Future Energy Scenarios: Changes 2024

ESO

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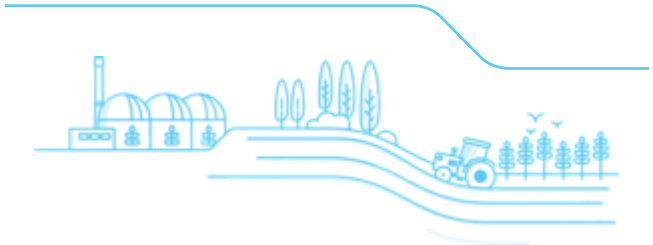

Navigation

To help you find the information you need quickly and easily we have published the report as an interactive document.

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Introduction

Future Energy Scenarios is in its thirteenth cycle, and has gone through a number of analytical and framework shifts during this period to support industry ambitions. This year our framework has changed in response to the need for strategic energy planning driven by Ofgem, feedback from our stakeholders, and to also mirror ESO's strategic transition to the independent National Energy System Operator (NESO) in 2024.

While direct comparison should not be made between last year's scenarios and this year's pathways due to the change in framework, this document sets out some of the key differences across emissions, energy demand and energy supply.

Framework and pathways

Scenarios to Pathways

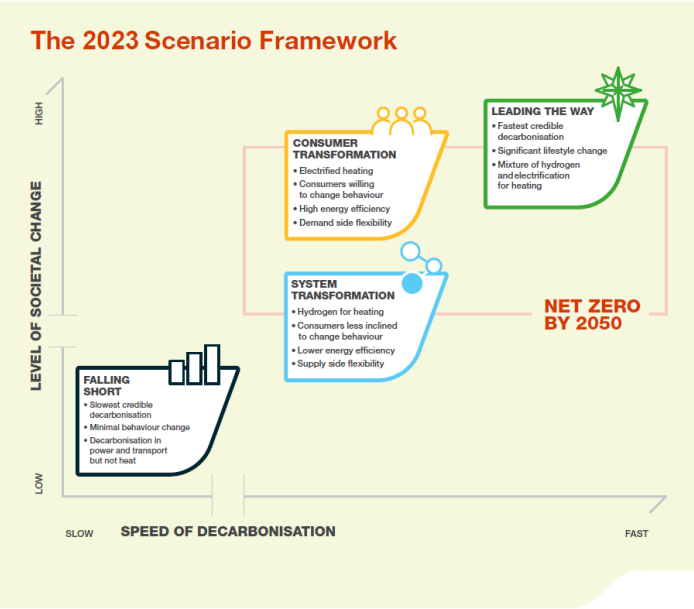
Where our previous analysis looked at what *could happen* by using scenarios to explore a wide range of credible outcomes for how the UK could meet net zero, our new framework seeks to identify narrower, credible and strategic routes for achieving net zero.

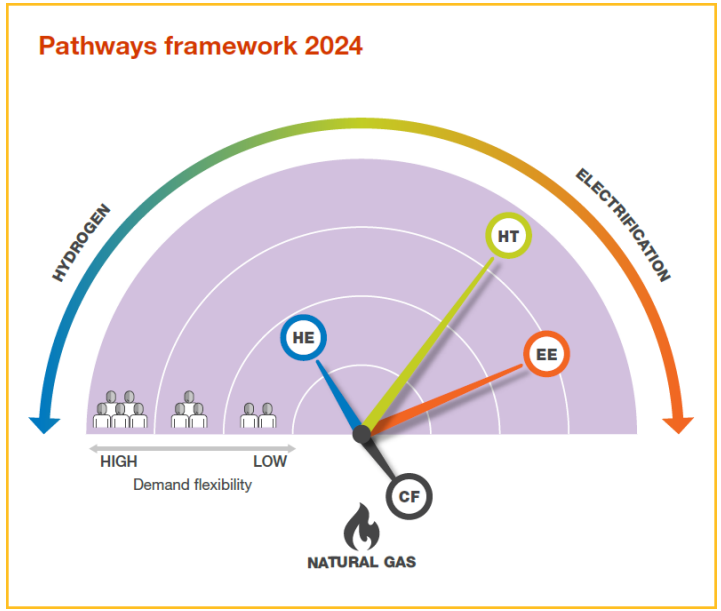
To mark this shift, we have presented pathways to net zero. The adjacent table sets out the key differences between scenarios and pathways.

Scenarios	Pathways
Range of credible outcomes for how the UK could meet net zero. Not all scenarios meet net zero.	Routes showing strategic direction to net zero. All pathways must meet net zero. A counterfactual that does not meet net zero is presented alongside the pathways.
Wide range of possible outcomes.	Provides a narrower, strategic range.
Creates scenarios that are cost agnostic.	Brings in additional economic modelling.
Potential efficiency savings through interactions between electricity and hydrogen networks are highlighted but not assessed.	Whole system optimisation fundamental to finding most efficient future energy system across all energy vectors – (*in development for future iterations*).
Built to emissions and Security of Supply (SoS) targets	Considers whole energy trilemma.
Seeks out the edges of credibility to ensure scenario range is wide enough to encompass uncertain future.	Explores a narrower range of outcomes to drive more strategic credible routes to net zero.
Assumes unconstrained network.	Assesses the impact of network constraints.

Changes to the framework

Our framework sets out the key areas of difference across the pathways. We have moved from a two dimensional axis setting out consumer behavioural change with speed of decarbonisation, to a visual that shows the level of fuel switching to hydrogen and electrification to reflect how these energy vectors will work together compared to today. Our new framework also sets out the level of consumer engagement in demand side flexibility and demand reduction measures across the pathways which is a key component of what makes the pathways differ from each other. All pathways decarbonise at the same pace to achieve net zero in 2050.





Pathway modelling

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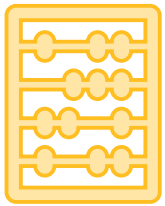
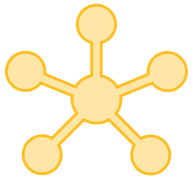
Key changes to modelling in 2024

New “Capacity Expansion Modules” for post-2030 electricity and hydrogen supply capacities

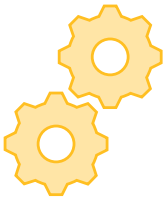
Data centre locations and demand growth reflecting increased expectation



Incorporated new data sources into supply modelling



Improved modelling of hydrogen network rollout for heating



Closer integration of energy supply component interaction

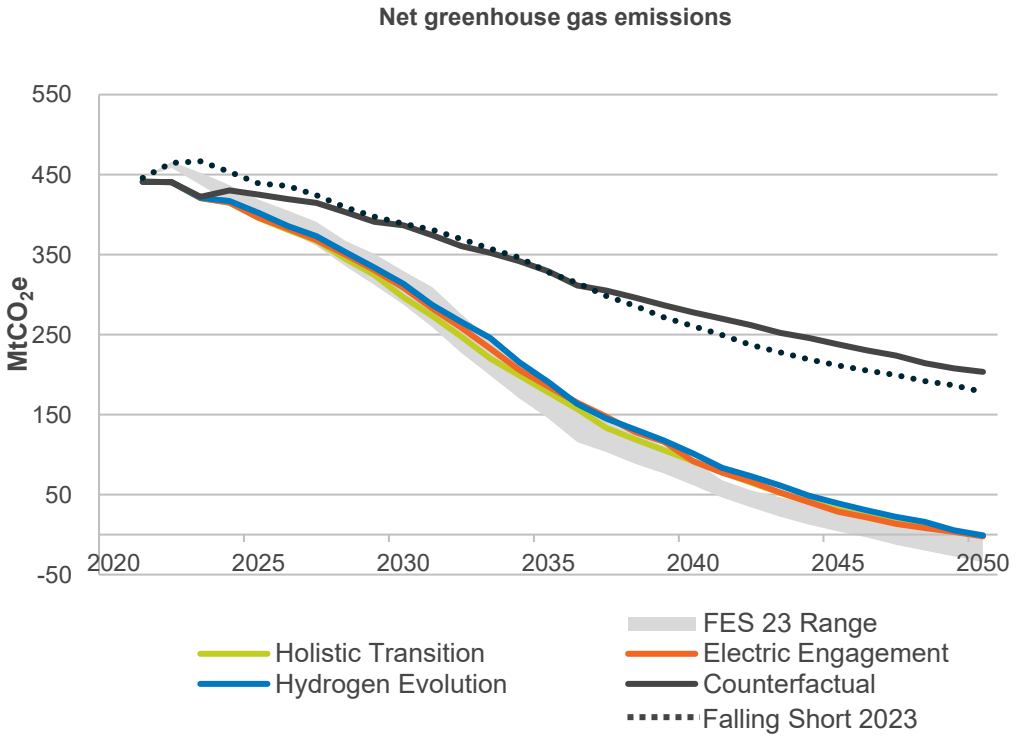
Updated approach to EV charging flexibility

Emissions

Emissions

All pathways meet net zero in 2050 due to removal of “speed of decarbonisation” from the framework.

In FES 2024 the speed of decarbonisation is the same across all pathways and they reach net zero in 2050, unlike in FES 2023 where Leading the Way achieved faster emissions reduction, hitting net zero in 2046. This change is due to the pathways driving a strategic route to net zero supported by stakeholder feedback. While we see quick deployment of clean technology in Holistic Transition, using the same Climate Change Committee projections for non-FES sectors across all pathways has resulted in slower decarbonisation compared to Leading the Way.



Emissions

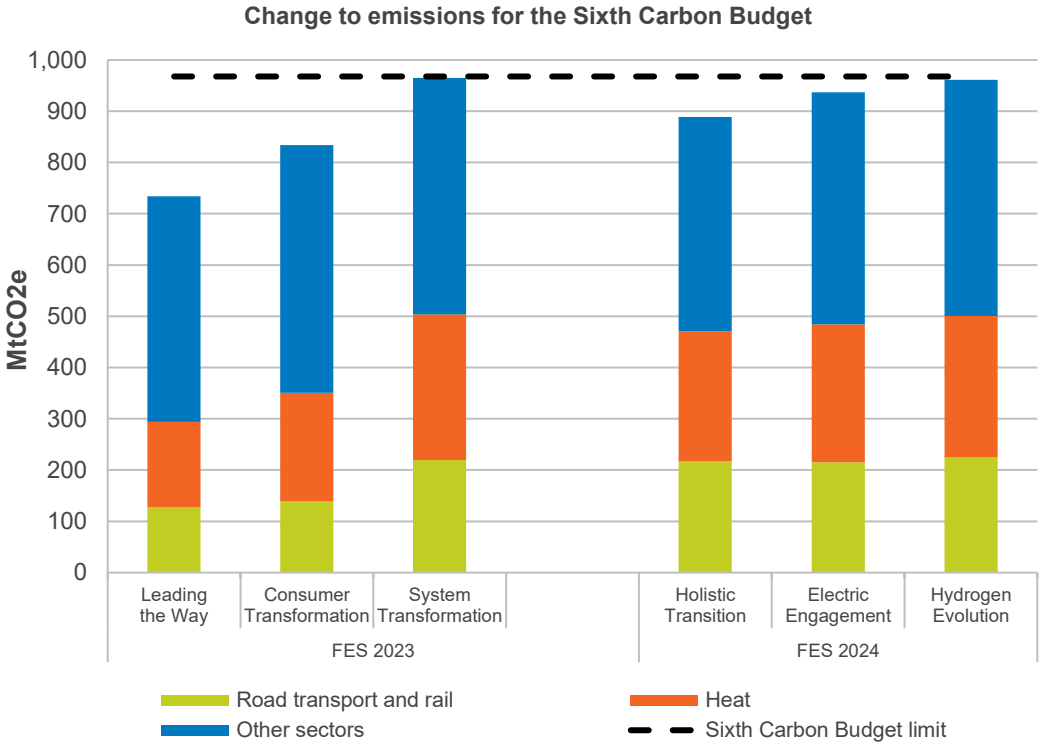
Headroom to the carbon budget targets is reduced.

Carbon budgets are legal commitments which cap the amount of greenhouse gas emissions over a five year period. All carbon budgets are met in each pathway. The Sixth Carbon Budget (2033 to 2037) is the first net zero compliant carbon budget.

The headroom available in the Sixth Carbon Budget has decreased from a range of; 3 - 233 $MtCO_2e$ in FES 2023, to 7 - 79 $MtCO_2e$ in FES 2024.

The reduction in headroom is mainly due to the slower rollout of low carbon technologies such as electric vehicles and heatpumps compared to FES 2023 in Holistic Transition and Electric Engagement. In FES 2023, road transport and rail sector had emissions which ranged from 127 - 220 $MtCO_2e$. For FES 2024, the range has decreased to 215 - 225 $MtCO_2e$ and now has higher minimum and maximum values.

In a similar way, heat emissions have increased from 167 - 284 $MtCO_2e$ in FES 2023 to 253 - 276 $MtCO_2e$ in FES 2024.



Note: Other sectors includes sectors that have negative emissions

Emissions

Bioenergy with Carbon Capture and Storage (BECCS) has slightly faster deployment in some pathways in FES 2024 between 2030 and 2037 to compensate for slower emissions reductions in other sectors to ensure the Sixth Carbon Budget is met.

FES 2024 sees Direct Air Carbon Capture and Storage (DACCS) now being used in all pathways at varying levels, whereas it was only used in Leading the Way in FES 2023. This is due to increased confidence in DACCS from trials and support.

All FES 2024 pathways now use Climate Change Committee's (CCC) Balanced Pathway for sectors not directly modelled by us[1]. Previously the scenarios used a mixture of the CCC's Balanced Pathway and Widespread Innovation aligning with the narrative of the scenario. This alignment in FES 2024 allows easier comparison of FES sectors compared to emissions targets.

We have rebaselined the CCC forecasts based on the latest recorded emissions for FES 2024.

		2023	2050							
			FES 2024				FES 2023			
Sector	Units		Holistic Transition	Electric Engagement	Hydrogen Evolution	Counterfactual	Leading the Way	Consumer Transformation	System Transformation	Falling Short
Annual average carbon intensity of electricity	gCO_2e/kWh	133	-28	-36	-36	21	-13	-41	-40	-10
Net annual emissions	$MtCO_2e$	422	-1	-2	-1	204	-34	-1	-9	178

[1] These sectors include aviation, shipping, agriculture, fuel supply, F-gases, BECCS for biofuels, waste and Land Use, Land Use Change and Forestry (LULUCF).

Energy demand

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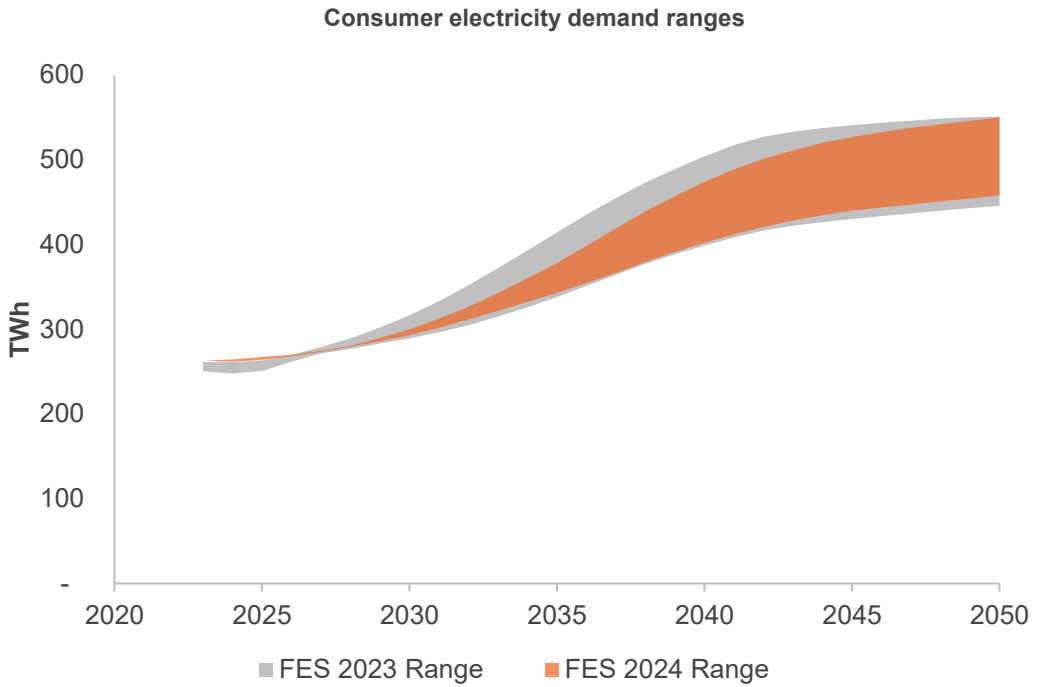
Energy demand

The energy demand range has narrowed, with FES 2024 net zero pathways generally within the boundaries of the FES 2023 net zero scenarios.

The FES 2024 pathways have less demand reduction in the short term, leading to higher demand, due to slower deployment of energy efficiency measures than FES 2023 scenarios.

In the 2020s and 2030s the pathways have slower fuel switching to electricity than Leading the Way or Consumer Transformation had, as the pathways all decarbonise at the same pace with minimum headroom to the Sixth Carbon Budget.

By 2050 the upper range of electrification in Electric Engagement remains similar to Consumer Transformation. Whereas Holistic Transition and Hydrogen Evolution see higher amounts of electrification than Leading the Way and System Transformation (13 TWh and 33 TWh respectively). This is all due to growing confidence in high levels of electrification in a net zero world.

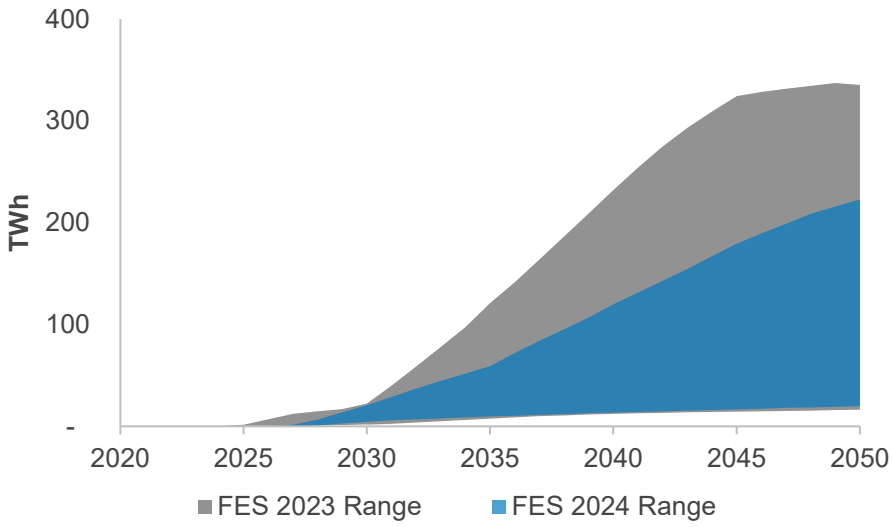


Energy demand

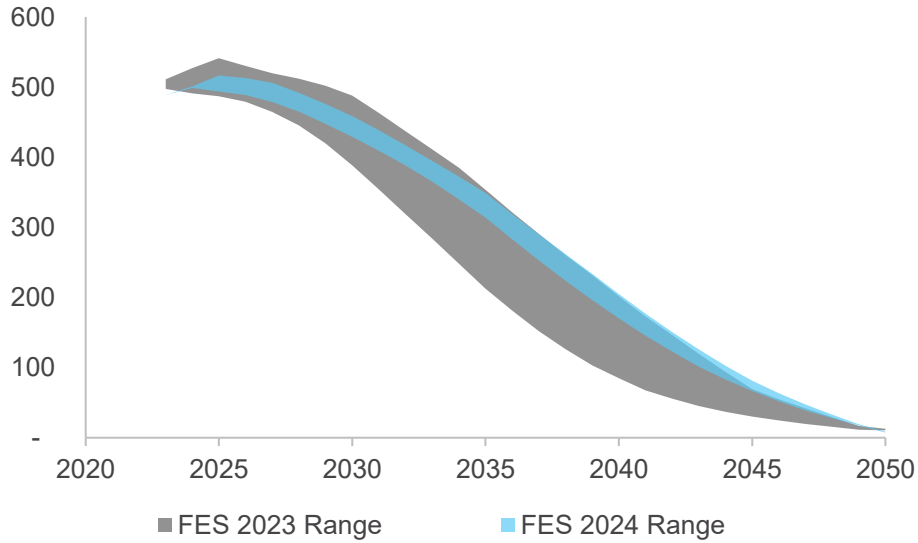
Hydrogen consumer demand across the pathways narrows in FES 2024. The highest now being Hydrogen Evolution at 223 TWh compared to System Transformation which had 335 TWh. This is driven by increasing confidence of the level of electrification in heat.

Natural gas demand in FES 2024 start off an average of 15 TWh lower than FES 2023, due to energy price-related demand suppression from the energy crisis. Fuel switching away from gas is slower in all FES 2024 pathways than Leading the Way and Consumer Transformation and by the late 2030s pathways are all closely aligned in gas use to the forecasts in System Transformation, as all FES 2024 pathways decarbonise at the same pace.

Consumer low carbon hydrogen demand ranges

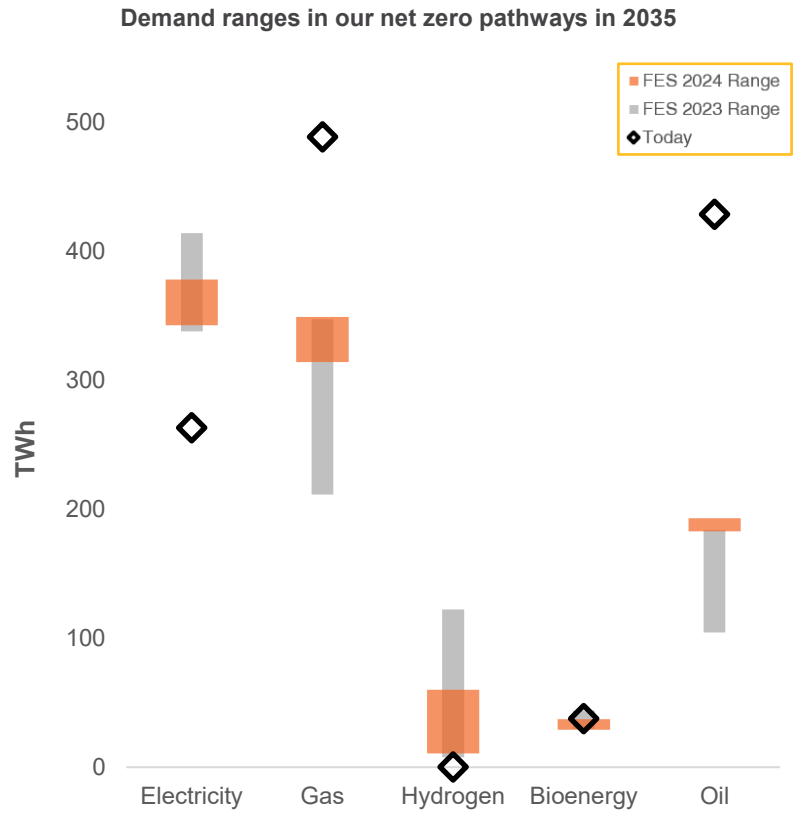


Consumer natural gas demand ranges



Note: The figures have different scales

Energy demand



The range in demand from each fuel has typically halved in 2035 in FES 2024 compared to FES 2023. This is driven by the need for FES 2024 to provide a more strategic route to net zero. In addition, as the speed of decarbonisation is also no longer a differentiator between our net zero pathways, as it was in FES 2023, this significantly narrows the ranges in 2035.

Demand for oil in 2035 has gone from a wide range of 104 - 184 TWh in FES 2023 to a much more narrow range of 183 - 193 TWh in FES 2024. This is primerily due to all net zero pathways now following the Zero Emissions Vehicle mandate. This therefore contributes to a narrower range in electricity demand in 2035 across the FES 2024 pathways.

Heat is another key area where the range of demand in 2035 has reduced. The slower deployment of hydrogen for heating has reduced the range of hydrogen to the lower end of that in FES 23. This in turn has driven more electrified heating technologies across a smaller range. The range for installed heat pumps by 2035 has reduced from 2.6 - 13.3 million in FES 2023 to 7.9 - 9.0 million in FES 2024.

Energy demand

Road Transport

The number of Battery Electric Vehicles (BEV) on the road in GB in 2023 reached 917,000.

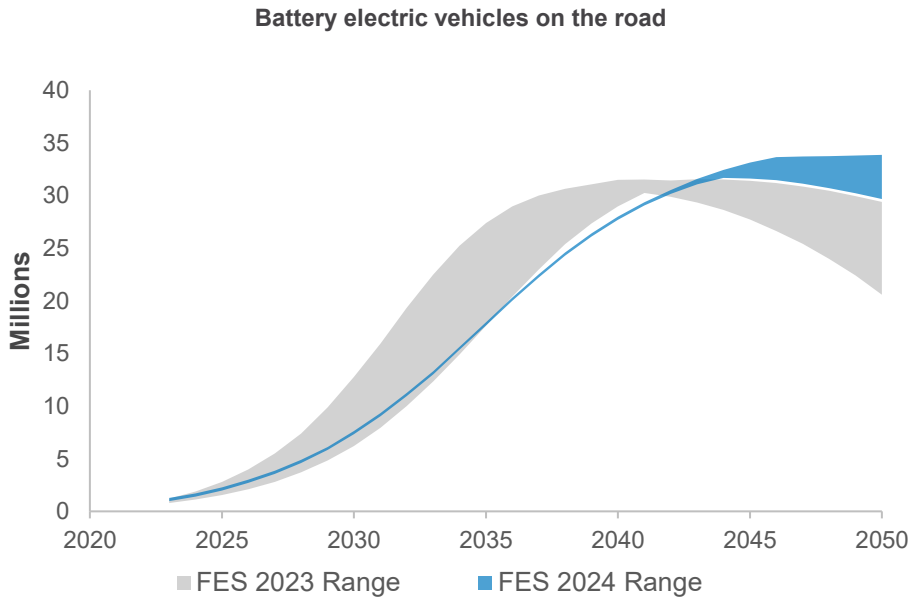
The uptake of electric cars and vans in FES 2024 is the area that has narrowed the range the most. This is because all net zero pathways follow the same projection matching the Zero Emissions Vehicle (ZEV) mandate for car sales, using a central forecast for overall size of the car market. Pathways have a slower uptake rate than Leading the Way and Consumer Transformation, but faster than System Transformation. This drives a narrowed range in oil and electricity demands in 2035 than in FES 2023.

Cars and vans are completely electrified in all FES 2024 net zero pathways. This is unlike FES 2023 that had a low level of hydrogen for these vehicles in System Transformation.

FES 2024 has reduced the rollout of autonomous vehicles, although they are still taken up from the mid 2040s, which leads to more total cars on the road in 2050 relative to FES 2023 scenarios beyond 2045.

Buses and coaches follow similar but slightly slower uptake rates of BEV in the pathways compared to FES 2023. Buses, HGVs and motorcycles all have lower levels of hydrogen use in these vehicle sectors in FES 2024.

Both HGVs and motorcycles have slightly faster uptake of BEVs in the net zero pathways compared to FES 2023, due to actual BEV sales being higher than forecast in FES 2023.



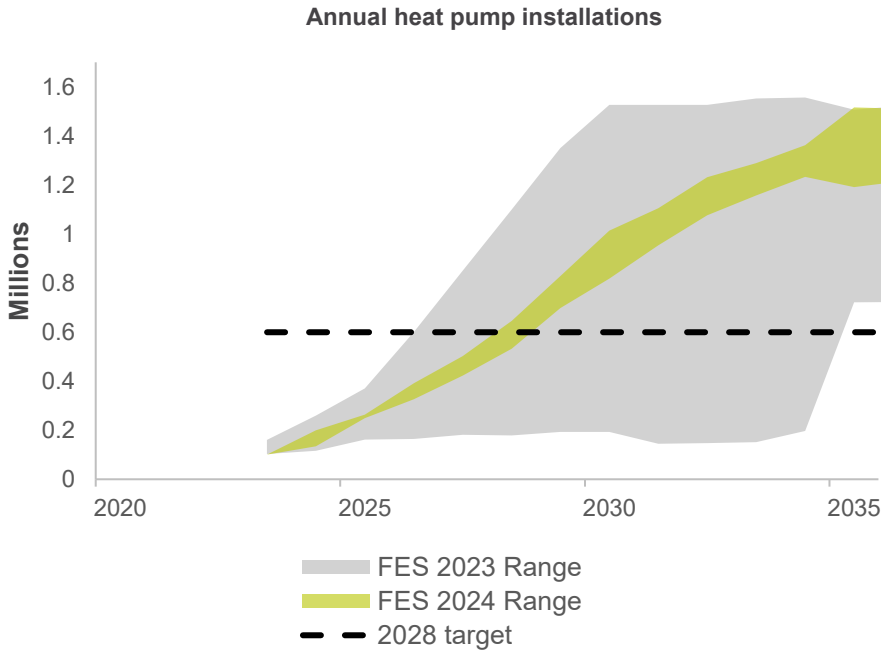
Energy demand

Residential heat

Holistic Transition and Electric Engagement consider an average 0.5°C indoor temperature reduction from climate-conscious consumers, the same as Consumer Transformation, but less than Leading the Way which was 1°C. The range was reduced due to price-related demand suppression during the recent energy crisis being equivalent to the 1°C turn. High insulation measures are adopted in all net zero pathways, unlike in FES 2023 where System Transformation has lower levels of insulation.

After actual installations of heat pumps in 2023 were lower than FES 2023 Falling Short, the uptake rates of this technology have been significantly reduced in FES 2024. The net zero pathways all have heat pump uptake rates between Consumer Transformation and System Transformation.

Hydrogen Evolution has the highest level of hydrogen for heat in FES 2024 with 77 TWh in residental homes compared to System Transformation that had 119 TWh. With hydrogen village trial delays and stakeholder feedback, Hydrogen Evolution has a national network available by 2050 after being built up from around industrial clusters in 2030. Holistic Transition considers hydrogen for heat only around industrial clusters as per Leading the Way. Electric Engagement has no hydrogen for heat use, similar to Consumer Transformation.



Energy demand

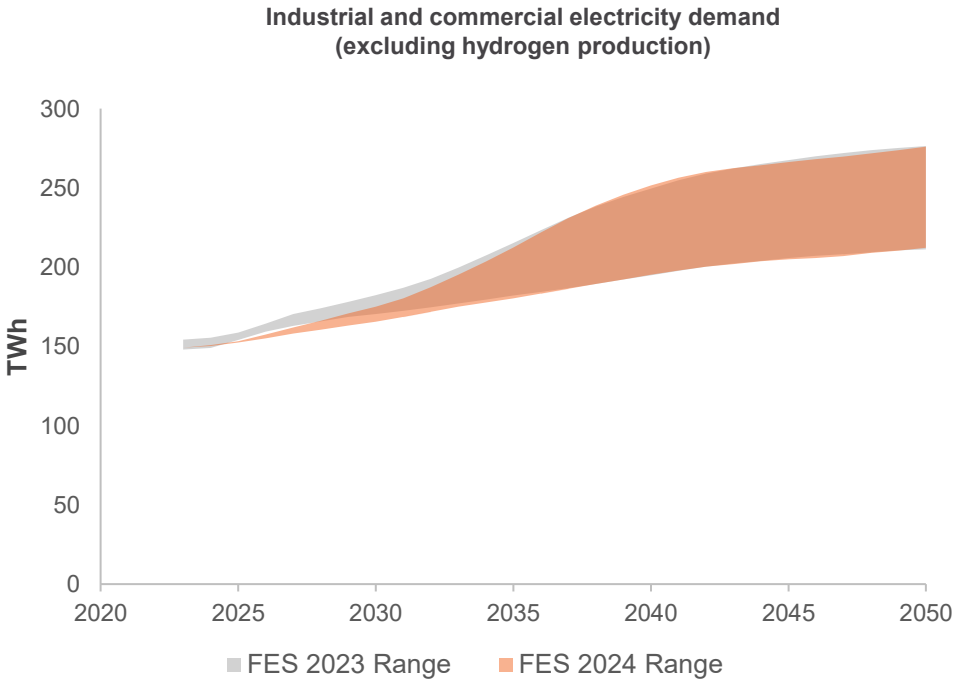
Industrial and Commercial (I&C)

Heating demand follows similar patterns and level of use of hydrogen for heat in I&C to that in the residential sector for the pathway.

Hydrogen use in industry sees Hydrogen Evolution lower than System Transformation and Holistic Transition lower than Leading the Way, but Electric Engagement higher than Consumer Transformation. The lower end of the range has been increased as there is increased confidence hydrogen will be used in industry.

The long term projection of growth in data centres has increased in FES 2024 compared to FES 2023, causing data centre demands in 2050 to increase over 20 TWh in each pathway compared to the FES 2023 scenarios. This is offset by lower levels of electrification in the industry sector in FES 2024.

The high levels of uncertainty in data centers drive the range in industry and commercial sectors to keep the overall range similar to FES 2023.



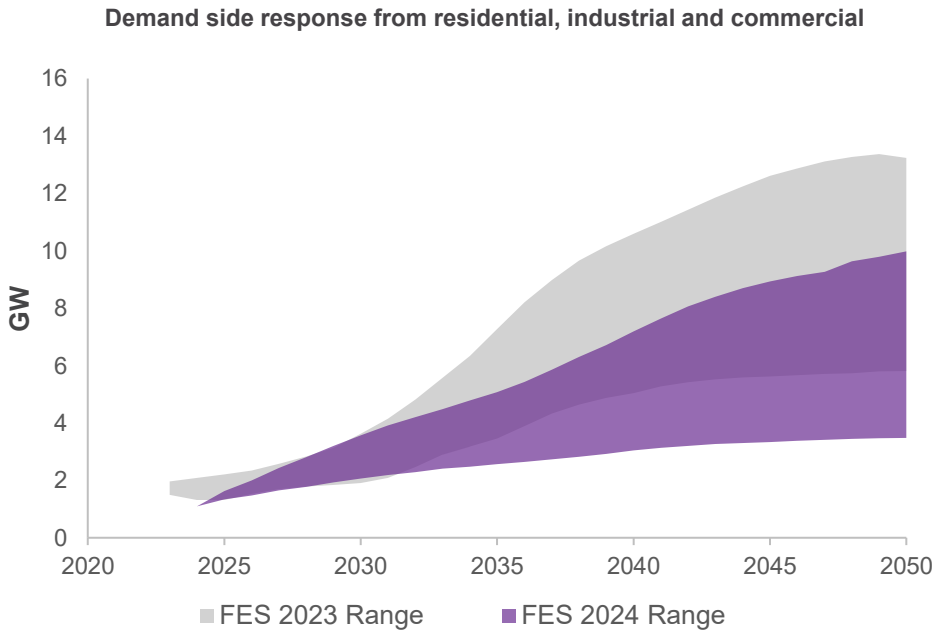
Energy demand

Demand flexibility

Our Demand Side Response (DSR) modelling has been improved in FES 2024 to better account for distribution connected generation and for EV charging that is starting to appear in outturn data. I&C engagement in DSR has decreased since triad payments ended. These factors reduced the baseline DSR compared to FES 2023.

The growth in DSR out to 2050 has decreased in FES 2024 compared to FES 2023. Consumer Transformation had the highest engagement with DSR reaching 13 GW in 2050 where nearly 12 GW of this was from I&C. All scenarios in FES 2023 had roughly 1 GW of DSR from the residential sector. The ratio between I&C DSR against residential DSR has changed in FES 2024, with residential now making up the majority. This is due to reduced forecasts in I&C DSR from the rebaseling mentioned, and higher residential DSR forecasts due to higher engagement levels in the Demand Flexibility Service (DFS).

The largest change in demand flexibility is driven by the increased number of vehicles on the road in FES 2024 (due to fewer autonomous vehicles) which leads to larger capacity for vehicle-to-grid (V2G) flexibility in FES 2024. The highest V2G value increased from 20 GW in FES 2023 to 32 GW in FES 2024. Note V2G is modelled separately to DSR.



Energy demand

Key consumer demand statistics

TWh		2023	2050							
			FES 2024				FES 2023			
Sector	Fuel		Holistic Transition	Electric Engagement	Hydrogen Evolution	Counterfactual	Leading the Way	Consumer Transformation	System Transformation	Falling Short
Transport	Electricity	5	122	127	101	121	115	118	90	123
Appliances	Electricity	77	45	57	58	69	47	64	72	94
Residential Heat	Electricity	23	75	78	74	60	65	80	60	69
	Hydrogen	0	15	0	77	0	29	0	119	0
Commercial	Electricity	77	161	160	142	121	128	138	111	108
	Hydrogen	0	6	2	18	0	21	2	46	0
Industrial	Electricity	72	86	117	71	91	100	139	100	111
	Hydrogen	0	49	16	78	17	54	11	88	9

Note: Peak electricity and gas demand is set out in the tables on page 29.

Energy supply

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Electricity supply capacity

We have changed our dispatch model and introduced a capacity expansion model to economically optimise the generation mix.

FES 2024 narrows the range where possible to provide strategic routes to net zero.

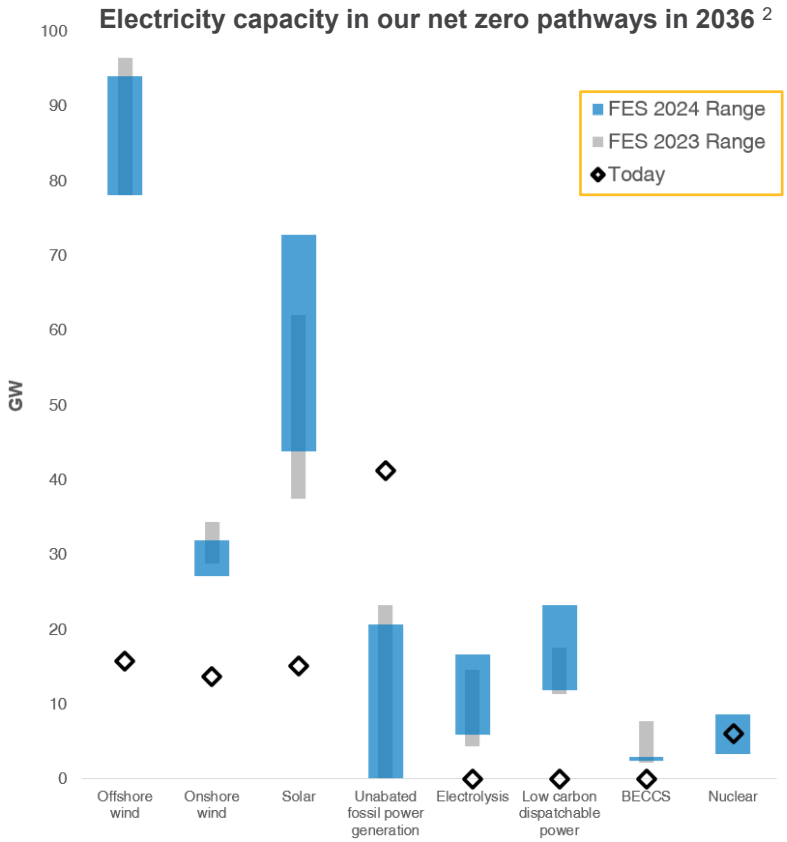
We have set minimum build limits for certain technologies based on government targets, ambitions and roadmaps. The pathways still have variation across these technologies to reflect the level of uncertainty and range of stakeholder views.

FES 2024 has a more narrow range in wind which are slower than the fastest pace scenario from FES 2023 capacity resulting from updated network build rates.

The upper limit of unabated fossil fuel generation has reduced as it is replaced by dispatchable power for security of supply.

Electrolysers are strategically located close to renewable generation in the north of Great Britain in FES 2024.

Nuclear and low carbon dispatchable power are the areas where the range has increased in FES 2024 to reflect stakeholder feedback. The maximum capacity for both technologies has increased due to policy and market updates



[2] The year 2036 is used as it is the first full year after net zero power is achieved in all net zero pathways.

Electricity supply in 2050

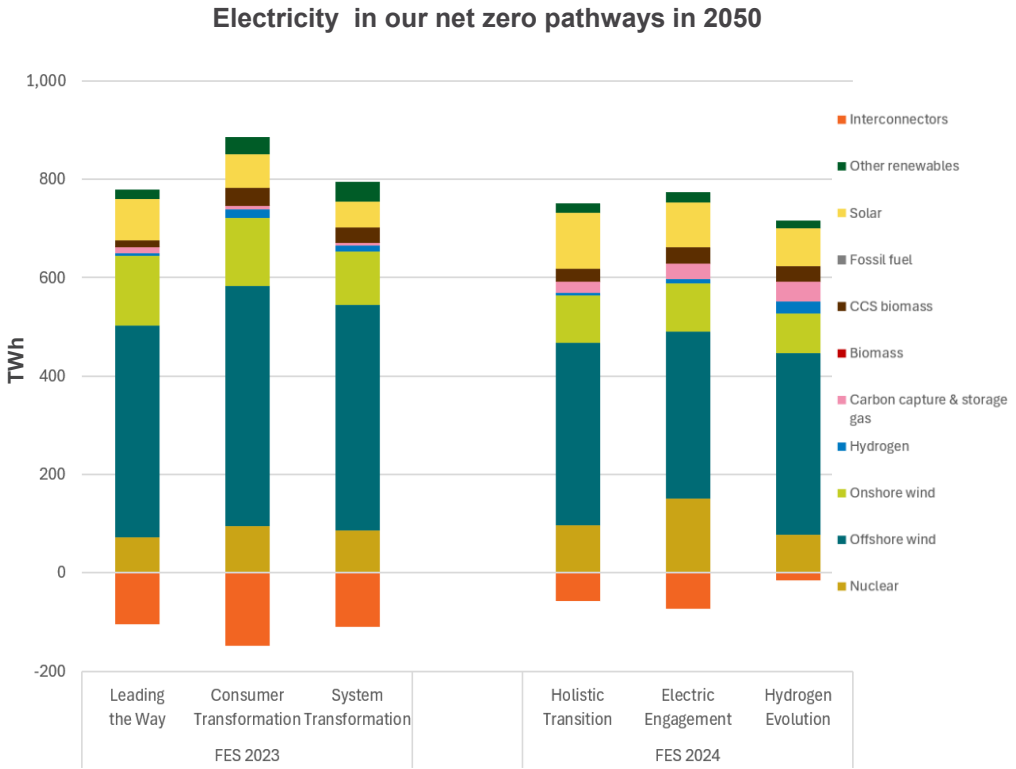
Installed capacities for certain technologies have changed in response to market updates and stakeholder feedback.

Nuclear

In 2050, annual nuclear generation in the net zero pathways has increased. This increase reflects growing ambition in the sector and the publication of the Nuclear Roadmap and establishment of Great British Nuclear. Electric Engagement has the highest nuclear capacity at 22 GW in 2050, up 6 GW from the highest level in FES 2023.

Wind

Wind capacity is also constrained to achieve minimum capacity levels to match expected ambition. For FES 2024, wind load factors have been updated, reducing the generation for both offshore and onshore wind. The range between the maximum and minimum of all wind generation has nearly halved from 566 to 627 TWh in FES 2023 to 439 to 467 TWh in FES 2024 due to the modelling optimisation, using the minimum constraints and load factor update.



Electricity supply in 2050

Flexibility has increased in importance in our FES 2024 electricity supply, this can come from a range of sources

Low carbon disptachable power

In the FES 2024 pathways there is growing use of low carbon dispatchable power compared to FES 2023. This is due to more economic modelling used in capacity build out putting more value on low carbon dispatchable power, updated achievable build out rates of all technologies and ensuring security of supply standards are met.

Interconnectors

The European data has been updated which now better reflects the development of renewable generation in our European partners. This has changed our electricity import and export positions. As a result FES 2024 has lower levels of exports compared to FES 2023. Interconnector capacities have remained similar in this years update.

Energy storage

A strong pipeline for battery energy storage has increased the ramp up of this technology in the 2020s in FES 2024 compared to FES 2023. By 2050 the upper boundary of the energy storage remains similar from 52 GW capacity in FES 2023 to 51 GW in FES 2024. However, the lower values has increased from 33 GW in FES 2023 to 40 GW capacity in FES 2024, as the new economic capacity modelling shows consistent benefits of energy storage across the pathways. Energy storage plays a key role in reducing the need for dispatchatble power currently provided by unabated gas.

Hydrogen production

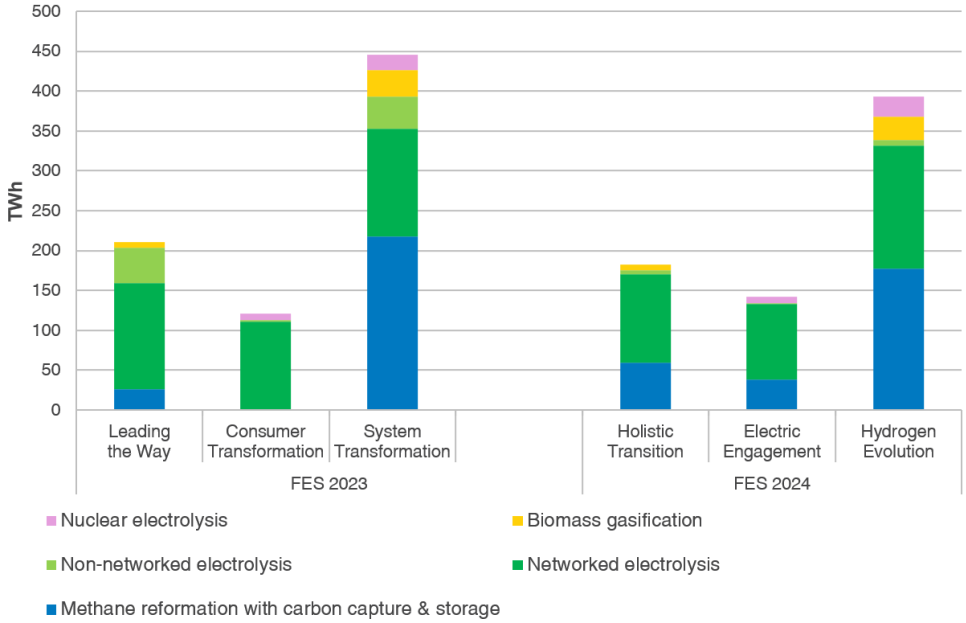
Hydrogen demand & supply narrow in FES 2024. Electrolysis and methane reformation both are required to achieve the pace and volume.

Overall hydrogen demand

Consumer[3] demand for hydrogen has decreased in FES 2024, although this is partially offset by an increase in use of hydrogen for power. This leads to a slight reduction in hydrogen use alongside a narrowing of the range from 120 TWh to 446 TWh in FES 2023 to 142 TWh to 393 TWh in FES 2024.

Modelling

The inclusion of a hydrogen capacity expansion model in FES 2024 improves the cost optimisation of the analysis this year. The modelling now also offers improved coupling between hydrogen and electricity in FES 2024. Electrolysis is now optimised in the electricity supply modelling this year. This has allowed the model to better optimise electrolyser locations. The hydrogen capacity expansion model also looks at the build-out of storage, gasification and the development of hydrogen transmission networks.



[3] residential, transport, industrial and commercial

Hydrogen production

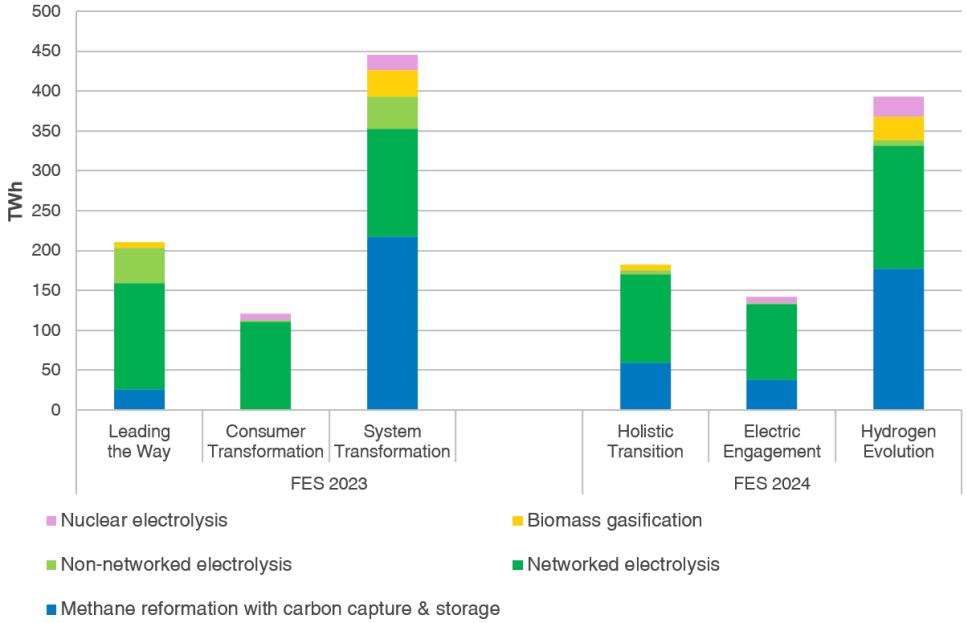
Methane Reformation

Higher levels of methane reformation with CCS are driven by the pace and scale of decarbonisation required to meet the Sixth Carbon Budget. By 2050 the ratio between methane reformation and total hydrogen supply is closer across FES 2024 pathways. Methane reformation with CCS now provides between 27% and 45% of overall demands, compared to 1% to 49% in FES 2023. Emphasising methane reformations role in security of supply of hydrogen irrelevant of the overall hydrogen demand.

Levels of hydrogen production from biomass gasification is similar in FES 2024 compared to FES 2023

Electrolysis

Electrolysis grows as more storage capacity and network increases. 2050 total electrolysis levels remain fairly similar in FES 2024 to that in FES 2023. However, non-networked electrolysis has decreased from an upper limit of 44 TWh in FES 2023 to 7 TWh in FES 2024 due to stakeholder feedback putting less emphasis on non-networked electrolysis. Nuclear electrolysis remains at similar levels between FES 2024 and FES 2023.



Energy supply

Key supply statistics

Sector	Units	2023	2050							
			FES 2024				FES 2023			
			Holistic Transition	Electric Engagement	Hydrogen Evolution	Counterfactual	Leading the Way	Consumer Transformation	System Transformation	Falling Short
Electricity										
Peak demand	GW	58	109	119	104	102	98	113	101	114
Total installed capacity	GW	116	411	386	343	285	387	386	344	285
Wind and solar capacity	GW	44	249	225	197	152	249	239	213	149
Interconnector capacity	GW	8	25	22	17	16	27	21	16	16
Total storage capacity	GW	7	83	66	50	34	72	64	41	26
Total storage capacity	GWh	34	269	258	208	132	197	166	116	62
Vehicle-to-grid capacity at peak	GW	0	65	40	19	8	39	34	16	8
Natural Gas										
Annual demand	TWh	872	138	127	303	636	74	29	330	513
1-in-20 peak demand	GWh /day	5,082	1,047	1,136	1,791	4,593	444	282	2,138	3,924
Imports	TWh	494	113	105	279	581	55	25	324	356

Energy supply

Key supply statistics continued

Sector	Units	2023	2050							
			FES 2024				FES 2023			
			Holistic Transition	Electric Engagement	Hydrogen Evolution	Counterfactual	Leading the Way	Consumer Transformation	System Transformation	Falling Short
Hydrogen										
Gas reformed hydrogen production	TWh	0	60	38	177	8	26	1	218	6
Electrolysed hydrogen production	TWh	0	116	95	161	17	177	111	175	8
Bioresources										
Bioresources demand	TWh	170	191	204	225	91	160	219	228	148

Continuing the conversation

Email us with your views on FES or any of our future of energy documents at: fes@nationalgrideso.com and one of our team members will get in touch.

Access our current and past FES documents, data and multimedia at: nationalgrideso.com/future-energy/future-energy-scenarios

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