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ENERGY RESEARCH

The future of dispatchable generation in GB

PUBLIC WEBINAR

13 December 2021

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Introducing the Aurora team

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Source: Aurora Energy Research

Agenda

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I. Executive summary

II. Dispatchable assets and their role in the power system

III. Adaptation of dispatchable gas assets to a Net Zero world

IV. Policy considerations for dispatchable generation

V. Cost of inaction on dispatchable generation policy

The future of dispatchable generation in GB: Key insights and executive summary

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Key insights from the analysis

30 GW

de-rated low carbon dispatchable capacity needed by 2035 to meet system requirements and achieve Net Zero power

Immediate policy action

required to meet 2035 decarbonisation targets with low carbon dispatchable generation

14 $MtCO_2e$

reduction in power sector emissions by 2035 as a result of policy supported dispatchable generation

£54 billion

savings in total system costs through to 2050 relative to a system with policy inaction

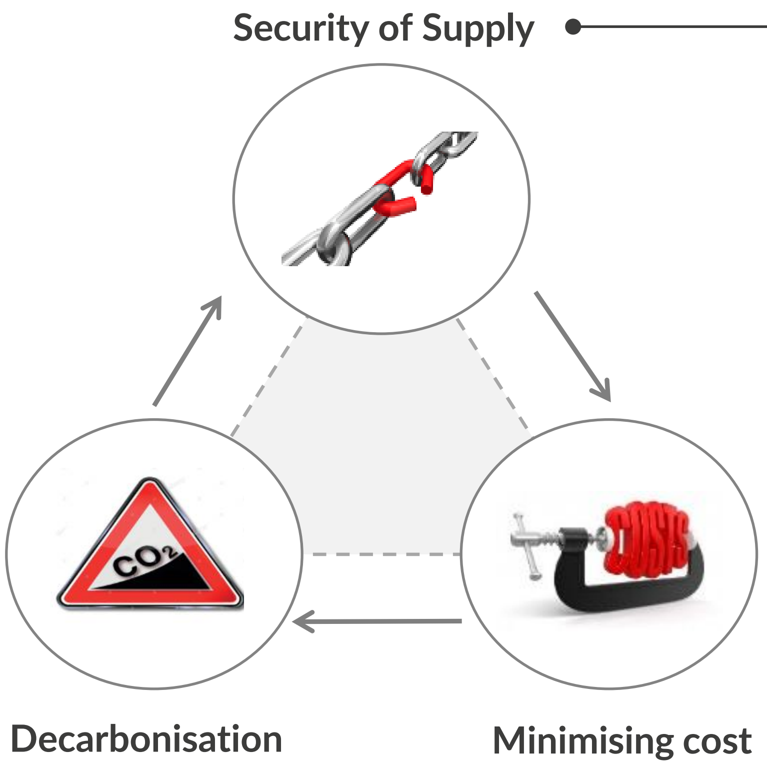
Executive summary of the report

- Net Zero power by 2035 will require c.30 GW of de-rated low carbon dispatchable capacity. Without action to incentivise investments, **there will be an undersupply of this critical dispatchable capacity** in the near future as the power sector decarbonises.
- Existing thermal assets are **critical for providing system security and flexibility requirements** to support the low-carbon transition up to 2035 and in abated form (CCS, Hydrogen, BECCS) will form a large-scale part of the Net Zero system in 2035 and beyond.
- Asset owners will require clear signals for investments, and **critical decisions will be required as early as in the 2020s** to ensure sufficient capacity is decarbonised and available by 2035. No clear policy pathway currently exists for these assets so **they may have to close.**
- **CCS and hydrogen are the front-running decarbonisation pathways** available for existing thermal assets and conversions will depend on **key considerations of policy support, costs, timing and location.**
- Current policies have secured firm capacity and reduced emissions but **need to adapt for Net Zero.** The proposed dispatchable power agreement (DPA) will further **require a suite of complementary policies and holistically reformed markets** to incentivise low carbon capacity.
- **Immediate policy action is required** to incentivise the deployment of low carbon dispatchable generation. Without policy action, **the UK may miss its decarbonisation targets** by c.14 $MtCO_2e$ in 2035 and incur a £54bn increase in total system costs.

Source: Aurora Energy Research

UK energy policy aims to meet three main objectives including security of supply which entails specific system requirements

UK energy policy aims to meet three overarching objectives, often referred to as the ‘energy trilemma’. Of the three, ensuring security of supply is most complex with several key requirements.



1 Firm Capacity

- Dispatchable assets are those that are able to produce power more or less on-demand, without being linked to the weather, and whose economics incentivise them to produce in response to the system needs. In addition, they have sufficient duration to have a sustained contribution to energy security at peak times.

2 Flexible Dispatchable Capacity

- Capacities that are able to ramp flexibly (i.e rapid warm start times) will be required to guarantee energy security as more intermittent renewable capacity comes on the system. This could see output vary significantly between settlement periods, increasing the need for balancing actions.

3 Frequency Response and Inertia[1]

- Deviations in system frequency can be detrimental to the grid resulting in blackouts. Inertia is critical to prevent sharp movements in system frequency and helps make the grid resilient to energy imbalances.
- Frequency response is equally essential to counteract sharp deviations if they occur. This is mitigated by generators that are able to react instantaneously to changes in system frequency by ramping generation up or down.

4 Voltage[1]

- It is essential to keep the voltage on the grid stable to prevent damage to grid infrastructure and blackouts. Maintaining grid voltage is dependent on reactive power and Short Circuit Levels which can come from a variety of assets and technologies.

1) The challenges with system requirements already exist and National Grid currently have a suite of products to procure ancillary services as required to manage the grid and have laid out plans for future procurement.

Sources: Aurora Energy Research, BEIS, National Grid

Traditional thermal assets currently serve a unique purpose on the power system, fulfilling niche system requirements

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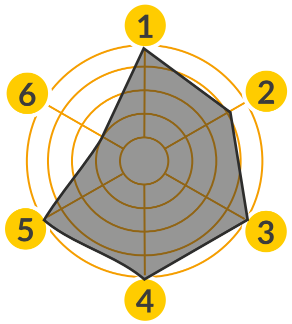
All metrics are scored based on technology performance today. Further considerations for abatement of thermal assets are explored in a later section of this report.

Unsuitable for Net Zero without conversion

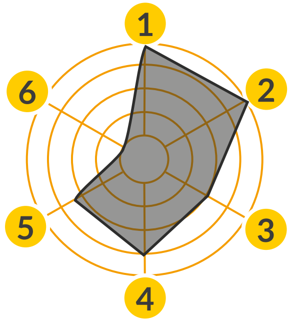
Unabated CCGTs

- *Generates electricity via combined gas and steam turbines*
- *Low capex and high efficiency have enabled CCGTs to run at baseload capacity historically*



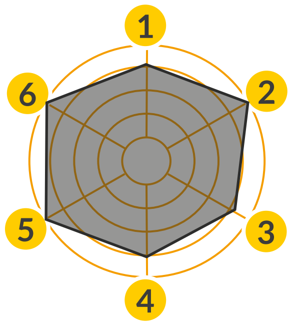
Gas peakers/OCGTs

- *Similar to CCGTs but without the steam cycle, these technologies are cheaper but less efficient*
- *Typically smaller capacity and operate as peakers*



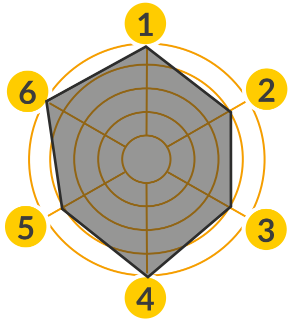
Pumped hydro

- *Pumps water uphill using excess electricity, to be stored until needed for regeneration of power*
- ***Finite capacity available**, most sites already exploited in UK*



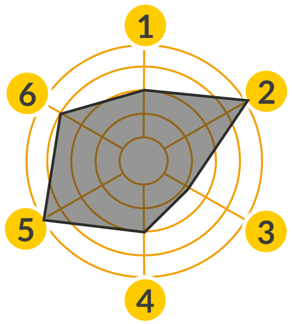
Biomass

- *Combustion of biomass[3] to generate steam which turns a turbine to generate electricity*
- *Slow ramp times means that biomass operates at baseload capacity*



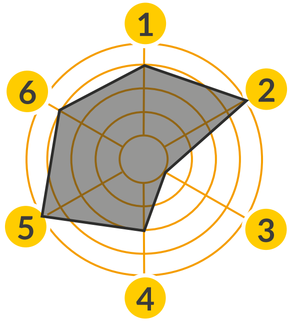
Battery storage[1,2]

- *Typically lithium-ion technology, batteries provide several services to the grid, including energy arbitrage, operation in the CM and BM, and ancillary services*



Interconnectors[2]

- *High voltage power lines connecting different power markets, in order to allow transfer of electricity from low to high demand*



Scores are on a 1-5 scale increasing with the diameter of the circles (i.e. largest circle = 5 = best). Scaling non-linear.

Key	1	2	3	4	5	6
Metric	Duration / continuous supply	Ramping speed	Contribution to inertia	Contribution to voltage	Minimising cost to consumer	Contribution to decarbonisation

1) Only mature assets referenced i.e. battery storage with durations ranging between half hour and 2 hours. 2) Carbon intensity of batteries and interconnectors based on assumptions that they only charge/discharge/transfer power in periods of low prices where low cost low carbon assets (e.g. renewables, nuclear) are generating. 3) Biological material obtained from living or recently living plant matter.

Sources: Aurora Energy Research, EMR, BEIS, National Grid

Owners of existing dispatchable thermal assets are facing a number of imminent key decisions as the UK looks towards Net Zero

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Dispatchable asset owners today are facing important near-term decisions as they look to decarbonise, to align with targets for a Net Zero power system by 2035.

Current UK policy is geared towards a Net Zero power system by 2035...

- The UK is mandated to achieve Net Zero carbon emissions across all sectors by 2050, and the government recently announced its intention to fully decarbonise the power sector by 2035
- Looking towards Net Zero, dispatchable thermal generation assets will face an uncertain future with several challenges:

1. Declining operations and profitability
2. Commodity price volatility
3. Policy support and incentives uncertainty
4. Dwindling investment signals

- **As decarbonisation efforts intensify, thermal asset owners will need to make several key decisions in the immediate future as to whether and how to stay relevant in a Net Zero world.**

...accelerating the decision-making process for thermal asset owners in the near-term future....

- Operators of dispatchable thermal assets face several key near-term decisions, with many assets due major and costly overhauls as they come to the end of their theoretical lifetimes
- Policy inaction risks un-ordered exit of gas assets, thus clear investment signals are needed well ahead of delivery, to inform key decisions for asset owners and the system operator
- At the overhaul date, asset owners will decide if to:

1. Cease operations, or
2. Extend asset lifetimes

- **Clear and urgent policy action will be required to inform the decision making process in order to achieve the best outcome for asset owners and for the system.**

...as conversions to low carbon alternatives present an opportunity to feature in Net Zero

- There remains a clear need for dispatchable generation in a Net Zero world which presents an opportunity for existing assets to remain relevant, provided they decarbonise
- **CCS and hydrogen are currently the front-running decarbonisation options for these assets**; the choice will depend on key factors such as:

1. Policy support
2. Plant technology and properties
3. Plant and site location
4. Conversion costs and timing

No clear policy pathway exists to support low carbon conversion of existing assets so they may be forced to close

Source: Aurora Energy Research

Decarbonisation of thermal dispatchable assets will be dependent on key considerations like policy support, costs and location

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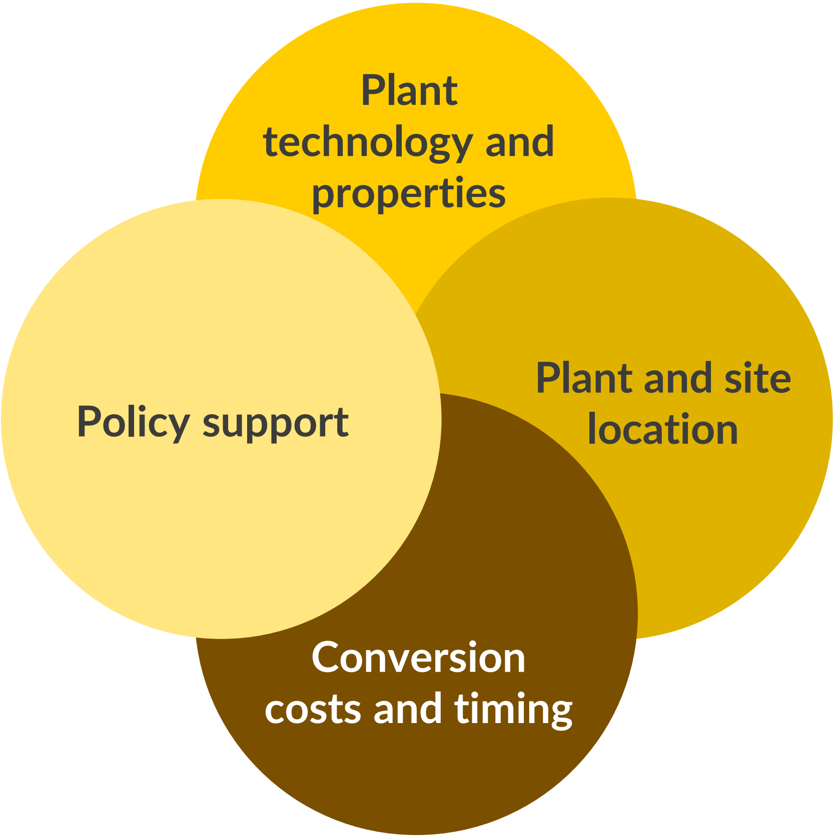
Developers will need to consider several key elements when deciding on a pathway for conversion



Plant technology and properties

- Additional energy requirement and intensity of CCS process imposes efficiency penalties of 6–9 percentage points on the host plant
- Parasitic nature of CCS further imposes capacity penalties[1] of about 10%
- High operational costs of hydrogen
- Expected generation profiles i.e. baseload or flexible or peaking

Plant and site location

- Need for relevant hydrogen and CCUS infrastructure
- Transport and storage (T&S) infrastructure including shipping ports, onshore and offshore pipelines, carbon storage sites
- Lack of hydrogen/CO2 network dictating proximity to supply infrastructure

Conversion costs and timing

- Large upfront CAPEX outlay, with limited financing options, and high operational costs for hydrogen-fuelled assets
- Downtime required for asset overhaul and conversion
- Lack of policy certainty and support for assets transitioning between policy support schemes

1) In addition to CCS efficiency penalties which impact power output, capacity penalties impact the usable capacity of a plant

Sources: Aurora Energy Research, BEIS, Zero Emissions Platform, Global CCS Institute

Low carbon thermal assets could cost over £250/MWh on an LCOE basis, conversions will outcompete new builds

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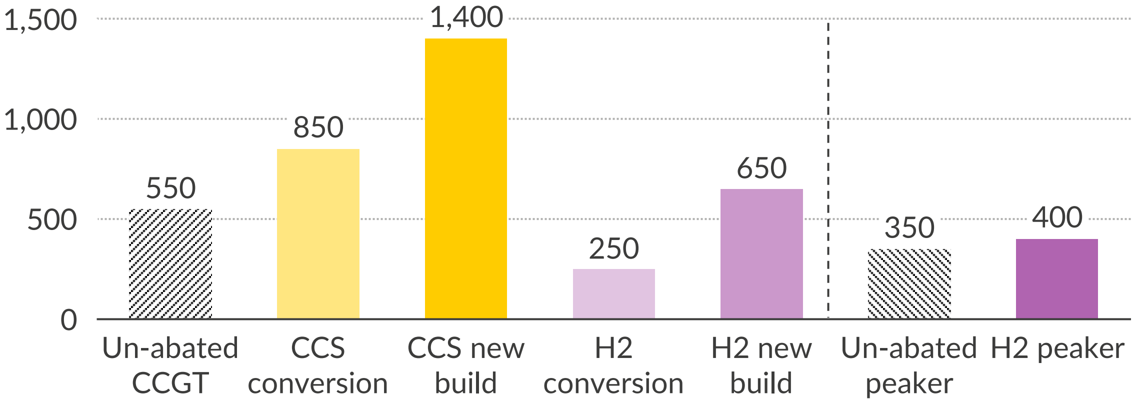
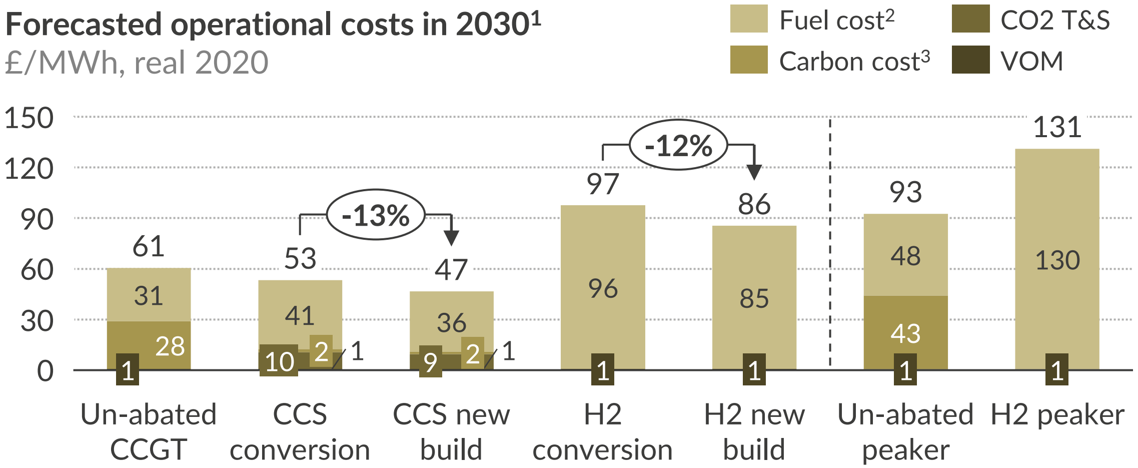
1 Existing asset conversions benefit from lower capex requirements

Forecasted CAPEX in 2030
£/kW, real 2020



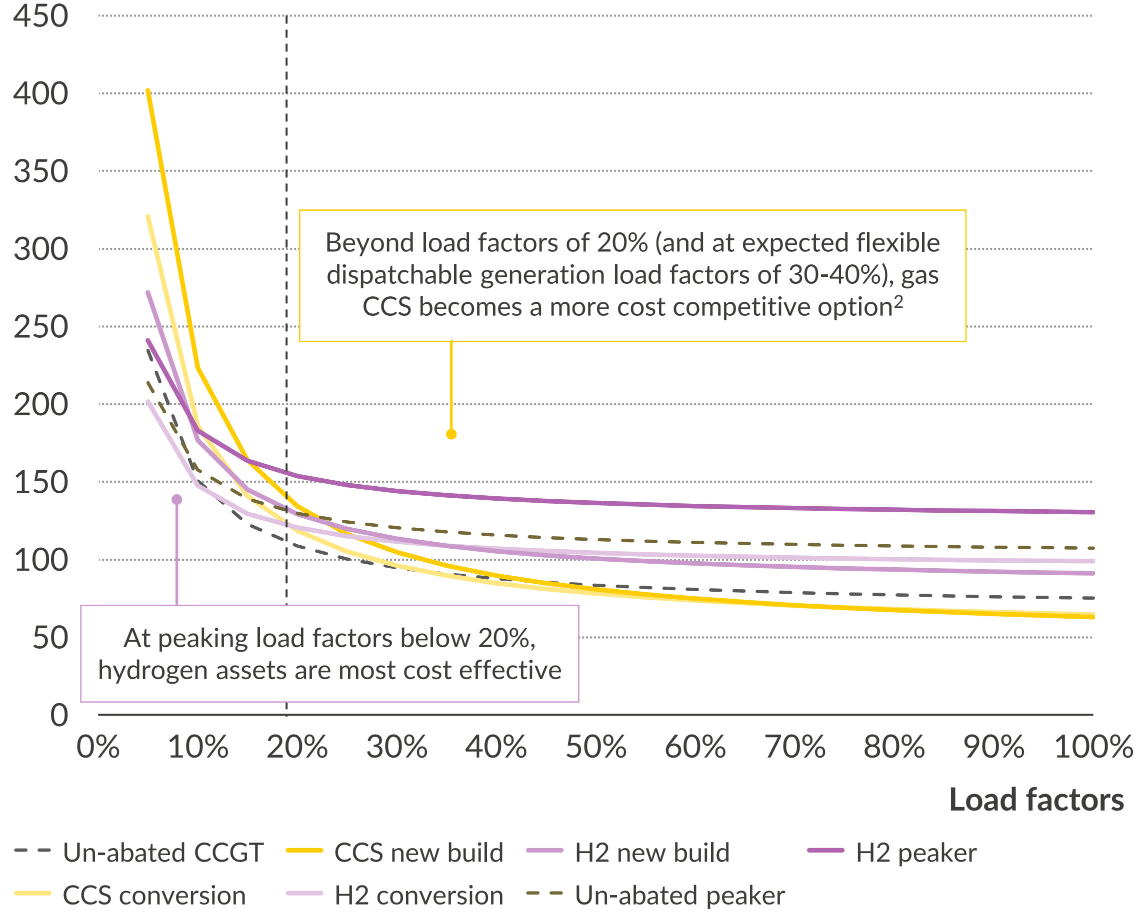
2 New builds benefit from lower operational costs due to higher efficiencies

Forecasted operational costs in 2030[1]
£/MWh, real 2020



3 Conversions outcompete new builds on an LCOE basis

LCOE[4] (assuming entry in 2030)
£/MWh, (real 2020)



1) Analysis shows all numbers excluding any subsidies. Note that costs other than those shown may be included, such as hydrogen transport and storage costs. 2) Fuel cost for hydrogen plants calculated using levelised cost of blue hydrogen and excluding any fuel subsidies. 3) Calculated using Aurora's October 2021 net zero forecast of UK carbon prices. 4) Assumed lifetimes: 30 years for newbuild CCGTs, 20 years for conversions and 25 years for new build peakers.

Source: Aurora Energy Research

Without urgent policy action, Net Zero power by 2035 could result in a 30 GW (de-rated) undersupply of critical capacity

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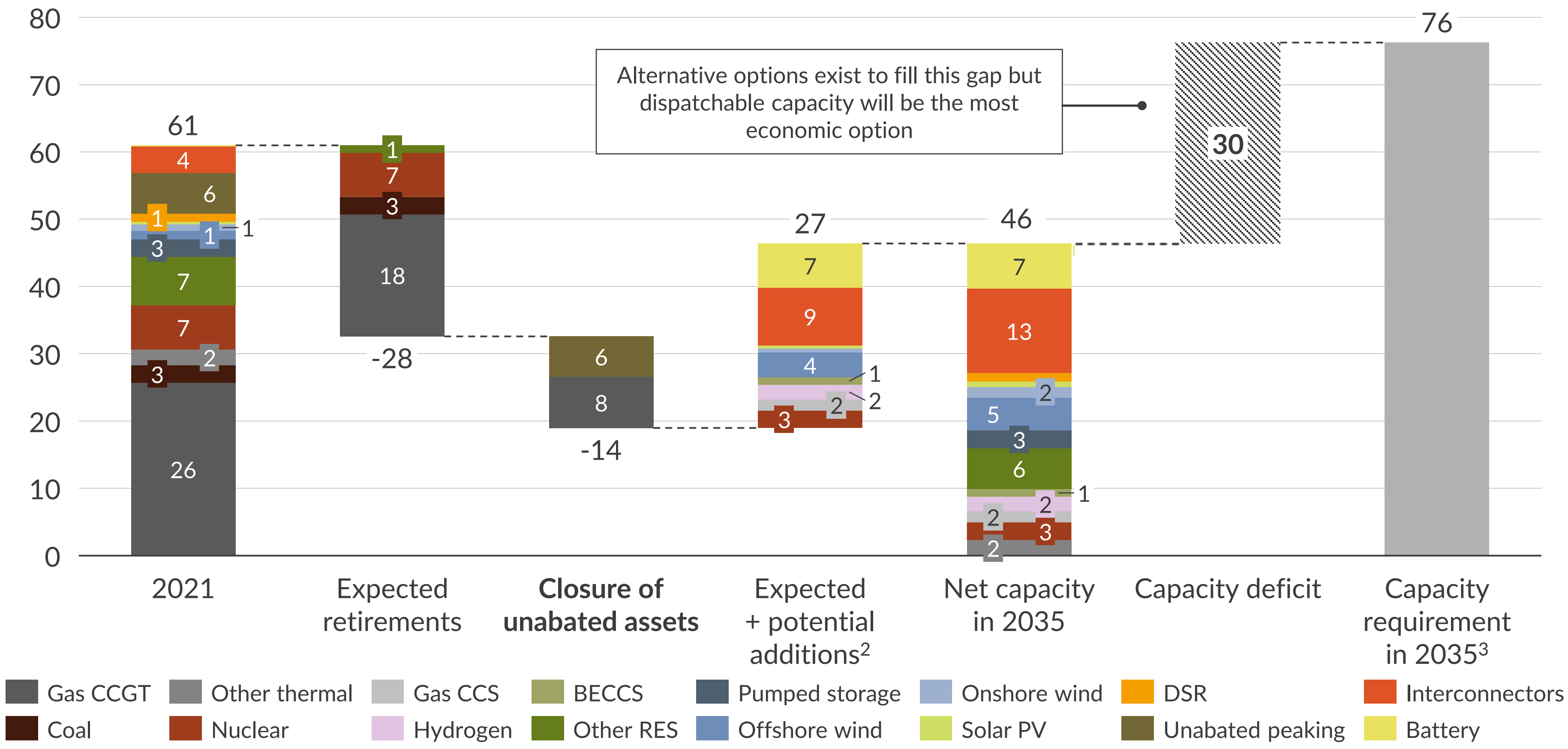
The analysis presented here explores the impact of the Government's Net Zero power by 2035 on energy security. It is based on the existing GB fleet and pipeline and presupposes that there is no new build of any carbon intensive capacity. Existing unabated assets are also estimated to be phased out without sufficient policy in place to support low carbon conversions.

Expected capacity retirements and additions by 2035[1]

GW, de-rated



1) Expected retirements reflect publicly announced dates for nuclear plant closures, policy mandated closure of coal assets and retirements of existing CCGTs based on a 30 year technical lifetime. 2) Expected and potential additions reflect confirmed and announced projects in the GB pipeline. 3) Estimated capacity requirement in 2035 (de-rated) based on Aurora's Net Zero scenario.

Sources: Aurora Energy Research, REPD, EDF, Drax

- GB's security of supply will be challenged by the impending retirements of ageing nuclear and large thermal plants and forced closure of unabated assets
- As these highly de-rated firm dispatchable capacities come off the system much faster than the deployment of other capacities, there could be a **capacity deficit of 30 GW (de-rated) by 2035**
- **This deficit could be further exacerbated based on actual market outturns** e.g. biomass is unable to stay on the system without subsidies or not all of the expected additions come through
- Decarbonising all existing gas assets on the system could fill this gap but not all assets will be suited for conversion so new builds will also be required
- **Given the timescales involved, policymakers need to take urgent action to incentivise deployment of low carbon dispatchable capacity to ensure energy security**

A suite of options is available to support the conversion of thermal assets, however they must satisfy certain requirements

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Assessment criteria[1] ○ Low ● High

	Policy option	Description	*Incentivise low carbon capacity*	*Incentivise low carbon flexible dispatch*	*Integration with wider market*	*Investor confidence*
Existing policies and potential modifications	A Capacity Market (CM)	▪ Design could be modified to a 2-stage auction, with low-carbon technologies able to access higher CM prices in earlier bidding rounds to incentivise dispatchable capacity	◕	◔	◑	◕
	B Contracts for Difference (CfD)	▪ Existing CfD auctions can be expanded to include a new pot for firm low carbon dispatchable technologies to enable cost reductions as seen in the renewables sector	◕	◔	◔	◕
	C Carbon pricing	▪ Higher carbon prices to price gas burning assets out of merit and incentivise low carbon alternatives	◔	◕	◕	◔
New policies	D Carbon Contracts for Difference (CCfD)	▪ A CfD that rewards emissions reduction with a fixed carbon strike price paid for every unit of carbon displaced	◔	◕	◔	◑
	E Dispatchable power agreement (DPA)	▪ Provide an availability payment to subsidise upfront costs and a variable payment to incentivise flexible dispatch ahead of unabated plants but after renewables and nuclear	◕	◕	◑	◕

Individual policies may be insufficient to incentivise low carbon dispatchable assets in isolation. Some combinations of policies could work well, although double subsidies will not receive government backing

1) Existing policies are assessed based on assumed versions which have the potential modifications implemented.

Sources: Aurora Energy Research, EMR, BEIS

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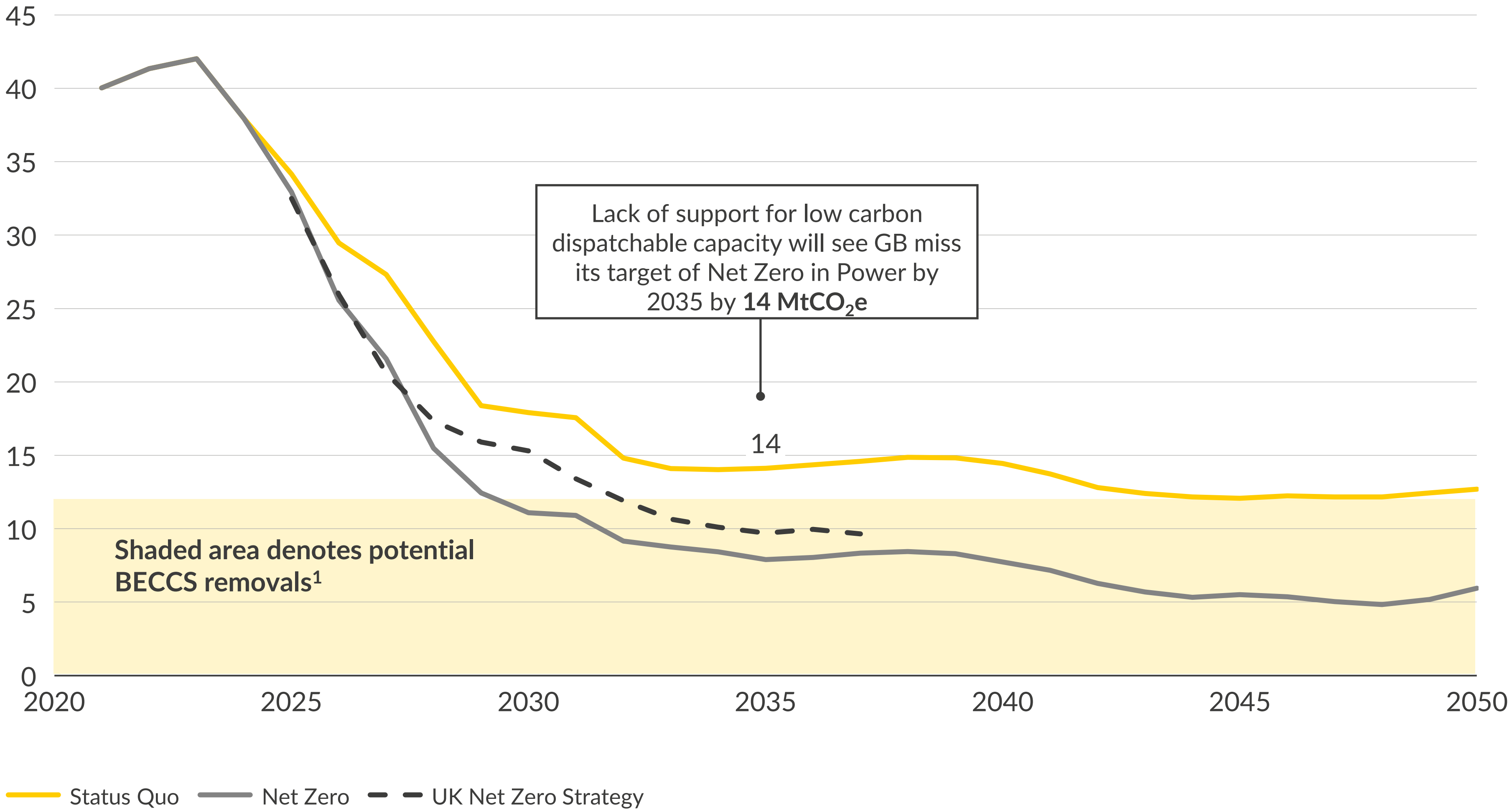
Support for low carbon dispatchable generation will see a 14 $MtCO_2$ reduction in power sector emissions by 2035

Total power sector carbon emissions (before BECCS)

$MtCO_2e$



1) Removals calculated using an assumption of 3 GW of BECCS capacity running at 47% load factor, using a carbon intensity of -941 gCO2/kWh.

Source: Aurora Energy Research

- A strong growth in renewables, driven by Government ambition depresses short term CCGT load factors and enables rapid decarbonisation in the 2020s
- The rate of decarbonisation however slows in the 2030s as demand picks up and power becomes harder to decarbonise
- Total emissions in the Status Quo scenario then falls to **14 $MtCO_2e$ by 2035**, 4 $MtCO_2e$ higher than the trajectory set in the UK Net Zero strategy
- Without support for low carbon dispatchable capacity including BECCS, gas CCS, hydrogen turbines, GB will miss its target of Net Zero in Power by 2035 by **14 $MtCO_2e$**
- **Across all trajectories, BECCS will be required to achieve Net Zero and so will require policy support**

Total system costs could increase by £54bn without further policy action, adding £58/year to the average household bill

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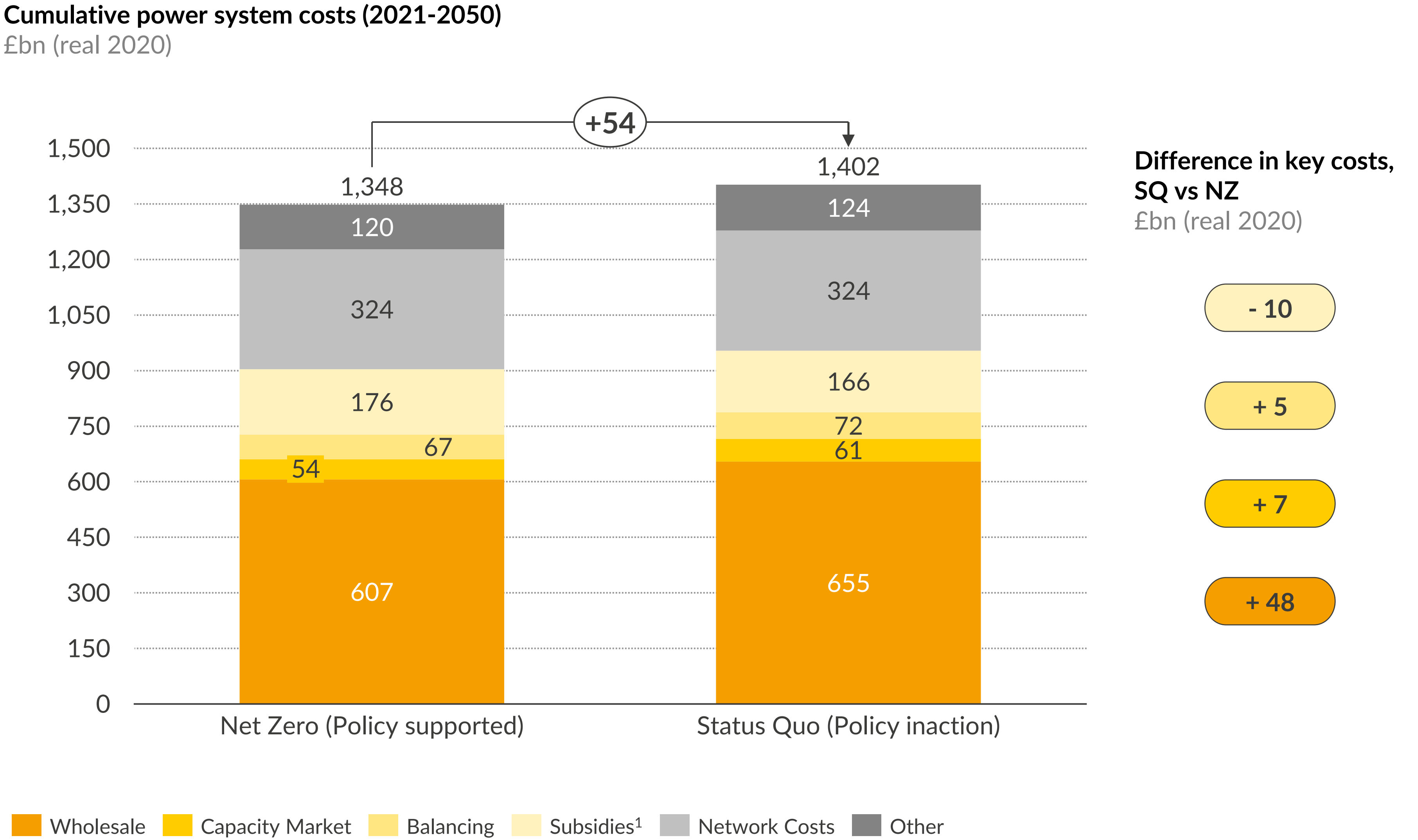

- In addition to missing emissions reductions targets[4], the Status Quo scenario results in a higher total system cost
- Relative to the policy supported Net Zero scenario, total system costs are £54 billion higher in the Status Quo scenario
- This translates to an additional £58/year in energy costs to the average household in UK **failing the objective of minimising costs to consumers**
- Majority of the increase comes from higher wholesale costs, driven by higher baseload prices due to more unabated gas capacity in this scenario, which drive up power prices
- Costs arising from the Capacity and Balancing Markets are also slightly higher, while subsidy costs are lower due to reduced subsidised capacity and higher power prices lowering the spend on top-up payments

1) Includes forecast cost of FiT, ROC and CfD payments. 2) Includes electricity, gas and hydrogen network costs. 3) Includes storage and transportation costs for hydrogen and carbon dioxide, as well as the cumulative cost of the hydrogen wholesale market. 4) Costs of missing emissions targets and potential carbon tax revenues not included in analysis.
Source: Aurora Energy Research

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