Continuing the conversation

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

Access our current and past *FES* documents, data and multimedia at: fes.nationalgrid.com
For further information regarding SO publications please visit: **www.nationalgrideso.com** and **www.nationalgridgas.com**

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

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

National Grid Electricity System Operator
1-3 Strand
London
WC2N 5EH United Kingdom
Registered in England and Wales
No. 11014226

www.nationalgrideso.com

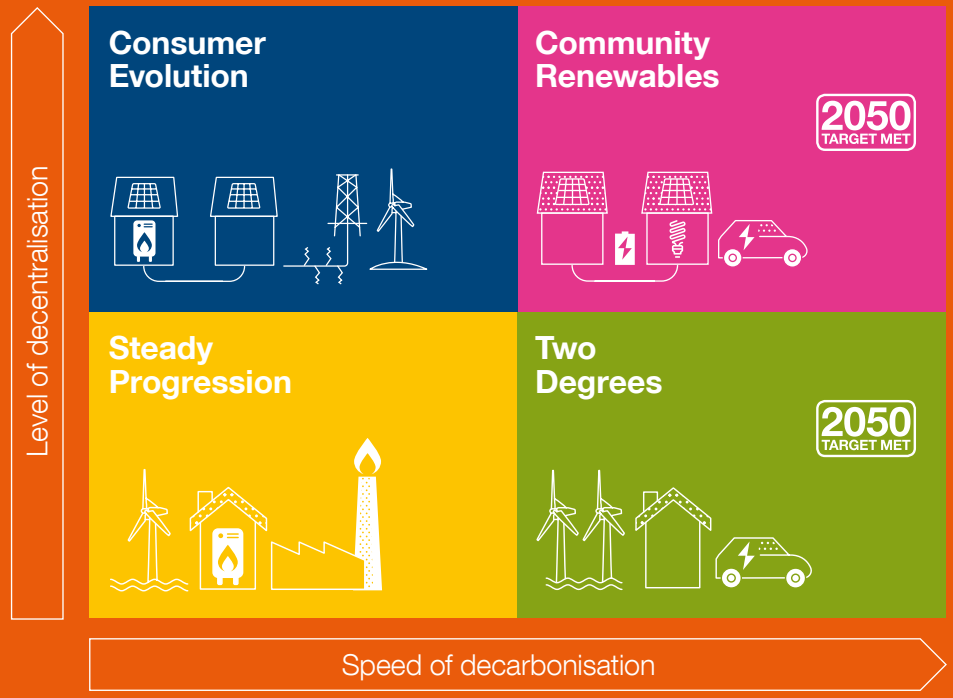
Future Energy Scenarios in five minutes

July 2019

nationalgridESO

What are the *Future Energy Scenarios (FES)*?
Our *Future Energy Scenarios* outline four different credible pathways for the future of energy for the next 30 years and beyond. Each scenario considers how much energy we might need and where it could come from.

***FES* is the product of in-depth analysis informed by over 400 industry experts and National Grid ESO's own insights.**



Welcome to our *Future Energy Scenarios*

Decarbonising energy is fundamental in the transition towards a sustainable future. Our *Future Energy Scenarios* aim to stimulate debate to inform the decisions that will help move us towards achieving carbon reduction targets and, ultimately, shape the energy system of the future.

Our energy system is already transforming as the trends of decarbonisation, decentralisation and digitisation revolutionise how we produce and use energy every day. This summer the electricity system operated coal free for over two weeks and carbon intensity of generation last winter reached a new low. We will continue to facilitate the energy transformation and, by 2025, our ambition is to be able to operate the electricity system at zero-carbon. These are significant milestones in the sustainability transition that will be required to meet the 2050 carbon target.

The UK government has responded to growing public focus on climate change by committing to a shift from the 2050 target of an 80 per cent reduction in CO_2 from 1990 levels to a net zero target. Policy changes combine with rapid technological progress and market forces to create a swiftly changing landscape, where it is impossible to accurately forecast a single energy future out to 2050. Instead, our *Future Energy Scenarios (FES)* creates a range of credible futures which allow us to continue supporting the development of the energy system that is robust against different outcomes. Following clear feedback from our stakeholders, we have kept the scenario framework the same as in *FES 2018*. Two of our scenarios meet the 2050 target[1], and we have also included a new, standalone sensitivity analysis on how net zero carbon emissions could potentially be achieved by 2050.

National Grid Electricity System Operator (ESO) became a legally separate entity within the National Grid Group on 1 April 2019. Separating the ESO business from National Grid's Electricity Transmission Owner business provides transparency in our decision-making and gives confidence that everything we do will promote competition and is ultimately for the benefit of consumers. While the *FES* is an ESO publication, our analysis continues to consider the whole energy system – ensuring the implications for, and interactions across, electricity, gas, heat and transport are fully considered.

Our scenarios reflect the year-round feedback received from all of our stakeholders right across the energy landscape and beyond. Please continue to share your views with us using the details on the Continuing the conversation page at the back of the document. This year, for the first time, we will also be building on the issues highlighted in our key messages through a series of industry discussions and collaborative analysis. Look out for the first of these in Autumn 2019.

Thank you for your continuing support and I hope you enjoy *FES 2019*.

Fintan Slye
Director, Electricity System Operator

[1] Throughout *FES in 5* we refer to the '2050 target'. This is the original Climate Change Act 2008 target of achieving 80 per cent reduction in greenhouse gas emissions by 2050, compared to 1990 levels. At the end of June 2019 this target was updated to a net zero emissions target, discussed on p14 of *FES in 5* and chapter six of the main *FES* document.

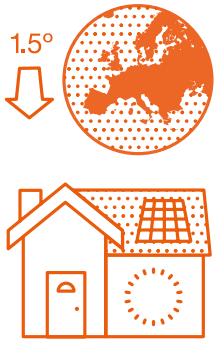
Key messages

Reaching net zero carbon emissions by 2050 is achievable. However, this requires immediate action across all key technologies and policy areas.

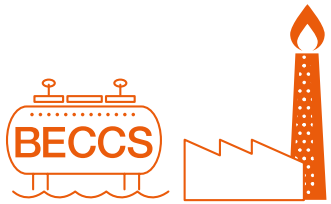
- Our analysis is aligned with that of the CCC and provides an approach to achieve net zero emissions by 2050.
- The 80 per cent decarbonisation target can be reached through multiple technology pathways, but **Net Zero** requires greater action across all solutions. Action on electrification, energy efficiency and carbon capture will all be needed at a significantly greater scale than assumed in any of our core scenarios.

What this means

- **The electricity system will need to operate using only zero carbon generation and the power sector will need to deliver negative emissions (e.g. biomass with CCUS).**
- **The gas system will need to be transformed to accommodate hydrogen.**
- **Gas appliance standards must require boilers to be "hydrogen-ready" in order to leverage replacement cycles.**



Homes in 2050 will need to use at least one third less energy for heating than today.



37 million tonnes of CO_2 removed from atmosphere. Residual emissions will be offset by negative emissions from biomass power generation paired with carbon capture and storage.

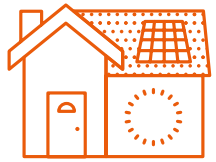
Heat decarbonisation pathways are uncertain and vary by region. However, there are clear, urgent no regrets actions that can remove barriers to deploying solutions at scale.

- There are immediate steps to decarbonise heat which are common across all scenarios. These include improving the thermal efficiency of homes so that the majority are rated at EPC Class C or higher by 2030, raising appliance efficiency standards and rolling out at least 2.5m domestic heat pumps by 2030.
- Multiple heat decarbonisation pathways are possible including electrification, decarbonised gas, and hybrid systems. But optimal solutions will vary by region and the combinations and interaction of these technologies must be considered to provide a flexible, operable and sustainable whole energy system.

What this means

- **Strong, no regrets policy action must be taken immediately to improve the thermal efficiency of housing, and to accelerate the rate of heat pump installation. This will have a direct impact on end consumers and so positive engagement and support measures will be key to ensuring uptake at scale.**
- **The current policy timeline of setting a clear heat strategy by 2025 can meet the 2050 target, but there is no room for delay. A regional plan will be required to optimise low-carbon heating solutions.**

More than 23m homes will need to install new low-carbon heating solutions by 2050[2].



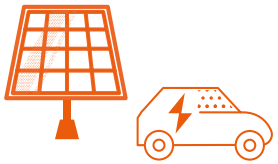
By 2050[2], up to 85% of homes need to be very thermally efficient (at EPC class C or higher).

[2] **Community Renewables** and **Two Degrees**

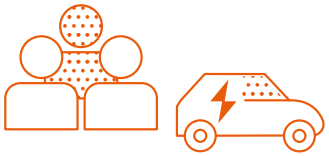
Key messages

Electric vehicles can help decarbonise both transport and electricity supply for Great Britain. The market needs to align vehicle charging behaviour to complement renewable generation and meet system needs.

- The charging of over 35m electric vehicles in 2050 will provide flexibility and integrate a higher level of renewable generation on the system. This amplifies the positive impact of electric vehicles on decarbonisation.
- The timing, location, and frequency of electric vehicle charging varies more than previously assumed and many factors influence this. This variability has positive implications for the operation of the electricity system.



Smart charging vehicles could enable the storage of roughly one fifth of GB's solar generation for when this energy is needed.



Over 75% of EVs could be using smart charging by 2050.

What this means

- **A smart flexible system will need new business models and services to match system needs with vehicle charging requirements and consumer preferences.**
- **The investment in infrastructure to support increasing numbers of electric vehicles indirectly benefits all energy consumers through lower prices and lower carbon generation intensity, as smart charging of EVs can support increased renewable generation.**

A whole system view across electricity, gas, heat and transport underpins a sustainable energy transformation. Widespread digitalisation and sharing of data is fundamental to harnessing the interactions between these changing systems.

- Existing interactions between gas and electricity networks will increase as gas generation provides more flexibility, and new technologies such as electrolysis and hybrid heat systems create new interfaces between electricity and gas systems.
- The complexity of the whole system is increasing, but so is the ability of data and technology to understand and manage this complexity.
- Investment decisions around potential new systems such as hydrogen and carbon transportation must be made on a whole energy system basis.

Over seven million hybrid heat pumps could be installed by 2050 with gas providing continued flexibility.

Well over 2.8 trillion data points will be collected in 2050 to understand where EVs are charging on the electricity system.

What this means

- **Significant digitalisation of legacy infrastructure is required to provide visibility and enable optimisation of the whole energy system. This must be done in a way that ensures data and systems are interoperable.**
- **Data must be made accessible to decision makers across interdependent systems such as gas, electricity, and transport.**
- **Appropriate governance and standards will be required in order to ensure a joined up and digitalised energy system.**

Community Renewables

- **Achieves the 2050 decarbonisation target.**
- **Decentralised pathway.**

In **Community Renewables**, local energy schemes flourish, consumers are engaged and improving energy efficiency is a priority.

UK homes and businesses transition to mostly electric heat. Consumers opt for electric transport early and simple digital solutions help them easily manage their energy demand.

Policy supports onshore generation and storage technology development, bringing new schemes which provide a platform for other green energy innovation to meet local needs.

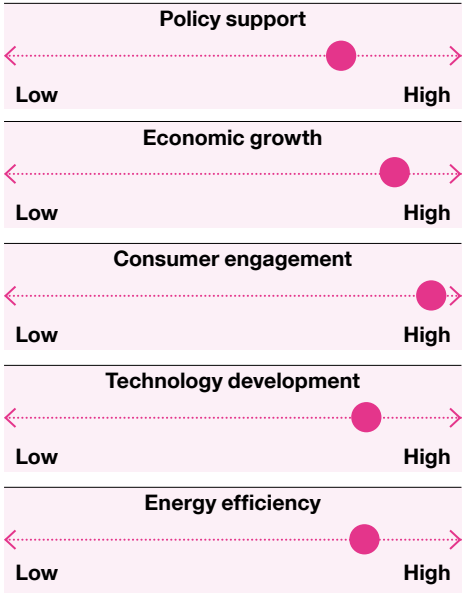
Up to 58% of generation capacity could be local by 2050

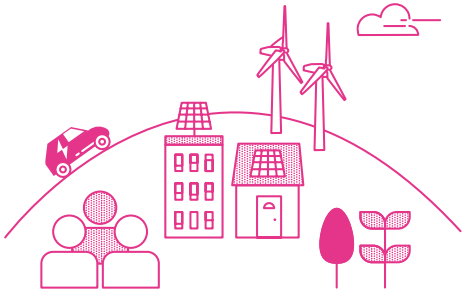
2017 emissions
503 $MTeCO_2$

2050 emissions
165 $MTeCO_2$

Scenario reaches 80% emissions reduction target

Community Renewables pathway





Two Degrees

- **Achieves the 2050 decarbonisation target.**
- **Large-scale centralised solutions.**

In **Two Degrees**, large-scale solutions are delivered and consumers are supported to choose alternative heat and transport options to meet the 2050 target.

UK homes and businesses transition to hydrogen and electric technologies for heat. Consumers choose electric personal vehicles and hydrogen is widely used for commercial transport.

Increasing renewable capacity, improving energy efficiency and accelerating new technologies such as carbon capture, usage and storage are policy priorities.

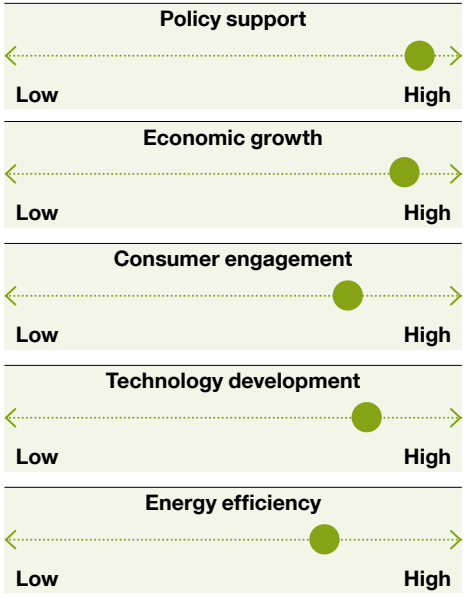
Over one third of homes could be heated by hydrogen by 2050

2017 emissions
503 $MTeCO_2$

2050 emissions
165 $MTeCO_2$

Scenario reaches 80% emissions reduction target

Two Degrees pathway



Steady Progression

- **2050 decarbonisation target not met.**
- **Large-scale centralised solutions.**

In **Steady Progression**, the pace of the low-carbon transition continues at a similar rate to today but then slows towards 2050.

Consumers are slower to adopt electric vehicles and take up of low-carbon alternatives for heat is limited by costs, lack of information and access to suitable alternatives.

Although hydrogen blending into existing gas networks begins, limited policy support means that new technologies such as carbon capture, usage and storage and battery storage develop slowly.

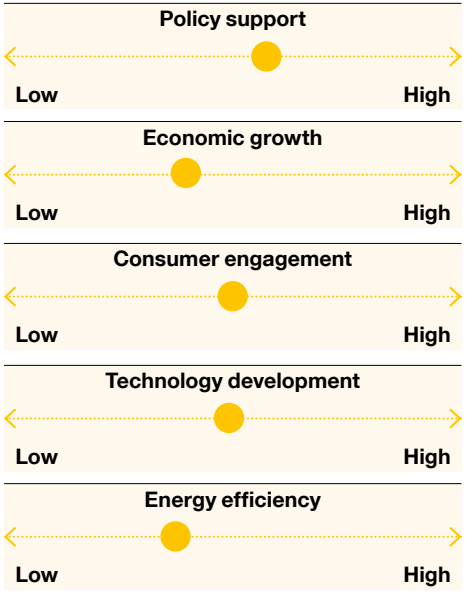
Least progress towards decarbonisation of heat

2017 emissions
503 $MTeCO_2$

2050 emissions
345 $MTeCO_2$

Scenario reaches 58% emissions reduction

Steady Progression pathway



Consumer Evolution

- **2050 decarbonisation target not met.**
- **Decentralised landscape.**

In **Consumer Evolution**, there is a shift towards local generation and increased consumer engagement, largely from the 2040s.

In the interim, alternative heat solutions are taken up mostly where it is practical and affordable, e.g. due to local availability. Consumers choose electric vehicles and energy efficiency measures.

Cost-effective local schemes are supported but a lack of strong policy direction means technology is slow to develop, e.g. for improved battery storage.

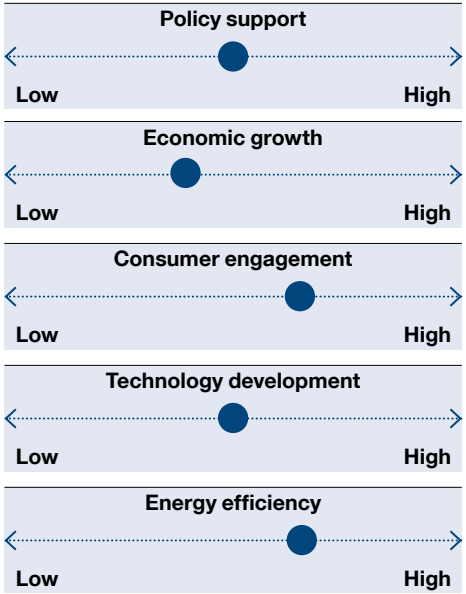
Greatest reliance on gas-fired generation for flexibility

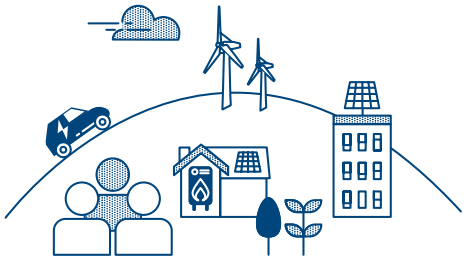
2017 emissions
503 $MTeCO_2$

2050 emissions
344 $MTeCO_2$

Scenario reaches 58% emissions reduction

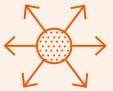
Consumer Evolution pathway





FES scenario key comparison chart

CR Community Renewables | TD Two Degrees | SP Steady Progression | CE Consumer Evolution | UK Government target

		2018	By 2025	By 2030	By 2035	By 2040	By 2045	By 2050	Maximum potential by 2050
Transport	 Approximately 75% of vehicles are electric	**<1%**			CR TD	2040 UK Government Road to Zero target[4]	SP CE		CR 99% 36m vehicles
	 Exceeds 1 GW of vehicle-to-grid capacity	**N/A**		CR TD	SP CE				CR 20.4 GW 3m vehicles
	 Over 300,000 gas or hydrogen vehicles	**1,900**				TD	SP CE	CR	TD 1.2m vehicles
Heating	 10% of homes using low carbon heating	**2%**		CR TD	CE			SP	CR 88%
	 Majority of homes rated EPC C or higher	**38% of homes**	CR	TD	2035 UK Government target to improve EPCs of homes[5]	CE	SP		CR 85% of homes
Electricity generation	 25% electricity output from distributed sources[3]	**19%**	CR TD CE					TD Falls below 25% in the late 2040s SP Does not reach 25%	CR 38%
	 60% renewable generation	**43%**	CR TD		SP CE				CR 84%
	 Carbon intensity of electricity generation below 100g CO_2/kWh	**248g CO_2/kWh**	CR TD	SP	CE				TD 7g CO_2/kWh
Electricity storage	 Exceeds 6 GW electricity storage technologies	**3.6 GW**	CR TD	SP CE					CR 28.1 GW
Gas supplies	 10% of supplies from onshore production (e.g. biogases)	**< 1%**		CE	CR SP			TD	CE 51%
Hydrogen	 Over 10 TWh hydrogen demand	**<1 TWh**			TD		CR SP		TD 312 TWh

[3] Data does not include V2G

[4] Road to Zero (2018) UK Government goal to ban the sale of conventional vehicles by 2040 https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy

[5] Clean Growth Strategy (2017), UK Government aspiration that as many homes 'as possible are improved to EPC Band C by 2035, where practical, cost-effective and affordable.' https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary#our-clean-growth-strategy

Key statistics in 2030 and 2050

Electricity	2018	2030				2050				Electricity
		CR	TD	SP	CE	CR	TD	SP	CE	
Annual demand (TWh)[6]	285	283	300	299	288	413	422	376	370	Annual demand (TWh)[6]
Peak demand (GW)	60	57.4	63.8	63	59.8	72.4	82.5	74.9	68.7	Peak demand (GW)
Total installed capacity (GW)[7]	108	154	158	140	131	233	227	175	176	Total installed capacity (GW)[7]
Low carbon and renewable capacity (GW)[8]	52	102	95	76	70	161	162	106	101	Low carbon and renewable capacity (GW)[8]
Interconnector capacity (GW)	4	17	20	15	12	17	20	15	12	Interconnector capacity (GW)
Total storage capacity (GW)[7]	4	13	12	8	7	38	31	21	27	Total storage capacity (GW)[7]
Vehicle-to-grid total capacity (GW)	0	1.3	1	0.2	0.2	20.4	16.6	15.2	19	Vehicle-to-grid total capacity (GW)

Gas	2018	2030				2050				Gas
		CR	TD	SP	CE	CR	TD	SP	CE	
Annual demand (TWh)	804	487	534	689	718	204	585	716	651	Annual demand (TWh)
1-in-20 peak demand (GWh/day)	5,191	3,873	4,394	5,594	5,697	2,068	3,301	5,615	5,077	1-in-20 peak demand (GWh/day)
Residential demand (TWh)	342	261	282	336	331	78	76	318	272	Residential demand (TWh)
Gas imports (%)	53%	68%	65%	60%	58%	54%	87%	87%	49%	Gas imports (%)
Shale production (bcm/yr)	0	0	0	7	13	0	0	7	33	Shale production (bcm/yr)
Hydrogen production (TWh)	0	1	9	2	0	31	312	14	2	Hydrogen production (TWh)
Green gas production (bcm/yr)	0	3	1.7	0.4	0.9	12	6.7	0.7	3.6	Green gas production (bcm/yr)

[6] Excludes losses

[7] Total installed capacity and total storage capacity include vehicle-to-grid

[8] CCUS, nuclear, solar, wind and other renewables

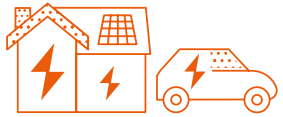
Reaching net zero

Our Net Zero sensitivity modelling examines how we could stretch the ambition of our core scenarios to reach net zero emissions.

Our conclusion that net zero emissions is achievable is based on consideration of a number of key areas. These include improved energy efficiency, consumer behaviour and new technologies.

CCUS[9] is essential across several sectors including hydrogen production, power generation and industry.

Almost half of homes could be heated by hydrogen.



Electricity demand almost doubles from today, all met by low-carbon sources.

Carbon emissions – tracking the journey to Net Zero

(Mt CO_2 equivalent)	2017	Net Zero 2050
Heat for buildings	85	0
Electricity before BECCS	73	0.35
BECCS in power sector	0	-37
Industry	105	10
Road transport	117	0
Hydrogen production	0	3
Other (non energy related)	123	59
Total	**503**	**35**
Relative to 1990 Emissions (% reduction)	39%	96%

By 2050, residual emissions in industry, hydrogen production and other sectors are partially offset by negative emissions from BECCS.

[9] CCUS (carbon capture, usage and storage).

Notes

Notes