (FOAK)	82	-42 to -25	13 to 23	-2 to -1	61 to 73
Onshore Wind	43	-8 to 3	5 to 21	6 to 8	56 to 73
Large-Scale Solar	41	6 to 13	1 to 17	0	53 to 66
Offshore Wind	54	1 to 10	0 to 10	6 to 13	69 to 85

Table 7.2: Enhanced levelised cost ranges for plants commissioning in 2030 across six low-carbon generation scenarios, £/MWh

	Original Levelised Cost (A)	Wider System Impact (excl. transmission network and other impacts) (B)	Other Impacts (C)	Transmission Network Impacts (D)	Enhanced Levelised Cost (A+B+C+D)
CCGT H Class	97	-92 to -41	18 to 36	-1 to 0	40 to 82
CCGT+CCUS Post Combustion (FOAK)	84	-65 to -37	22 to 45	-2 to 0	63 to 80
Onshore Wind	42	-5 to 7	6 to 28	6 to 10	59 to 87
Large-Scale Solar	37	8 to 15	1 to 16	0	48 to 66
Offshore Wind	45	7 to 17	1 to 10	5 to 13	62 to 82

Table 7.3: Enhanced levelised cost ranges for plants commissioning in 2035 across six low-carbon generation scenarios, £/MWh

	Original Levelised Cost (A)	Wider System Impact (excl. transmission network and other impacts) (B)	Other Impacts (C)	Transmission Network Impacts (D)	Enhanced Levelised Cost (A+B+C+D)
CCGT H Class	112	-201 to -80	68 to 119	-1 to 2	27 to 127
CCGT+CCUS Post Combustion (NOAK)	78	-81 to -47	22 to 43	-2 to 0	38 to 61
Onshore Wind	42	1 to 14	6 to 23	6 to 9	60 to 87
Large-Scale Solar	33	8 to 19	1 to 11	0	45 to 61
Offshore Wind	41	12 to 22	1 to 7	5 to 11	59 to 79

Annex 1: Additional Estimates

Projects commissioning in 2025, technology-specific hurdle rates

Table 8: Levelised Cost Estimates for Projects Commissioning in 2025, Technology-specific Hurdle Rates, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
Pre-Development Costs	<1	1	5	6	7	7	17
Construction Costs	7	12	63	73	88	89	150
Fixed O&M	2	4	18	20	23	23	33
Variable O&M	4	6	4	4	4	4	5
Fuel Costs	40	64	61	63	62	62	61
Carbon Costs	32	49	50	51	50	51	50
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	-14	0	0	0	0	0
Total	**85**	**124**	**199**	**216**	**234**	**236**	**315**

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
Pre-Development Costs	1	2	2	2	4	1	4
Construction Costs	16	19	22	23	38	22	89
Fixed O&M	6	7	8	8	11	-12	-40
Variable O&M	4	4	4	4	5	3	3
Fuel Costs	61	63	62	62	61	141	141
Carbon Costs	50	51	50	51	50	48	48
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0	0
Total	**137**	**144**	**148**	**149**	**169**	**203**	**245**

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
Pre-Development Costs	20	1	4	2	6	3	3
Construction Costs	509	30	118	39	88	27	31
Fixed O&M	-219	-12	-40	13	46	10	19
Variable O&M	3	3	3	9	13	6	3
Fuel Costs	141	65	65	35	44	0	0
Carbon Costs	48	39	39	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	1
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	-29	0	0
Total	**502**	**125**	**188**	**98**	**168**	**46**	**57**

	Large-Scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW	EfW CHP	AD
Pre-Development Costs	3	0	0	0	3	4	6
Construction Costs	30	66	78	94	95	177	66
Fixed O&M	10	8	8	20	27	37	22
Variable O&M	0	0	0	0	27	58	58
Fuel Costs	0	0	0	0	-114	-145	-10
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	-28	0
Total	**44**	**74**	**86**	**114**	**39**	**101**	**142**

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geother mal CHP
Pre-Development Costs	7	3	7	9	1	12	5
Construction Costs	84	76	96	176	38	134	210
Fixed O&M	31	42	36	36	19	26	13
Variable O&M	58	22	42	42	10	14	13
Fuel Costs	-12	-62	-51	-54	0	0	0
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	-32	0	0	-14	0	0	-107
Total	**135**	**82**	**130**	**193**	**67**	**186**	**133**

	Hydro Large Storage	Hydro 5-16MW	Wave	Tidal stream 2015	CCGT + CCS Post Combustion (FOAK)	Biomass CCS (FOAK)
Pre-Development Costs	1	1	7	7	<1	2
Construction Costs	55	65	229	185	23	53
Fixed O&M	9	16	34	54	4	21
Variable O&M	9	6	26	8	5	4
Fuel Costs	0	0	0	0	45	99
Carbon Costs	0	0	0	0	3	0
CO2 Transport and Storage	0	0	0	0	4	26
Decommissioning and waste	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0
Total	**75**	**88**	**296**	**253**	**85**	**205**

Table 9: Levelised Cost Estimates for Projects Commissioning in 2025, Technology-specific Hurdle Rates, Sensitivities, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
High capex	87	127	209	237	298	295	383
Central	85	124	199	216	234	236	315
Low capex	84	121	192	201	207	206	286
High capex, high fuel	102	146	232	261	322	319	406
Low capex, low fuel	71	105	174	182	187	187	267

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
High capex	140	150	164	164	186	219	308
Central	137	144	148	149	169	203	245
Low capex	136	141	141	141	161	196	215
High capex, high fuel	163	173	188	187	209	339	428
Low capex, low fuel	117	121	122	122	143	234	253

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass 2015	Biomass CHP	Onshore Wind	Offshore Wind
High capex	864	150	285	106	192	52	63
Central	502	125	188	98	168	46	57
Low capex	330	114	144	91	141	39	51
High capex, high fuel	984	175	310	184	284		
Low capex, low fuel	368	94	124	68	123		

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW*	EfW CHP	AD
High capex	51	90	104	136		138	165
Central	44	74	86	114	39	101	142
Low capex	39	58	67	91		60	125
High capex, high fuel						181	167
Low capex, low fuel						42	122

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
High capex	164	96	209	326	90	237	209
Central	135	82	130	193	67	186	133
Low capex	114	56	86	112	44	100	14
High capex, high fuel	160	105	216	331			185
Low capex, low fuel	121	49	80	110			49

	Hydro Large Storage*	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (FOAK)	Biomass CCS (FOAK)
High capex		96	391	338	90	222
Central	75	88	296	253	85	205
Low capex		57	195	169	80	195
High capex, high fuel					107	249
Low capex, low fuel					66	186

***EfW and Hydro Large Storage – due to potential issues with the reliability of the range of cost estimates, no capex or fuel sensitivity shown for EfW and Hydro Large Storage.**

Projects commissioning in 2030, technology-specific hurdle rates

Table 10: Levelised Cost Estimates for Projects Commissioning in 2030, Technology-specific Hurdle Rates, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
Pre-Development Costs	<1	1	5	6	7	7	17
Construction Costs	7	12	63	73	88	89	150
Fixed O&M	2	4	18	20	23	23	33
Variable O&M	4	6	4	4	4	4	5
Fuel Costs	41	68	64	66	64	65	64
Carbon Costs	45	70	69	71	70	71	69
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	-15	0	0	0	0	0
Total	**99**	**146**	**222**	**239**	**257**	**258**	**337**

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
Pre-Development Costs	1	2	2	2	4	1	4
Construction Costs	16	19	22	23	38	22	89
Fixed O&M	6	7	8	8	11	-12	-40
Variable O&M	4	4	4	4	5	3	3
Fuel Costs	64	66	64	65	64	147	147
Carbon Costs	69	71	70	71	69	75	75
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0	0
Total	**159**	**167**	**170**	**171**	**191**	**236**	**278**

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
Pre-Development Costs	20	1	4	2	6	3	3
Construction Costs	509	30	118	39	87	26	25
Fixed O&M	-219	-12	-40	13	46	10	17
Variable O&M	3	3	3	9	13	6	3
Fuel Costs	147	69	69	35	44	0	0
Carbon Costs	75	61	61	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	1
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	-30	0	0
Total	**535**	**151**	**214**	**98**	**166**	**45**	**47**

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW	EfW CHP	AD
Pre-Development Costs	3	0	0	0	3	4	6
Construction Costs	26	61	74	89	94	175	66
Fixed O&M	10	7	7	18	27	36	22
Variable O&M	0	0	0	0	26	57	58
Fuel Costs	0	0	0	0	-114	-145	-10
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	-29	0
Total	**39**	**68**	**81**	**107**	**37**	**97**	**142**

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
Pre-Development Costs	7	3	7	9	1	12	5
Construction Costs	84	73	92	169	38	134	205
Fixed O&M	31	41	35	35	19	26	13
Variable O&M	58	22	40	40	10	14	13
Fuel Costs	-12	-62	-51	-54	0	0	0
Carbon Costs	0	0	0	0	0	0	0

CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	-32	0	0	-14	0	0	-111
Total	**134**	**77**	**123**	**184**	**67**	**186**	**124**

	Hydro Large Storage	**Hydro 5-16MW**	**Wave**	**Tidal stream**	**CCGT + CCS Post Combustion (FOAK)**	**Biomass CCS (FOAK)**
Pre-Development Costs	1	1	7	7	<1	2
Construction Costs	55	65	182	151	22	53
Fixed O&M	9	16	25	41	4	21
Variable O&M	9	6	18	6	5	4
Fuel Costs	0	0	0	0	47	99
Carbon Costs	0	0	0	0	5	0
CO2 Transport and Storage	0	0	0	0	4	26
Decommissioning and waste	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0
Total	**75**	**88**	**232**	**205**	**87**	**205**

Table 11: Levelised Cost Estimates for Projects Commissioning in 2030, Technology-specific Hurdle Rates, Sensitivities, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
High capex	101	150	231	260	321	318	406
Central	99	146	222	239	257	258	337
Low capex	98	143	214	224	229	228	307
High capex, high fuel	116	169	254	284	345	341	429
Low capex, low fuel	85	127	195	204	209	208	287

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
High capex	162	172	187	186	209	252	341
Central	159	167	170	171	191	236	278
Low capex	158	163	163	164	183	228	247
High capex, high fuel	185	196	210	210	232	380	469
Low capex, low fuel	138	143	143	144	164	266	285

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
High capex	897	175	311	105	190	51	53
Central	535	151	214	98	166	45	47
Low capex	363	140	169	90	140	39	43
High capex, high fuel	1025	200	336	183	283		
Low capex, low fuel	401	119	148	68	122		

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW*	EfW CHP	AD
High capex	46	83	99	129		133	165
Central	39	68	81	107	37	97	142
Low capex	35	54	63	86		56	125
High capex, high fuel						177	167
Low capex, low fuel						39	122

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
High capex	163	90	198	311	90	237	198
Central	134	77	123	184	67	186	124
Low capex	113	52	81	106	44	100	7
High capex, high fuel	160	99	206	316			176
Low capex, low fuel	121	45	75	104			47

	Hydro Large Storage*	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (FOAK)	Biomass CCS (FOAK)
High capex		96	309	276	94	222
Central	75	88	232	205	87	205
Low capex		57	151	136	81	195
High capex, high fuel					111	249
Low capex, low fuel					67	186

***EfW and Hydro Large Storage – due to potential issues with the reliability of the range of cost estimates, no capex or fuel sensitivity shown for EfW and Hydro Large Storage.**

Projects commissioning in 2035, technology specific hurdle rates

Table 12: Levelised Cost Estimates for Projects Commissioning in 2035, Technology-specific Hurdle Rates, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
Pre-Development Costs	<1	1	5	6	7	7	17
Construction Costs	7	12	63	73	88	89	150
Fixed O&M	2	4	18	20	23	23	33
Variable O&M	4	6	4	4	4	4	5
Fuel Costs	42	69	65	67	66	66	65
Carbon Costs	59	94	91	94	92	93	91
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	-15	0	0	0	0	0
Total	**115**	**172**	**245**	**263**	**280**	**282**	**361**

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
Pre-Development Costs	1	2	2	2	4	1	4
Construction Costs	16	19	22	23	38	22	89
Fixed O&M	6	7	8	8	11	-12	-40
Variable O&M	4	4	4	4	5	3	3
Fuel Costs	65	67	66	66	65	147	147
Carbon Costs	91	94	92	93	91	109	109
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0	0
Total	**183**	**191**	**194**	**194**	**214**	**271**	**313**

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind

Pre-Development Costs	20	1	4	2	6	3	2
Construction Costs	509	30	118	39	86	25	22
Fixed O&M	-219	-12	-40	13	46	10	16
Variable O&M	3	3	3	9	13	6	3
Fuel Costs	147	70	70	35	44	0	0
Carbon Costs	109	89	89	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	1
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	-30	0	0
Total	**570**	**181**	**244**	**98**	**166**	**44**	**43**

	Large-scale Solar	**PV 10-50kw**	**PV 4-10kw**	**PV <4kw**	**EfW**	**EfW CHP**	**AD**
Pre-Development Costs	3	0	0	0	3	4	6
Construction Costs	23	61	74	89	94	174	66
Fixed O&M	9	7	7	18	26	36	22
Variable O&M	0	0	0	0	26	56	58
Fuel Costs	0	0	0	0	-114	-145	-10
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	-29	0
Total	**36**	**68**	**81**	**107**	**36**	**96**	**142**

	AD CHP	**ACT Standard**	**ACT Advanced**	**ACT CHP**	**Landfill gas**	**Sewage gas**	**Geothermal CHP**
Pre-Development Costs	7	3	7	9	1	12	5
Construction Costs	84	71	90	166	38	134	202
Fixed O&M	31	41	34	34	19	26	13
Variable O&M	58	21	40	40	10	14	13
Fuel Costs	-12	-62	-51	-54	0	0	0
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	-32	0	0	-14	0	0	-111
Total	**134**	**74**	**120**	**180**	**67**	**186**	**121**

	Hydro Large Storage	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (NOAK)	Biomass CCS (NOAK)
Pre-Development Costs	1	1	7	7	<1	2
Construction Costs	55	65	165	139	15	48
Fixed O&M	9	16	21	37	4	20
Variable O&M	9	6	16	5	5	4
Fuel Costs	0	0	0	0	47	99
Carbon Costs	0	0	0	0	7	0
CO2 Transport and Storage	0	0	0	0	2	21
Decommissioning and waste	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0
Total	**75**	**88**	**209**	**188**	**81**	**193**

Table 13: Levelised Cost Estimates for Projects Commissioning in 2035, Technology-specific Hurdle Rates, Sensitivities, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
High capex	116	175	254	284	345	341	429
Central	115	172	245	263	280	282	361
Low capex	113	169	237	248	252	251	330
High capex, high fuel	131	194	277	308	368	365	452
Low capex, low fuel	100	152	217	227	232	231	310

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
High capex	185	196	210	210	232	287	376
Central	183	191	194	194	214	271	313
Low capex	181	187	187	187	207	263	282
High capex, high fuel	208	220	234	233	255	415	504
Low capex, low fuel	161	166	166	166	186	301	320

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
High capex	932	205	341	105	190	50	48
Central	570	181	244	98	166	44	43
Low capex	398	170	199	90	139	38	39
High capex, high fuel	1060	230	366	183	282		
Low capex, low fuel	435	148	177	68	122		

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW*	EfW CHP	AD
High capex	42	83	99	129		131	165
Central	36	68	81	107	36	96	142
Low capex	31	54	63	86		54	125
High capex, high fuel						175	167
Low capex, low fuel						37	122

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
High capex	163	88	194	305	90	237	195
Central	134	74	120	180	67	186	121
Low capex	113	50	79	103	44	100	6
High capex, high fuel	160	97	202	310			173
Low capex, low fuel	121	43	73	102			46

	Hydro Large Storage*	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (NOAK)	Biomass CCS (NOAK)
High capex		96	279	254	83	209
Central	75	88	209	188	81	193
Low capex		57	134	124	78	184
High capex, high fuel					100	236
Low capex, low fuel					63	174

***EfW and Hydro Large Storage – due to potential issues with the reliability of the range of cost estimates, no capex or fuel sensitivity shown for EfW and Hydro Large Storage.**

Projects commissioning in 2040, technology specific hurdle rates

Table 14: Levelised Cost Estimates for Projects Commissioning in 2040, Technology-specific Hurdle Rates, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
Pre-Development Costs	<1	1	5	6	7	7	17
Construction Costs	7	12	63	73	88	89	150
Fixed O&M	2	4	18	20	23	23	33
Variable O&M	4	6	4	4	4	4	5
Fuel Costs	42	69	65	67	66	66	65
Carbon Costs	70	113	108	111	109	109	108
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	-15	0	0	0	0	0
Total	**125**	**191**	**261**	**280**	**297**	**298**	**377**

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
Pre-Development Costs	1	2	2	2	4	1	4
Construction Costs	16	19	22	23	38	22	89
Fixed O&M	6	7	8	8	11	-12	-40
Variable O&M	4	4	4	4	5	3	3
Fuel Costs	65	67	66	66	65	147	147
Carbon Costs	108	111	109	109	108	137	137
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0	0
Total	**199**	**208**	**210**	**211**	**231**	**299**	**340**

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
Pre-Development Costs	20	1	4	2	6	3	2
Construction Costs	509	30	118	39	86	25	20
Fixed O&M	-219	-12	-40	13	46	10	15
Variable O&M	3	3	3	9	13	6	3
Fuel Costs	147	70	70	35	44	0	0
Carbon Costs	137	112	112	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	1
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	-29	0	0
Total	**598**	**203**	**267**	**98**	**166**	**44**	**40**

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW	EfW CHP	AD
Pre-Development Costs	3	0	0	0	3	4	6
Construction Costs	21	61	74	89	94	174	66
Fixed O&M	9	7	7	18	26	36	22
Variable O&M	0	0	0	0	26	56	58
Fuel Costs	0	0	0	0	-114	-145	-10
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0
Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	-28	0
Total	**33**	**68**	**81**	**107**	**36**	**96**	**142**

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
Pre-Development Costs	7	3	7	9	1	12	5
Construction Costs	84	71	90	166	38	134	202
Fixed O&M	31	41	34	34	19	26	13
Variable O&M	58	21	40	40	10	14	13
Fuel Costs	-12	-62	-51	-54	0	0	0
Carbon Costs	0	0	0	0	0	0	0
CO2 Transport and Storage	0	0	0	0	0	0	0

Decommissioning and waste	0	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0	0
Additional Costs	-32	0	0	-14	0	0	-111
Total	**135**	**74**	**120**	**181**	**67**	**186**	**122**

	Hydro Large Storage	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (NOAK)	Biomass CCS (NOAK)
Pre-Development Costs	1	1	7	7	<1	2
Construction Costs	55	65	165	139	15	48
Fixed O&M	9	16	21	37	4	20
Variable O&M	9	6	16	5	5	4
Fuel Costs	0	0	0	0	47	99
Carbon Costs	0	0	0	0	8	0
CO2 Transport and Storage	0	0	0	0	2	21
Decommissioning and waste	0	0	0	0	0	0
Steam Revenue	0	0	0	0	0	0
Additional Costs	0	0	0	0	0	0
Total	**75**	**88**	**209**	**188**	**82**	**193**

Table 15: Levelised Cost Estimates for Projects Commissioning in 2040, Technology-specific Hurdle Rates, Sensitivities, £/MWh, 2018 prices

	CCGT H Class	CCGT CHP mode	OCGT 600MW 500 hr	OCGT 400MW 500 hr	OCGT 300MW 500 hr	OCGT 299MW 500 hr	OCGT 100MW 500 hr
High capex	127	194	271	301	361	358	446
Central	125	191	261	280	297	298	377
Low capex	124	188	254	265	269	268	347
High capex, high fuel	142	213	294	324	385	381	469
Low capex, low fuel	111	171	234	244	248	247	327

	OCGT 600MW 2000 hr	OCGT 400MW 2000 hr	OCGT 300MW 2000 hr	OCGT 299MW 2000 hr	OCGT 100MW 2000 hr	Recip Diesel 2000 hr	Recip Diesel 500 hrs
High capex	202	213	227	226	248	315	404
Central	199	208	210	211	231	299	340
Low capex	197	204	203	203	223	291	310
High capex, high fuel	225	237	250	249	271	442	532
Low capex, low fuel	177	183	183	183	203	329	348

	Recip Diesel 90 hrs	Recip Gas 2000 hr	Recip Gas 500 hrs	Dedicated biomass	Biomass CHP	Onshore Wind	Offshore Wind
High capex	960	228	363	105	190	50	44
Central	598	203	267	98	166	44	40
Low capex	426	192	222	90	140	38	36
High capex, high fuel	1088	253	388	183	283		
Low capex, low fuel	463	170	200	68	122		

	Large-scale Solar	PV 10-50kw	PV 4-10kw	PV <4kw	EfW*	EfW CHP	AD
High capex	39	83	99	129		132	165
Central	33	68	81	107	36	96	142
Low capex	28	54	63	86		55	125
High capex, high fuel						176	167
Low capex, low fuel						37	122

	AD CHP	ACT Standard	ACT Advanced	ACT CHP	Landfill gas	Sewage gas	Geothermal CHP
High capex	164	88	194	306	90	237	195
Central	135	74	120	181	67	186	122
Low capex	114	50	79	103	44	100	7
High capex, high fuel	161	97	202	311			174
Low capex, low fuel	121	43	73	102			46

	Hydro Large Storage*	Hydro 5-16MW	Wave	Tidal stream	CCGT + CCS Post Combustion (NOAK)	Biomass CCS (NOAK)
High capex		96	279	254	85	211
Central	75	88	209	188	82	193
Low capex		57	134	124	79	183
High capex, high fuel					102	237
Low capex, low fuel					64	173

Table 16: Levelised Cost Estimates for Projects Commissioning in 2025, 2030, 2035 and 2040, technology-specific hurdle rates, £/MWh, 2018 prices. Highs and lows reflect high and low capital and pre-development cost estimates and capital cost reductions over time.

Commissioning		2025	2030	2035	2040
CCGT H Class	High	87	101	116	127
	Central	85	99	115	125
	Low	84	98	113	124
CCGT CHP mode	High	127	150	175	194
	Central	124	146	172	191
	Low	121	143	169	188
OCGT 600MW 500 hr	High	209	231	254	271
	Central	199	222	245	261
	Low	192	214	237	254
OCGT 400MW 500 hr	High	237	260	284	301
	Central	216	239	263	280
	Low	201	224	248	265
OCGT 300MW 500 hr	High	298	321	345	361
	Central	234	257	280	297
	Low	207	229	252	269
OCGT 299MW 500 hr	High	295	318	341	358
	Central	236	258	282	298
	Low	206	228	251	268
OCGT 100MW 500 hr	High	383	406	429	446
	Central	315	337	361	377
	Low	286	307	330	347
OCGT 600MW 2000 hr	High	140	162	185	202
	Central	137	159	183	199
	Low	136	158	181	197
OCGT 400MW 2000 hr	High	150	172	196	213
	Central	144	167	191	208

	Low	141	163	187	204
OCGT 300MW 2000 hr	High	164	187	210	227
	Central	148	170	194	210
	Low	141	163	187	203
OCGT 299MW 2000 hr	High	164	186	210	226
	Central	149	171	194	211
	Low	141	164	187	203
OCGT 100MW 2000 hr	High	186	209	232	248
	Central	169	191	214	231
	Low	161	183	207	223
Recip Diesel 2000 hr	High	219	252	287	315
	Central	203	236	271	299
	Low	196	228	263	291
Recip Diesel 500 hrs	High	308	341	376	404
	Central	245	278	313	340
	Low	215	247	282	310
Recip Diesel 90 hrs	High	864	897	932	960
	Central	502	535	570	598
	Low	330	363	398	426
Recip Gas 2000 hrs	High	150	175	205	228
	Central	125	151	181	203
	Low	114	140	170	192
Recip Gas 500 hrs	High	285	311	341	363
	Central	188	214	244	267
	Low	144	169	199	222
Dedicated biomass	High	106	105	105	105
	Central	98	98	98	98
	Low	91	90	90	90
Biomass CHP	High	192	190	190	190
	Central	168	166	166	166
	Low	141	140	139	140
Onshore Wind	High	52	51	50	50
	Central	46	45	44	44
	Low	39	39	38	38
Offshore R3 2015	High	63	53	48	45
	Central	57	48	44	40
	Low	51	43	39	37
Large-scale Solar	High	51	46	42	39
	Central	44	39	36	33
	Low	39	35	31	28
PV 10-50kw	High	90	83	83	83
	Central	74	68	68	68
	Low	58	54	54	54
PV 4-10kw	High	104	99	99	99

	Central	86	81	81	81
	Low	67	63	63	63
PV <4kw	High	136	129	129	129
	Central	114	107	107	107
	Low	91	86	86	86
EfW*	High				
	Central	39	37	36	36
	Low				
EfW CHP	High	154	150	147	148
	Central	118	114	111	112
	Low	76	72	70	71
AD	High	138	133	131	132
	Central	101	97	96	96
	Low	60	56	54	55
AD CHP	High	165	165	165	165
	Central	142	142	142	142
	Low	125	125	125	125
ACT Standard	High	96	90	88	88
	Central	82	77	74	74
	Low	56	52	50	50
ACT Advanced	High	209	198	194	194
	Central	130	123	120	120
	Low	86	81	79	79
ACT CHP	High	326	311	305	306
	Central	193	184	180	181
	Low	112	106	103	103
Landfill gas	High	90	90	90	90
	Central	67	67	67	67
	Low	44	44	44	44
Sewage gas	High	237	237	237	237
	Central	186	186	186	186
	Low	100	100	100	100
Geothermal CHP	High	209	198	195	195
	Central	133	124	121	122
	Low	14	7	6	7
Hydro Large Storage*	High				
	Central	75	75	75	75
	Low				
Hydro 5-16MW	High	96	96	96	96
	Central	88	88	88	88
	Low	57	57	57	57
Wave	High	391	309	279	279
	Central	296	232	209	209
	Low	195	151	134	134

Tidal stream	High	338	276	254	254
	Central	253	205	188	188
	Low	169	136	124	124
CCGT + CCS Post Combustion**	High	90	94	83	85
	Central	85	87	81	82
	Low	80	81	78	79
Biomass CCS**	High	222	222	209	211
	Central	205	205	193	193
	Low	195	196	184	182

***EfW and Hydro Large Storage – due to potential issues with the reliability of the range of cost estimates, no capex or fuel sensitivity shown for EfW and Hydro Large Storage.**

**** CCGT + CCS Post Combustion and Biomass CCS are assumed to be FOAK for plants commissioning before 2035, and NOAK for plants commissioning from 2035 onwards.**

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