July 2024

Future Energy Scenarios:

Pathways at a Glance

ESO

Foreword

Claire Dykta
Director of Strategy & Policy

The evolving dynamics of the energy system call for decisive action within the next two years to deliver the fundamental changes required to achieve a fair, affordable, sustainable and secure clean energy system by 2050. This means we must prioritise steps that will enable the delivery of cleaner, cheaper energy generation whilst ensuring a resilient system that delivers security of supply for consumers.

As the Electricity System Operator (ESO), we have set a target to be able to operate a net zero carbon electricity system for short durations by next year, which sets us up to be able to operate a clean power system throughout the year in the 2030s. Ongoing global conflict continues to create international uncertainty in energy markets, with the long-term consequences yet to be determined, and the cost-of-living and energy crisis continues to impact households and businesses across Great Britain.

Later this year, we will transform to become the National Energy System Operator (NESO). We will put our customers, homeowners, businesses and local communities at the heart of our work; building on the strong foundations of the ESO we will deliver a future where everybody has access to clean, reliable, affordable energy.

As NESO, we will take a holistic approach to planning and facilitating whole energy system decarbonisation. We will be involved in the strategic planning of gas and electricity networks, integrating them for the first time to develop a comprehensive whole system plan for future network development. We will develop a whole energy system view of future market direction so we can recommend actions to optimise markets across vectors and reduce costs for consumers. And we will also provide independent advice to Government and Ofgem on energy policy developments.

Decarbonisation of the energy system is the challenge of our generation. In recognition of the expansive industry transformation required to Great Britain's energy network planning, this year's Future Energy Scenarios (FES) framework has evolved from 'scenarios' to 'pathways' to explore narrower ranges and strategic, credible choices to propel us on the route to decarbonisation. This transition has also been reflected in our new publication name - Future Energy Scenarios: ESO Pathways to Net Zero.

FES creates the foundation upon which our future network investment plans will be built. We look forward to working with industry, the Government, Ofgem and our stakeholders and customers as we transition to NESO and build upon our analysis and insights to deliver on our critical role for society and the economy.

FES 2024 / Pathways at a Glance 02

Introduction

We are in a period of significant change for the energy industry as a whole and the Future Energy Scenarios framework has adapted to support strategic network planning.

Our previous framework, used since 2020, presented a wide range of credible outcomes on the route to net zero. This year, our new framework seeks to explore a narrower range by identifying strategic choices that can be made on the route to net zero. This strategic evolution forms part of a wider industry overhaul to Great Britain's energy network planning, with FES underpinning the foundations of this network investment by feeding into NESO's Centralised Strategic Network Plan (CSNP), working alongside the Strategic Spatial Energy Plan (SSEP).

Hits net zero by 2050

- Holistic Transition
- Electric Engagement
- Hydrogen Evolution

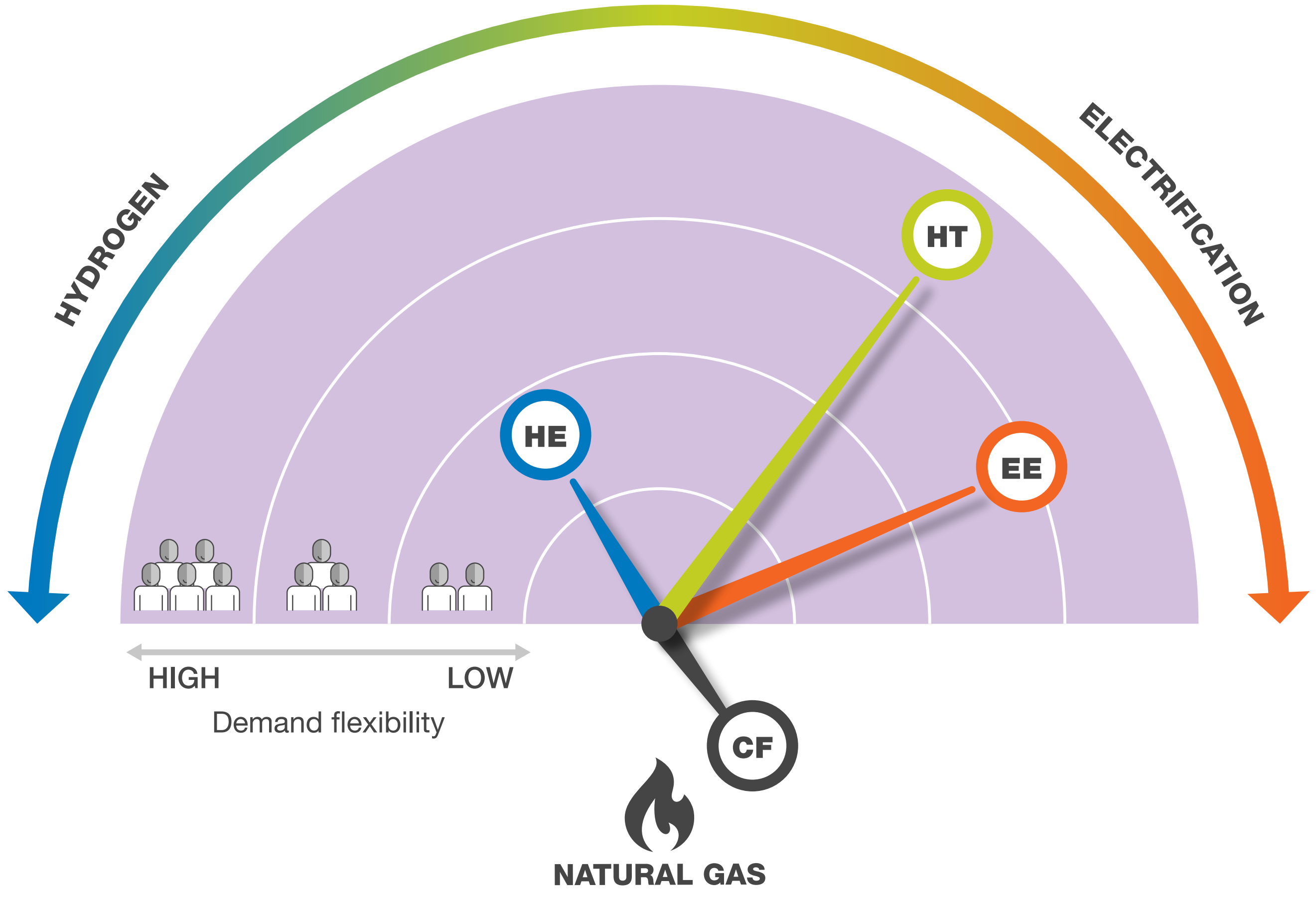
Misses net zero by 2050

- Counterfactual

Our new pathways – Holistic Transition, Electric Engagement and Hydrogen Evolution – explore strategic routes to net zero based on our extensive stakeholder engagement, research and analysis.

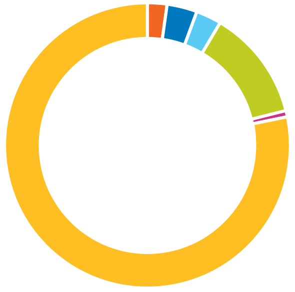
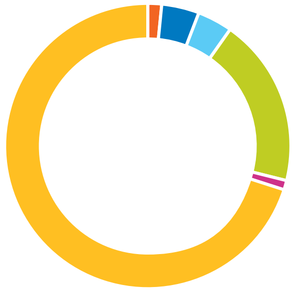
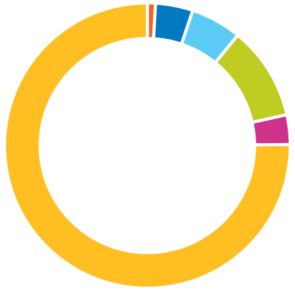
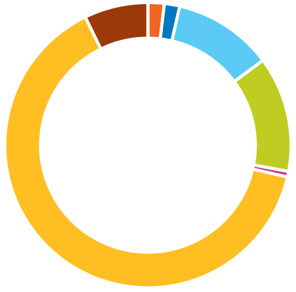
In comparison, the Counterfactual is used to understand the gap between successful tracking of the pathways versus enabling change too slowly and missing key targets.

Pathways framework 2024



FES 2024 / Pathways at a Glance 2024 03

Comparing our pathways

	Holistic Transition	Electric Engagement	Hydrogen Evolution	Counterfactual
2050 energy demand	Net zero met through a mix of electrification and hydrogen, with hydrogen mainly around industrial clusters. Consumer engagement in the transition is very strong with demand shifting, with smart homes and electric vehicles providing flexibility to the grid. Total energy supply **1218 TWh**	Net zero met through mainly electrified demand. Consumers are highly engaged in the energy transition through smart technologies that reduce energy demands, utilising technologies such as electric heat pumps and electric vehicles. Total energy supply **1222 TWh**	Net zero met through fast progress for hydrogen in industry and heat. Many consumers will have hydrogen boilers, though energy efficiency will be key to reducing cost. There are low levels of consumer engagement. Hydrogen will be prevalent for heavy goods vehicles but electric car uptake is strong. Total energy supply **1292 TWh**	Net zero missed, though some progress is made for decarbonisation compared to today. While home insulation improves, there is still a heavy reliance on gas across all sectors, particularly power and space heating. Electric vehicle uptake is slower than the net zero pathways, but still displaces petrol and diesel. Total energy supply **1423 TWh**
2050 energy supply	Highest renewable capacity pathway with unabated gas dropping sharply to zero after 2036. Moderate levels of nuclear capacity and lowest levels of hydrogen dispatchable power present. Supply side flexibility is high, delivered through electricity storage and interconnectors. 	Highest peak electricity demand requiring high nuclear and renewable capacities. Natural gas plants have lower utilisation post-2035. Supply side flexibility is high, delivered through electricity storage, interconnectors and low carbon dispatchable power. 	Pathway with high levels of hydrogen dispatchable power plants leading to lower needs for renewable and nuclear capacities. Natural gas plants have lower utilisation post 2035. Hydrogen storage provides most flexibility in this pathway. 	Counterfactual sees the least renewable capacity and has heavy reliance on natural gas, which leads to net zero missed. Because of the lower needs for flexibility, lower electricity storage, interconnectors and low carbon dispatchable power are present. 
Emissions	Negative emissions of 51 $MtCO_2e$ needed, delivered through mix of bioenergy with carbon capture and storage for power and direct air carbon capture and storage.	Negative emissions of 51 $MtCO_2e$ needed, delivered mainly through bioenergy with carbon capture and storage for power with low levels of direct air carbon capture and storage.	Negative emissions of 51 $MtCO_2e$ needed, delivered mainly through power bioenergy with carbon capture and storage.	Negative emissions only provided through bioenergy with carbon capture and storage for power, but net zero is missed.

■ Storage ■ Carbon capture and storage biomass ■ Carbon capture and storage gas ■ Nuclear ■ Hydrogen ■ Renewable ■ Fossil fuel

FES 2024 / Pathways at a Glance 2024 04

Key message and actions

Decisive action is needed within the next two years to deliver the fundamental change required for a fair, affordable, sustainable and secure net zero energy system by 2050.

Actions:

1. Accelerate the delivery of whole system infrastructure through a strategic approach to network investment and introduction of planning reforms.
2. Deliver market reform, considering electricity, gas, hydrogen and CO_2, to ensure we have energy markets that provide for and work with a reliable and strategically planned energy system.
3. Prioritise the use of hydrogen for hard-to-electrify applications. Agree business models and kick-start delivery of the hydrogen and CO_2 transport and storage infrastructure needed for system flexibility.
4. Accelerate progress on low carbon heating including faster rollout of heat pumps irrespective of a decision on hydrogen for heat.
5. Deliver innovation and build consumer trust in affordable smart technology, enabling consumers to save on energy costs while helping with the management of Great Britain's electricity system.
6. Focus on energy efficiency improvements across all sectors to reduce overall energy demand.
7. Expedite the delivery of clean, low-cost and reliable new technologies and long-duration energy storage connected to the system by reforming the connections process.
8. Invest in supply chain and skills to deliver the low carbon technologies and infrastructure needed for net zero and enable the UK to become a world leader.

FES 2024 / Pathways at a Glance 2024 05

Key comparison chart of decarbonisation milestones

Key comparison chart of demand side policies

This chart contains a selection of recent policy ambitions in relation to net zero and energy security and highlights how they compare to the different pathways. The chart also shows non policy-related items that are key decarbonisation milestones.

Note that energy demand will be affected by policy on the supply side which is set out in the comparison chart on the following page. It is critical that policy considers the whole energy system and not supply and demand in isolation.

Please note analysis for FES 2024 commenced before the publication of several key policy documents and the UK general election and reflects policy targets and ambitions at the time of analysis.

		2023	2025	2030	2035	2040	2045	By 2050	Maximum potential by 2050	Maximum potential pathway
Transport	Sales of petrol and diesel cars and vans banned	1.6m petrol, diesel and hybrid cars and vans sold			HT EE HE (Government policy)	CF			39m battery electric cars and vans	HE
	Zero tailpipe emissions for all new heavy goods vehicles	<1% of heavy goods vehicles sold				HT EE HE (Government policy)	CF		Zero diesel heavy goods vehicles still on the road	HT EE HE
Heating	600,000 heat pumps installed per year (by 2028)	Approximately 100,000		HT EE HE (Government policy)		CF			1.5m per year	EE
	4 in 5 homes not using natural gas boiler as primary heat source	1 in 5					HT EE HE (Government policy)		100%	HT EE HE
Natural gas	Gas grid connection for new homes ends	80%	HT EE HE (Government policy)	CF					0%	HT EE HE
Industry	Annual industrial hydrogen demand over 10 TWh	<0.5 TWh		HT HE (Government policy)		EE			78 TWh	HE

In developing the pathways we balance current ambitions, progress towards targets, stakeholder feedback and what we have modelled for an optimal pathway. Policy assumptions vary across the pathways in line with the pathway narrative. More information can be found in our "Future Energy Scenarios: Pathway Assumptions 2024" document.

HT Holistic Transition
EE Electric Engagement
HE Hydrogen Evolution
CF Counterfactual
Government policy

FES 2024 / Pathways at a Glance 2024 06

Key comparison chart of decarbonisation milestones

Key comparison chart of supply side policies

This chart contains a selection of recent policy ambitions in relation to net zero and energy security and highlights how they compare to the different pathways. The chart also shows non policy-related items that are key decarbonisation milestones.

Note that energy demand will be affected by policy on the demand side which is set out in the comparison chart on the previous page. It is critical that policy considers the whole energy system and not supply and demand in isolation.

Please note analysis for FES 2024 commenced before the publication of several key policy documents and the UK general election and reflects policy targets and ambitions at the time of analysis.

		2023	2025	2030	2035	2040	2045	By 2050	Maximum potential by 2050	Maximum potential pathway
Emissions	Meets 2050 net zero target	422 $MtCO_2e$						HT EE HE (Government policy)	Net zero by 2050	HT
	Meets Fifth Carbon Budget			HT EE HE CF						
	Meets Sixth Carbon Budget				HT EE HE (Government policy)					
Electricity generation	50 GW of offshore wind	15 GW		HT (Government policy)	EE HE CF				101 GW	HT
	5 GW floating offshore wind	0 GW			HT EE HE	CF			20 GW in HT 19 GW in EE and HE	HT EE HE
	70 GW of solar	15 GW			(Government policy)	HT	EE	HE	108 GW	HT
	No unabated natural gas-fired generation capacity, subject to security of supply	36 GW			(Government policy)	HT	EE	HE	HT reaches this target in 2036	HT
	24 GW nuclear generation capacity	6.1 GW						(Government policy)	22 GW	EE

In developing the pathways we balance current ambitions, progress towards targets, stakeholder feedback and what we have modelled for an optimal pathway. Policy assumptions vary across the pathways in line with the pathway narrative. More information can be found in our "Future Energy Scenarios: Pathway Assumptions 2024" document.

HT Holistic Transition
EE Electric Engagement
HE Hydrogen Evolution
CF Counterfactual
Government policy

FES 2024 / Pathways at a Glance 2024 07

Key comparison chart of decarbonisation milestones

Key comparison chart of supply side policies (continued)

		2023	2025	2030	2035	2040	2045	By 2050	Maximum potential by 2050	Maximum potential pathway
Hydrogen	10 GW low carbon hydrogen production capacity in operation or construction	<1 GW		HE	HT	EE			75 GW	HE
	5 GW hydrogen production from electrolysis	<1 GW			HT HE	EE			49 GW	HE
	2 GW of low carbon hydrogen production capacity in operation or construction	<1 GW		HT EE HE	CF				75 GW	HE
Natural gas	40% reduction in gas consumption				HT EE	HE			85% reduction	EE
Bioenergy	Biomass supply consistent with Climate Change Committee Sixth Carbon Budget - not directly modelled									
Energy storage	100 GWh of non-battery electrical storage	2.75 GW / 28 GWh				HT			118 GWh in HT	HT
	30 GWh of battery electrical storage	4.7 GW / 5.8 GWh		HT EE HE					65 GWh in HT	HT
Interconnectors	18 GW capacity	8.4 GW			HT EE				25 GW in HT	HT

HT Holistic Transition
EE Electric Engagement
HE Hydrogen Evolution
CF Counterfactual
Government policy

FES 2024 / Pathways at a Glance 2024 08

Emissions reductions

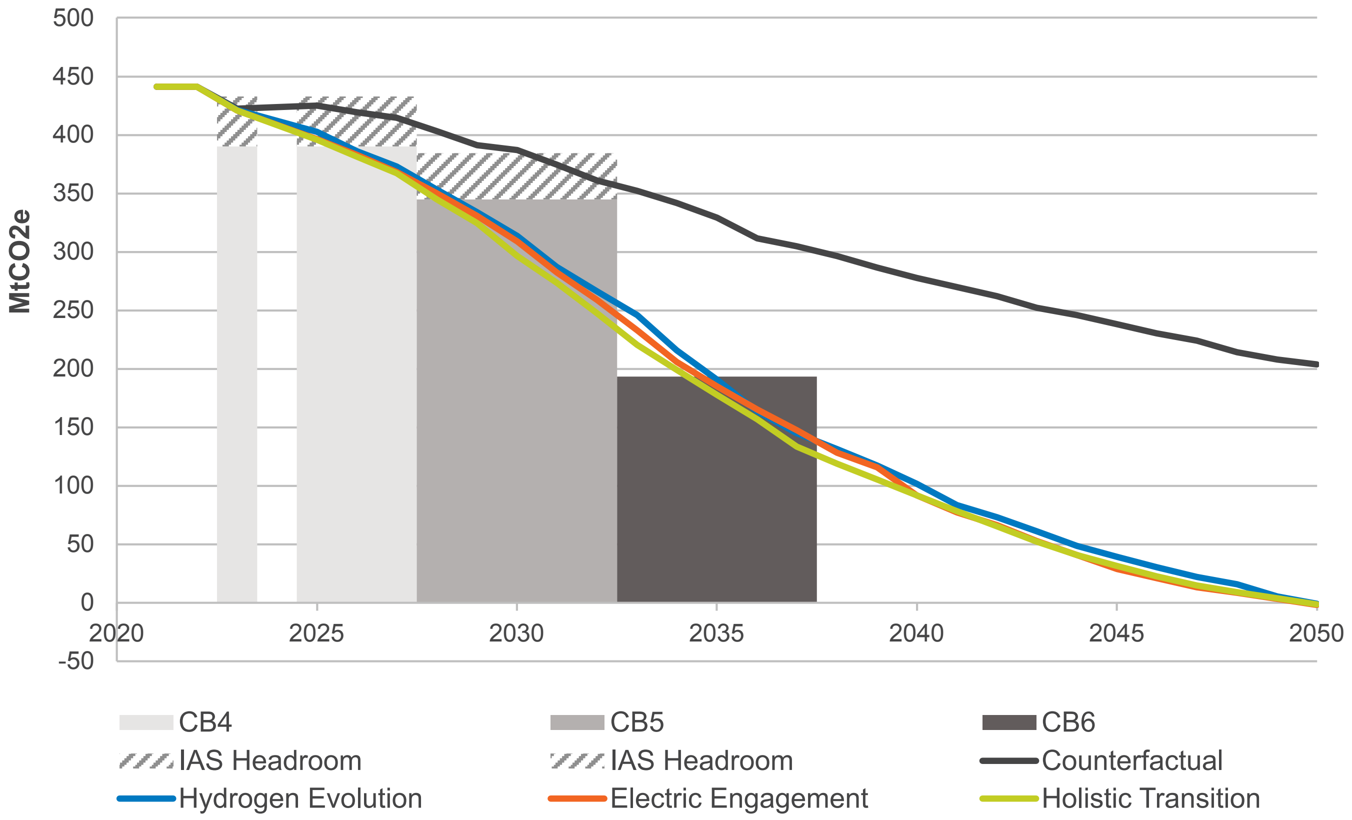
We must go further and faster to deliver the emissions reductions needed for the Sixth Carbon Budget on the route to net zero. Our pathways show ambitious strategic routes to net zero and without decisive action within the next two years there is a risk of emissions remaining high, particularly in the heat sector.

All net zero pathways achieve the Sixth Carbon Budget, although there is limited headroom, reinforcing the challenge of achieving this. Holistic Transition has the largest margin of 79 $MtCO_2e$ over the five year Sixth Carbon Budget period. Electric Engagement has a margin of 31 $MtCO_2e$, whilst the margin in Hydrogen Evolution is 7 $MtCO_2e$.

All pathways achieve net zero in 2050, with net emissions of -0.9 $MtCO_2e$ to -1.9 $MtCO_2e$. This is not a significant margin, highlighting the importance of continued, focused decarbonisation efforts over the next 26 years.

The **Counterfactual** does not meet net zero and instead has close to just over 200 $MtCO_2e$ of residual annual emissions in 2050. This is due to either slow or lack of decarbonisation across many sectors. The Sixth Carbon Budget is missed by a significant margin.

NZ.03: Net greenhouse gas emissions and carbon budgets



! *IAS stands for international aviation and shipping*

FES 2024 / Pathways at a Glance 2024 09

Key statistics

	2023	2030				2035				2050				
Emissions		HT	EE	HE	CF	HT	EE	HE	CF	HT	EE	HE	CF	**Emissions**
Annual average carbon intensity of electricity (g CO_2/kWh)	133	41	73	74	134	-17	-11	-9	69	-28	-36	-36	21	Annual average carbon intensity of electricity (g CO_2/kWh)
Net annual emissions ($MtCO_2e$)	422	297	309	314	387	178	185	191	329	-1	-2	-1	204	Net annual emissions ($MtCO_2e$)
Electricity														**Electricity**
Annual demand (TWh)[1]	285	334	328	332	311	419	425	422	351	667	700	671	533	Annual demand (TWh)[1]
Electricity demand for heat (TWh)	40	42	44	44	42	51	57	53	43	108	114	107	83	Electricity demand for heat (TWh)
Peak demand (GW)[2]	58	62	65	64	64	76	81	76	70	109	119	104	102	Peak demand (GW)[2]
Total installed capacity (GW)[3]	116	219	205	191	166	289	264	244	206	411	386	343	285	Total installed capacity (GW)[3]
Wind and solar capacity (GW)	44	121	106	94	71	189	156	141	113	249	225	197	152	Wind and solar capacity (GW)
Interconnector capacity (GW)	8	12	12	12	12	24	19	17	14	25	22	17	16	Interconnector capacity (GW)
Total storage capacity (GW)[4]	7	34	29	26	22	48	38	30	27	83	66	50	34	Total storage capacity (GW)[4]
Total storage volume (GWh)[5]	34	130	92	86	63	172	112	105	87	269	258	208	132	Total storage volume (GWh)[5]
Maximum vehicle-to-grid capacity (GW)[6]	0	2	1	0	0	18	10	1	0	65	40	19	8	Maximum vehicle-to-grid capacity (GW)[6]
Natural Gas														**Natural Gas**
Annual demand (TWh)[7]	872	642	649	724	790	433	478	545	666	138	127	303	636	Annual demand (TWh)[7]
1-in-20 peak demand (GWh/day)	5082	3811	4327	4726	5352	2786	3289	3786	4933	1047	1136	1791	4593	1-in-20 peak demand (GWh/day)
Residential demand (TWh)[8]	292	266	266	288	307	200	199	215	291	0	0	0	188	Residential demand (TWh)[8]
Imports (TWh)	494	430	446	510	586	308	360	418	540	113	105	279	581	Imports (TWh)
Hydrogen														**Hydrogen**
Annual demand (TWh)	0	32	6	36	1	64	38	134	4	182	138	393	24	Annual demand (TWh)
Residential hydrogen demand for heat (TWh)	0	0	0	0	0	0	0	12	0	15	0	77	0	Residential hydrogen demand for heat (TWh)
CCS enabled hydrogen production (TWh)[9]	0	26	4	42	0	38	25	82	0	60	38	177	8	CCS enabled hydrogen production (TWh)[9]
Electrolytic hydrogen production (TWh)[10]	0	12	5	14	1	25	16	46	4	116	95	161	17	Electrolytic hydrogen production (TWh)[10]
Bioresources														**Bioresources**
Bioresource demand (TWh)	170	151	139	149	102	167	163	176	86	191	205	225	91	Bioresource demand (TWh)

1. Customer demand plus on-grid electrolysis meeting Great Britain hydrogen demand only, plus losses, equivalent to GBFES System Demand Total in 'ED1' of data workbook
2. Refer to data workbook for further information on winter average cold spell peak demand
3. Includes all networked generation as well as total interconnector and storage capacity (including vehicle-to-grid available at winter peak)
4. Includes vehicle-to-grid capacity available at winter peak
5. Excludes vehicle-to-grid
6. Less capacity will be available during peak 5-6pm due to vehicle usage
7. Includes shrinkage, exports, biomethane and natural gas for methane reformation
8. Residential demand made up of biomethane and natural gas
9. Carbon capture and storage enabled hydrogen is created using natural gas as an input, with carbon capture and storage
10. Electrolytic hydrogen is created via electrolysis using zero carbon electricity (this figure does not include hydrogen produced directly from nuclear or bioenergy)

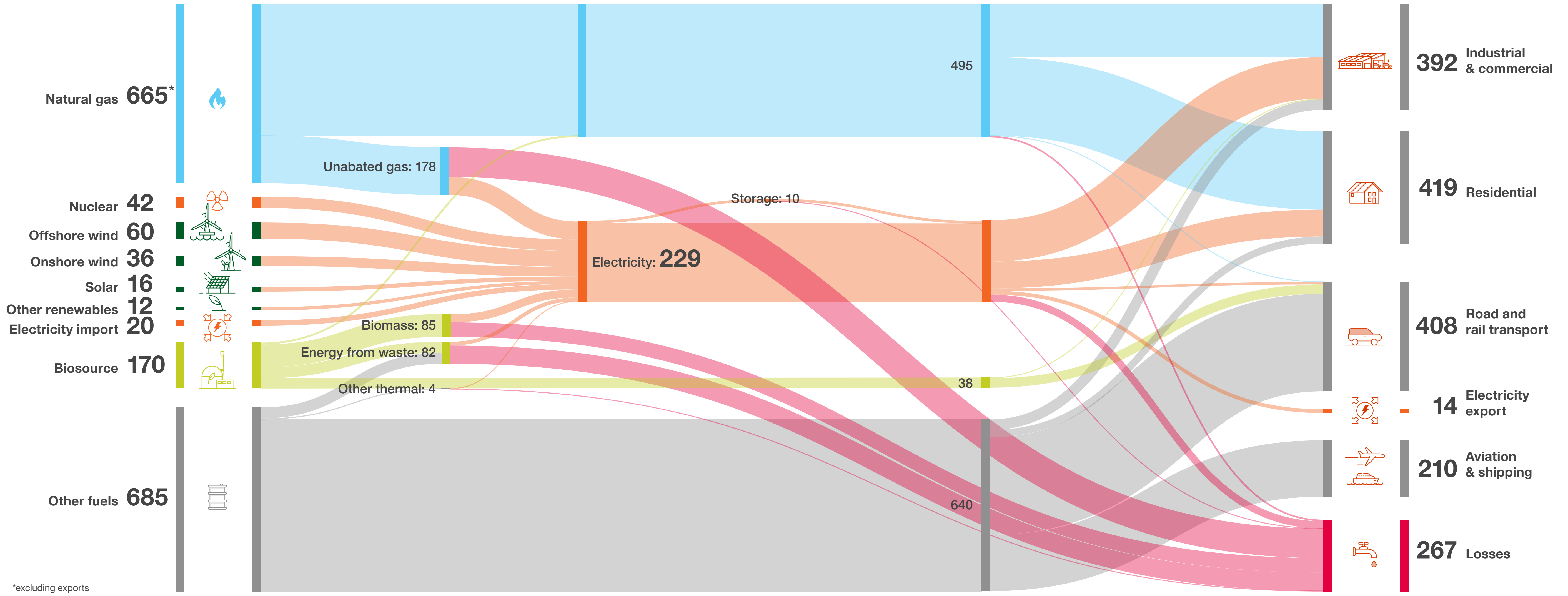
FES 2024 / Pathways at a Glance 2024 10

Energy supply and demand today

2023

Interactions between different fuels are low, demonstrating limited whole system thinking or cross-sector decarbonisation. Fossil fuels make up 79% of total energy supply. Petroleum supplies over 90% of road transport demand and 100% of aviation and shipping demand.

Total energy supply
1706 TWh



*excluding exports

Please note that TWh figures are rounded to the nearest number.

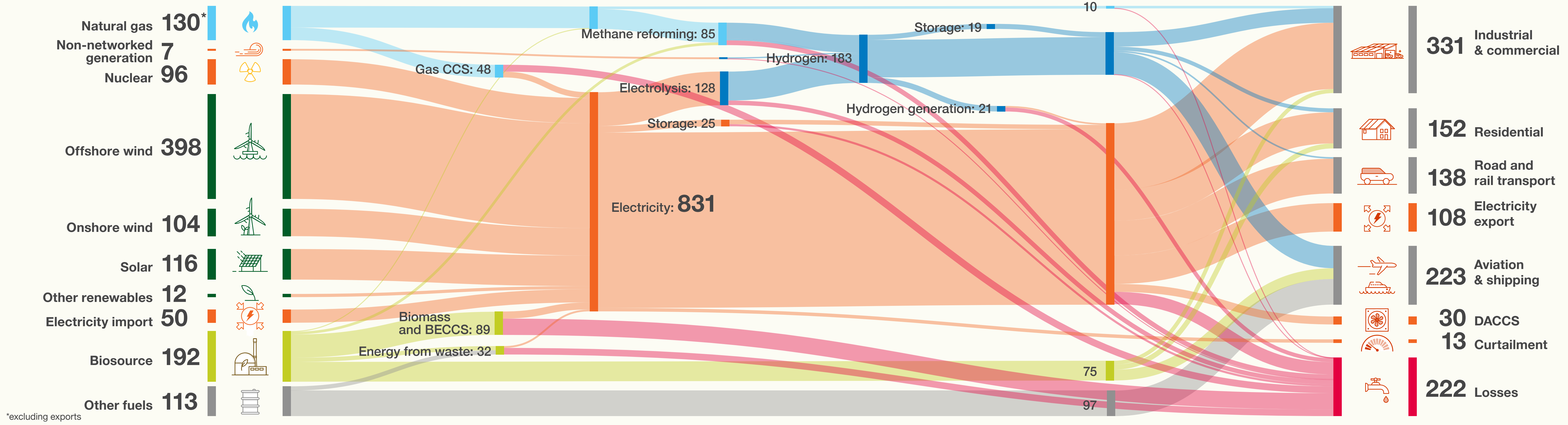
FES 2024 / Pathways at a Glance 2024 11

Energy supply and demand in 2050

Holistic Transition

Reliance on fossil fuels has significantly reduced, with nearly all the remaining gas used for power and hydrogen production being abated through carbon capture and storage (CCS). Overall energy demand falls by 488 TWh from 2023 driven by efficiency improvements and electrification. Electricity and hydrogen work together to supply 60% and 19% of the 2050 energy demand respectively.

Total energy supply
1218 TWh



*excluding exports

Please note that TWh figures are rounded to the nearest number.

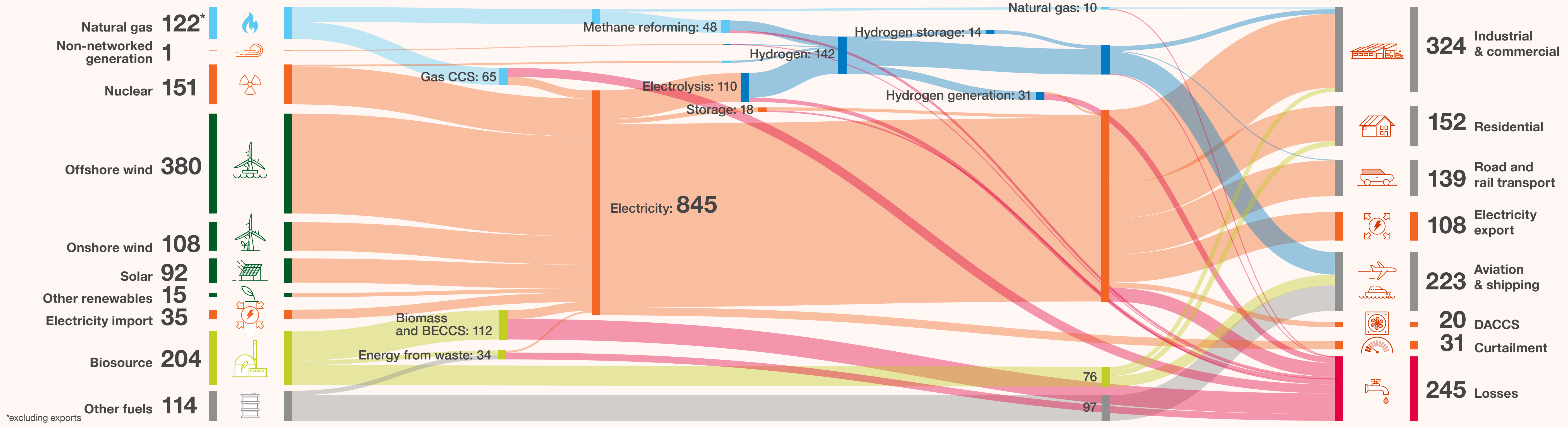
FES 2024 / Pathways at a Glance 2024 12

Energy supply and demand in 2050

Electric Engagement

Electricity supplies 66% of overall energy demand in 2050. Electricity generated increases by 616 TWh but overall energy demand falls by 484 TWh compared to today. This is driven by consumer engagement, insulation and efficiency gained through electrification. Hydrogen provides 19% of the overall energy needed for industry, aviation and shipping.

Total energy supply
1222 TWh



FES 2024 / Pathways at a Glance 2024 13

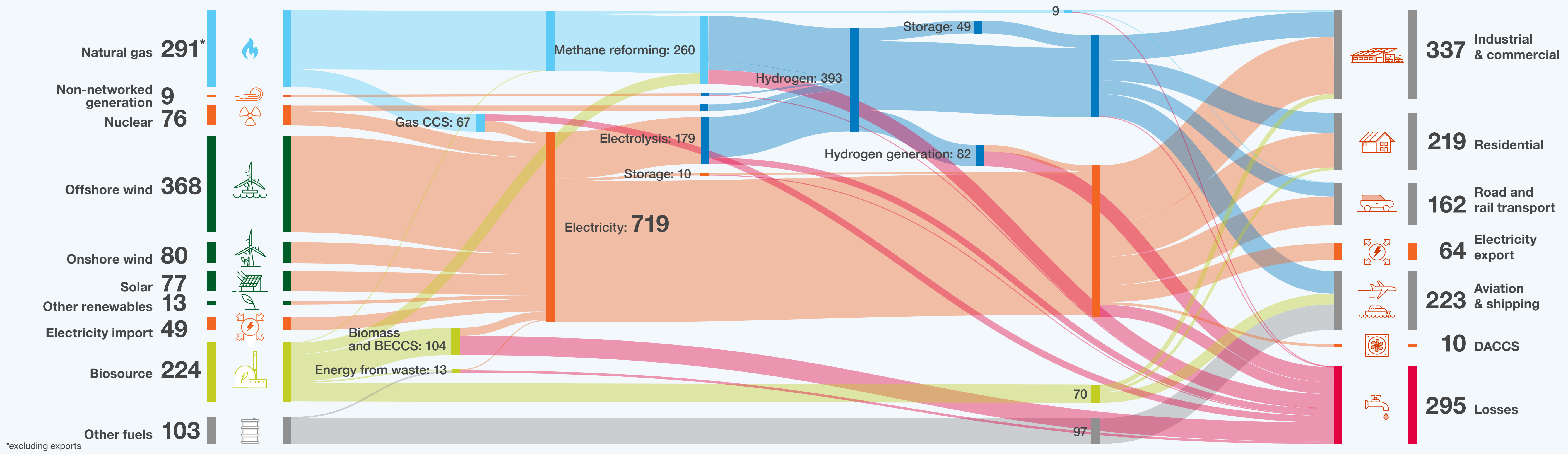
Please note that TWh figures are rounded to the nearest number.

Energy supply and demand in 2050

Hydrogen Evolution

Hydrogen supplies 30% of overall energy needed in 2050 used across all sectors. Overall energy demand drops by 414 TWh driven primarily by the remaining demand that is electrified. Natural gas is still used for electricity and hydrogen production in 2050 but it is abated through CCS.

Total energy supply
1292 TWh



Please note that TWh figures are rounded to the nearest number.

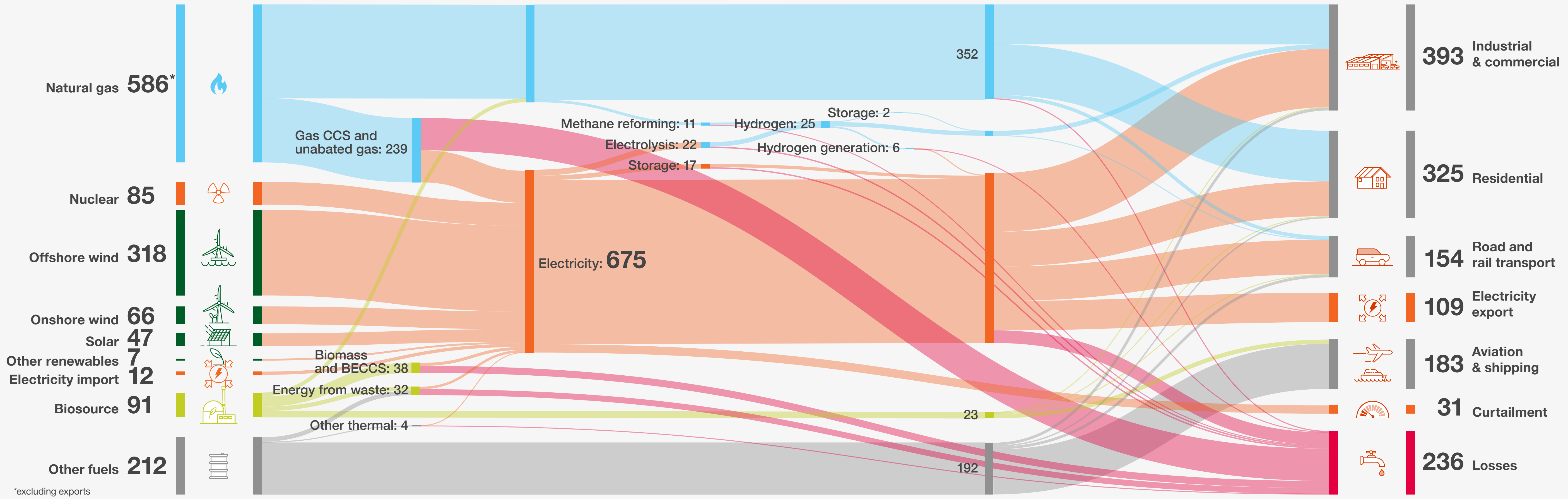
FES 2024 / Pathways at a Glance 2024 14

Energy supply and demand in 2050

Counterfactual

Heavy reliance on fossil fuel remains, supplying 56% of energy needed across all sectors, predominantly supplied by natural gas. Hydrogen use is limited due to the continued use of natural gas. Road transport sees the most decarbonisation with 85% of demand met by low carbon fuels.

Total energy supply
1423 TWh



FES 2024 / Pathways at a Glance 2024 15

Please note that TWh figures are rounded to the nearest number.

Glossary

Acronym	Description
ACS	Average Cold Spell
BECCS	Bioenergy with Carbon Capture and Storage
CB4	Fourth Carbon Budget
CB5	Fifth Carbon Budget
CB6	Sixth Carbon Budget
CCC	Climate Change Committee
CCS	Carbon Capture and Storage
CF	Counterfactual
CO_2	Carbon Dioxide
CSNP	Centralised Strategic Network Plan
DACCS	Direct Air Carbon Capture and Storage
EE	Electric Engagement

Acronym	Description
ESO	Electricity System Operator
FES	Future Energy Scenarios
GB	Great Britain
GW	Gigawatt
GWh	Gigawatt hour
HE	Hydrogen Evolution
HT	Holistic Transition
IAS	International Aviation and Shipping
$MtCO_2e$	Million Tonnes of CO_2 Equivalent
NESO	National Energy System Operator
SSEP	Strategic Spatial Energy Plan
TWh	Terawatt Hour
V2G	Vehicle-to-Grid

FES 2024 / Pathways at a Glance 2024 16

Thanks for reading, we hope you found Future Energy Scenarios: Pathways at a Glance 2024 insightful and useful

Continuing the conversation

We look forward to continuing the conversation to inform you about our future insights and analysis.

Ways to connect and stay in touch

Keep an eye out for any surveys, energy articles and engagement opportunities via our FES website and newsletter.

If you are not already subscribed you can do so by using our online contact form, or by using the FES email address below.

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

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

Get involved in the debate on energy and join our LinkedIn group Future of Energy by National Grid ESO.

Write to us at:
Energy Insights & Analysis
Electricity System Operator
Faraday House
Warwick Technology Park
Gallows Hill Warwick
CV34 6DA

FES 2024 / Pathways at a Glance 2024 17

ESO