Future Energy Scenarios in five minutes

July 2021

Introduction

What are the Future Energy Scenarios and why are they important?

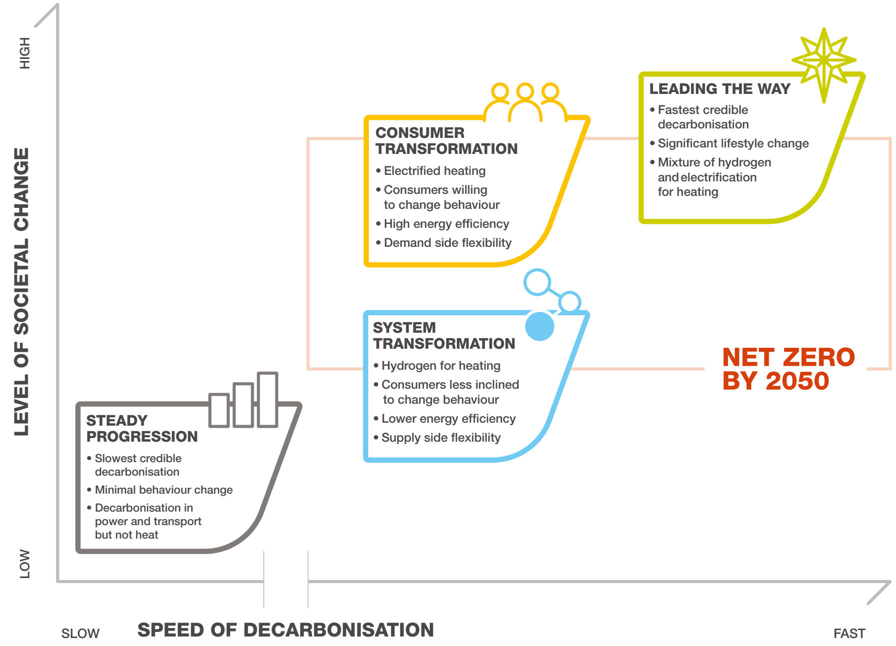
With an ambitious target for net zero emissions by 2050, our energy system will need to transform rapidly while continuing to deliver reliability and value for consumers. We believe decarbonising energy is possible but also that it will be complex, not least because there are many ways to reach net zero, each with their own trade-offs.

Our Future Energy Scenarios (FES) outline four different, credible pathways for the future of energy between now and 2050. Each one considers how much energy we might need and where it could come from. The overall scenarios remain consistent with those in FES 2020 but the details within them are new for 2021 following extensive modelling, research and stakeholder engagement.

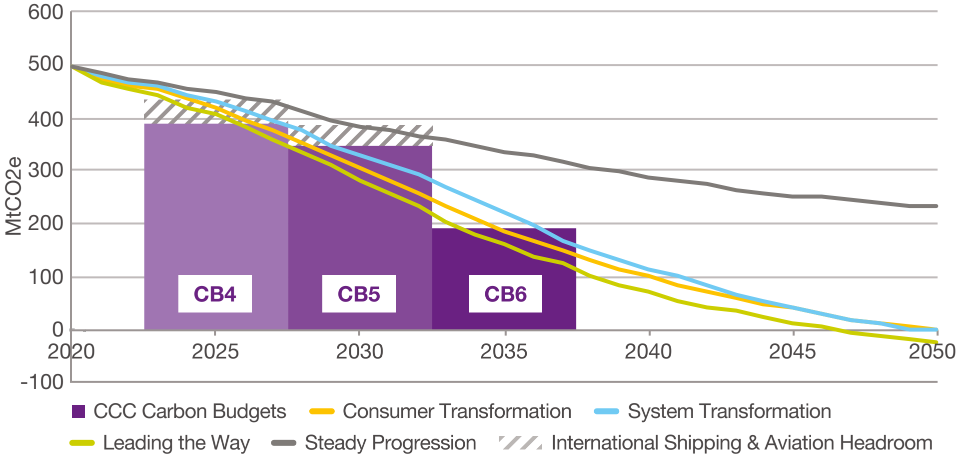
FES can be used to inform a range of energy system activities including network operation, investment decisions and energy policy.

The Scenario Framework

These are our four scenarios: you can learn more about them in the introduction section of the main FES 2021 document.



29 years to net zero



All of our FES 2021 scenarios have lower emissions by 2030 compared to FES 2020. Three of those reach net zero by 2050.

Consumer Transformation and System Transformation represent two different ways to get there - either by changing the way we use energy or by changing the way in which we generate and supply it. In Leading the Way, a combination of high consumer engagement and world-leading technology and investment help to enable our fastest credible decarbonisation journey. In this scenario, the UK reaches net zero in 2047 and goes on to reduce emissions by 103% by 2050 (compared to 1990 levels) - in other words, it is net negative. Decarbonisation happens slowest in Steady Progression, where 2050 emissions are reduced by 73% of 1990 levels.

Some sectors don’t get to zero emissions by 2050 so any residual emissions must be offset by use of greenhouse gas removal (GGR) technology in other sectors.

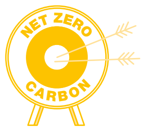
COVID-19 impact

- Since the first COVID-19 lockdown, average daily electricity demand has reduced by around 5-10% compared to normal levels (as much as 18% at times during summer 2020).
- Reasons include less travel, reduced economic activity due to social restrictions and people spending more time at home rather than their normal place of work.
- Our analysis suggests long term impact is likely to be small. We will continue to monitor the impact of the COVID-19 restrictions and build our understanding into FES 2022.

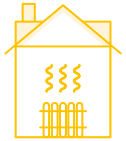
Key Message 1

Policy and delivery

Achieving net zero requires detailed policies and clear accountabilities, coupled with an immediate and sustained focus on delivery, to maintain the momentum provided by the Energy White Paper.

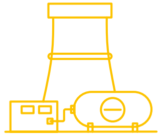


Leading the Way reaches net zero in **2047**



Thermal efficiency of buildings is as important for hydrogen boilers as it is for heat pumps

Close to zero unabated natural gas generation from **2035** in Leading the Way



Emissions from power sector net negative by **2034** in all net zero scenarios

What this means

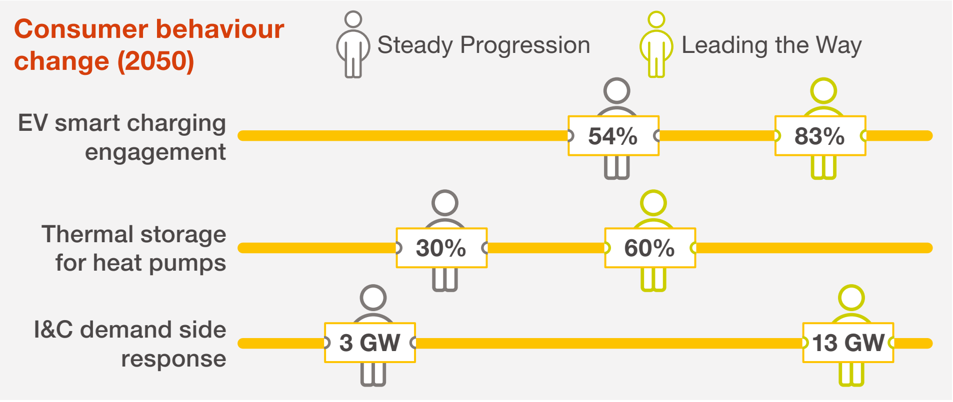
- FES 2021 sets out different routes to net zero to capture uncertainty but, to support action on delivery, important policy decisions need to be made on:
  - Relative roles of electrification and hydrogen for residential heating
  - Level of support for energy efficiency measures
  - Timings for transitioning away from unabated gas
  - Extent to which natural gas is used in hydrogen production
- Competitive markets and strategic planning are both needed to meet net zero. Coordination and collaboration are key when setting policy direction and parameters whereas competitive markets are the best tool to deliver that policy at least cost and to foster innovative solutions.
- Clear roles are needed between government, regulator and industry to facilitate efficient transitions and market changes whilst maximising value to end consumers.
- Improvements in energy efficiency of buildings, vehicles and appliances should be a ‘no-regret’ policy priority in all scenarios as reducing demand reduces the costs of energy security across the scenarios.

Key Message 2

Consumer and digitalisation

Consumer behaviour is pivotal to decarbonisation – how we all react to market and policy changes, and embrace smart technology, will be vital to meeting net zero.

Every scenario sees some level of societal change compared to today, even Steady Progression, but the scale and type of change assumed varies significantly across them.



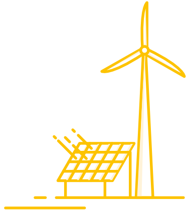
What this means

- Historically, changes to deliver decarbonisation have been on the supply side and largely invisible to consumers. However, to reach net zero there will need to be direct changes to consumer behaviour. What got us here, won’t get us there!
- The journey to net zero by 2050 will involve multiple generations of consumers. Improved understanding of how we as consumers can help is required as polling currently suggests a significant gap.
- How consumers engage with energy balancing will often be through upfront investment in smart technology that then optimises demand on their behalf (e.g. EV charging patterns). Digital solutions are required to prevent swings in demand caused by multiple smart systems responding to the same price signal.
- As smart technologies and innovative business models develop, digitalisation and data will become increasingly important. A balance between open data and privacy must be found to promote trust and to unlock demand side flexibility – while embracing digitalisation.

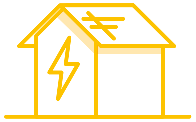
Key Message 3

Markets and flexibility

Holistic energy market reform is needed to drive the investment and behaviour changes needed to deliver net zero and ensure security of supply at a fair and reasonable cost for all consumers.



Between **34 GW** and **77 GW** of new wind and solar generation could be required to meet demand in **2030**



This could require as much as **13 GW** of new electricity storage in 2030 to help balance periods of high and low renewable output

6 GW of new flexible residential demand reduction is available in Leading the Way by 2030

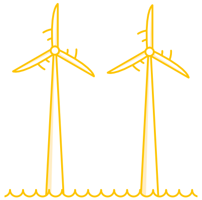
What this means

- Changes are needed to market and code designs to ensure that the right kind of flexibility can be harnessed to balance supply and demand across different locations and time periods – from “second by second” to “seasonal”.
- To attract new market participants, especially from the demand side, and to drive efficient signals, the market design arrangements must prioritise accessibility and competition.
- A sustainable route to market is required to ensure financing of renewable electricity capacity when the majority of generation operates at zero marginal cost. Market rules, processes and data must be transparent to build trust from participants and investors.
- Whilst roll-out of ‘time of use tariffs’ (TOUTs) is required alongside appliance automation, protection must be put in place to ensure fairness and to shield potentially vulnerable consumers from extreme price volatility.
- Initiatives to incentivise new renewable or flexible capacity (e.g. Ofgem’s work on full chain flexibility) must continue to consider the impact on system operability. Similarly, markets must be designed coherently to deliver efficient, interoperable and co-optimised investment signals across the whole energy system.

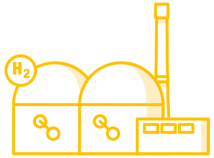
Key Message 4

Infrastructure and whole energy system

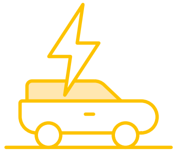
Significant investment in whole energy system infrastructure will be required over the coming decade – this should be optimised to ensure timely delivery and value for consumers.



Across the scenarios, between **31 GW** and **47 GW** of offshore wind is connected by **2030** – as well as at least **16 GW** of interconnector capacity



By **2035**, at least **2 TWh** of hydrogen storage is required in net zero scenarios to provide whole energy system resilience



Even Steady Progression (our slowest decarbonising scenario) sees **4.7 m** EVs and **1.9 m** heat pumps connected by **2030**

What this means

- Coordinated offshore network development is required to integrate the target level of offshore wind with the wider electricity system by 2030. This development will also include multi-purpose interconnectors and potentially hydrogen in the future and so may require changes to industry roles and processes.
- Onshore network reinforcement will also be required to avoid significant constraint costs caused by accelerated renewable connections, interconnectors and increased electrification of heat and transport – or to transition from natural gas to hydrogen. This can be minimised by deploying smart and innovative non-build solutions and integrated planning but remains a key challenge to delivering net zero fairly and at pace.
- Hydrogen storage is necessary to support whole energy system security of supply as well as to accommodate electrolysed hydrogen at times of excess wind or solar. A strategic approach to its development is required to bring forward investment given the likely lead times involved.
- Regional planning work across the electricity and gas transmission and distribution interfaces is required to ensure a fair and coordinated approach to network development and to minimise cost and disruption to end consumers.

Whole energy system view

As well as a chapter on reaching **net zero**, FES 2021 has dedicated chapters on the **consumer view (residential, transport** and **industrial & commercial)**, the **system view (bioenergy, natural gas, hydrogen** and **electricity supply)** and **flexibility** to explore these in detail. To create and operate an optimal whole energy system, the important links between demand, supply and flexibility must be clearly understood.

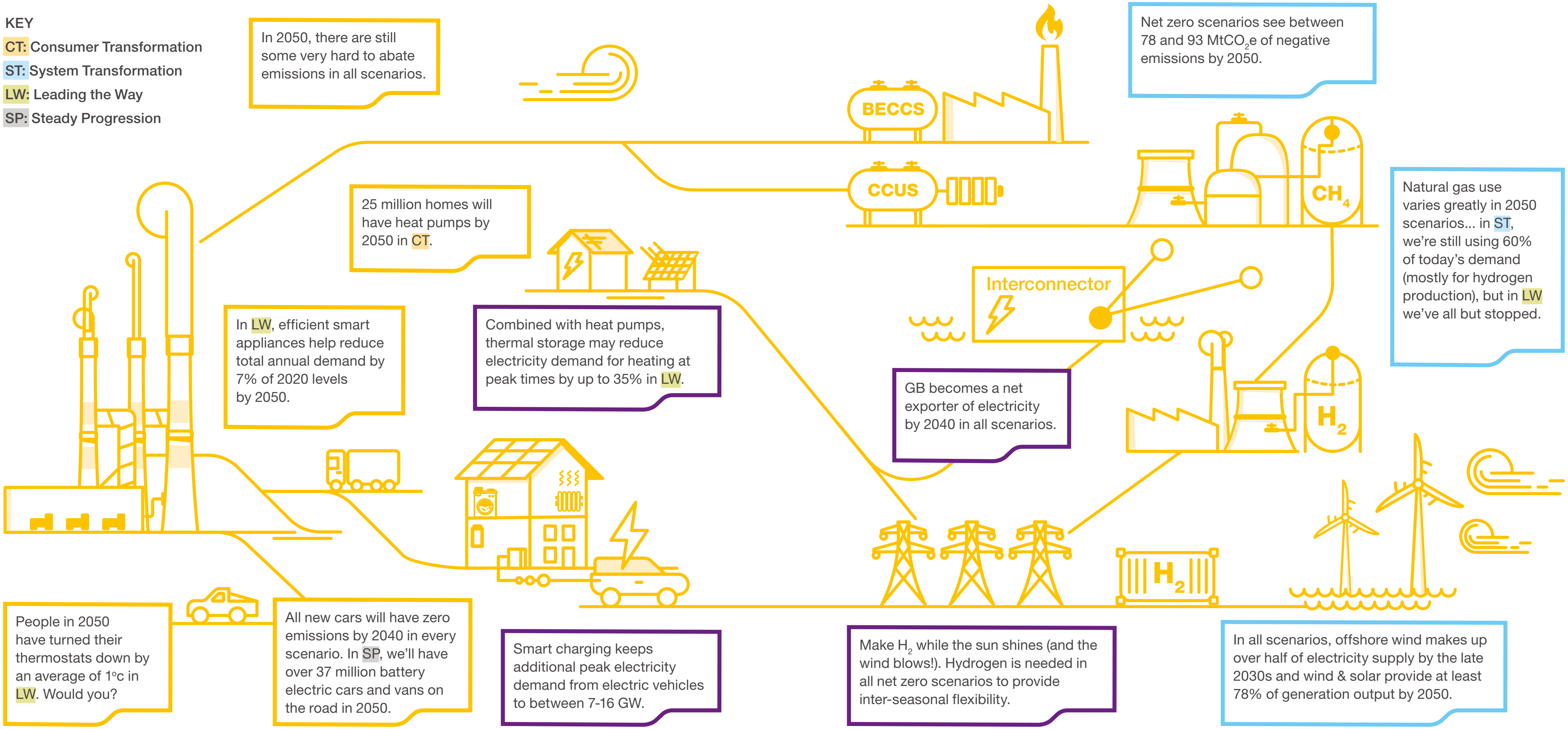
Today, the electricity system is designed and operated to ensure supply meets demand. However, the whole energy system of the future will be based more around supply, with demand adjusting to use or store energy as required. It will also involve increased interaction across fuels like natural gas, bio-resources and hydrogen.

The importance of flexibility increases with electrification in all scenarios – especially when the electricity comes from weather-driven renewables. Consumers and the energy system must support each other to manage peaks and troughs in supply and demand.

Consumer View

Flexibility

System View



KEY
CT: Consumer Transformation
ST: System Transformation
LW: Leading the Way
SP: Steady Progression

In 2050, there are still some very hard to abate emissions in all scenarios.

25 million homes will have heat pumps by 2050 in CT.

In LW, efficient smart appliances help reduce total annual demand by 7% of 2020 levels by 2050.

Combined with heat pumps, thermal storage may reduce electricity demand for heating at peak times by up to 35% in LW.

People in 2050 have turned their thermostats down by an average of 1°c in LW. Would you?

All new cars will have zero emissions by 2040 in every scenario. In SP, we'll have over 37 million battery electric cars and vans on the road in 2050.

Smart charging keeps additional peak electricity demand from electric vehicles to between 7-16 GW.

GB becomes a net exporter of electricity by 2040 in all scenarios.

Make H_2 while the sun shines (and the wind blows!). Hydrogen is needed in all net zero scenarios to provide inter-seasonal flexibility.

Net zero scenarios see between 78 and 93 MtCO$_2$e of negative emissions by 2050.

Natural gas use varies greatly in 2050 scenarios... in ST, we're still using 60% of today's demand (mostly for hydrogen production), but in LW we've all but stopped.

In all scenarios, offshore wind makes up over half of electricity supply by the late 2030s and wind & solar provide at least 78% of generation output by 2050.

FES key comparison chart

CT Consumer Transformation
LW Leading the Way
ST System Transformation
SP Steady Progression
▨ UK Government target

		2020	By 2025	By 2030	By 2035	By 2040	By 2045	By 2050	Maximum potential by 2050
Emissions	78% reduction in net greenhouse gas emissions vs. 1990 levels[1]	497 MtCO$_2$e			▨ CT LW	ST			103% reduction (-28 MtCO$_2$e) LW
Transport	Sale of petrol and diesel cars and vans banned[2]	1.6 mil. petrol and diesel cars and vans sold (COVID-19 impacted)		▨ CT LW	ST	SP			37.4 mil. battery electric cars and vans on the road SP
	Zero tailpipe emissions for all new cars[2]	7% of cars sold (COVID-19 impacted)			▨ CT LW ST	SP			~0 petrol or diesel cars (including hybrids) remaining on the road CT ST LW
	Exceeds 1GW of total vehicle-to-grid (V2G) capacity	N/A		CT LW		ST	SP		39 GW LW
Heating	600,000 heat pumps installed per year[3]	<30,000	LW	▨ CT		ST	SP		1,700,000 CT
	4 in 5 homes using a primary heat source other than a natural gas boiler	1 in 5				LW	CT ST		100% CT ST LW
Natural Gas	Gas grid connection for new homes ends[4]	>60%	▨ CT LW		ST				0% LW
Electricity Generation	80% of GB generation output from renewables	50%	CT LW	ST SP					94% LW
	Offshore wind installation reaches 40 GW[3]	10.5 GW		▨ CT LW	ST	SP			113 GW CT
	Carbon intensity of electricity net negative[5]	155g CO$_2$/kWh			CT LW ST				-55g CO$_2$/kWh ST
	First Carbon Capture Usage and Storage (CCUS) power station[3]	0		▨ CT LW ST	SP				26 CCUS power stations ST
Hydrogen	5 GW of hydrogen production capacity[3]	<1 GW		▨ LW	ST	CT	SP		74 GW ST
Flexibility	10 GW or more of electrolysis capacity	<1 GW			LW	CT ST			58 GW[6] LW
	Exceeds 20 GW electricity storage technologies (excluding V2G)	4 GW			CT LW		ST	SP	43 GW LW
	I&C electricity demand side response exceeds 2.5 GW	1.3 GW	CT LW	ST			SP		16.0 GW CT

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1. 20/04/2021 - UK Government Legal Commitment on CCC Sixth Carbon Budget recommendation.
2. 18/11/2020 - UK Government Legal Commitment.
3. 14/12/2020 - Energy White Paper.
4. 20/01/2021 - Future Homes Standard (proposal).
5. These values represent the case where no generation output is adjusted to overcome network or operability constraints. The real values will be higher.
6. This 58 GW includes only electrolysers connected to the electricity system (including directly from nuclear).

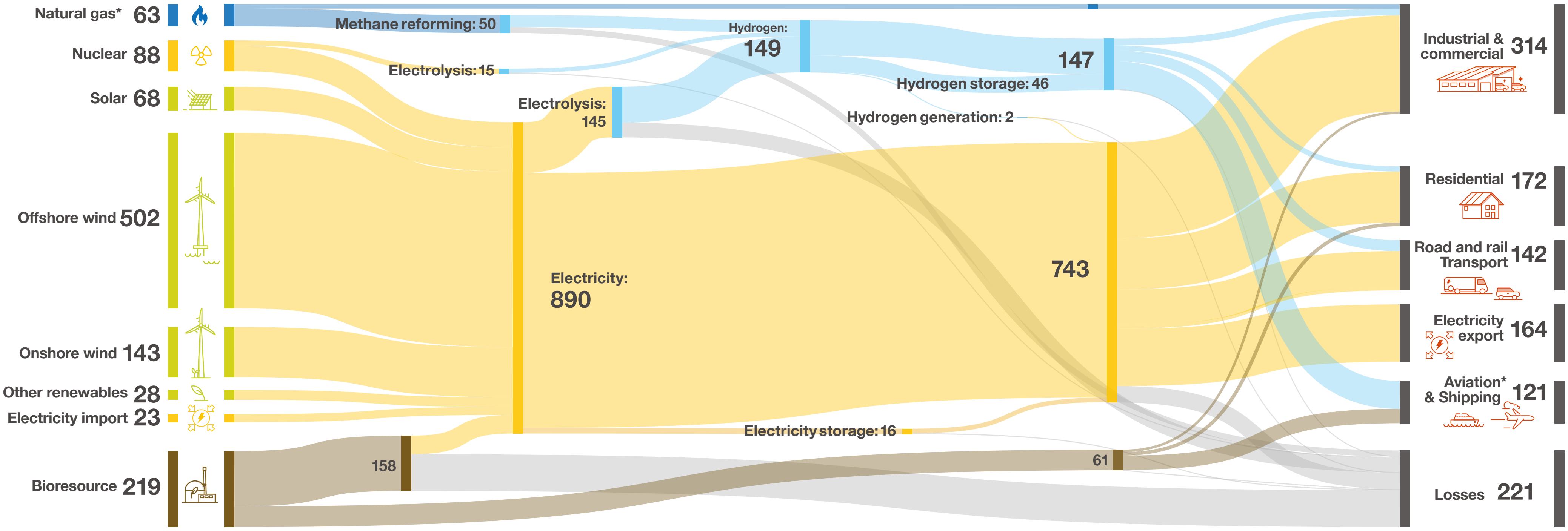
Key statistics in 2030 and 2050

	2020	2030				2050				
Emissions		CT	ST	LW	SP	CT	ST	LW	SP	**Emissions**
Annual average carbon intensity of electricity (g CO_2/kWh)	155	20	22	6	42	-54	-55	-43	14	Annual average carbon intensity of electricity (g CO_2/kWh)
Electricity										**Electricity**
Annual demand (TWh)[1]	294	333	309	340	324	702	559	686	459	Annual demand (TWh)[1]
Peak demand (GW)[2]	58	69	65	67	68	113	99	95	92	Peak demand (GW)[2]
Total installed capacity (GW)[3]	104	182	168	200	158	374	313	339	242	Total installed capacity (GW)[3]
Wind and solar capacity (GW)	36	100	87	113	70	236	183	216	132	Wind and solar capacity (GW)
Interconnector capacity (GW)	5	19	16	22	16	27	20	28	17	Interconnector capacity (GW)
Total storage capacity (GW)	4	14	9	18	8	58	36	63	24	Total storage capacity (GW)
Total vehicle-to-grid capacity (GW)[4]	0	2	0	3	0	34	16	39	8	Total vehicle-to-grid capacity (GW)[4]
Natural Gas										**Natural Gas**
Annual demand (TWh)[5]	891	633	714	545	789	66	512	19	752	Annual demand (TWh)[5]
1-in-20 peak demand (GWh/day)	5,832	4,138	4,688	3,197	5,221	431	2,375	156	4,910	1-in-20 peak demand (GWh/day)
Residential demand (TWh)[6]	334	255	297	196	313	3	1	5	255	Residential demand (TWh)[6]
Import dependency (%)	57%	73%	68%	64%	63%	95%	98%	46%	69%	Import dependency (%)
Hydrogen										**Hydrogen**
Annual demand (TWh)	0	2	8	13	1	149	475	297	52	Annual demand (TWh)
Blue hydrogen production (TWh)[7]	0	0	6	0	0	34	332	0	50	Blue hydrogen production (TWh)[7]
Green hydrogen production (TWh)[8]	0	2	1	12	1	103	78	246	2	Green hydrogen production (TWh)[8]
Bioresources										**Bioresources**
Bioresource demand (TWh)	–	105	118	116	118	219	246	200	143	Bioresource demand (TWh)

1. Customer demand plus on-grid electrolysis plus losses.
2. Refer to data workbook for further information on winter average cold spell (ACS) peak demand.
3. Total installed capacity and total storage capacity including vehicle-to-grid. Includes all network connected generation.
4. Less capacity will be available during winter peak 5-6pm due to vehicle usage.
5. Includes shrinkage, exports, biomethane and natural gas for methane reformation.
6. Residual demand made up of biomethane and natural gas.
7. Blue hydrogen is created via methane reformation using natural gas as an input, plus CCUS.
8. Green hydrogen is created via electrolysis using renewable electricity (does not include hydrogen produced directly from nuclear or bioenergy).

2050 energy flows in Consumer Transformation (TWh)

- Home heating, transport and industry largely electrified
- Hydrogen produced in the UK, primarily through electrolysis
- Electricity generation capacity and output is highest in this scenario to meet high annual electricity demands
- High levels of energy efficiency measures, lowest end user demand

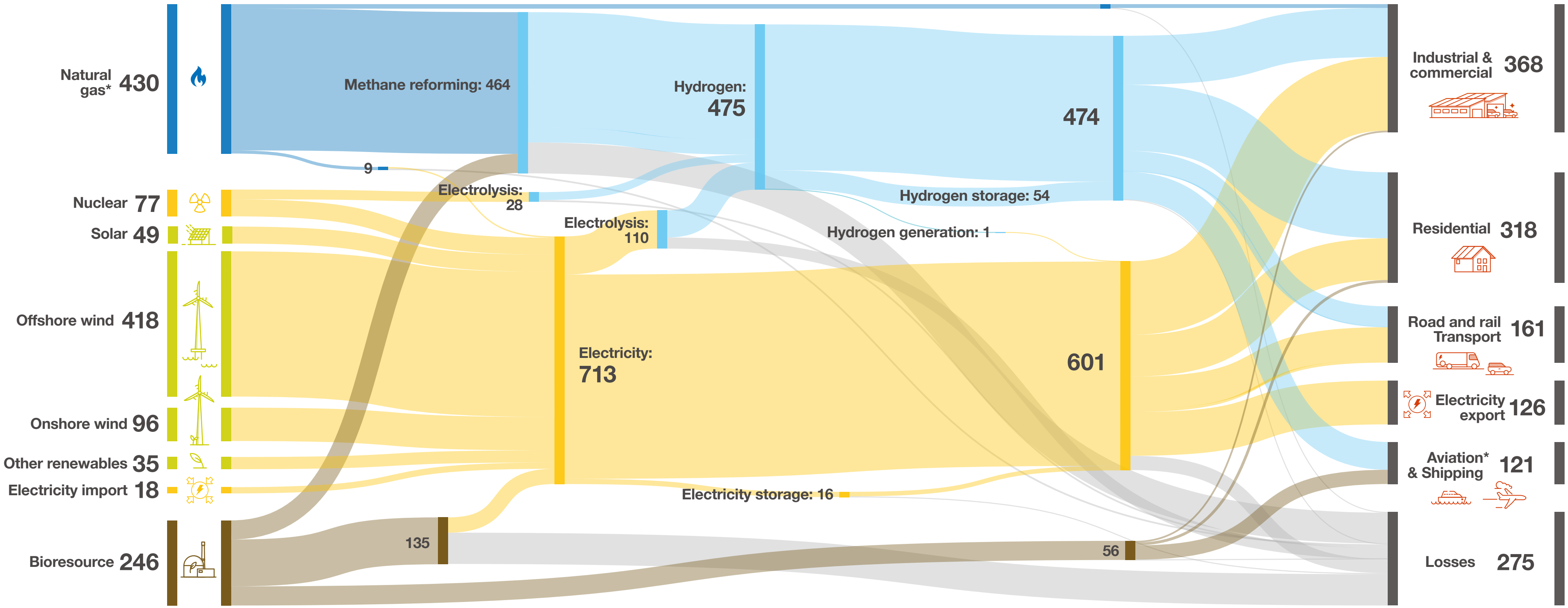


*excluding exports

*Aviation excludes some demand met by petroleum products

2050 energy flows in System Transformation (TWh)

- Highest proportion of hydrogen with widespread use for home heating, industry and HGVs
- Hydrogen produced in the UK, mainly through methane reforming, with large requirement for natural gas with CCUS
- Some negative emissions from hydrogen production from bioresources with CCUS
- Highest level of bioresource use, particularly for bioenergy with carbon capture and storage (BECCS) in the power sector

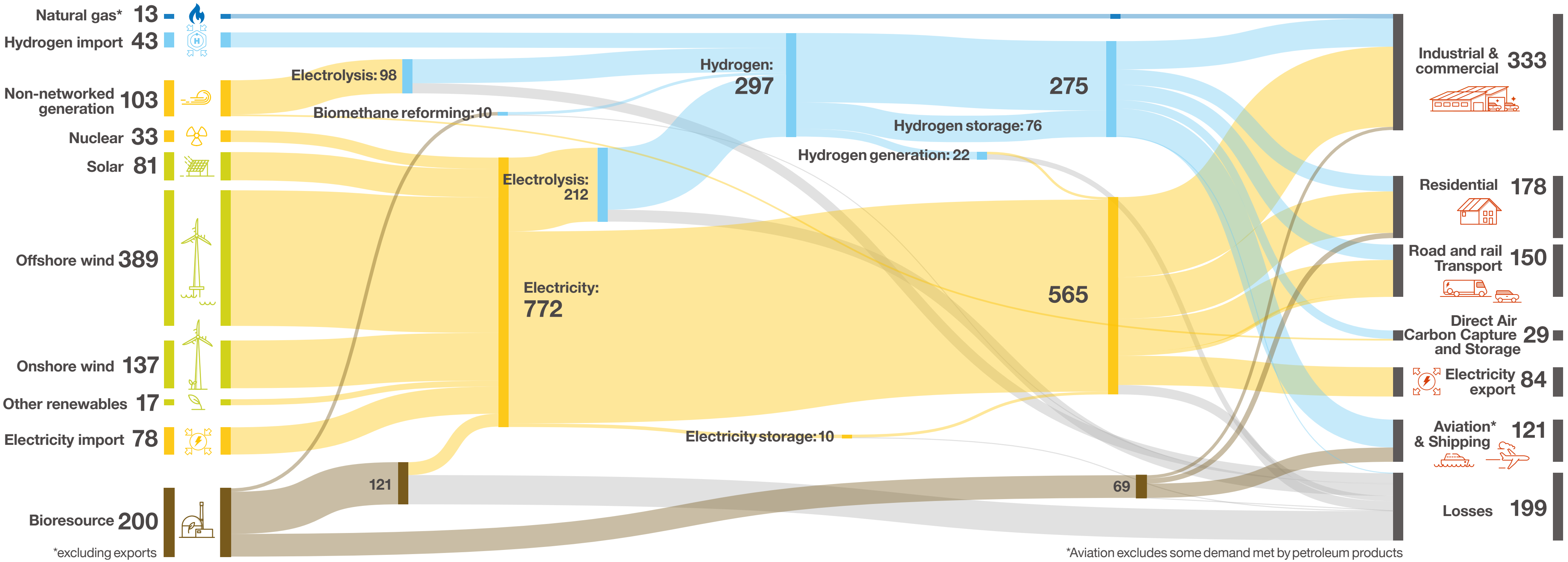


*excluding exports

*Aviation excludes some demand met by petroleum products

2050 energy flows in Leading the Way (TWh)

- Combination of hydrogen and electricity used in industry and to heat homes using hybrid heat pumps or hydrogen boilers
- No natural gas used to produce hydrogen
- Some use of direct air carbon capture and storage (DACCS) for negative emissions
- The only scenario to include non-networked electricity generation and hydrogen imports

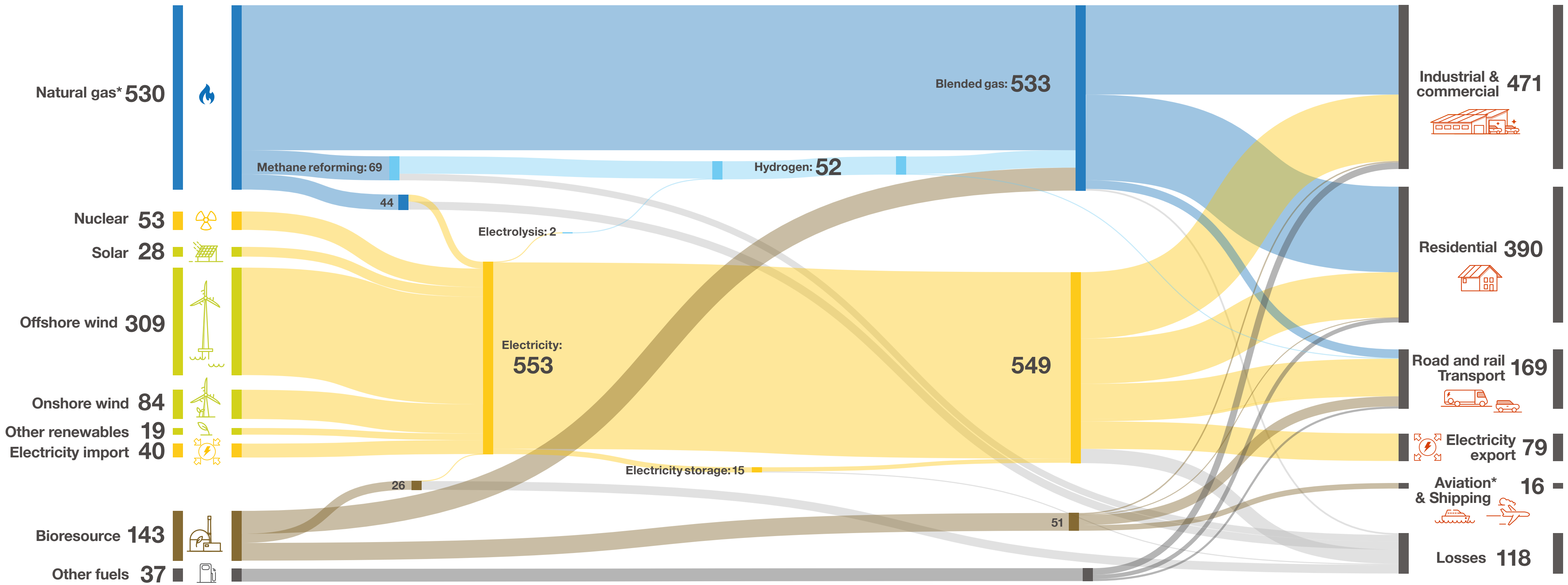


*excluding exports

*Aviation excludes some demand met by petroleum products

2050 energy flows in Steady Progression (TWh)

- Continued high usage of natural gas, particularly for domestic heating and industry
- Small private vehicles fully electrified (including some plug-in hybrids) whilst HGVs rely on fossil fuels
- Low use of hydrogen as production isn't decarbonised
- Highest total end-user energy demand due to minimal increase in energy efficiency measures and reliance on inefficient fossil fuels

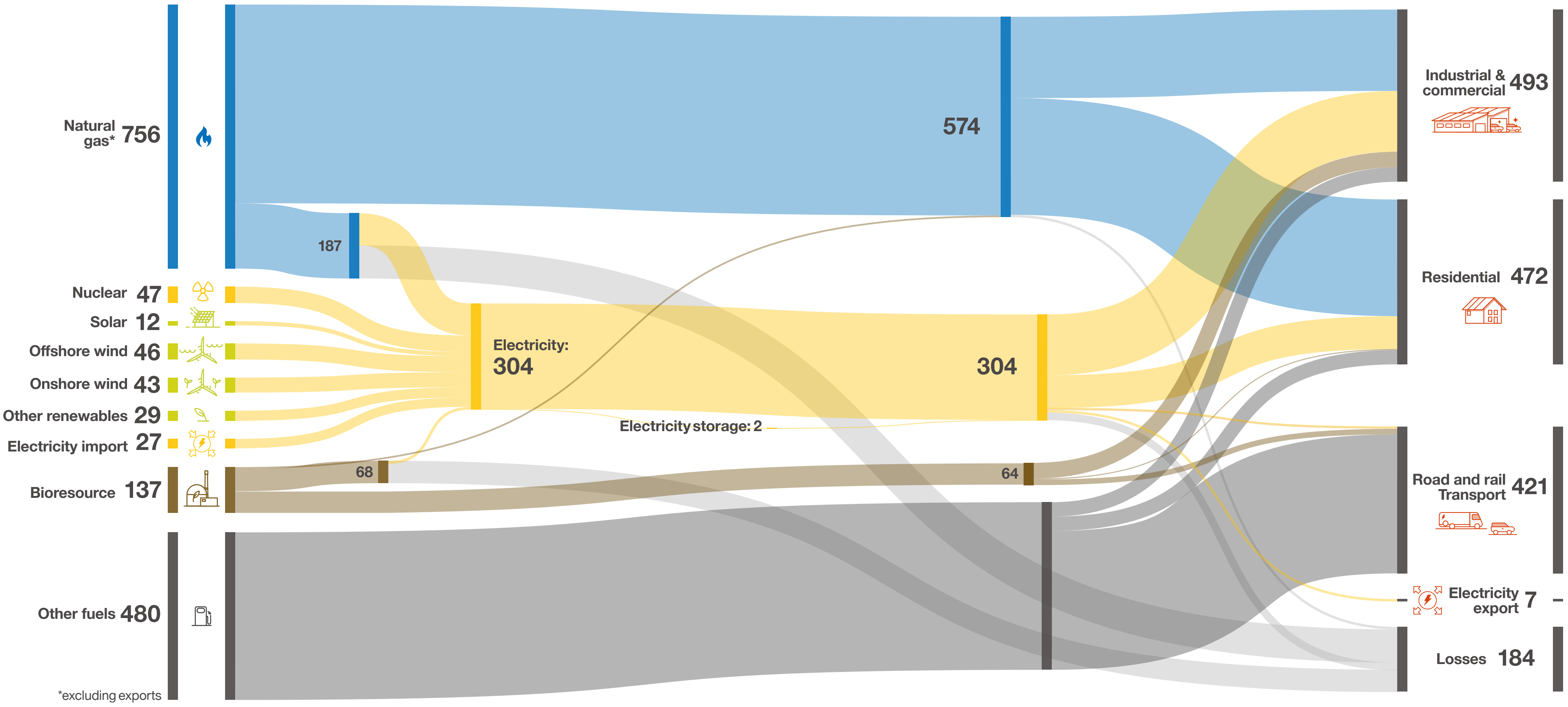


*excluding exports

*Aviation excludes some demand met by petroleum products

2020 energy flows (TWh)

- Relative to net zero scenarios energy demand is much higher today than in 2050
- Fossil fuels provide the majority of energy supply
- Energy demand for transport is much higher today than in 2050 due to the relative inefficiency of ICE vehicles compared to electric vehicles



*excluding exports

Continuing the conversation

Working together in the future

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

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