BBC Briefing: Energy

Introduction

Supplying energy for our everyday lives reliably and affordably has always been a key goal of government policy.

But the UK's commitment to do so while almost completely eliminating carbon emissions over the next three decades poses an unprecedented challenge for government, business and individuals.

BBC Briefing explores how that challenge can be met.

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Part 1/9

What do we want from our Energy System?

Any nation's energy system has to meet a number of goals simultaneously. It must be secure, reliable, safe, affordable and compatible with its environmental goals.

Balancing these often conflicting demands is a significant challenge.

The UK's energy needs are met from a range of different sources

The uses of energy

- In our everyday lives, we use energy for a wide variety of purposes to:
    - power machinery
    - drive vehicles
    - cook and heat our homes
    - use appliances
    - generate electricity

Sources of energy

- Before the modern era, people used to burn wood or peat to release energy
- Nowadays we:
    - burn coal, gas and oil
    - generate nuclear power
    - increasingly use renewable technologies, like hydro, bioenergy, wind turbines and solar power
- Some of this energy is converted into electricity to power our everyday lives
- But electricity is only one part of our energy provision: we use most of our energy directly – for example, by burning petrol in cars or cooking with gas

Energy supply needs to be reliable and continuous to avoid disruption

Impact of political and economic disruption

- In 2000, lorry drivers protested against higher fuel prices by blockading fuel depots, causing nationwide petrol shortages and long queues at petrol stations
- In 1973, an oil embargo, imposed by the Organisation of Arab Petroleum Exporting Countries (Oapec) on countries supportive of Israel during that year's Arab-Israeli war, led to mass fuel shortages in the UK and a quadrupling of the oil price
- Between 1 January and 7 March 1974, Britain adopted a three-day working week during a miners' strike, severely limiting electricity generation

Impact of power failures

- In August 2019, nearly a million people across England and Wales were left without power. The National Grid called it an "incredibly rare event" involving the disconnection of two power stations. Train passengers were stranded, traffic lights failed to work and thousands of homes were plunged into darkness
- In July 2019, an electrical failure in Manhattan left 73,000 people without power for three hours
- In June 2019, a power failure hit Argentina and Uruguay – reportedly at a hydroelectric plant on the border – and left tens of millions of people without power. It took 12 hours to restore most of the supply

Energy supply has to be safe

Dangerous accidents and effects

Coal

- There has been a series of coal mining accidents in the UK, the worst being at Senghenydd colliery, south Wales in 1913, when 439 men and boys died

Air pollution

- According to a report by the Health Effects Institute, an estimated 1.2 million people died across India in 2017 as a result of air pollution, caused largely by energy use by industry, vehicles, and the burning of crop residues, rubbish and solid fuel like wood and coal

Gas

- In Scotland's worst gas explosion, 22 people were killed in East Renfrewshire in 1971
- 141 gas leak incidents occurred in the UK between 2010 and 2016

Chernobyl's nuclear power plant in February 2019

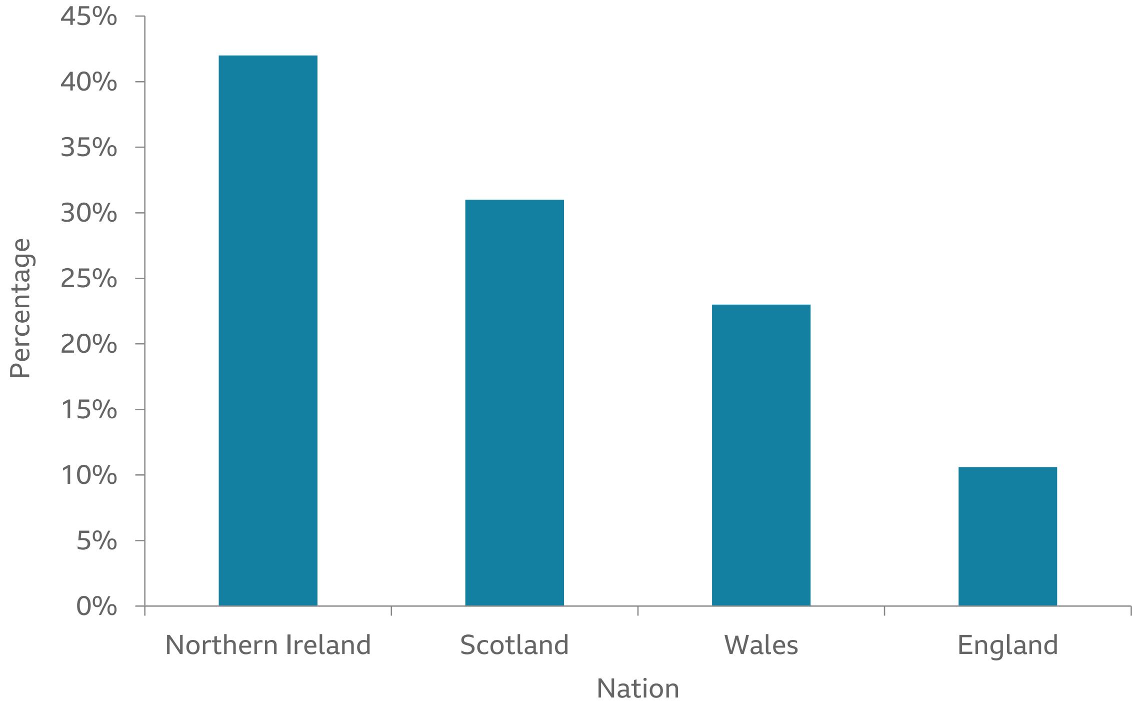
Nuclear radiation

- In Fukushima, Japan, in 2011, a tsunami triggered a meltdown in three reactors in the world's worst nuclear accident since Chernobyl in 1986. At least 160,000 people were evacuated from their homes. In 2018 the government confirmed one death from radiation exposure

Health Effects Institute (2019) State of Global Air 2019 pg.11

Energy needs to be affordable: Many households in Britain cannot afford their heating bills

Percentage of households in fuel poverty by nation in the UK



Fuel poverty

- In England, a household is considered fuel poor if it has fuel costs above average, and which leave it with a residual income below the official poverty line
- In Scotland, Wales and Northern Ireland, a household is considered to be fuel poor if 10% or more of its income needs to be spent on fuel to maintain adequate warmth
- The average UK household spends 5% of its income on energy including road fuel, while the poorest 20% of households spend 10% of their income on energy
- The most effective way to save on home heating is to ensure homes are better insulated

The CCC (March 2017) Energy Prices and Bills

The UK's energy goals are now also driven by the scientific consensus on climate change

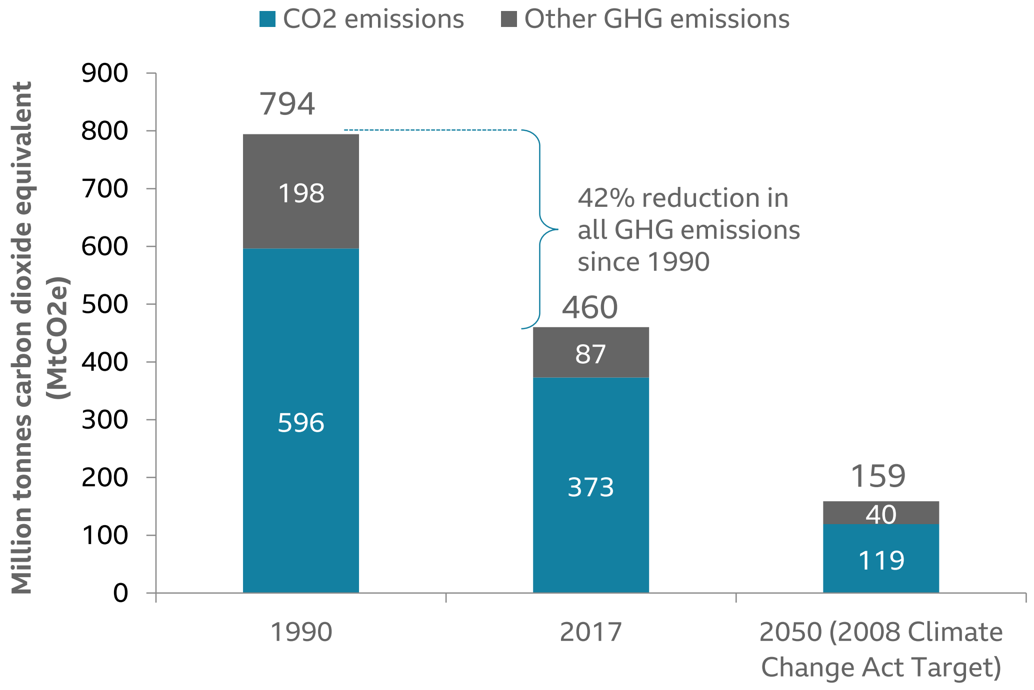
The issue of climate change

- Almost all scientists agree that the data shows the earth is warming, and that the larger part of the increase is because of human activity
- They identify a significant increase in the amount of greenhouse gases emitted by human activity as the cause of rising temperatures
- The main greenhouse gases are: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur fluorides and water vapour
- Scientists predict that if the increase continues, it is likely to have a devastating effect on many parts of the planet, including rising sea levels and more extreme weather events
- The scientific consensus has forced the majority of governments, including the UK's, to agree international treaties and policies to limit global warming – mainly by reducing their use of energy sources which produce greenhouse gases, and to adapt to the inevitable heating to come


BBC

In 2008, the UK government passed the Climate Change Act requiring major reductions in greenhouse gas emissions

Greenhouse gas commitment in 2008 Climate Change Act



UK emissions reductions since 1990 and the 2008 Climate Change Act

- In 2008, the UK passed the Climate Change Act, requiring all greenhouse gas emissions, which keep the planet warmer on average, to be reduced by 80% compared with 1990 levels by 2050
- This target was in line with the international protocols agreed in Kyoto in 1997 and Doha in 2012, and was aimed at keeping global temperature rises to less than 2C above pre-industrial levels
- The UK has already cut its total annual territorial GHG emissions by 42% since 1990
- CO_2 made up 81% of all UK GHG emissions in 2017

BEIS (March 2019)

Pressure for a more ambitious 'net-zero' emissions target has culminated in the Climate Change Act amendment of June 2019

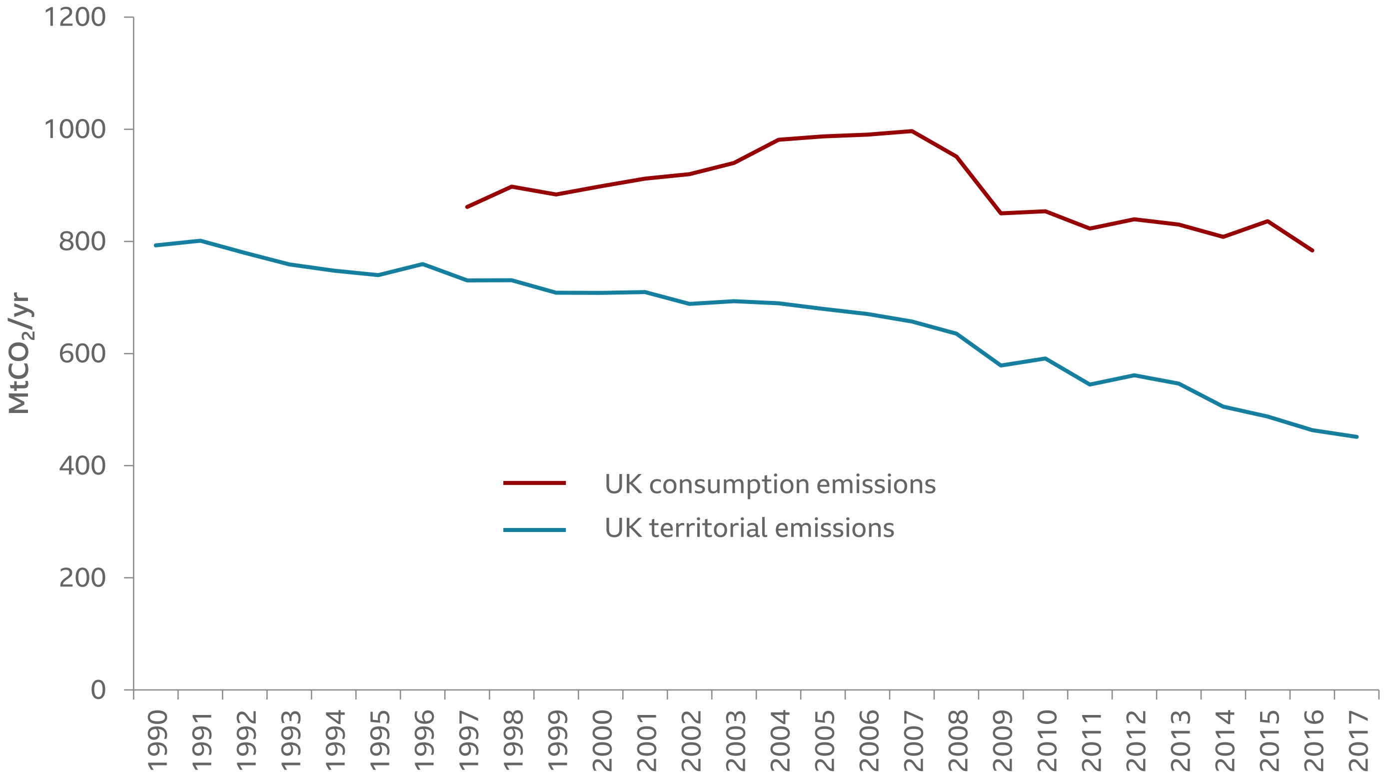
Date	Event	Outcomes
2015	The Paris Agreement	• 195 country signatories agreed actively to pursue efforts to limit rises in global temperature to no more than 1.5C above pre-industrial levels
2018	The Katowice Conference Agreement	• The UK, along with 195 other countries, agreed a "rulebook" to specify how governments will measure, report on and verify their emissions reduction efforts
April 2019	Extinction Rebellion Protests	• Activists launched 11 days of disruption, occupying five central London sites and calling for the government to declare a "climate emergency" and commit to net zero by 2025
May 2019	Climate emergency motion passed	• A non-binding motion declaring a "climate emergency", following the lead of Scottish, Welsh and many local governments, was passed by the House of Commons
May 2019	Committee on Climate Change Net Zero report	• The Committee on Climate Change (CCC), set up in 2008 to advise the government, published a report recommending the adoption of a net-zero emissions target by 2050
June 2019	Government committed to net zero by 2050	• The UK government introduced a statutory instrument in Parliament, to amend the 2008 Climate Change Act, committing to a net-zero 2050 emissions target

Meeting the net-zero target by 2050 requires a huge reduction in annual CO_2 emissions

<u>Emissions reduction targets</u>

- The government has yet to set out detailed interim targets for greenhouse gas emissions based on the net-zero scenario, but the Committee on Climate Change suggests cutting annual CO_2 emissions by around 93% from 1990 levels – which is 13% more than the requirement in the 2008 Climate Change Act
  - Most of the target can only be reached by producing energy via non-carbon means
  - Extra CO_2 will have to be captured or extracted from the atmosphere ("engineered removals") to:
    - counteract residual CO_2 emissions which might be expensive or impossible to eliminate, such as from international aviation
    - compensate for remaining emissions of non-CO_2 greenhouse gases - especially from farming - which are costly to eliminate
  - CO_2 extraction methods include planting trees (afforestation) and direct air capture
  - The government has not adopted all CCC recommendations, including that the target should include emissions from international aviation and shipping which refuel in the UK

The CCC argues that in reaching net zero, the UK must not increase emissions produced overseas on its behalf



Emission reduction targets

- Significant GHG emissions result from the production and transport of goods and services imported from overseas and consumed in the UK
- These "consumption emissions" are not counted in the figures used for the UK's carbon footprint and are higher than the "territorial emissions", on which our net-zero target is based
- The CCC says that in our effort to reach net-zero territorial emissions, we should ensure that consumption emissions do not increase
- Eliminating them is much more difficult, as they occur outside UK borders
- International agreements with other governments may be necessary

CCC 'Net Zero' report figure B3.3

Reaching net zero in the UK would have only a limited impact on global greenhouse gas emissions

Global leadership

- As the only member of the G20 group of major economies to have committed to net zero, the UK may have a head start in developing and exporting green energy technology
- Competition between countries may spur innovation and drive down the cost of renewable energy
  - *"Ambitious climate policies don't just help limit the worst consequences of climate change, they also offer chances for innovation and therefore growth and prosperity worldwide"* Angela Merkel, 2018
- Net-zero targets are now being considered in France and Germany

Global responsibility

- The UK accounts for only about 1% of global greenhouse gas emissions
- The United States, which produces 15% of global emissions, has withdrawn from the Paris Agreement
  - *"I cannot in good conscience support a deal that punishes the United States — which is what it does -– the world's leader in environmental protection, while imposing no meaningful obligations on the world's leading polluters"* Donald Trump, June 2017
- Other major emitters, including China and India, have seen their CO_2 emissions continue to grow, by 4.7% and 6.3% respectively in 2018, although both have policies to restrict emissions growth

CCC 'Net Zero' report figure B3.3
https://www.globalcarbonproject.org/carbonbudget/

Summary

What do we want from our Energy System?

The UK's energy policy has long been built around the four goals of security, reliability, safety and affordability.

But now a fifth goal – energy which is environmentally sustainable – has assumed critical importance, and has prompted a major reconsideration of how the UK's future energy needs will be met.

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Part 2/9

The UK's Current Energy System

How does the UK use energy today? Are we using more or less energy to travel and for heat, light and industry?

How does energy use vary across the day, week and season?

Where do we get our energy from and how much do we spend on it?

And how do we compare with other countries?

Energy and power are measured differently, but both are important to understanding the energy system

Units of power and energy

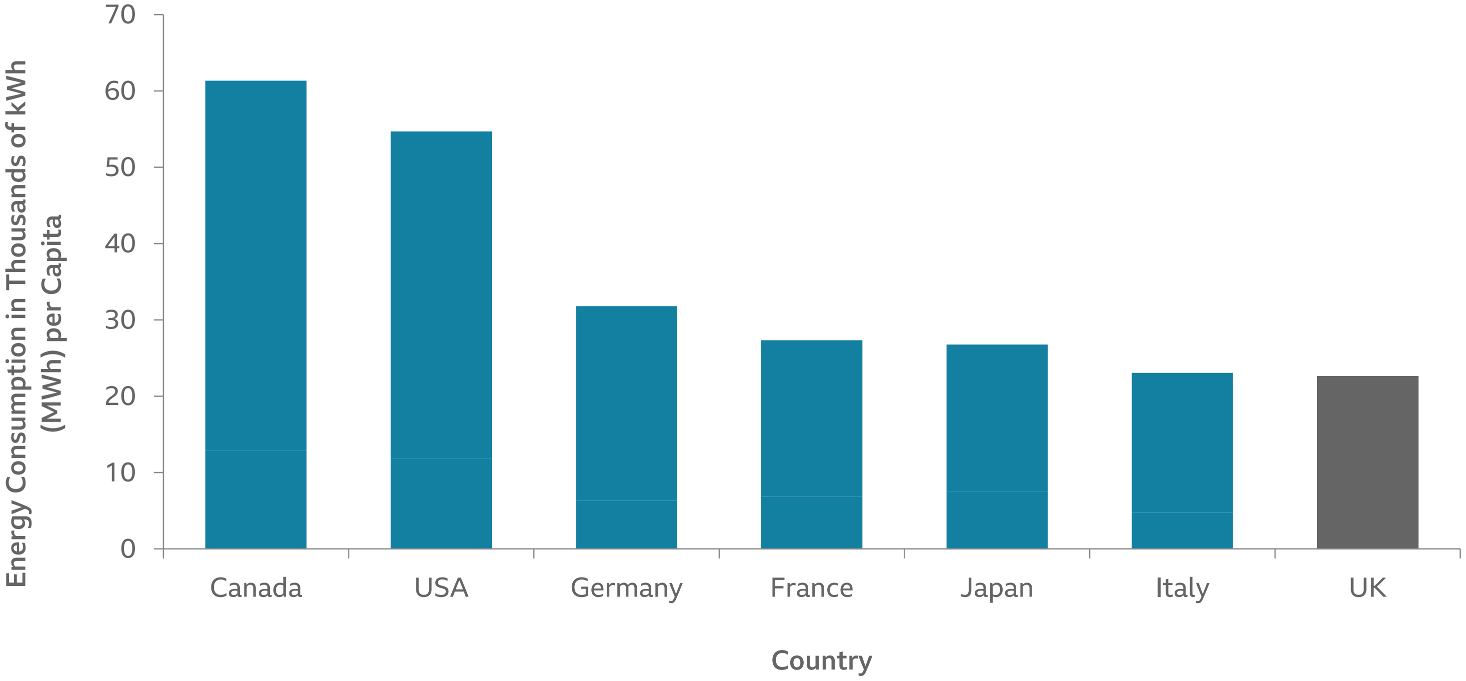
- **Energy**, **power** and **electricity** are often used interchangeably, but are different metrics for describing the "energy" system
- **Power** is the rate at which energy is generated or used. It is measured in watts (W) or - for larger figures - in kilowatts, megawatts, gigawatts etc.
- **Energy** is the power multiplied by the time period, and is typically expressed as kilowatt-hours (kWh)
- Both measures are important for understanding the energy system:
  - Measuring power at any given moment is essential for keeping the demands on the energy system within its capacity, so that the required rate of usage is not greater than the rate at which power is being delivered
  - Measuring total energy is useful to help quantify total usage, in order to manage energy use over a time period, for example to calculate a household energy bill

Typical uses of energy and power measures

Power (kW)	Energy (kWh)
Power plant capacity	Household bills
Household appliance energy consumption	Annual energy usage for the UK
Peak energy consumption at a given time	Battery storage

The UK consumes less total energy per person than other major industrialised nations

Energy consumption in the G7 countries per capita

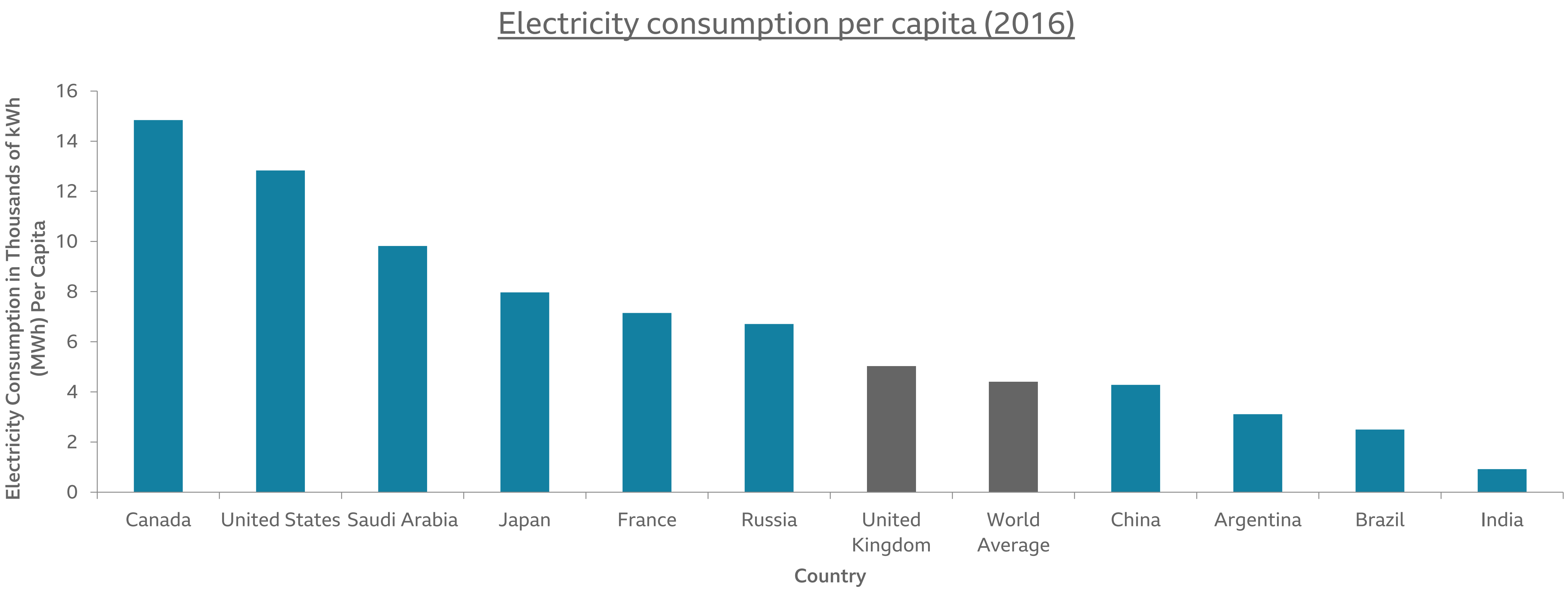


Why the UK uses less energy

- It has a temperate climate
- It has experienced more de-industrialisation than others in the last four decades
- The cost of energy for industry and consumer energy prices in the UK are higher than in many other countries in the Organisation for Economic Co-operation and Development (OECD), because energy is not as heavily subsidised, and this tends to reduce usage

IEA (2018) TPES by Source for World CIA World Factbook

UK electricity use per person is below many other major economies



IEA (2018) Electricity Consumption

Climate helps explain national differences in electricity usage

Canada

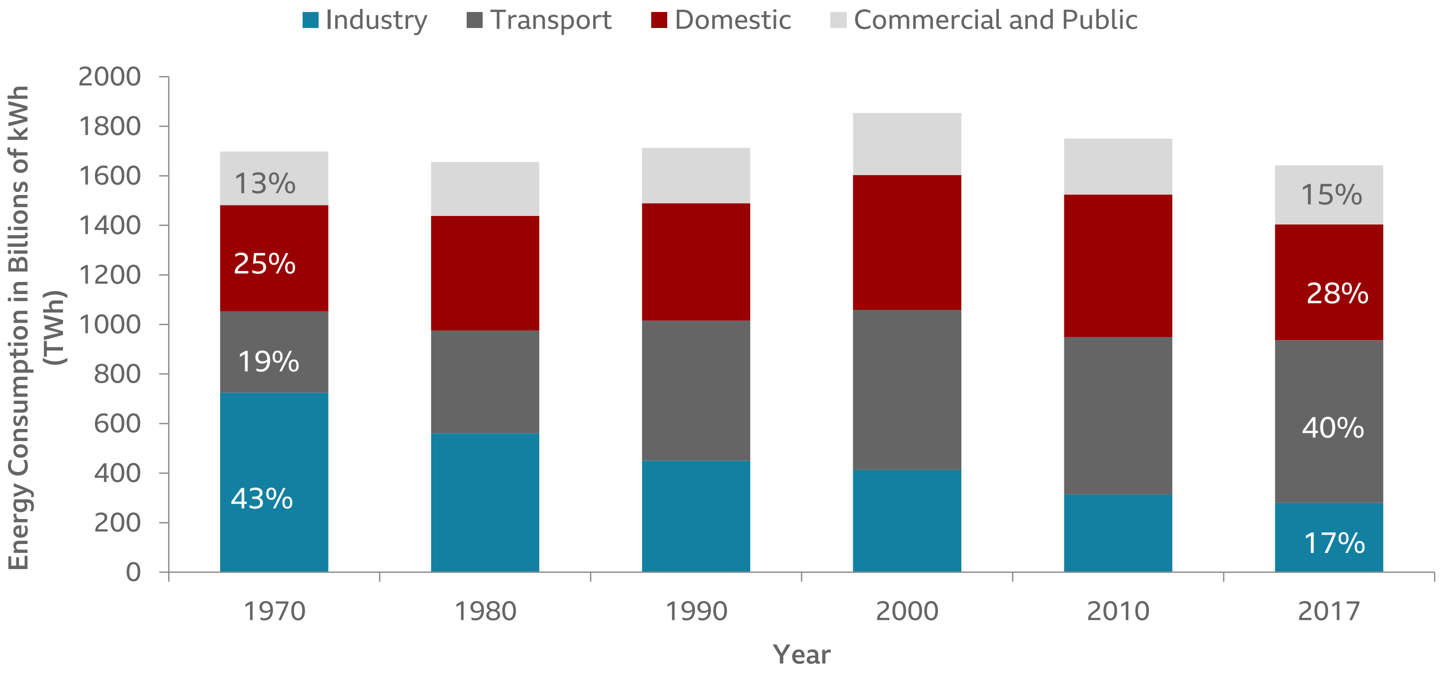
- Canada has some of the coldest regions on the planet
- Its GDP per capita is four times the world average, and its economy uses energy 60% less efficiently than the world average
- Canada has the third largest hydrocarbon reserves in the world
- Electricity prices are about half those in the UK

Saudi Arabia

- Temperatures in Saudi Arabia can reach highs of 39C between June and August, and 47C under certain wind conditions
- GDP per capita is twice the world average, and its economy is 20% more energy intensive than the average
- Saudi Arabia has the second largest hydrocarbon reserves in the world
- Energy provision generally is highly subsidised, and electricity prices are a quarter of those in the UK

Overall energy use in the UK has declined since 2000

Energy consumption by sector in billions of kWh, 1970-2017



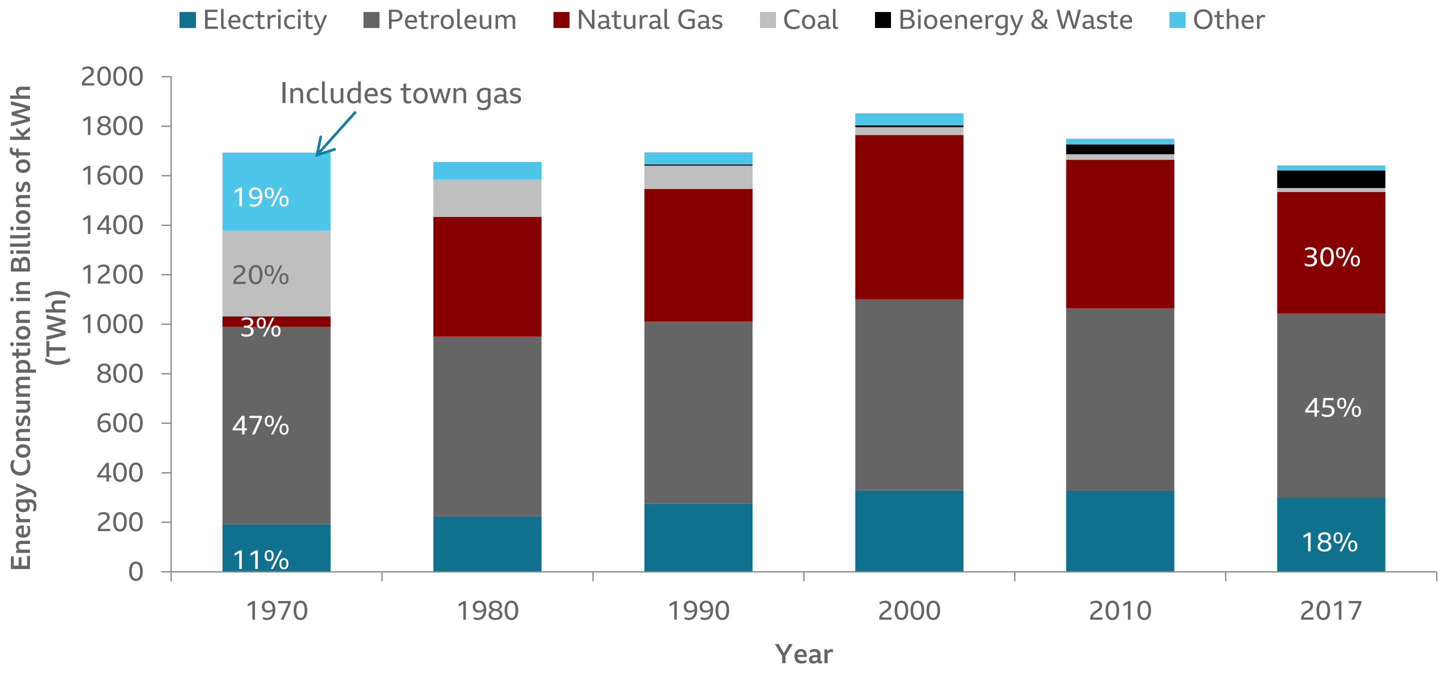
Factors in energy use declining

- Energy use in the UK has declined by over 11% since 2000
- The main factors are :
    - more efficient devices
    - better insulated homes
    - more efficient industrial processes
    - warmer winters
    - fewer car miles
    - slower growth in the UK economy
    - greater deindustrialisation

BEIS (July 2018) DUKES

Carbon-based fuels still provide the vast majority of the UK's energy input at the point of use

Energy supplied for consumption in billions of kWh, 1970-2017



How the UK produces energy at the point of use

- Domestic and industrial use of coal is now negligible
- Natural gas has gone from the least used energy source in 1970 to the second most widely used – in particular for heating
- Petroleum is the largest source of direct energy use in the UK
- "Town gas" is released when coal is burned. Before natural gas started to become generally used in the 1970s, it was the main source of gas for heating and cooking

BEIS (July 2018) DUKES

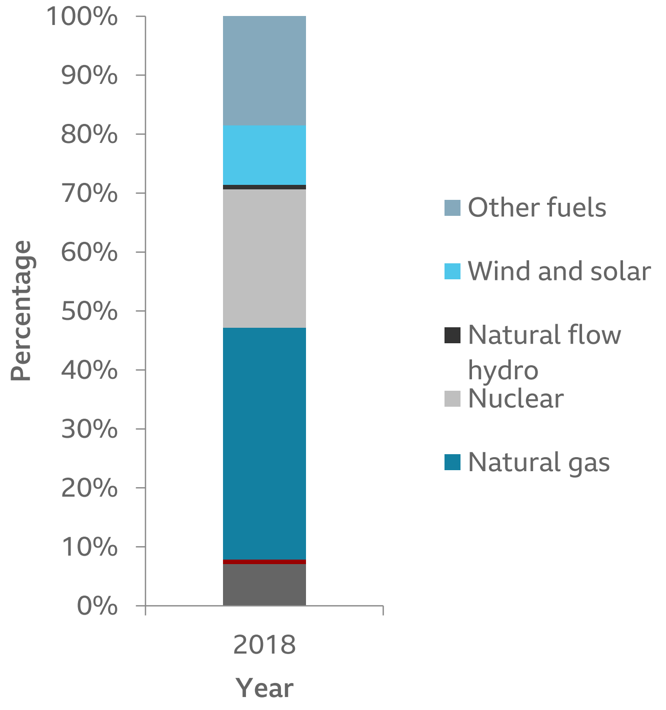
Natural gas has become a major source of energy worldwide

The rise of natural gas

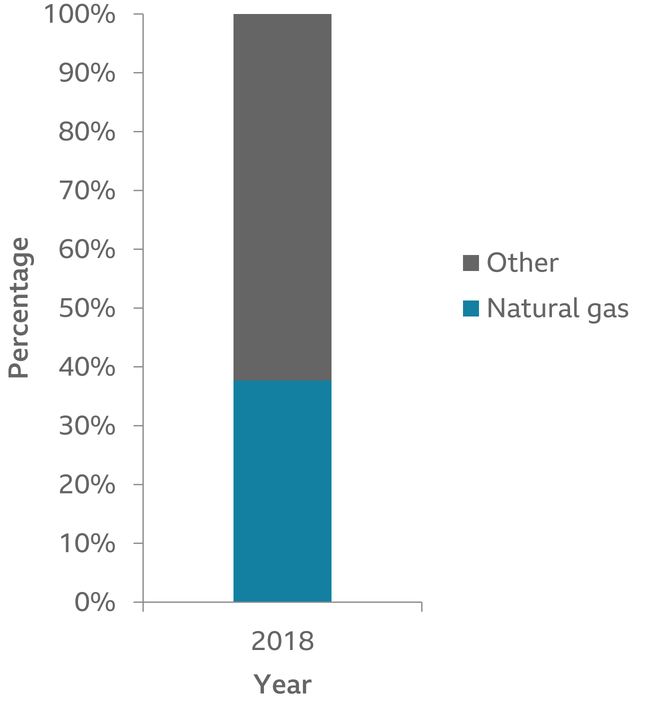
- Natural gas was originally seen as an inconvenient by-product of oil extraction and was often burnt off
- Following growing use in industry, and the discovery of major reserves in the North Sea in the 1960s, the UK converted its heating system to natural gas
- Natural gas was only used in power generation in Europe from 1990
- Now natural gas is used around the world and is transported in liquefied form by ship as well as by pipeline
- Natural Gas reserves are now developed for their own sake and new technologies such as the fracking of shale gas have increased supply in some countries (notably the US)

Natural gas is the UK's second biggest source of energy after petrol and diesel

Electricity generation by fuel type as % of total



Energy demand by fuel type as % of total



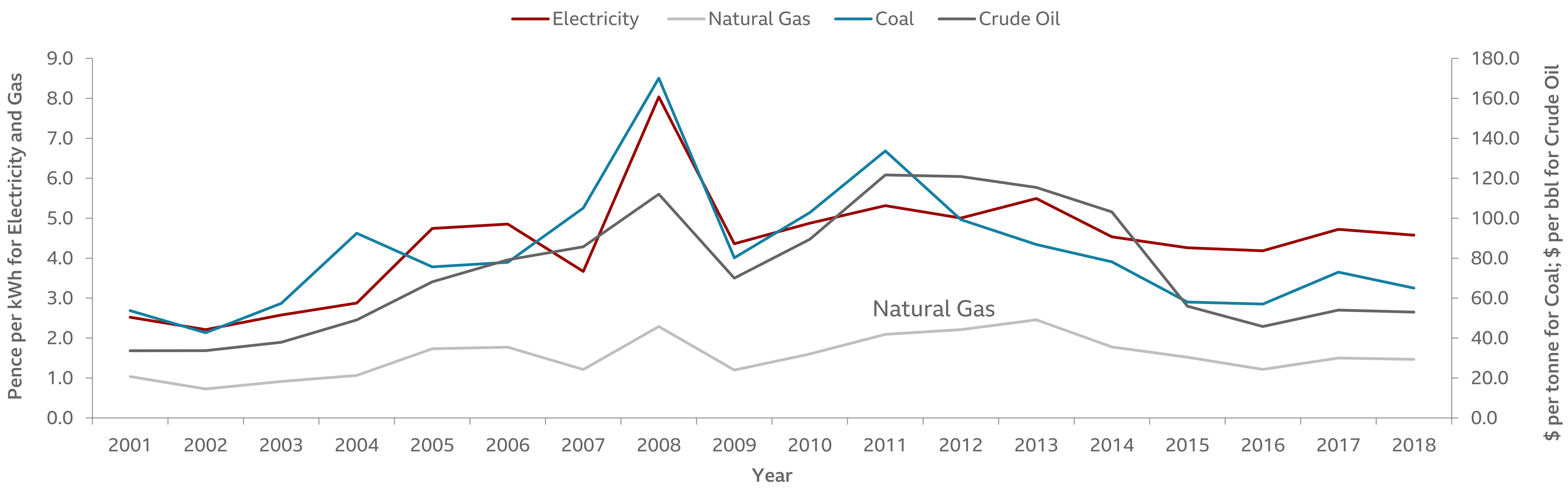
Natural gas

- Natural gas now accounts for 40% of electricity generation, from zero in 1990
- It also accounts for about 38% of the UK's energy demand
- It is a key source of heating and is used in industry

BEIS (July 2019) DUKES

The price of natural gas in the UK has been lower and more stable than other energy sources

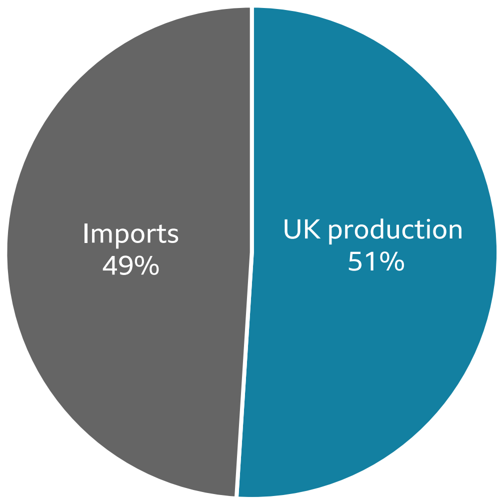
Wholesale energy prices 2001-2018



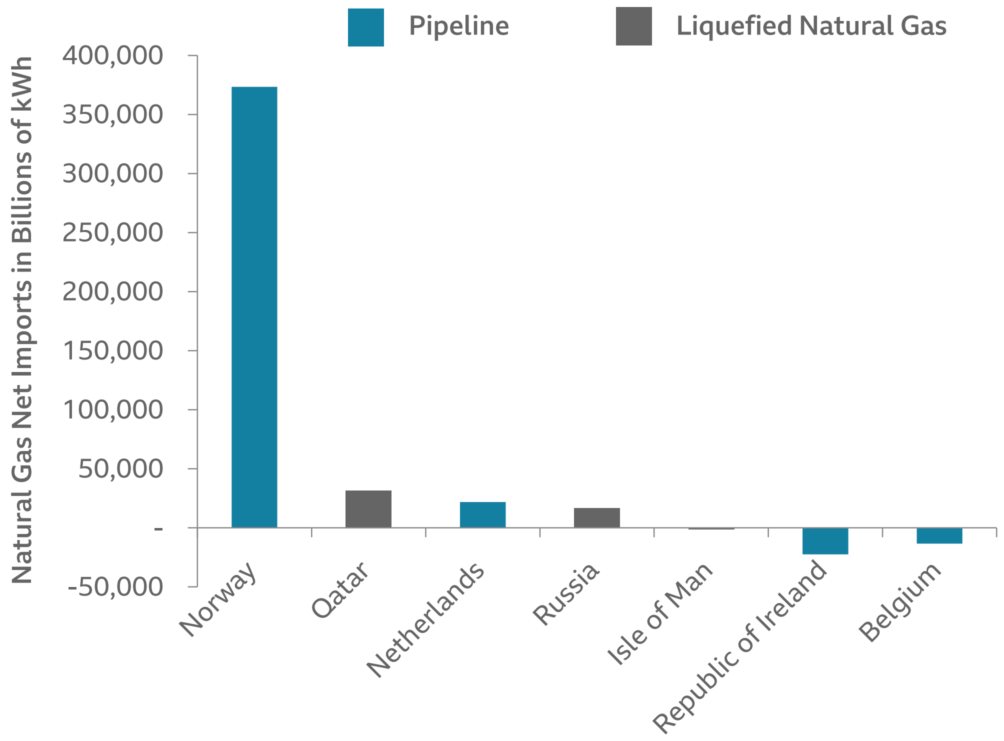
BEIS (January 2018) Updated Energy and Emissions Projections

With North Sea gas reserves depleting, the UK now imports almost half its natural gas

UK natural gas production and net imports, 2018



Natural gas net imports by country of origin, in billions of kWh 2018



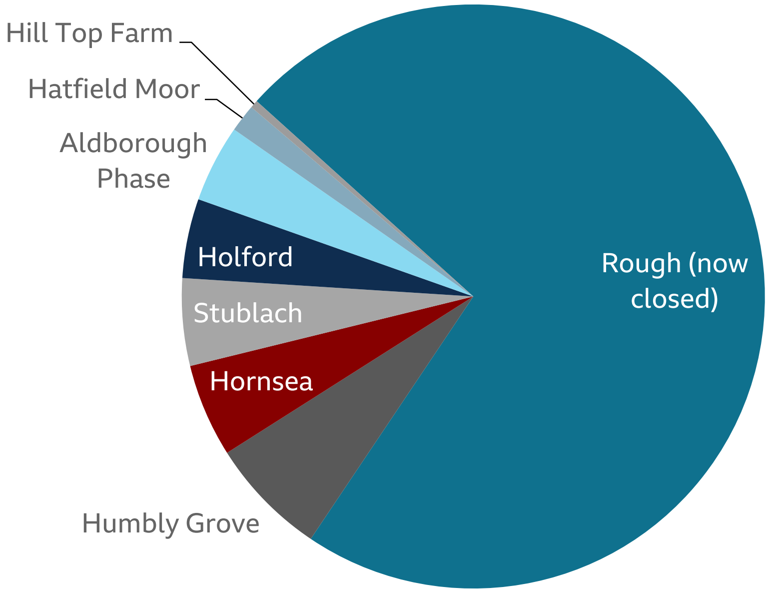
The UK and natural gas

- Almost all the UK's gas imports come from Norway and Qatar
- The UK exports to Belgium and the Republic of Ireland
- The UK's increased dependence on imported gas carries some supply risk
- Russia supplied 3.2% of the UK's imported gas in 2018

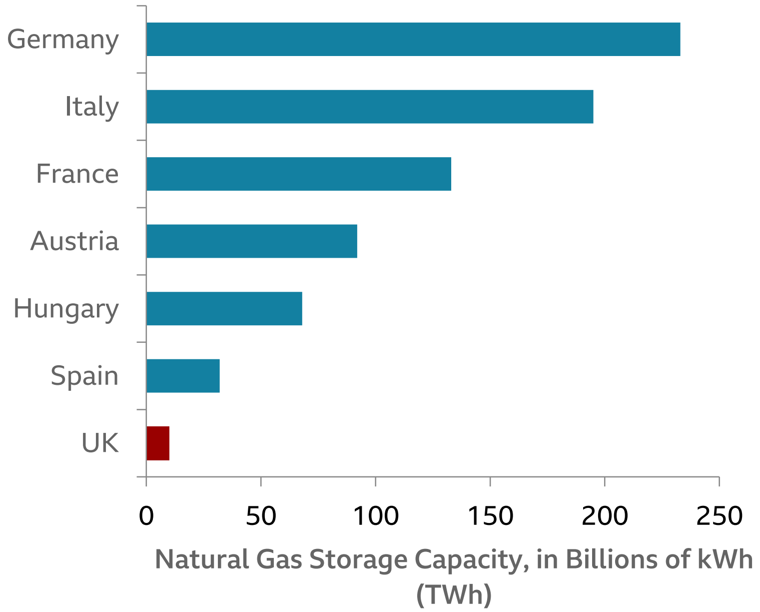
BEIS (July 2019) DUKES

The UK has limited gas storage compared with many EU countries

Natural gas storage sites in the UK, 2019



Natural gas storage capacity of European countries, in billions of kWh, 2019



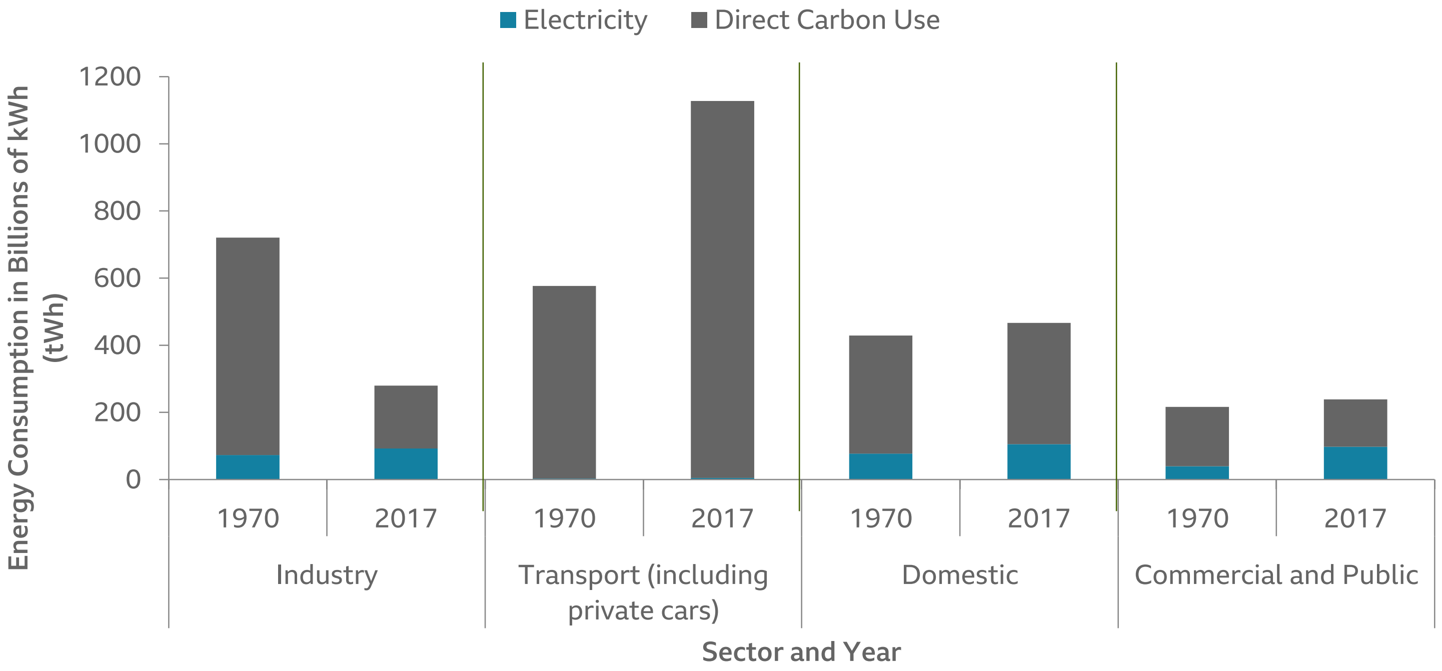
The UK's gas storage

- The Rough storage facility in the North Sea provided around two-thirds of UK gas storage capacity until its closure in 2017
- The facility was shut down as it was ageing, and the integrity of its undersea wells could not be maintained at reasonable cost
- Its closure significantly reduced the UK's domestic gas storage capacity, which is now just 16.5 billion kWh – the equivalent of 8 days' supply
- With limited gas storage, the UK depends heavily on constant supplies being reliably available (which it traditionally had from North Sea gas), and has not considered it worth spending money on more storage

BEIS (July 2019) DUKES
Ofgem (2019)
GIE (2019)

Transport is the most carbon-dependent sector

Energy consumption by sector and by fuel source in billions of kWh, 1970 and 2017 comparison



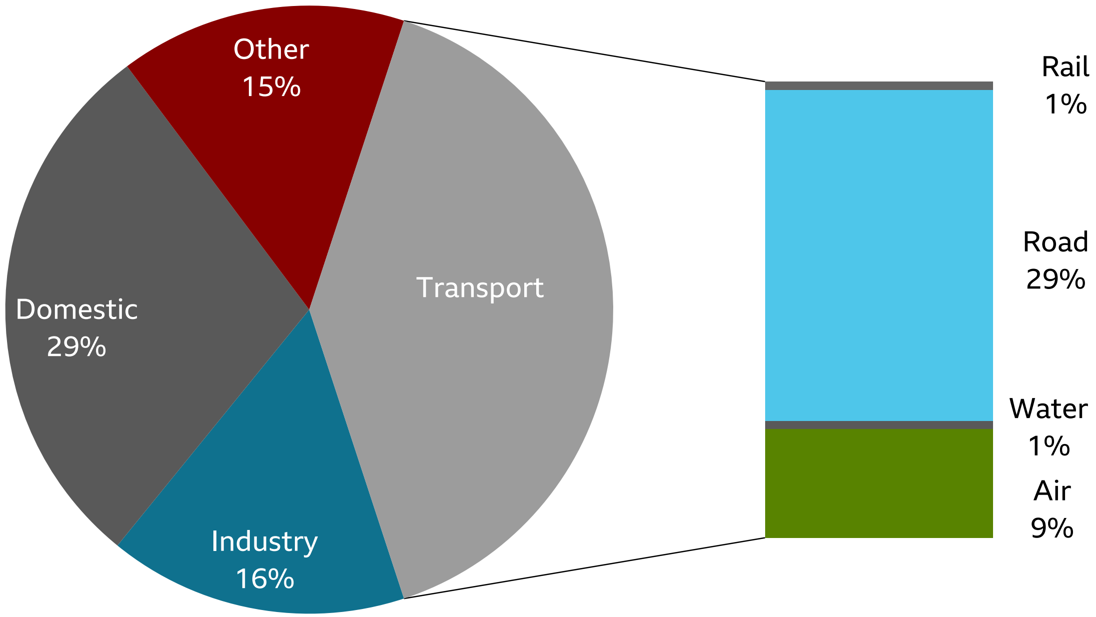
Energy use by sector

- Transport has almost doubled its energy use since 1970
- Transport is almost entirely reliant on direct carbon fuel use
- Industrial and domestic heating are also highly carbon-dependent pro rata
- The domestic sector is the next most direct carbon fuel-dependent after transport, largely due to the use of gas for heating
- Direct industrial use of carbons is now about 40% of the 1970 level

BEIS (July 2018) DUKES

Households account for more than a quarter of all UK energy consumption

Percentage of total energy consumption (1637.68 Billion kWh) by sector 2017



UK energy consumption

- Domestic use accounts for 29% of UK energy consumption
- This does not include the energy consumption by cars
- Transport accounts for the greatest use of energy

BEIS (July 2019) DUKES

Households consume much more gas and petrol than electricity

Household energy use by activity in billions of kWh (TWh)

Activity	Electricity	Gas / Oil / Other Fuel	% of Total Energy Consumption
Lighting	100%	-	3%
Cleaning and Washing	100%	-	4%
TV and Computers	100%	-	1%
Refrigeration	100%	-	3%
Cooking	50%	50%	3%
Heating and Cooling	5%	95%	38%
Car and Light Vehicle Use	2%	98%	48%
TOTAL	**15%**	**85%**	**100%**

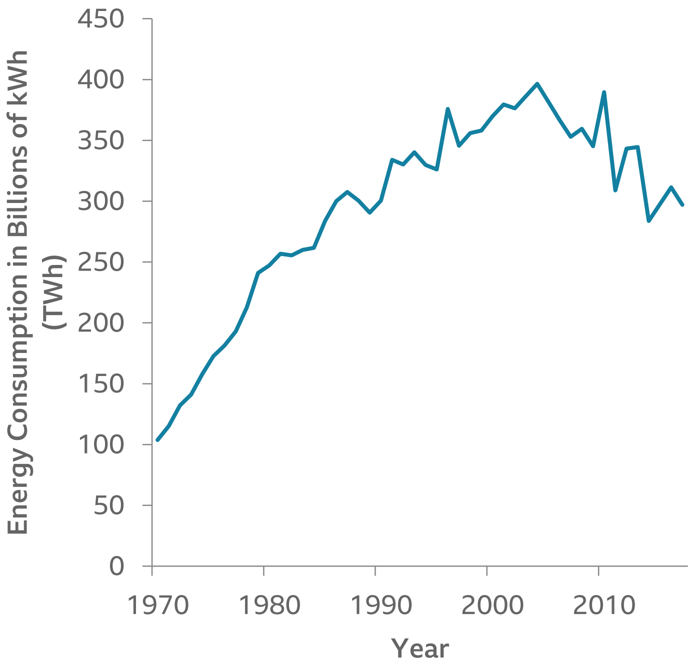
UK Household Energy Survey (2012)

Household energy

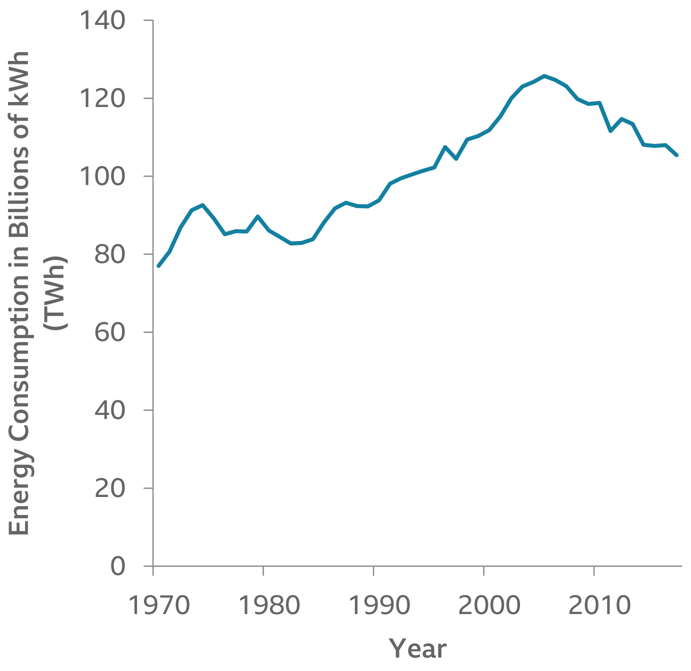
- Electricity provides only 15% of household energy
- Gas, petrol and other carbon fuels supply the rest

Domestic energy use has fallen over the last decade, largely due to increased energy efficiency

Domestic energy consumption of natural gas 1970-2017



Domestic energy consumption of electricity 1970-2017



Natural gas

- Domestic demand for natural gas has been falling because of:
  - more efficient boilers
  - better-insulated homes
  - warmer winters

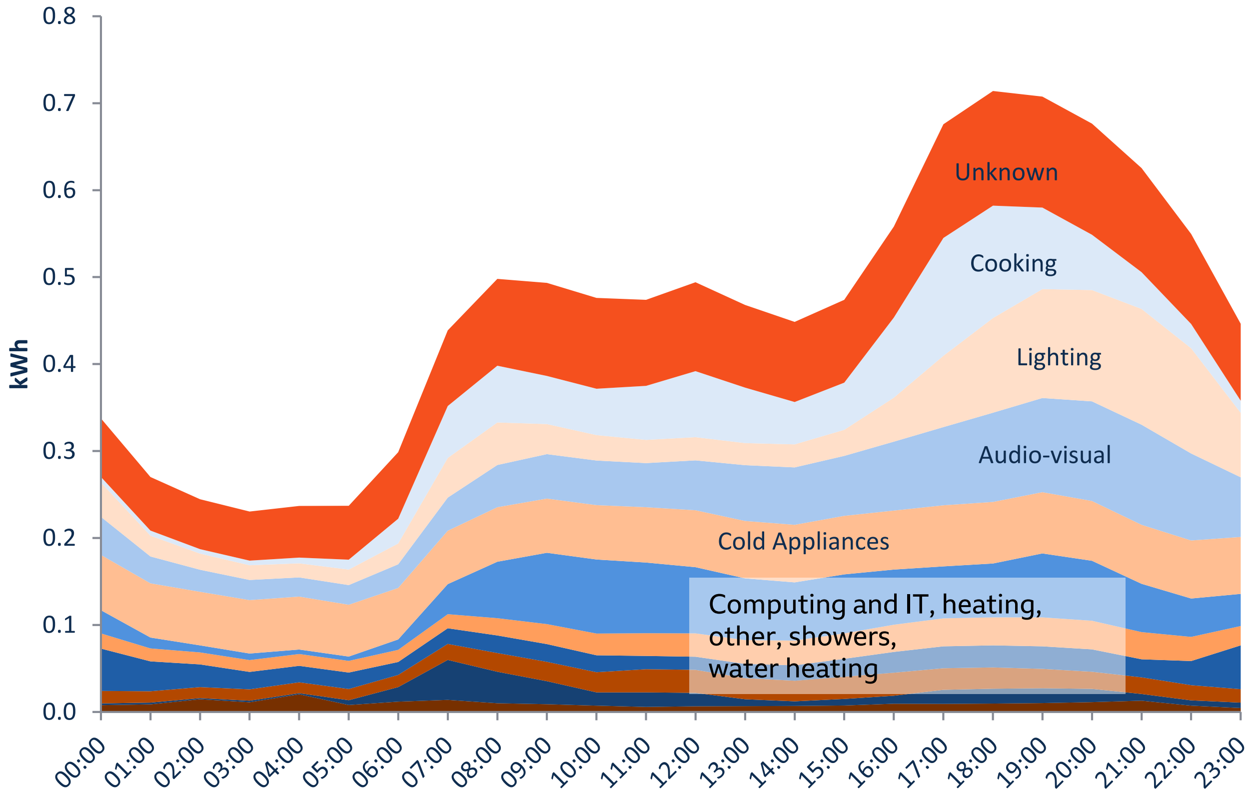
Electricity

- Domestic demand for electricity has been falling because of:
  - more efficient appliances
  - energy-efficient lighting
  - reduced growth in appliance take-up

BEIS (July 2018) DUKES

Household electricity consumption peaks in the early evening and is lowest during the night

UK household typical daily electricity consumption profile



Fluctuations in household electricity consumption

- Peak demand for electricity is about four times greater than night-time demand
- Electricity consumption increases rapidly in the morning as people wake up, shower and begin to use appliances
- Many people are out during the day, which keeps consumption steady
- Electricity consumption peaks in the evening when most people are at home cooking, using lights, and when TV viewing is at its height
- Major national events, such as a Wimbledon final, can cause sharp drops and increases in demand

BEIS (2016) Energy Consumption in the UK

Energy demand for heating is highly variable

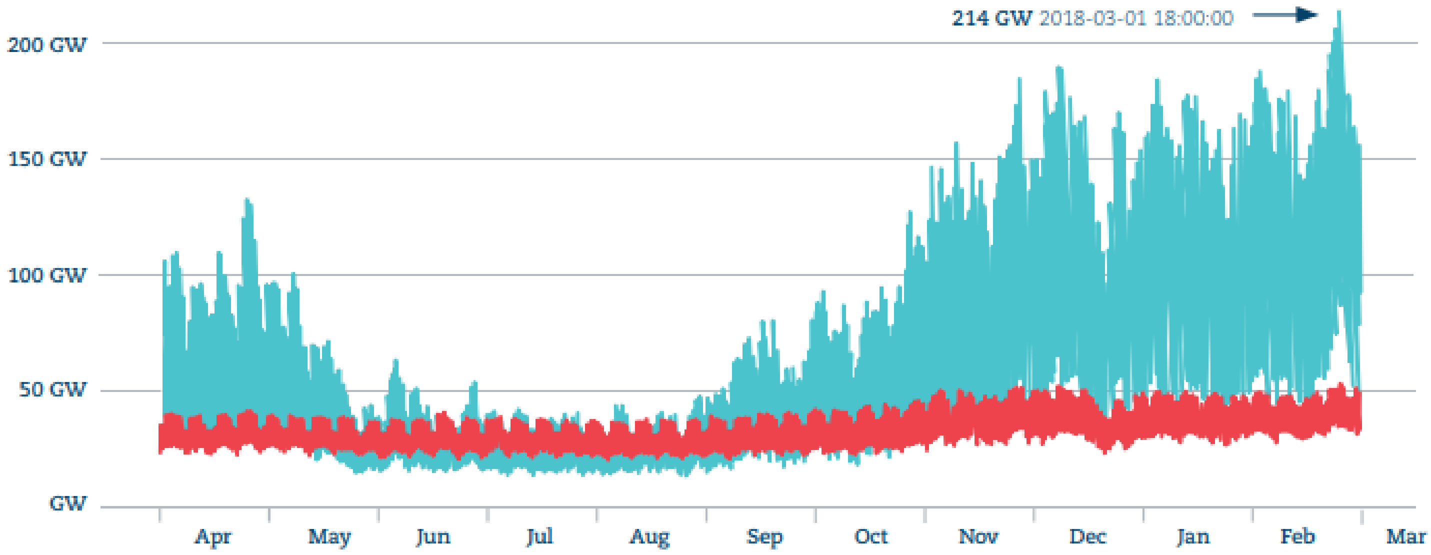
Demand for heating and electricity

- Heating demand varies greatly, depending both on the season and on daily temperature variations
- Heating demand is highest in the morning when people wake up, and the early evening when they return from work
- Domestic heating contributes upwards of 12% of UK greenhouse gas emissions
- Electricity supplies only 10% of total UK heating demand
- At its winter peak, demand for (mostly gas) heating can be six times higher than the summer low

The challenges of decarbonising space and water heating, Dr Robert Samson, Imperial College (2015)

Cold snaps prompt a significant increase in gas demand

Britain's hourly local gas demand and electrical system supply 2 April 2017 - 6 March 2018



Gas- local distribution zone demand   Electricity- supply

The Beast from the East

- The cold and wintry snap known as the Beast from the East in early 2018, led to the highest gas consumption of the 2017-18 heating season

The challenges of decarbonising space and water heating, Dr Robert Samson, Imperial College (2015)

Variations in demand can be managed both by price incentives and by home storage

Peak and non-peak tariffs

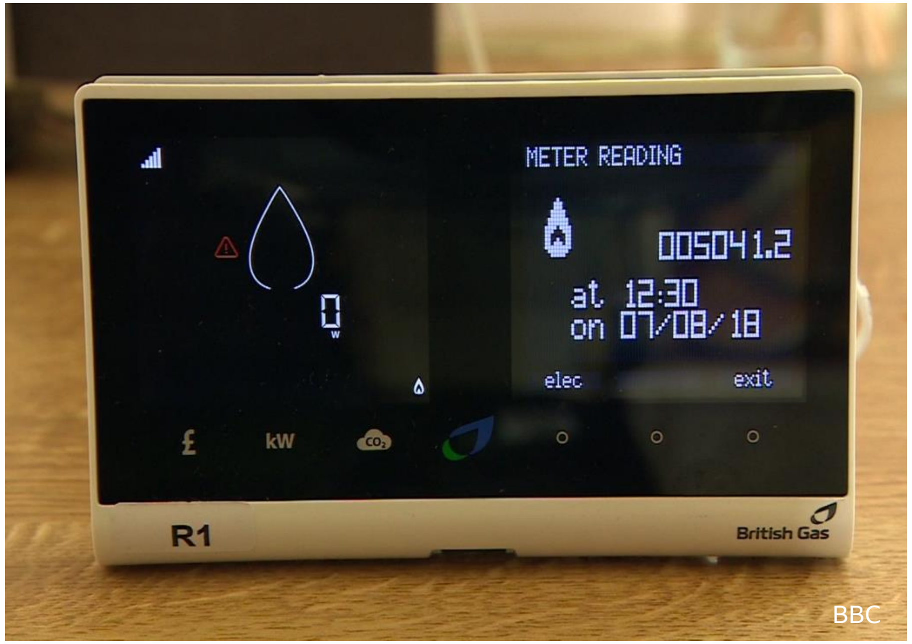
- Most electricity retailers offer customers different prices for energy at peak and at non-peak times
- The introduction of smart meters to measure electricity use could facilitate the rollout of a wider range of tariffs by time of day and device

Hot water tanks and storage heaters

- Lagged hot water tanks and night storage heaters can allow customers to draw cheaper energy at non-peak times to be used at peak times
- However, both options are only suitable for managing short-term variations in demand

Smart homes

- Digital technology offers firms and households the opportunity to use smart appliances more efficiently, to turn on washing machines when electricity is cheap and plentiful, or turn off freezers for a few minutes when demand spikes



Every UK home is supposed to have a smart meter fitted by the end of 2020

The UK's electricity grid is the system for distributing electricity

How the national electricity grid works

- Large-scale sources of electricity generation are connected to the grid
- It transports electricity along high voltage powerlines from where local companies distribute it to homes and businesses
- 98% of UK homes are covered by the electricity grid
- There has been a rapid increase in recent years in small generators connected to local grids

The evolution of the national grid

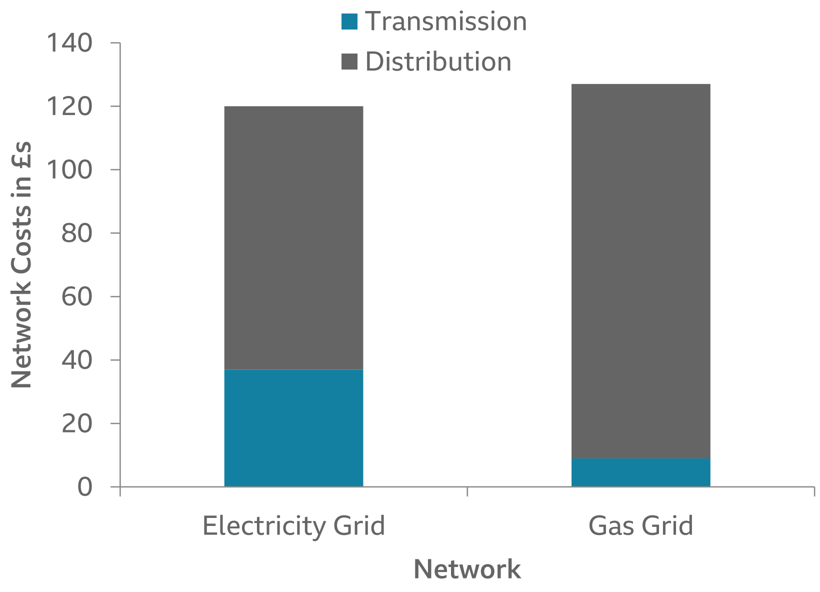
- It was nationalised in 1947, but then privatised in 1990
- It is operated in England and Wales by National Grid, a public limited company listed on the stock exchange FTSE 100
- The Scottish grid is owned by two companies (SP Transmission and SHE Transmission)
- The local distribution grid is owned by a variety of different companies
- The UK has more than 25,000km of high voltage lines


BBC

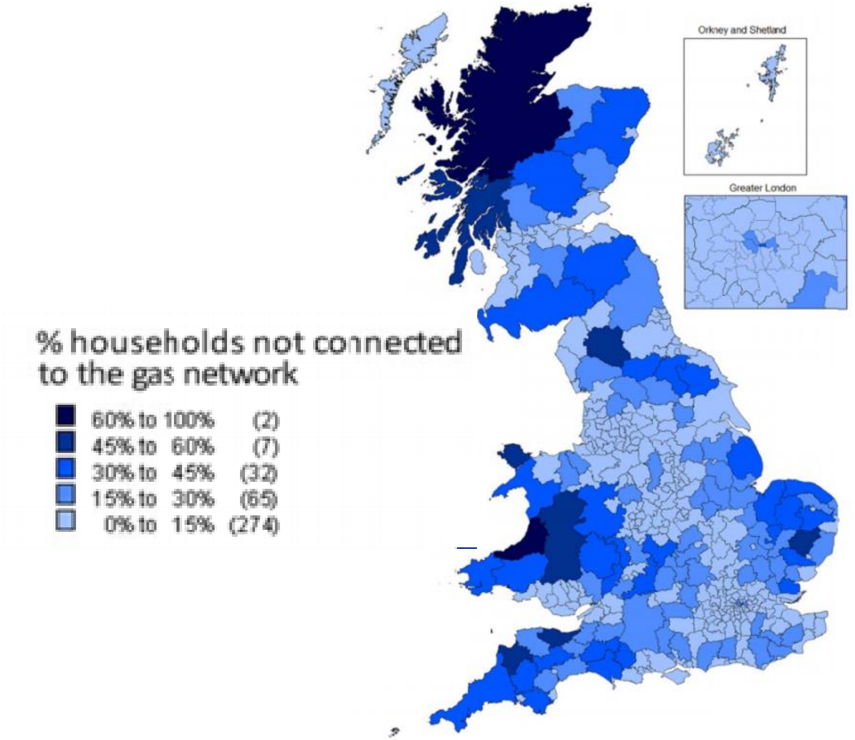
The gas grid does not reach as many homes as the electricity grid

Estimated annual network costs per domestic customer in pounds December 2018

- Currently, 85% of homes are connected to the gas grid



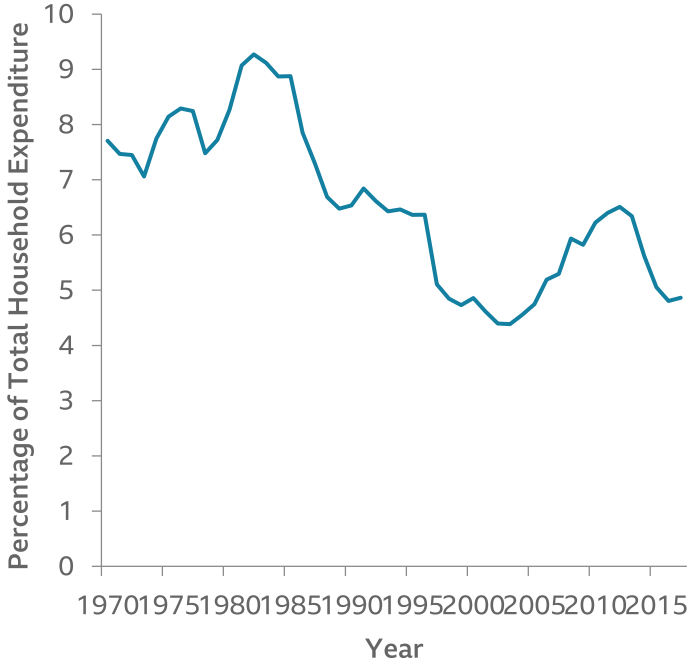
The UK gas grid



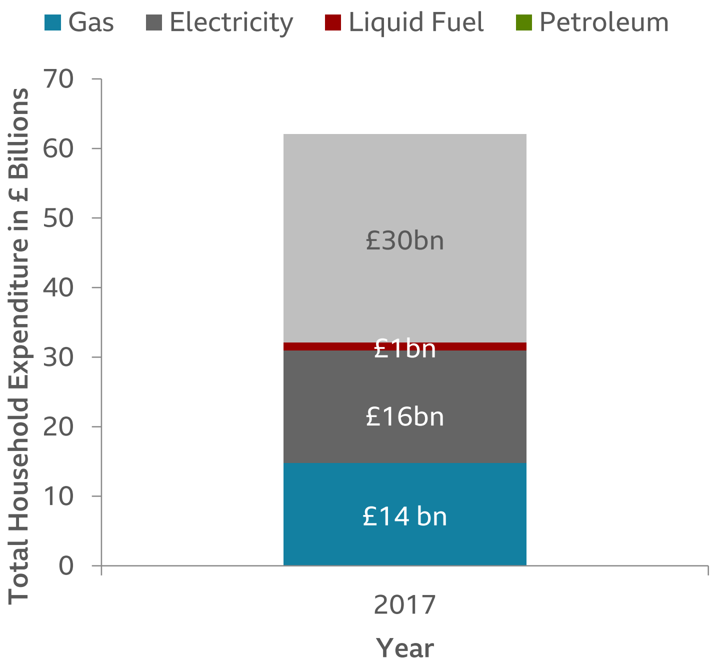
[NEED Analysis (December 2013)]
[OFGEM (March 2019) Estimated network costs]

UK households spend proportionately less on energy than in 1970

Energy spend as % total household



Total household energy spend in £bns by energy source



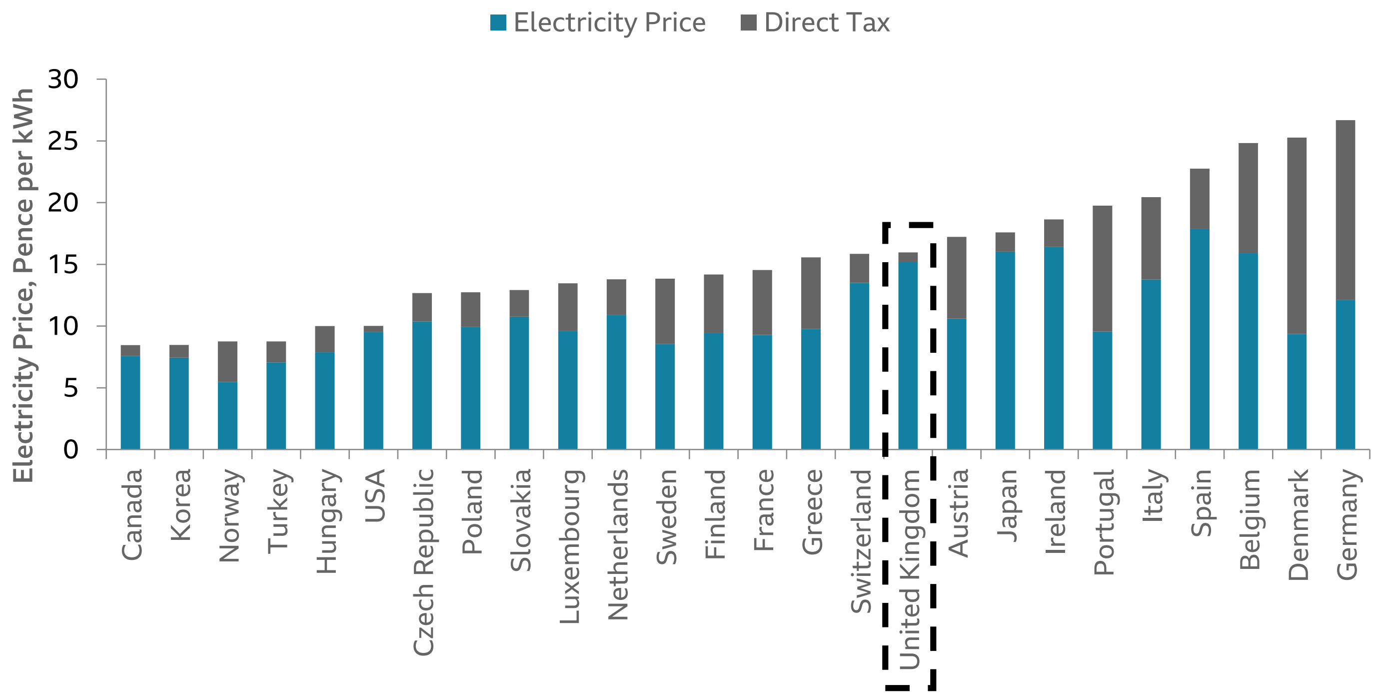
Household expenditure on energy

- On average, we spend:
  - 2.4% of our income on gas and electricity
  - 2.3% on petrol or diesel for transport
- As a proportion of overall household expenditure, the money we spend on energy has almost halved since 1970

BEIS (December 2018) Annual Domestic Energy Bills

UK domestic customers pay average electricity prices for a developed nation

Domestic electricity price in developed nations in pence per kWh 2017



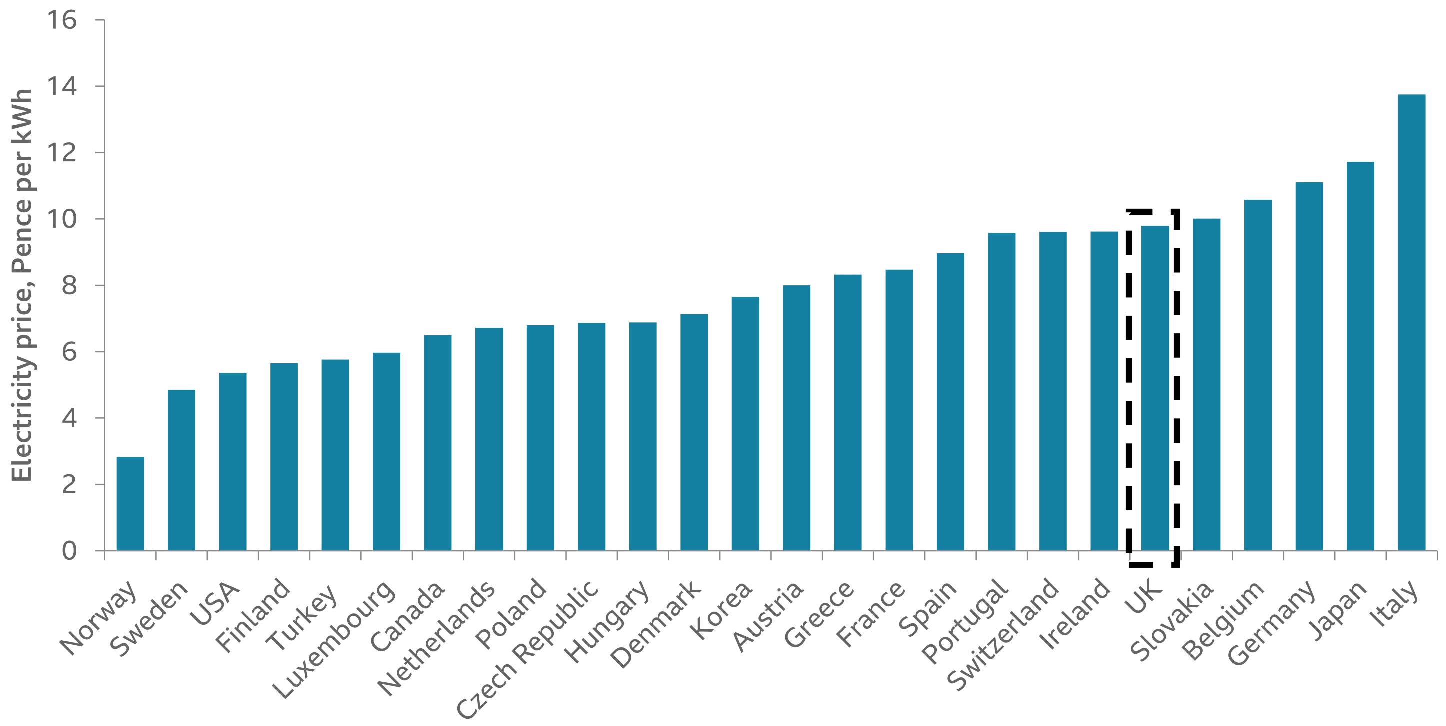
BEIS (December 2018) International Domestic Energy Prices

Domestic electricity pricing

- The domestic unit price is made up of direct taxes and the underlying price of electricity (wholesale and transmission charges)
- Direct taxes vary from country to country
- In the UK, direct taxes on electricity are among the lowest in the world
- But the underlying cost in the UK is higher than elsewhere, partly because its limited interconnection with the European market makes it harder to import electricity from cheaper providers
- So, ranked against other developed economies, domestic UK customers pay relatively average electricity prices

UK industry pays higher electricity prices than many other developed economies

Industrial electricity price by industrialised nation in pence per kWh 2017



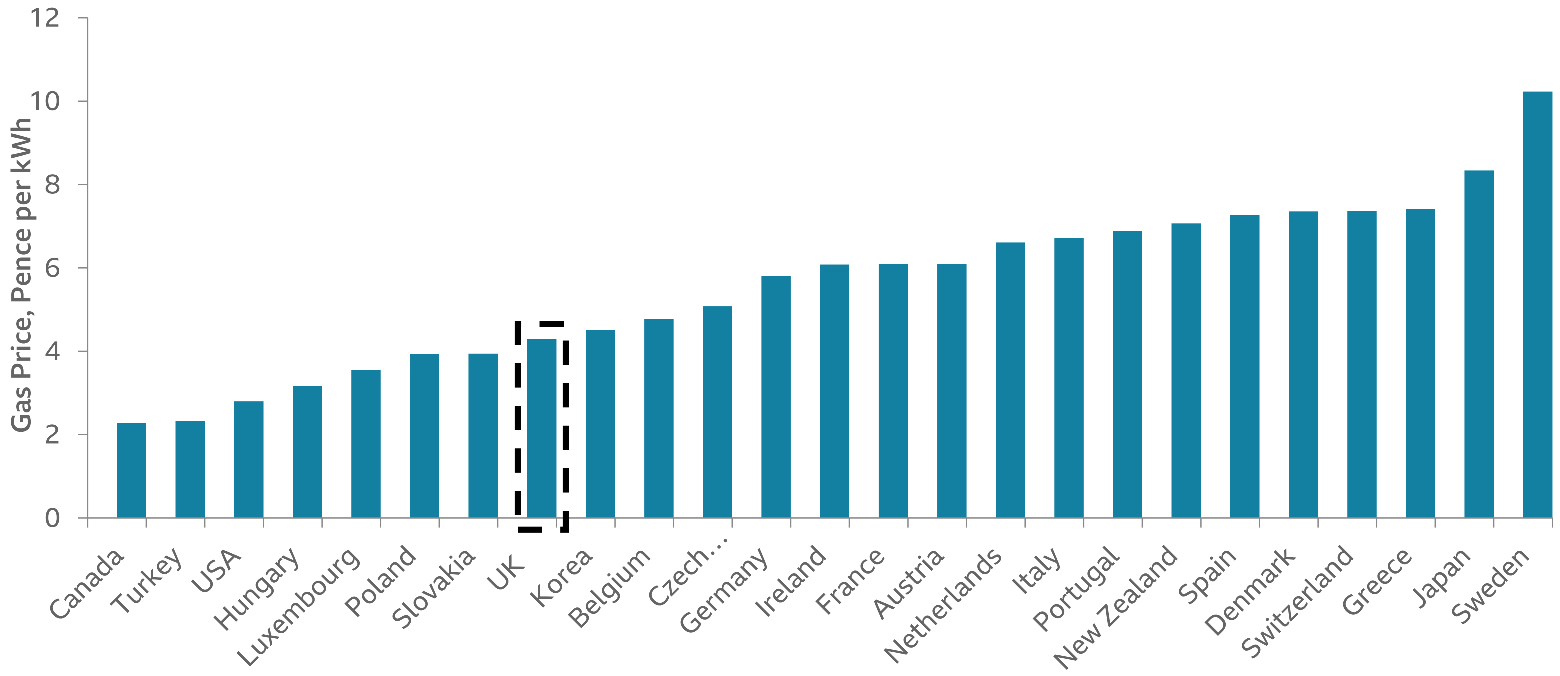
Industrial electricity pricing

- The UK has among the highest industrial electricity unit prices of any developed nation
- The higher prices reflect the costs passed to industry through government legislation e.g. to fund renewables and energy efficiency
- In other countries, these costs are more heavily subsidised
- The high industrial electricity unit price may reduce the competitiveness of UK industry

BEIS (December 2018) International Industrial Energy Prices

The UK retail price of domestic gas is quite low compared with other countries

Domestic gas prices including tax in industrialised nations 2017



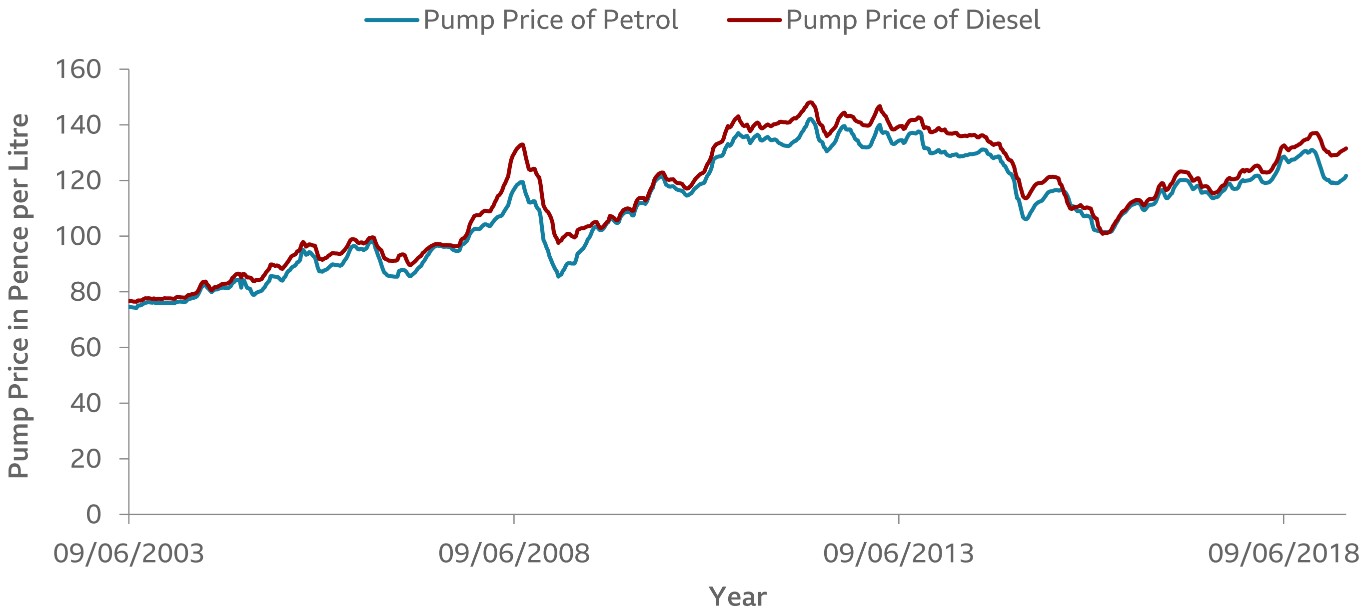
UK domestic gas price

- The price of domestic gas in the UK is relatively low because:
  - it still produces a lot of its own gas
  - the gas it imports goes through pipelines instead of being shipped as Liquefied Natural Gas (LNG), which is more expensive
  - the UK has lower VAT rates than other countries
  - it has a competitive domestic gas market

BEIS (December 2018) Domestic Gas Prices

The pump price of both petrol and diesel has increased by around 50% over the past 15 years

Weekly pump price of petrol and diesel in pence per litre July 2003-April 2019



Petrol and diesel prices

- In May 2018, petrol rose by 6p a litre, the biggest increase in a month since 2000
- At the time, the RAC attributed the rise to higher crude oil prices and a weaker pound
- World events also affect fuel prices at the pump. In 2018 the re-imposition of sanctions on Iran pushed global oil prices up by 3% in May
- In the UK, duty on petrol and diesel continued to rise until 2011
- Taxes and duties account for about two-thirds of pump prices

BEIS (April 2019) Weekly Road Fuel Prices
https://www.bbc.co.uk/news/business-44361016

Summary

The UK's Current Energy System

Overall, the amount of energy people use in the UK has been falling since 2000. In the last decade, domestic gas and electricity consumption has declined, and industry has experienced a sharp drop. Conversely, transport has seen a rise.

Natural gas has become the UK’s second biggest energy source after petrol or diesel, and is the country’s leading source of energy for heating and generating electricity.

Pricing of consumer electricity is average by global standards but prices for UK industry are high.

Approximately one-fifth of our energy needs are met by electricity, but four-fifths of energy consumed is carbon-fuelled.

Part 3/9

The UK's Energy Challenge

In order to meet its emissions targets over the next 30 years, the UK must change from an over-reliance on carbon fuels to near carbon-free energy generation.

What will this transformation mean for individuals, business and government?

"Energy efficiency is the first fuel of a sustainable global energy system"

International Energy Agency

"Our kingdom in 2050 will no longer make any contribution whatsoever to the destruction of our precious planet, brought about by carbon emissions, because we will have led the world in delivering that net-zero target"

Boris Johnson (UK Prime Minister)

July 2019

Coal has powered two industrial revolutions in Britain, and was critical to its economic success as a nation

First industrial revolution

(18th-19th Century)

- In 1712, Thomas Newcomen's original and highly inefficient steam engine was developed to pump water from coal mines
- The process made coal extraction more effective
- In the 19th Century, James Watt's improved steam engine, fuelled by coal, transformed UK manufacturing

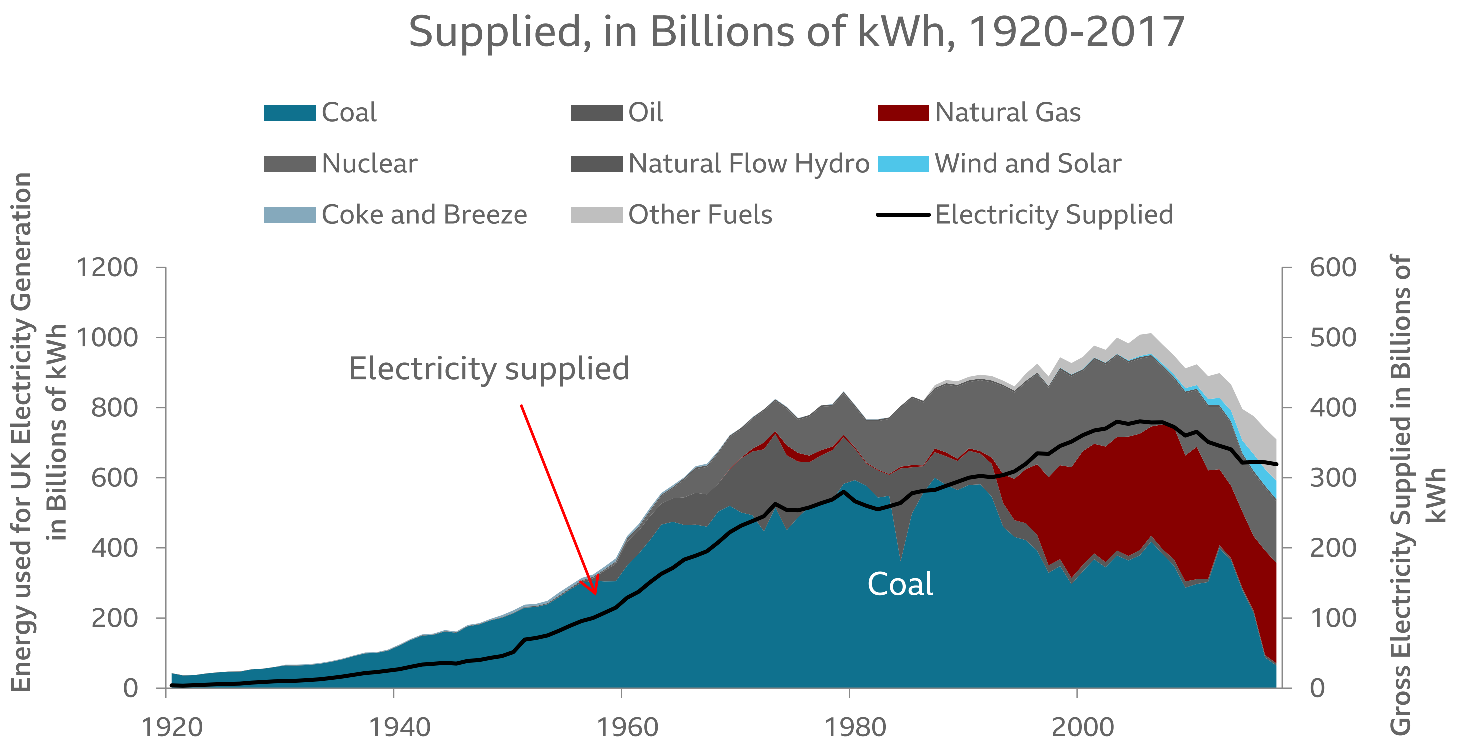
Second industrial revolution

(late 19th – early 20th Century)

- In the late 18th and early 19th Century, the invention of the steam turbine and the advances in electricity by Faraday, Edison and others led to the development of centralised power generation based on coal
- This brought widespread use of electricity from the late 19th Century

The use of coal to generate electricity will be phased out by 2025

Energy used for electricity production and gross supply in the UK



Use of coal in the UK

- The UK coal mining industry has largely closed down
- The last coal-fired power station is due to shut in 2025
- Until that point, small quantities of coal will be imported from Colombia, Russia and the United States

BEIS (January 2013) Historical Electricity Data

The last deep coal mine in the UK closed in 2015, ending a key chapter of the nation's social and industrial history

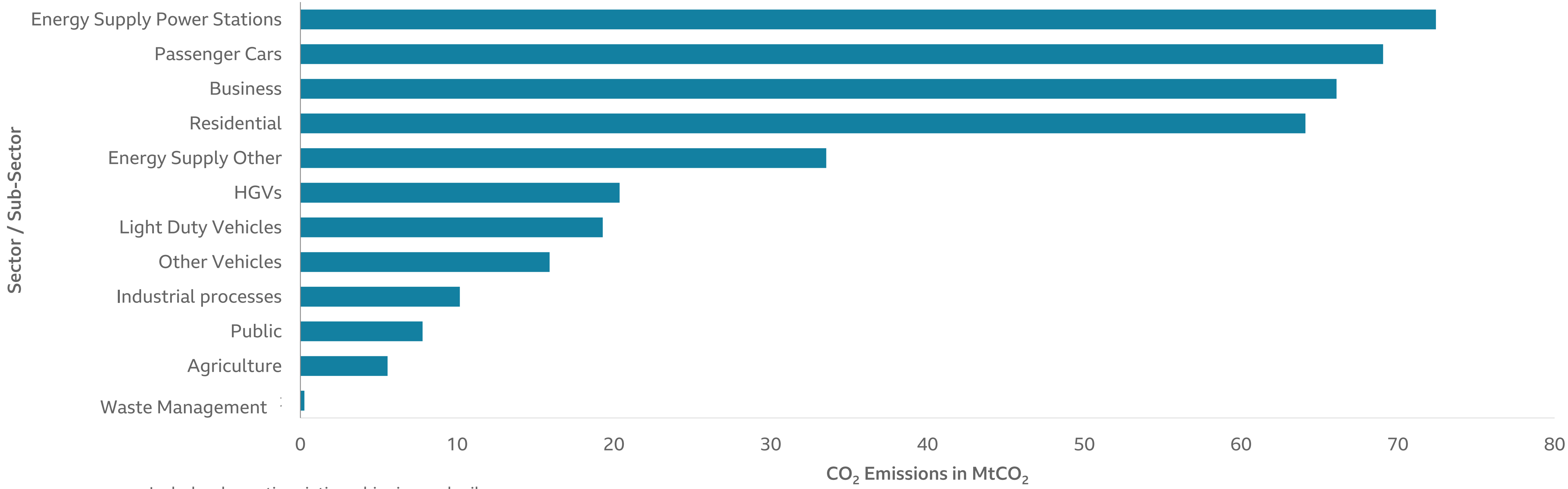
Electricity generation from coal

- Until the 1980s coal provided more than half of the UK's power generation needs
- At its peak in 1913, UK coal production was 292m tonnes a year
- There were 3,024 deep mines in production at the time
- In 1920, British coal mining was employing 1.2m people
- Coal for electricity generation was at its highest in 1980
- 21 April 2017 was the first day since the Industrial Revolution when no power was produced from coal in the UK
- In March 2019, Cumbria County Council backed plans for Britain's first new deep coal mine in 30 years

BEIS (January 2013) Historical Coal Data

The UK's largest CO_2 emitters are power stations, cars and business

CO_2 emissions by sector and sub-sector in 2016

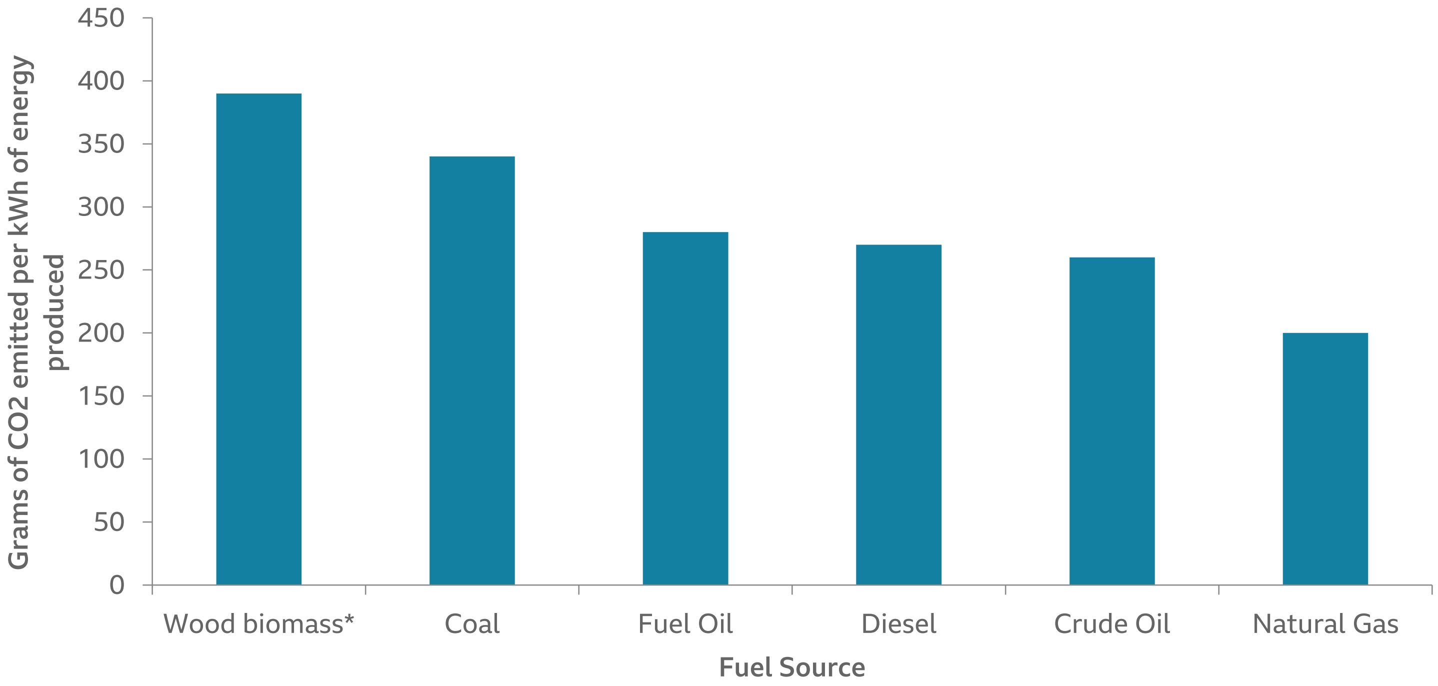


*Includes domestic aviation, shipping and railways

BEIS (March 2018) Final UK Greenhouse Gas Emissions

Carbon-based fuels vary significantly in the amount of CO_2 they emit while producing energy

Grams of CO_2 emitted per kWh of energy produced by fuel source



*Wood biomass is not sustainable without matching reforestation

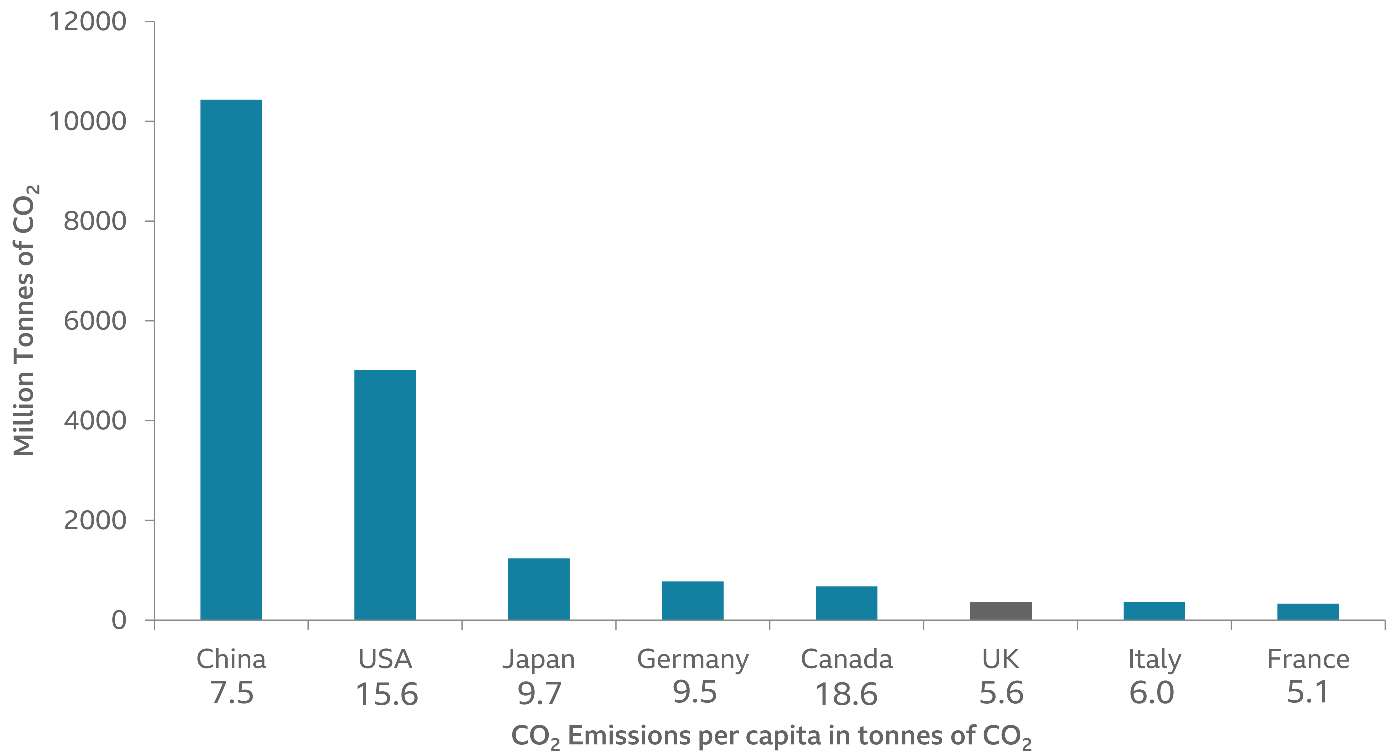
EIA (June 2019) Carbon Dioxide
Dr Volker Quaschning (June 2015)

Why fuel sources vary

- CO_2 emissions depend on the efficiency of energy production for each fuel, and on their individual carbon content
- Different fuels yield very different energy outputs and CO_2 rates
- Burning wood emits the highest amount of CO_2 per unit of energy produced, natural gas the least

The UK has low per person CO_2 emissions compared with most developed countries

Tonnes of CO_2 emissions by country in 2016



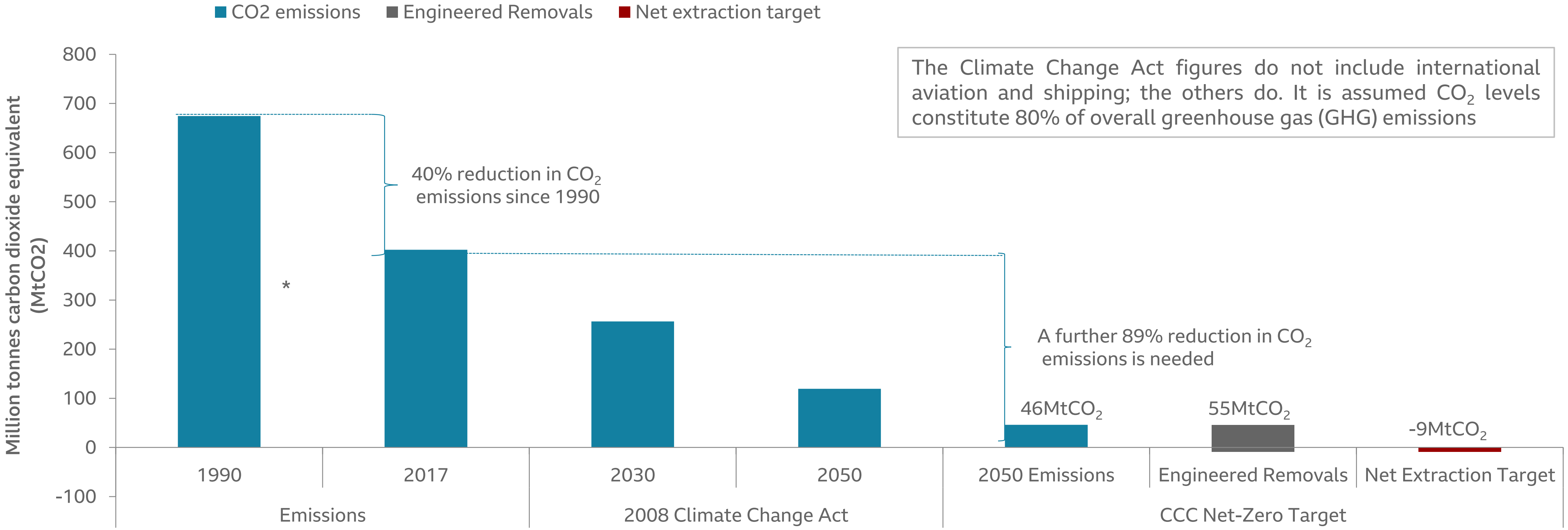
EDGAR (October 2017)

CO_2 emissions per capita rankings

- Canada has one of the highest levels of CO_2 emissions per capita - more than 18 tonnes in 2016. But with a small population, its overall levels are low
- By contrast, despite a high level of CO_2 emissions as a country, China produces a mid-range level of CO_2 emissions per capita - around eight tonnes in 2016
- Ranked alongside other major economies, the UK is one of the lowest carbon emitters - around six tonnes of CO_2 emitted per capita in 2016
- But the emissions produced in manufacturing many of Britain's imported goods are attributed to the producing countries

To reach net zero by 2050, the UK has to cut CO_2 emissions by 89% and find ways to remove the rest

UK CO_2 emissions in 1990 and 2017, the previous 2008 Climate Change Act, and the net-zero target for 2050

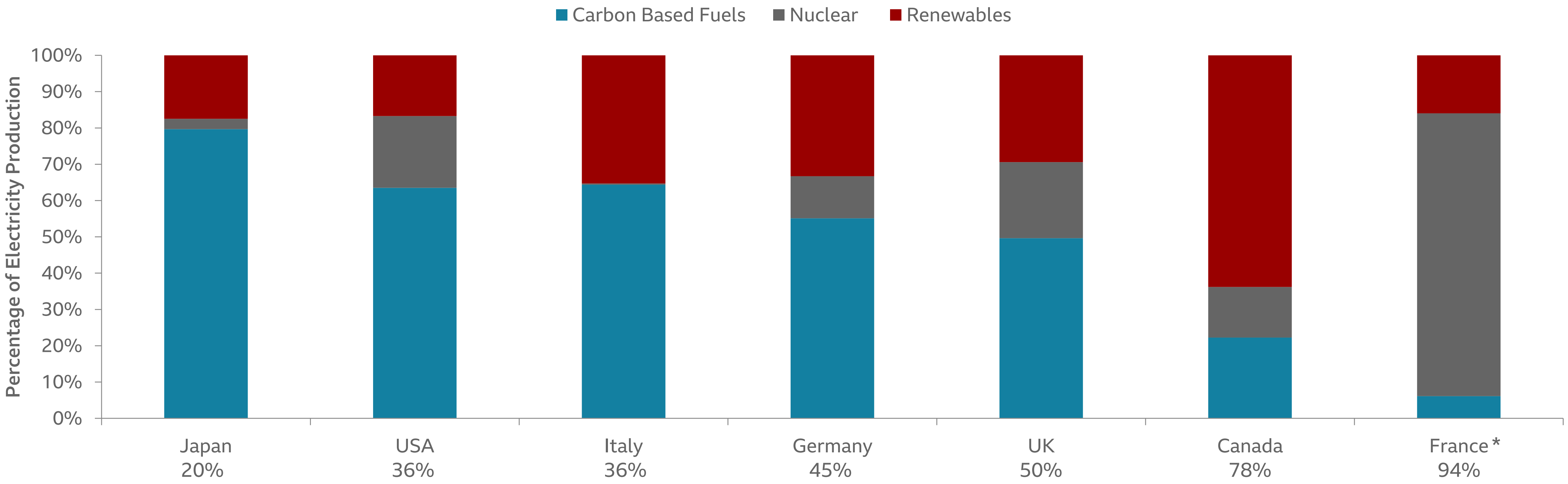


The Climate Change Act figures do not include international aviation and shipping; the others do. It is assumed CO_2 levels constitute 80% of overall greenhouse gas (GHG) emissions

CCC (May 2019) Net Zero
CCC Carbon Budgets

Of the G7 richest nations, France depends least - and Japan most - on carbon fuel for electricity

Sources of electricity production in the G7 countries as % of total electricity production in 2017



Percentage of electricity generation from nuclear power and renewable sources as a total of each country's electricity generation shown on graph

*Latest data available for France i(with its pronounced nuclear fleet) is from 2015 from World Bank data
others BP (June 2018) Review of World Energy

The UK needs several strategies to meet its 2050 carbon target

Strategy	Actions
A double electric revolution	• Replace direct carbon use (petrol and gas) with electricity across households, transport and industry • Produce electricity through wind, solar and nuclear power instead of gas, coal and oil
Decarbonisation of fuel supply	• Use hydrogen gas – which produces no CO_2 emissions - for heating and transport • Continue using natural gas, but with carbon capture technology and storage • Use biomethane from waste, or biomass and biofuels directly
Greater efficiency and lifestyle changes	• Cut energy use in the home, industry and transport, by changing behaviour and lifestyle, or by reducing energy needs (using measures like better home insulation) • Convert input energy to output energy more efficiently

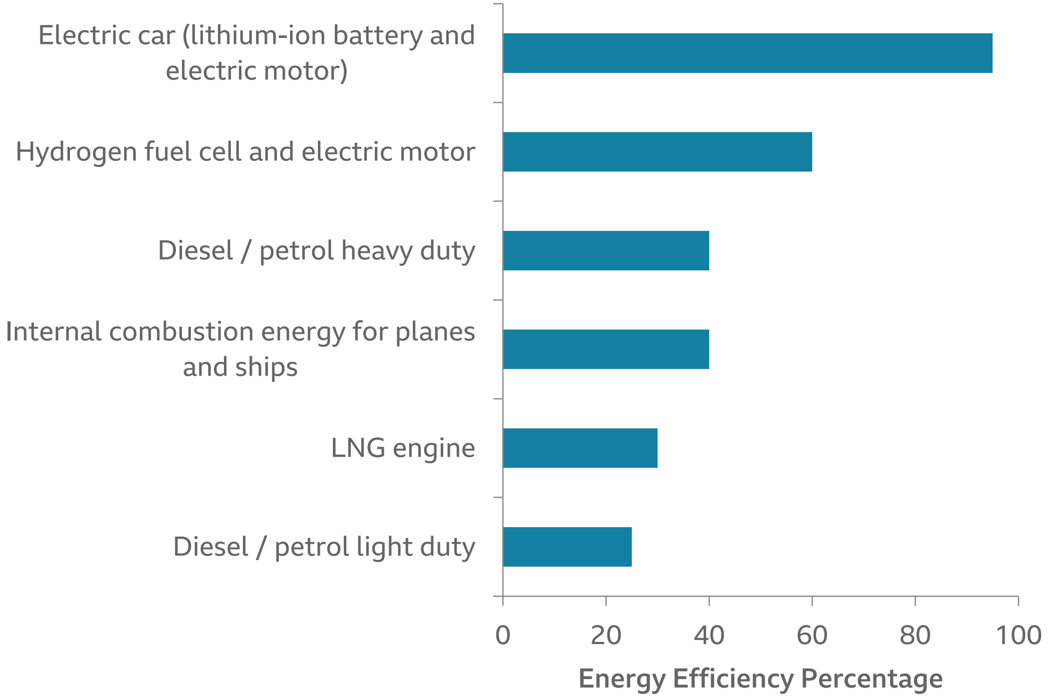
Government (April 2018) Clean Growth Strategy

Each strategy for cutting emissions requires radical initiatives

Strategy	Method	Initiatives				
Double electric revolution	Electricity replaces carbon	Electric cars	Electrical heating pumps			
	Renewables and nuclear in electricity generation	Onshore wind	Offshore wind	Solar	Marine	Nuclear
Direct replacement or removal of carbon	Hydrogen production and usage	Hydrogen gas heating	Hydrogen fuel cell for cars and lorries			
	Carbon capture and offsetting	Carbon capture in power generation	Carbon capture in hydrogen production	Biomethane/ Biomass/ Biofuels		
Efficiency and lifestyle changes	Better input / output energy use ratios	More efficient engines and turbines	More efficient fuel mix	More efficient battery use		
	Less end use of energy by households etc.	Smart metering	Home insulation	Private to public or shared transport		

Electric cars are more energy-efficient than conventional fuel cars, and will play a key role in reducing emissions

Typical energy efficiency for engines by power source in 2018



The Economist December 1st 2018, pg.7
ETCn (April 2017) Pathways to Low-Carbon

Battery efficiency and electric cars

- The sale of new petrol and diesel cars will be banned by 2040, or sooner if CCC recommendations are adopted
- The government's aim is for half of newly registered cars to be electric by 2030
- Electric cars are around four times more energy-efficient per mile than conventional petrol cars
- In 2017 only 400,000 - or 1% of the UK's registered car fleet - were plug-in hybrid and fully electric cars
- Incentives for buying electric cars include:
  - Plug-in car grants
  - Congestion charge concessions
  - Grants for home charging points
- The Automated and Electric Vehicles Act 2018 empowers local governments to insist on charge point installations

Electric heat pumps in the home will help reduce emissions

Electric heat pumps

- Traditional electric heating is termed “resistive’”– for example, bar fires and immersion water heaters
- These appliances are relatively inefficient users of energy
- Heat pumps draw heat from the atmosphere or land and pump it through the home as warm air
- Electric heat pumps are three times more energy efficient per degree of heat produced than current gas boilers
- Heat pump systems take time to gather heat, making them less effective in dealing with sudden winter cold snaps
- The ambient temperature produced by heat pumps is below most people’s comfort level, unless their home is well-insulated, so they have to be supplemented by other forms of low-carbon heating

3D representation of a home electric heating pump system

Electrification of all domestic heating and vehicles may require a threefold increase in electricity

Energy use	Energy consumption in billions of kWh	Efficiency of substitute electrical device	Potential equivalent electricity use in billions of kWh	Multiple of current household electricity demand
Household lighting	108	-	108	1.0x
Household heating	292	Electric heat pumps around three times more efficient than gas boilers	97	0.9x
Car and light vehicle transport	363	Electric cars around four times more efficient than petrol engines	90	0.8x
Total	**762**	**-**	**295**	**2.7x**

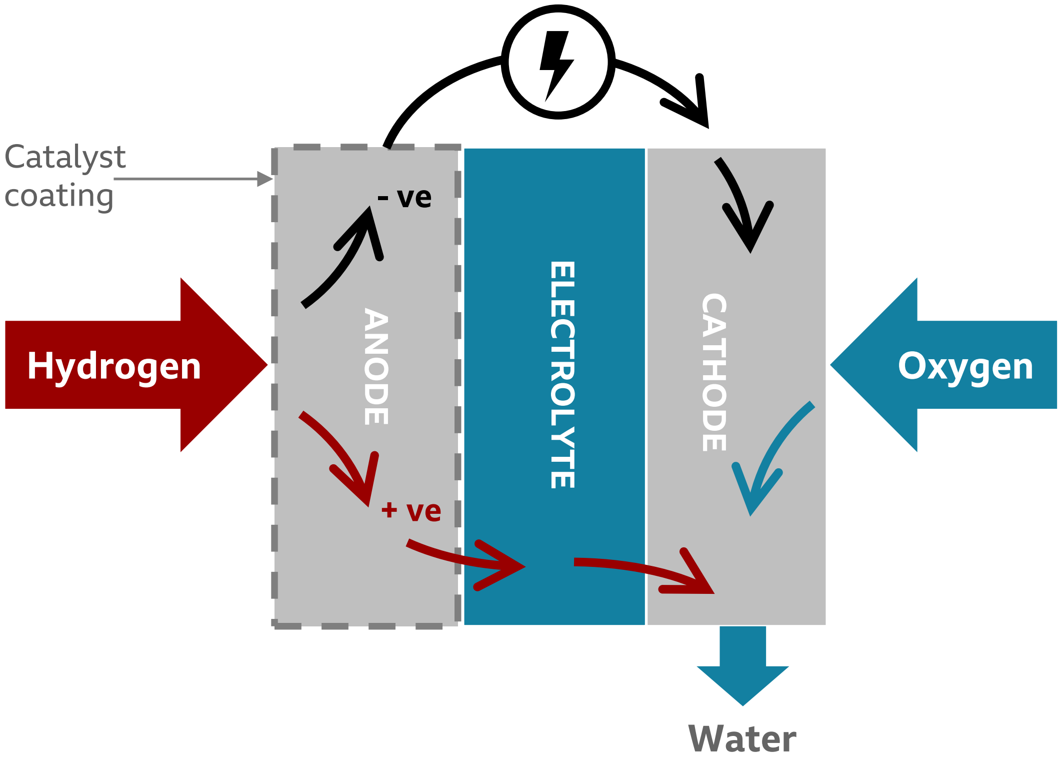
Electricity increase needed

- If electric heat pumps were used in all domestic heating, demand for electricity would almost double
- This would need to be coupled with upgrades to improve energy efficiency
- It would almost double again, if all private cars were electric too
- With full electrification, the total combined domestic and private vehicle demand for electricity would be almost three times (2.7x) its current level

BEIS (July 2018) DUKES

Hydrogen can produce electricity using a fuel cell without directly releasing CO_2

How a typical fuel cell works



Hydrogen fuel cells

- Hydrogen fuel cells have been used for 50 years by the American space agency Nasa to power spacecraft
- In a hydrogen fuel cell, hydrogen reacts with a chemical catalyst (usually platinum)
- A stream of hydrogen electrons is released, which travel around the cell, producing electricity
- At the end of the process, the electrons combine with oxygen to produce water vapour, the only waste product. Because the fuel cells produce no carbon emissions directly into the atmosphere while in use, hydrogen is perceived as a clean fuel
- China is investing in hydrogen fuel cell technology, and aims to have one million fuel cell vehicles by 2030
- China has the world's most ambitious hydrogen vehicle target, as part of the government's plan to encourage the development of cleaner vehicles

Financial Times (January 2019)

Hydrogen power could play a key role in transport and heating but is very expensive

The role of hydrogen

In transport:

- hydrogen fuel cells can be used to power vehicles and machinery through an electricity generator
- stored hydrogen weighs about a tenth of the equivalent battery storage, and the gas operates better at low temperatures. This makes it potentially more efficient covering longer distances - especially important for lorries, shipping and trains
- hydrogen fuel cell power is three to four times more expensive than battery power per kWh produced

For heating:

- hydrogen is as efficient in cold weather as natural gas
- the town gas developed from coal which was used in the UK before 1970 was 50% hydrogen

Current infrastructure:

- hydrogen could use the existing gas grid infrastructure (with significant extra investment)

- The Committee on Climate Change’s Net Zero report says the UK may need a hydrogen production capacity by 2050 similar in size to the UK’s fleet of gas-fired power stations (for industrial processes, long-distance HGVs and ships, and for electricity and heating in peak periods)

Hydrogen is mainly produced in two ways

Method	Input	Action	Pros	Cons	Wholesale costs compared to natural gas
Steam methane + carbon capture	Natural Gas	Heating natural gas (with renewable energy) and extracting the hydrogen	Not as energy intensive as electrolysis ; plentiful supply of natural gas	Hydrogen produced needs further purification before it can be used in fuel cells; and the process still produces CO_2 and therefore requires carbon capture	1.5x to twice as expensive per kWH with current technology
Electrolysis	Water	Electric current (from renewable electricity) passes through water to separate hydrogen from oxygen	Can be used directly for fuel cells	More energy-intensive and much more expensive than steam methane	Three times more expensive

Hydrogen production

- Both methods of hydrogen production require significant amounts of energy, with one involving storing CO_2 as a by-product
- The cost of hydrogen through electrolysis would fall if a very cheap source of electricity could be found
- It could be produced with cheap solar energy in other regions, then be shipped to Northern Europe as liquid ammonia
- Hydrogen could be produced at times of low demand, if there are enough wind turbines

Source: Committee on Climate Change 2018 Hydrogen in a Low Carbon Economy

Using hydrogen for domestic and other heating requires huge capital investment

Investment costs of hydrogen

- Hydrogen for heating households and commercial enterprises could be distributed using the current natural gas system but this would involve large sums of extra money:
  - £17bn to upgrade domestic pipe work and boilers
  - £5bn on hydrogen storage facilities
  - £4bn for upgrading the gas network
  - £3bn in hydrogen production facilities for the steam methane method
- Carbon capture would also need serious investment to deal with the waste product of hydrogen production from natural gas

3D representation of hydrogen storage being used alongside renewable energy sources

CCC (November 2018) Hydrogen in a Low Carbon Economy

Previously there were concerns over the safety of hydrogen as an everyday fuel

Hydrogen accidents

- In 1930, the hydrogen-fuelled British airship R101 exploded on its way to India, killing 48 people
- In 1937, 36 people died when the hydrogen-fuelled German airship Hindenburg burst into flames while attempting to dock in New Jersey
- Following a series of earlier accidents, these two incidents led to the widespread perception that hydrogen was dangerous
- After the Hindenburg disaster, hydrogen airships were abandoned

Current safety status

- Manufacturers of hydrogen technology have tried to improve its reputation by investing heavily in hydrogen storage tanks, and conducting safety experiments
- The US Government Office of Energy Efficiency and Renewable Energy concludes:

  'testing of hydrogen systems—tank leak tests, garage leak simulations, and hydrogen tank drop tests—shows that hydrogen can be produced, stored, and dispensed safely"

- Hydrogen is more volatile than petrol and needs to be kept under high pressure to be used as fuel

EERE Safe Use of Hydrogen :

Direct use of biomass, biofuels and biomethane could play a part in providing energy

Biomethane

- Biomethane is emitted from waste and landfill sites, and is a potent greenhouse gas
- Burning biomethane could match or beat natural gas at helping to limit greenhouse gas increases, but - without enough of it - only in combination with other solutions
- Biomethane is already being added to the gas grid or used by large community or commercial heating systems

Biofuels

- Biofuels are produced from natural plants, such as corn, rapeseed and switchgrass
- They are two to three times the cost of petrol or kerosene, but could be used in aviation where electric power may prove difficult, especially for long-haul flights
- Biofuels are considered to be carbon-neutral because the CO_2 absorbed by the plants equals the carbon dioxide released when the fuel is burned
- Critics claim diverting cropland to fuel leads to more trees being felled to grow food

Biomass

- Biomass is processed wood or plant matter
- Burning biomass could be net carbon-neutral if it is replaced by new planting, which puts CO_2 back in the air
- However, the process of burning biomass currently needs constant monitoring, so is inconvenient for some uses
- Biomass is most suited to large community or commercial heating systems
- The Committee on Climate Change Net Zero report suggests 10% of the UK's primary energy consumption could potentially be provided by bio resources by 2050

Fracking could boost tax revenues but there are many environmental concerns

The role of fracking

- Fracking (hydraulic fracturing) involves drilling through rocks to release deposits of natural gas trapped underground
- Such deposits exist in many parts of the UK and Europe, but there's no certainty that the gas can be economically drilled
- Fracking could provide additional income through tax revenues but there is little evidence it would reduce reliance on imported gas
- Fracking produces a form of natural gas and does not therefore help to achieve net zero unless combined with Carbon Capture and Storage (CCS), which drives up the price

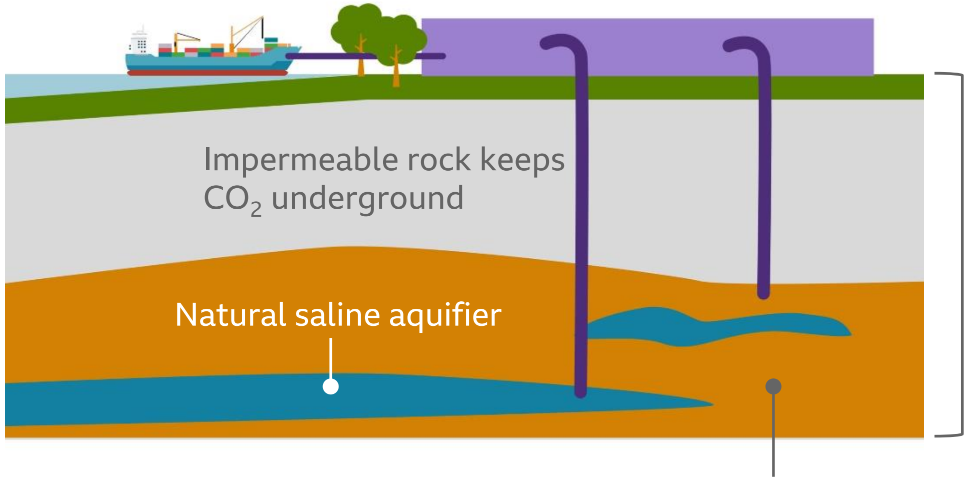
Environmental arguments

- Fracking could leak shale gas (methane) into surrounding groundwater, when rocks are split during extraction
- Fracking contributes to air pollution and noise disturbance
- Fracking is often conducted near built-up areas, and can cause very minor earth tremors
- The world already has found more supplies of fossil fuel than we can afford to burn; simply adding to them by fracking and lowering the price of gas may deter consumers from switching to lower carbon sources

HoC (November 2018) Shale Gas and Fracking
Royal Society & RAE (June 2012) Shale gas extraction in the UK
AQEG (July 2018) Air Quality Impacts of Shale Gas Extraction

Carbon Capture and Storage (CCS) technology can offset the impact of using carbon-based fuels

How CCS works



- Methods of CO_2 extraction depend on whether the process takes place pre or post-combustion of the fuel
- Once the CO_2 has been captured, it is compressed into a liquid form ready for transportation and storage
- When it arrives by ship or pipeline, the liquid CO_2 is pumped into porous rock formations around a mile below the Earth's surface
- The storage site has an impermeable rock layer above the porous rock which prevents the liquid CO_2 from escaping

Cosmos (September 2016)
European Commission (February 2017)

Carbon Capture is in its very early stages

Global reach and cost

- There are 18 active carbon capture facilities around the world
- They capture 28 million tonnes of CO_2 a year, less than 0.1% of global emissions
- Cost depends on individual plant characteristics and the transport and storage infrastructure needed
- The process of extracting and compressing CO_2 reduces efficiency and raises costs
- According to UK government estimates, by 2025 the cost of using carbon capture would be:
  - an extra £18 per MWh of electricity produced by using coal
  - an extra £7 per MWh for electricity produced at the latest natural gas-based power stations

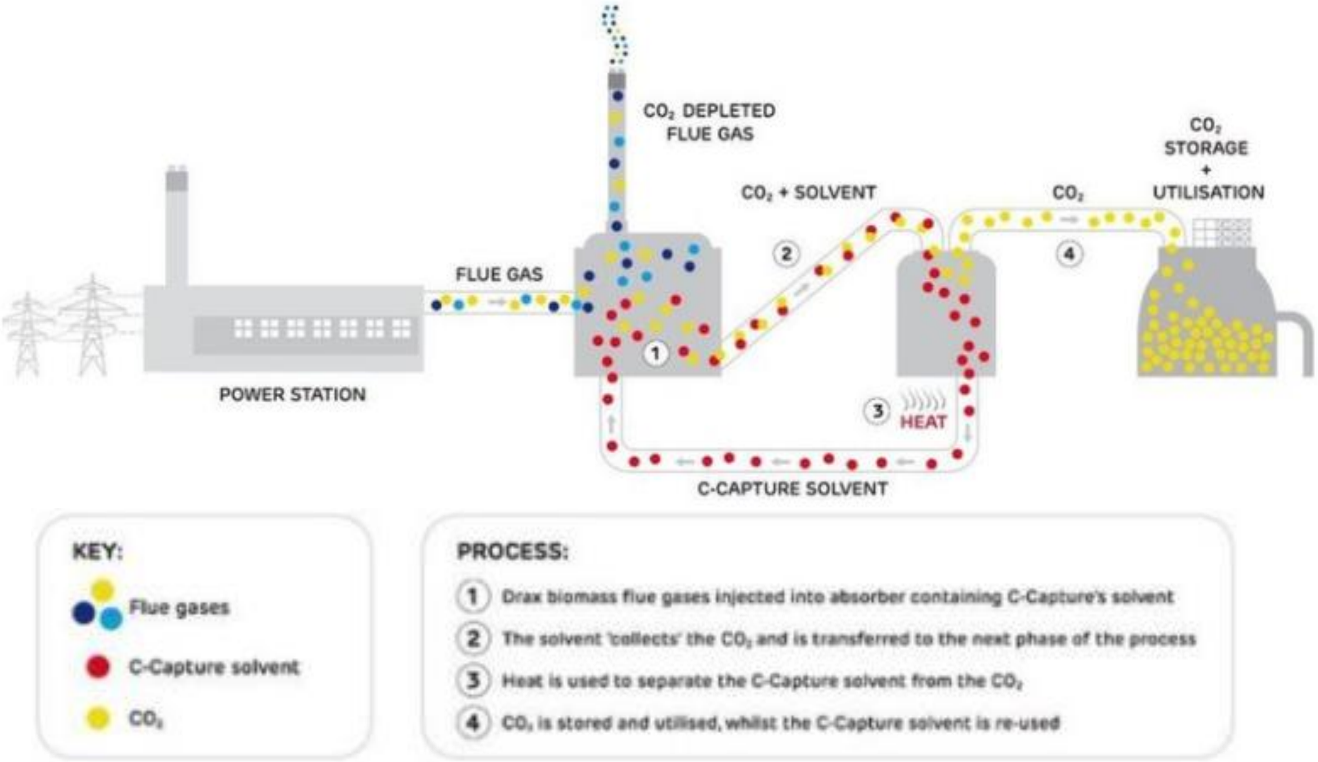
Carbon Capture and Storage (CCS) sites around the World

Credit: Global CCS database

Global CCS Institute: Large scale projects
BEIS (November 2016) Electricity Generation Costs

The UK's Drax power station is converting from coal to biomass and trialling carbon capture

Biomass energy plus carbon capture and storage (BECCS) at Drax



Biomass use at Drax

- Drax produces 7% of UK electricity, mostly from biomass (wood burning)
- In November 2018, Drax launched a six-month carbon capture trial
- The method involves mixing CO_2 with solvent to stop it releasing into the atmosphere, before separating out the carbon
- Drax captures one tonne of CO_2 emissions a day. But as the pilot was to test the capture technology, Drax has not yet been storing the captured emissions
- Carbon capture adds around 50% to the cost of electricity generation from gas or biomass, and compressed storage would increase that. How much of these extra costs should be passed on to energy consumers forms part of the big debate about CCU viability

BBC News

CO_2 can be captured and used, not only stored

Carbon Capture and Usage (CCU) project in Cheshire

- In June 2019 Tata Chemicals Europe won a £4.2m government grant to capture and use 40,000 tonnes of CO_2 from a gas plant in Northwich, Cheshire, which powers its production of chemicals
- Captured gas will be purified and liquefied, and used directly in the manufacture of sodium bicarbonate on the site, reducing emissions by 11%
- Sodium bicarbonate can then be used in a range of products, from eye drops to biscuits
- It will be the UK's first large-scale CCU project, but several British firms have already begun smaller ones
- CCU is likely to play only a small part in reaching net zero, and most CO_2 will need to be stored

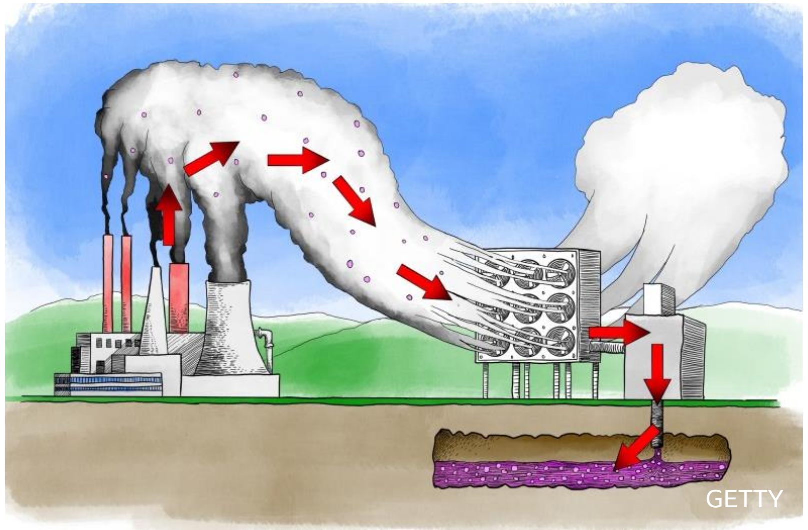
The carbon capture plant at Tata Chemicals' site in Cheshire will recycle 40,000 tonnes of CO_2 a year

Tata Chemicals Europe (June 2019)
Drax (February 2019)

Extracting CO_2 from the atmosphere is technically possible but very expensive

Direct air carbon capture and storage (DACCS)

- In DACCS, air flows through a filter which:
    - absorbs the CO_2 by causing it to react with a chemical solvent, or
    - causes the CO_2 to adhere to a chemical membrane which traps it, or
    - makes it react with chemicals to form carbonate minerals that store the CO_2
- Cost estimates for the capture process (excluding storage) for early stage projects typically range from £150 to £500 per tCO_2 (tonne of CO_2) although companies are aiming to reduce this to £80
- Exploiting waste heat from nearby industry could reduce energy costs associated with DACCS
- The UK has no commercial or near-commercial DACCS operations
- The CCC assumes a limited role for DACCS in reaching net zero by 2050, accounting for 1 $MtCO_2$ from the atmosphere at a cost of £300/tCO_2 in 2050, down from £450 in 2025



Carbon capture technology filters CO_2 from the air and stores it underground

Royal Society & RAE: greenhouse gas removal

Planting trees can contribute to net CO_2 emissions reductions

Carbon extraction rates from afforestation

Annual afforestation	Proportion of extra UK land area covered in forest annually	Total UK land area covered by forest in 2050	Reduction in annual emissions from 2017
30,000 Hectares	4%	17%	6%
50,000 Hectares	6%	19%	8%

Currently less than 10,000 hectares of extra trees a year are being planted

Renewable UK
BEIS (February 2017) Solar deployment)
BEIS (July 2018) DUKES

The UK will come under increasing pressure to reduce demand for energy across the economy

Limiting demand for energy

- In the past, governments have tried to meet increasing demand for energy, but it is cheaper to reduce it, and the UK will come under increasing pressure to do so
- This is already under way in electricity, where demand is decreasing. The trend is likely to continue, with firms offering incentives to people and firms to use electricity when it is cheap, and stop using it when demand peaks
- At Aggregate Industries near Heathrow - which makes road materials - bitumen can be stored in containers between 130C and 185C. If a rise in demand is predicted for later in the day, the company is advised by a computer to heat the bitumen to the maximum temperature, then turn off the power until the demand (and the price) subsides

GETTY

CREDS (July 2019)

Summary

The UK's Energy Challenge

The UK has made significant progress in reducing CO_2 emissions, most importantly by phasing out coal.

But 90% of the UK’s energy is still obtained by burning hydrocarbons, either directly or to produce electricity. If it is to meet its 2050 emissions target, it will have to reduce carbon dependence to one-eighth of its current level, and find ways to offset the rest.

This will involve a major transformation of how homes and buildings are insulated, and how vehicles and businesses are powered. It will require the wholesale adoption of new technologies, like electric vehicles or hydrogen power or electric heat pumps. A significant increase in the electricity the country generates will be needed, and mostly generated without emitting carbon.

This is the UK's energy challenge.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FedEx
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LLYNCH
Highway Maintenance
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Swift Valley
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FUSION
ENGEL EUROPA
enterprise

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Part 4/9

The Transport Revolution

When will we all be driving electric or hydrogen cars? Will all Heavy Goods Vehicles (HGVs) be fuelled by hydrogen? Will hydrogen have a role in rail and shipping? Can we convert air travel to non-carbon fuels? And can people be persuaded to travel less by road and air?

"We will not stop until every car on the road is electric"

Elon Musk, founder and CEO of Tesla

"If we all switched from car to bus for just one journey a month, it would mean one billion fewer car journeys on our roads and would save two million tons of CO_2 every year"

Caroline Lucas MP (July 2018)

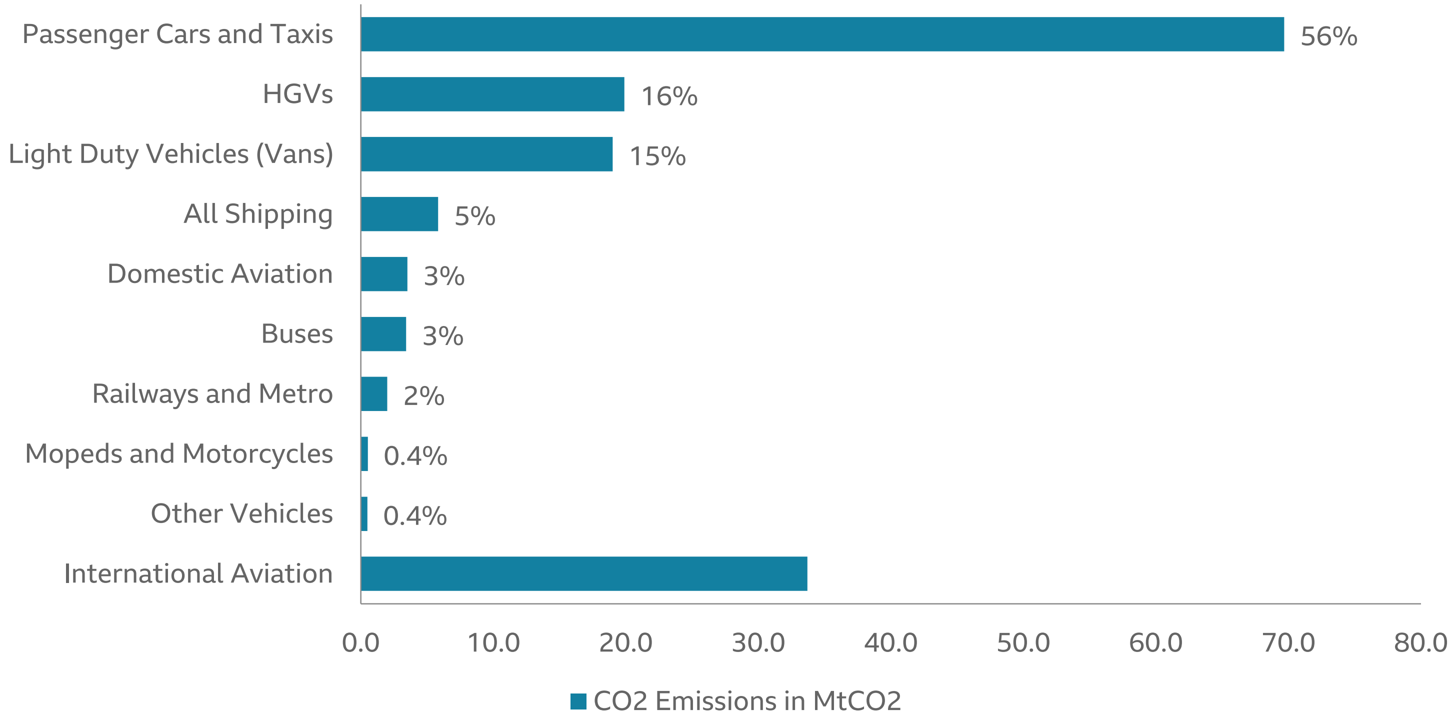
Electric vehicles have been with us for almost two centuries

History of electric vehicles

- Electric vehicles first appeared in the early to mid-nineteenth century, and their invention is attributed to various people
- One of the earliest records of an electric model car is in 1828, when Hungarian inventor Ányos Jedlik used an electric motor to power a small model car
- The first known electric locomotive was built in 1837 by Scottish chemist Robert Davidson. His seven tonne vehicle travelled at 4mph, but its limited power from batteries made it impractical to use
- In 1899, *La Jamais Contente* (*The Never Satisfied*) became the first road vehicle to travel over 100kmh (62mph)
- *La Jamais Contente* was a Belgian electric vehicle powered by two 25kW motors running at 200 Volts

Road vehicles emit more than 90% of the UK's transport-based CO_2

UK CO_2 emissions in $MtCO_2$ by transport means in 2016



CO_2 emissions by vehicle type

- Passenger travel by car, taxi and bus accounts for almost 60% of transport CO_2 emissions
- Trains - per passenger mile travelled - produce a fifth of the CO_2 emissions from passenger cars
- 37% of the UK's rail and metro system energy use is currently electric
- International aviation was not incorporated into the UK's 2008 Climate Change Act emissions target – but the Committee on Climate Change wants it included in the 2050 net-zero target

BEIS (March 2018) UK Greenhouse Gas Emissions
DfT (December 2018) Passenger transport by mode from 1952

The UK is among the countries planning to ban or end the sale of new petrol and diesel cars

At least 14 countries have set dates or aims *

Ban / Target Date	Country
2025	Norway
2030	Iceland, Ireland, Israel, Slovenia, Netherlands
2035	Denmark
2040	UK (except Scotland 2032), Canada, Spain, Portugal, France, Sri Lanka
2050	Costa Rica

* includes bans that have been announced, proposed and put into law, and excludes countries with a target of only no full petrol or diesel (eg Japan) or a partial target (eg Mexico)
IEA research, July 2019 (Pages 60-61)

The government's vehicles strategy, called the Road to Zero, sets out objectives for going electric

The Road to Zero 2018

Objectives

- All cars to be zero emission by 2050, a date the Committee on Climate Change (CCC) suggests is too late
- A ban on new petrol and diesel cars from 2040, which the CCC suggests needs bringing forward to at least 2035
- By 2030, half of new car sales and 40% of new van sales to be Ultra Low Emission Vehicles (ULEVs). The CCC prefers the target to be 100% electric by 2050
- An ULEV is a vehicle (both electric and hybrid) emitting less than 50g of CO_2 per km travelled.

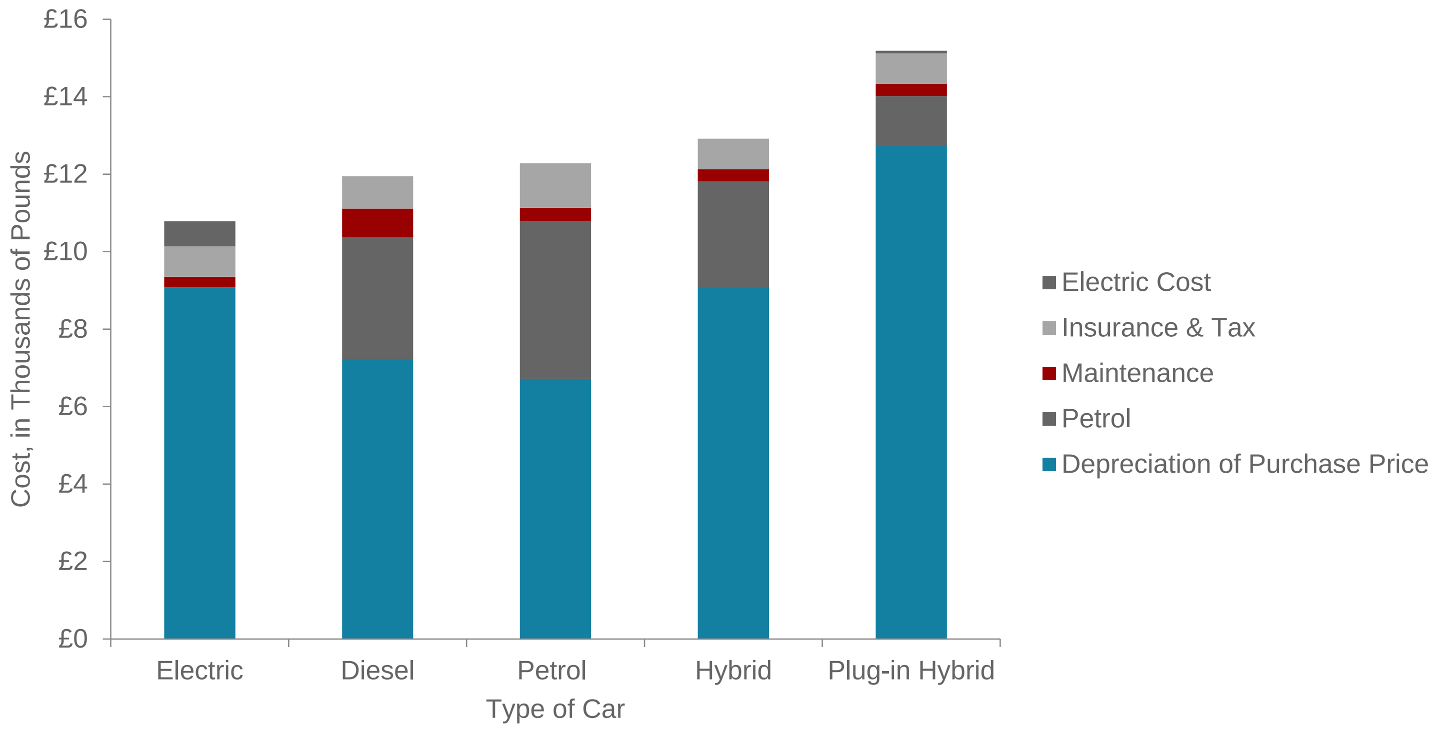
Incentives introduced

- The CCC recommends incentives until ULEVs achieve cost-parity with petrol and diesel vehicles, which it predicts will happen in the early 2020s
- Incentives introduced so far include:
  - Plug-in car and van grants initially up to £4,500 for an electric car and £2,500 for a hybrid car
  - In 2018, this was revised to £3,500 for electric cars only, and the hybrid subsidy was dropped
  - A grant of up to £500 towards installing a personal electric car charger at home
  - Local authority powers to require the installation of charging points

DfT (July 2018) Industrial Strategy: The Road to Zero:
CCC (May 2019) Net Zero

Electric cars are cheaper to run than petrol cars

Cost over four years in the UK by car type



Car purchase and running costs

- Electric cars cost more to buy than petrol cars, even with the purchase grant, due to battery costs and the lack of scale economies
- Some forecasts suggest they may become cost-competitive by the mid-2020s
- Electric cars are cheaper to run than petrol cars, which are more expensive per mile driven
- Plug-in hybrid cars are the most expensive, as consumers are paying for both batteries and a petrol engine

Applied Energy (January 2018)

The road to an all-electric car future by 2050 has its challenges

<u>Infrastructure</u>

- The UK's electrical infrastructure will need to be substantially upgraded
  - Although electric engines are more energy efficient, a move to electric vehicles (EVs) could increase household electricity demand by 80%, and nationwide electricity demand by around 30%
  - Local networks will have to be re-configured to create extensive domestic and public charge points

<u>The pace of uptake</u>

- Only one in 40 new car sales is currently electric
- Sales of hybrid cars, which also use petrol, outnumber fully electric cars 6:1. To achieve zero emissions, hybrid cars will need to be phased out
- 40% of cars are more than 10 years old. Banning petrol car sales from 2040 means not all cars will be zero emissions by 2050, unless further restrictions are imposed

Electric car at a charging station in London

Concerns over range and charging points have inhibited demand for electric cars

Refuelling a petrol car v recharging an electric car

- The average petrol car can hold between 300 and 400 miles' worth of fuel in its tank
  - An average car journey is between eight and 10 miles
  - On average, petrol cars manage 30 journeys before refuelling
  - Most electric cars on the road have an average 80-mile range, so need charging after every 10 journeys. Newer EV models can go further
  - This has led to "range anxiety", with short-range and sparse charging points leaving drivers anxious they might be stranded before reaching their destination
- In May 2019, there were 8,546 charging locations across the UK, hosting 13,688 charging devices
- Electric vehicle charging takes significantly longer and must be done more frequently than refuelling with petrol

An electric vehicle charging station in a residential street in London

good energy (May 2019)

Falling battery prices and enhanced support infrastructure could accelerate the take-up of electric cars

Improving charging infrastructure

- Even allowing for the increasing range of electric cars, the Committee on Climate Change suggests 29,000 charging points may be needed by 2030, if 60% of new cars are electric by then
- Upgrading the vast majority of current charging points to either rapid (43kWh or more) or fast (22kWh) will be necessary
- Fast charging points at home, on the kerbside or in car parks and a network of rapid and very rapid charging points along major roads, at current petrol stations and lay-bys will be needed
- Home power walls can store electricity at cheap rates overnight
- Shell and BP plan to offer high-powered charging points on filling station forecourts; more than 1,200 forecourts should be upgraded from 2020

Falling battery costs

- A typical electric car currently has 50 kWh of storage, meaning the batteries cost £10,000 today
- This cost is forecast to come down to £4,000 by 2020, so the range of electric cars will more than double at stable prices
- The cost of batteries per kWh has fallen by 80% since 2010, and is expected to drop by a further 50% by 2030
- Many new electric cars have a range of 200 miles or more

CCC (January 2018) Plugging the gap
Bloomberg NEF (July 2017)

Hydrogen power is an alternative to electric power for vehicles

Advantages of hydrogen fuel cells in vehicles

- Hydrogen cell technology uses compressed hydrogen fuel to create electricity
- Hydrogen fuel cells to power an engine were first invented in 1839, and some car manufacturers, such as Toyota, are developing hydrogen cars
- The gas is expensive to produce and compress but enough energy can be stored in a car to enable it to travel 300 miles
- Hydrogen only weighs one-tenth of the equivalent battery storage
- Hydrogen's main application may be for heavy duty vehicles, given their need to carry a lighter energy storage load and cover greater distances
- Several vehicle manufacturers, like Toyota and Hyundai, are developing hydrogen fuel cell lorries

A hydrogen fuel cell London bus

Only about a third of the UK’s rail network is currently electrified

Britain’s rail network

- By 2019, 36% of the UK’s 10,000-mile rail network has been electrified
- The Committee on Climate Change has recommended rolling out electrification of the rail network, because electricity for trains can be supplied from non-polluting sources, while diesel trains unavoidably emit greenhouse gases
- In 2012, the government announced a £38bn package to upgrade the rail infrastructure, which would have included electrifying an extra 850 route miles in the network by 2019
- In 2017, the main electrification programme was cancelled in favour of adding more “bi-mode” trains, which can run on diesel and electricity, thereby allowing trains forced to run on partially non-electrified routes to switch to electricity when they can
- The most recent plans announced by Britain’s main rail network operator, Network Rail, favour performance and reliability improvements over new infrastructure
- The French company, Alstom, and the British rolling stock company, Eversholt, have unveiled designs for hydrogen-powered trains for the UK: they are currently assessing how such trains could be used on the network, and hope to have some running by 2022

ORR (October 2018)
HoC (June 2018) Rail infrastructure investment

Short-haul flights may eventually be powered by electric engines

Plans for air electrification

- More than 100 electric aircraft projects are under way around the world
- The American company Zunum Aero aims to build:
  - a 12-seater electric aircraft by 2022
  - a 50-seater with a 1,000 mile range by 2027
  - a 100-seater with a 1,500 mile range by 2030
- The low-cost airline EasyJet has pledged to develop a fleet of electric short-haul planes by 2030
- Norway has set a target for all short-haul flights to be electric by 2040
- Short-haul flights emit more CO_2 per mile travelled than long-haul ones, because a quarter of air emissions occur during take-off, landing and taxiing on the runway

GETTY

BBC News
CNN (October 2018)

Reducing emissions from aviation and shipping requires international co-ordination

Aviation

- In 2018, aviation accounted for 2%-2.5% of global CO_2 emissions, of which international flights accounted for 1.3% of emissions
- Two approaches have been adopted to try to limit emissions:
  - Since 2012, the amount each airline can emit is capped under the EU's emissions trading system (ETS). If they exceed their limit, they can buy an allowance from an airline which has emitted less than the limit (hence a trading system)
  - From 2022, the International Civil Aviation Organization is introducing a scheme requiring airlines to pay for carbon reduction projects in developing countries (eg tree-planting) if they exceed specified targets
- The Committee on Climate Change is allowing for 31MtCO_2e from international aviation in the UK by 2050 as they do not expect low-carbon aeroplanes to be available by then. These emissions will need to be offset to meet the net-zero target

European Parliament (January 2018)
Carbon Brief (April 2019)
UNFCCC (April 2018)

Shipping

- International shipping accounts for about 2% -2.5% of global CO_2 emissions
- In 2018, 173 countries adopted an International Maritime Organization (IMO) strategy for reducing their global shipping carbon emissions by at least 50% by 2050, compared with 2008
- Efforts in pursuit of this goal have largely focused on improving the energy efficiency of ships
- The IMO introduced a mandatory Energy Efficiency Design Index for new ships, and the Ship Energy Efficiency Management Plan for all ships from 2011
- The relatively short range and heavy weight of battery technologies mean they are not viable for long shipping routes
- Hydrogen fuel cells, which produce only water as a waste product, could replace current diesel engines in future, although no designs have yet progressed beyond the early trial stage

New sustainable aviation biofuels could reduce carbon emissions from long-haul flights

Long-haul aviation

- Sustainable Aviation Fuel (SAF) is seen as key to reducing long-haul aviation carbon emissions, and does not require modifications to plane engines
- Most SAF is low-carbon biofuel - fuel from plants which absorb CO_2 as they grow - and if replaced when harvested can be considered carbon-neutral
- SAFs still produce some emissions, because biofuels currently need mixing with fossil fuels for aviation use
- The first flight using blended biofuel was in 2008, and more than 150,000 flights have since used biofuels worldwide
- International Energy Agency forecasts say SAF will meet 10% of aviation fuel demand by 2030, rising to 20% by 2040

Issues for sustainable aviation fuel

- In 2018, biofuels accounted for less than 0.1% of total aviation fuel consumption
- As with all applications of bioenergy, biofuel production requires appropriation of land, itself releases CO_2, and reduces land for food production – all of which make it highly controversial
- Biofuels need appropriate airport infrastructure; only five airports – Bergen, Brisbane, Los Angeles, Oslo and Stockholm – have regular biofuel distribution
- 90% of international flights are from fewer than 5% of airports, so converting a small number of airports could cover a large share of demand
- At present SAF is two to three times more expensive than fossil fuel, so its use may affect the price of air travel

New York Times (Augustl 2017)
Roland Berger (May 2019)
IEA (March 2019)

Reducing emissions from transport requires behavioural change to reduce demand

Difficulties in changing transport behaviour

- Transport is the sector where it is possibly hardest to cut greenhouse emissions
- The Department for Transport hopes that electric and hydrogen cars will help – but progress on this has been slow, and some experts say this alone will not solve all transport problems anyway
- Current trends are towards bigger cars, which use more energy - whether petrol or electric. The big batteries needed for large cars also produce more CO_2 when being manufactured
- Government spending is heavily weighted towards roads (£50bn) compared with buses, walking and cycling (£6bn). The Department for Transport is regularly criticised by the CCC for failing to do more, eg using the taxation system to deter people from buying big SUVs

Flying less

- The Commission on Travel Demand, an academic body, says climate change targets will not be met unless people fly less
- Scientists warn that the increase in emissions which would follow any expansion of flying is also incompatible with a low-carbon future
- To discourage people travelling regularly by air to work, campaigners want a graduated frequent flyer tax

New York Times (August 2017)
BBC News
IEA (March 2019)

Summary

The Transport Revolution

Transport is the greatest contributor to CO_2 emissions; and if the UK is to reach its emissions targets, most transport will need to abandon carbon fuels.

Passenger cars and taxis are likely to be fully electric by 2050. HGVs, buses and shipping may have to adopt hydrogen technology. Trains may have to go electric or convert to hydrogen from diesel.

Aeroplanes may increasingly adopt biofuels for long-haul flights and electric for short-haul. So the technology challenge of carbon-free air travel is still evolving.

Whatever happens, technological changes may have to be accompanied by difficult behavioural change.

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Part 5/9

The Housing Revolution

How will we heat our homes and stay warm in the zero-carbon future? And how much will heating in the future cost us?

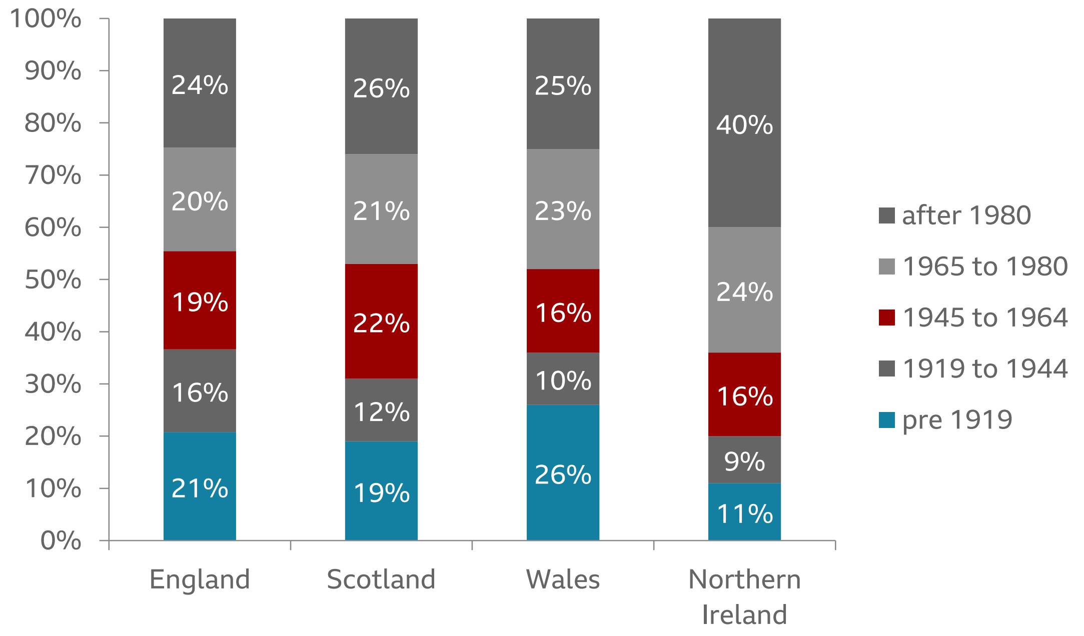
"Over 10 years after the Climate Change Act was passed, there is still no serious plan for decarbonising UK heating systems and no large-scale trials have begun for either heat pumps or hydrogen"

Climate Change Committee Report
May 2019

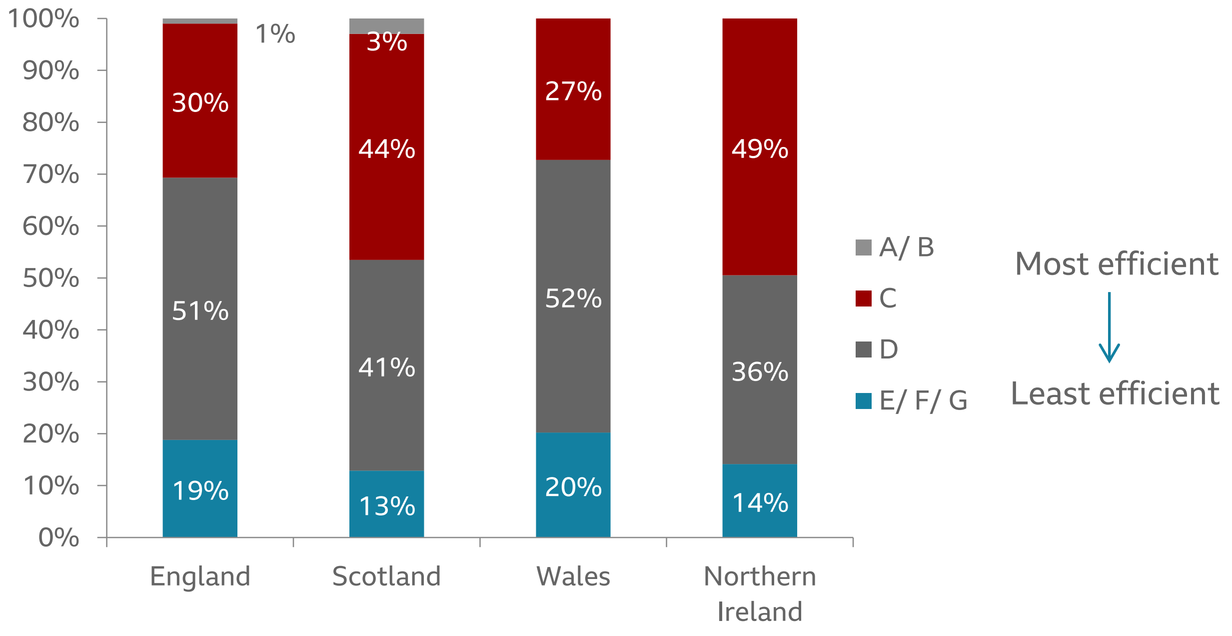
The UK’s housing stock is old and energy-inefficient

UK housing stock

- Only about a quarter of homes were built in the last 40 years (except Northern Ireland)

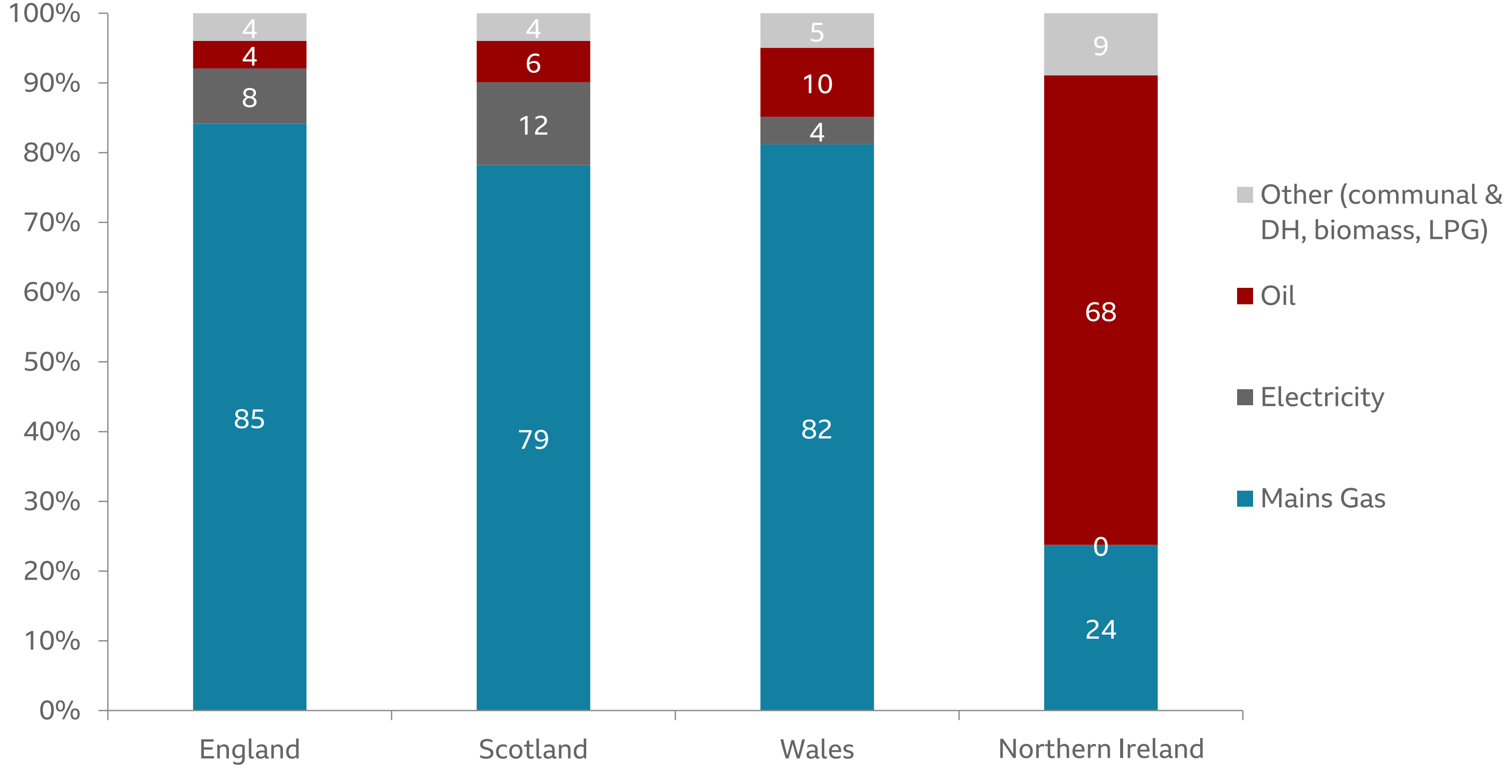


- Most homes have only moderate energy efficiency



MHCLG(January 2019) English Housing Survey
MHCLG(January 2019) English Housing Survey,
Ofgem (December 2015) Insights paper

Almost all homes are heated using carbon-based fuels



Housing heating fuel

- More than four-fifths of UK homes are heated from the mains gas grid
- Northern Ireland is an exception as only a quarter of homes are on the gas grid, with 68% relying on burning oil

MHCLG(January 2019) English Housing Survey
MHCLG(January 2019) English Housing Survey
Ofgem (December 2015) Insights paper

Reducing CO_2 emissions from home heating is a major challenge

The challenge of home heating

- Heating UK homes currently accounts for 17% of all carbon emissions
- Reducing or eliminating domestic carbon emissions would involve transforming the UK's entire housing stock

Better-insulated homes	Smart homes	Less CO_2 -intensive heat
• Loft and water tank lagging • Internal and external insulation as well as cavity wall insulation • Double and triple glazed windows and draft excluders • Better ventilation to avoid the need for air conditioning	• Monitoring energy usage • Automated temperature control by room and time of day • Automated appliance control	• Electric heating • Electric heat pumps • Hydrogen gas heating • Biomass and waste heat • Communal heating systems • Home-based renewable power • Hybrid electric heat pumps and gas systems

POST (May 2016) Carbon Footprint of Heat Generation

Progress in insulating UK homes has slowed

Insulating our housing stock

Progress in insulating England's housing stock since 2012

Form of Insulation	Uptake in 2017	Average annual installation 2008-2012	Average annual installation 2012-2017
Loft insulation	38%	1.2m	0.1m
Cavity wall insulation	47%	0.5m	0.2m
Solid wall insulation	3%	0.1m	0.2m

- The Climate Change Committee says there is evidence that many new-builds underperform on energy efficiency
- A push to increase efficiency standards on new-builds was withdrawn to help the building industry recover from the 2008-10 recession
- In 2015, the government scrapped plans to make new homes zero-carbon from 2016
- The government said they were dropped to reduce regulation on housebuilders and to encourage construction
- To get the rate of home insulation measures going again, the CCC has pointed out that new policies are needed
- Progress in the devolved nations has followed a similar pattern

MHCLG (January 2019) English Housing Survey

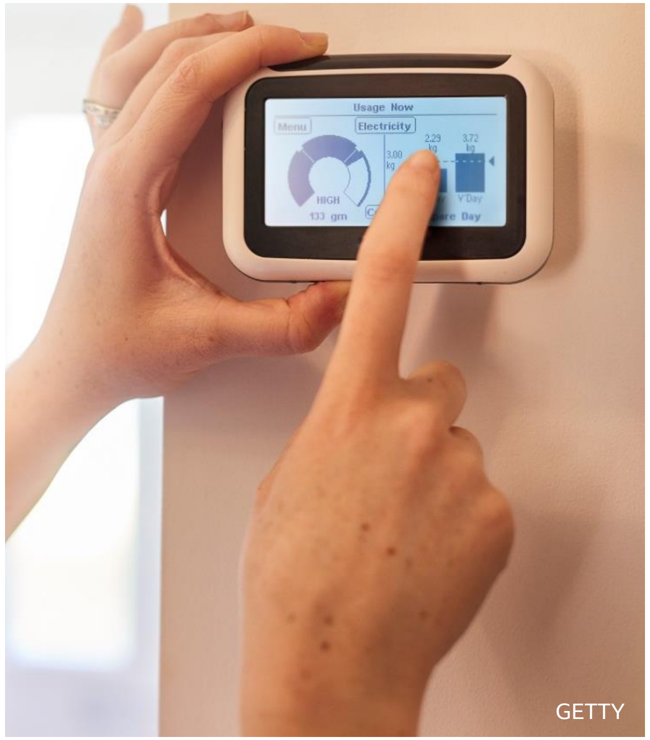
By 2020 we will know if the UK promise of smart metering energy is complete

Energy efficiency using smart meters

- The display shows consumers how much their energy use is costing
- The data is sent automatically to the energy supplier, ensuring greater accuracy of bills
- Research shows smart meters encourage consumers to reduce energy consumption, although the scale of the reduction ranges from 3% to 15%
- Smart meters can help encourage a shift in demand to off-peak times with cheaper tariffs and incentives

UK progress in smart metering

- In 2011, energy companies were asked to offer smart meters to every home and small business by 2020
- The aim was to install 50 million smart meters by 2020 in 30 million homes and smaller non-domestic sites across the UK
- As of March 2019, 14.3 million smart meters had been installed
- While the government says it is on track to reach its ambition by 2020, not all homes are likely to have smart meters by then



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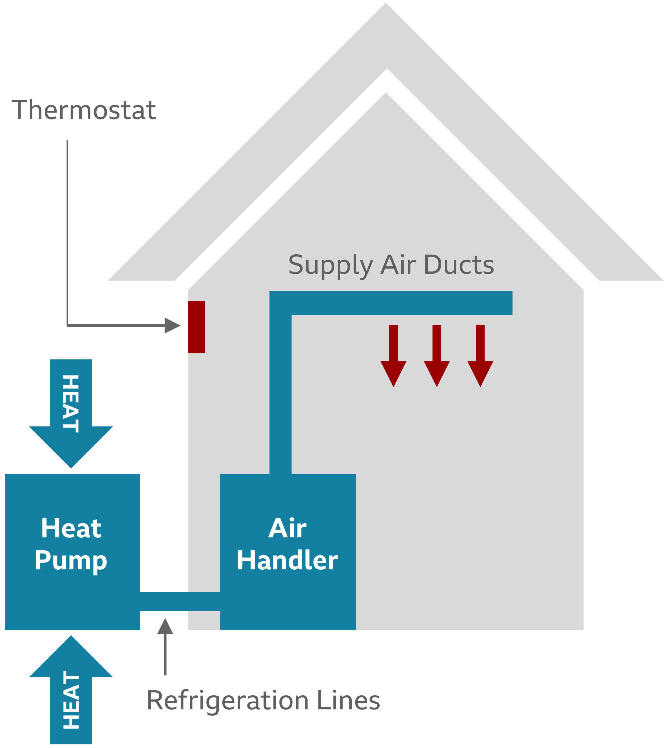
HoC Library Briefing (April 2019) Energy Smart Meters
BEIS (May 2019) Smart Meter Statistics Quarterly Report

Electric heat pumps offer an option for heating the home without carbon emissions

Heat pump system



IAEE (June 2017)

Electric heat pumps

- Electric heat pumps take heat from the air or ground and, using reverse-refrigeration technology, boost the heat and then pump it around the home or business
- They use a quarter of the energy of other heating systems, by relying on the sun and not on "creating" their own heat
- Installation is expensive - about £5,000 for a new-build home and £25,000 to install it in an older home
- Running costs are about half those of other heating systems
- Electric heat pumps need to be coupled with improved building energy efficiency

Drawbacks

- The heat produced is not as hot as from – for example - a gas system, so the property needs good insulation to maintain temperature levels
- Electric heat pumps take time to warm up and cannot respond quickly to cold snaps
- Converting every home to electric heating would place new burdens on the system:
  - an 80% rise in electricity generation for households
  - a major expansion and upgrading of the grid

Hydrogen is currently considered a potential top-up for home heating with electric heat pumps

Feasibility of hydrogen for heating

- Before the 1950s, town gas was typically 50% hydrogen
- Hydrogen-fuelled boilers would be used mainly as a back-up for electric heat pumps at periods of peak demand
- To produce hydrogen in large enough quantities, however, would require more low-carbon energy (or possibly carbon capture and storage to achieve carbon neutrality)
- Whether the costs of hydrogen heating at scale would make financial sense is not yet fully understood
- The commercial development of modern hydrogen heating systems is still largely experimental
- The Committee on Climate Change says the combination of electric-hydrogen heating could in principle "*almost completely displace fossil fuel use in buildings*'"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CCC (November 2018) Hydrogen in a low carbon economy
NIC (December 2018) Carbon capture and storage

Households will increasingly generate and store electricity

Household electricity generation and storage

- About 2.5% of UK households generate their own electricity. There are:
  - 7,500 wind turbines
  - around 800,000 solar installations
- There are plans to make electric vehicle charging in the home two-way:
  - at peak energy demand the grid would take energy from batteries in cars parked at home
  - the same cars would be recharged at non-peak energy times, particularly overnight
- Any large-scale switch to electric home heating could require major increases in household storage or in centralised electricity generation or other technologies – for which batteries are not suitable - to store the energy over long time periods

BEIS (July 2018) DUKES

The complete conversion of UK home heating to zero carbon is likely to be very costly

Complete conversion

- Resistive electric heating:
  - would require an enormous increase in electricity generating capacity, especially to meet peak demands
- Hydrogen replaces natural gas:
  - large capital cost needed to upgrade the gas grid
  - quantity of hydrogen needed implies using electrolysis to produce hydrogen, which would be very expensive
  - hydrogen would also require changes to appliances, the cost of which is currently unknown
- Electric heat pumps only:
  - high capital cost for old housing stock
  - ineffective at low temperatures and during cold snaps
  - large increase in demand for electricity and winter peak demand
  - need to upgrade energy efficiency of the building stock

Alternative solutions

- Electric heat pumps plus natural gas for winter peaks:
  - lower capital costs
  - more effective winter heating
  - low peak electricity load, but still produces significant CO_2 emissions
- Electric heat pumps plus hydrogen for winter peaks:
  - lower capital costs
  - no need for hydrogen production from electrolysis, as the cheaper form of hydrogen conversion will be possible
  - CO_2 emissions significantly reduced
- More extensive use of biomass or biomethane, with heating derived from burning plant or animal material (and which recycles CO_2 back into plants):
  - biomethane could reduce emissions from natural gas
  - biomass most practical for community and commercial heating systems

Summary

The Housing Revolution

The transition from an old, poorly insulated housing stock heated by carbon fuels, to smart, well-insulated homes heated by zero-carbon means is one of the country's most costly challenges in reaching its net zero target by 2050.

The UK home of the future could be heated by electricity, biogas, hydrogen or heat pumps; and the family electric car might be storing energy to supply the grid at peak demand.

The scale and cost of the transformation will be enormous.

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Part 6/9

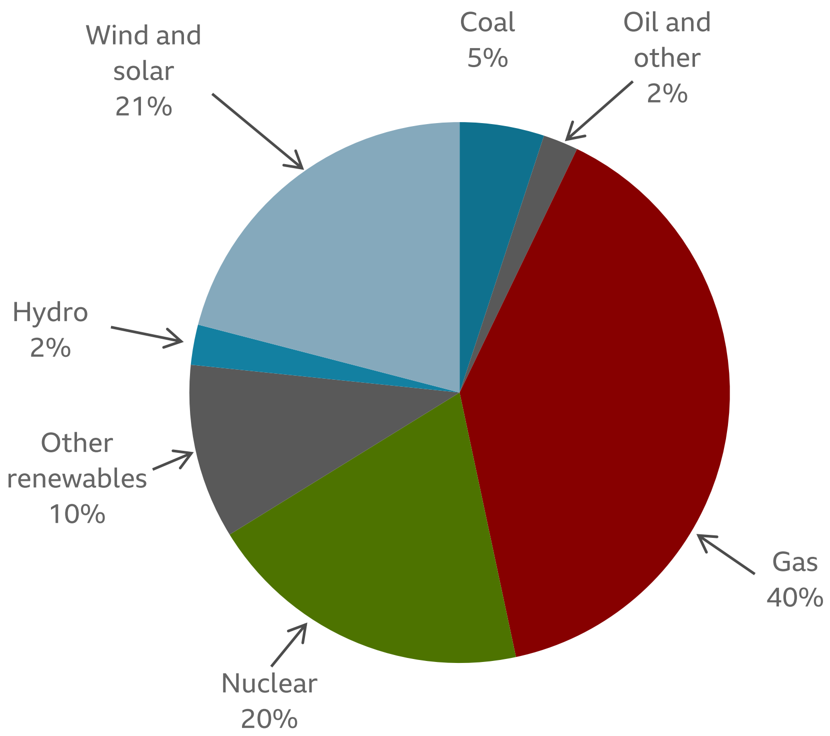
The Electricity Challenge

How much electricity will the UK need in the net-zero age? How will it supply this need carbon-free?

What will the energy mix look like in future? Which technologies can meet overall demand? How do the different options compare in cost? Can nuclear and carbon-based fuels help manage the limitations of renewables? Is energy storage part of the solution to the intermittency problem?

Carbon-based fuels generate around half the UK's electricity

% Share electricity generation by fuel in TWh in 2018



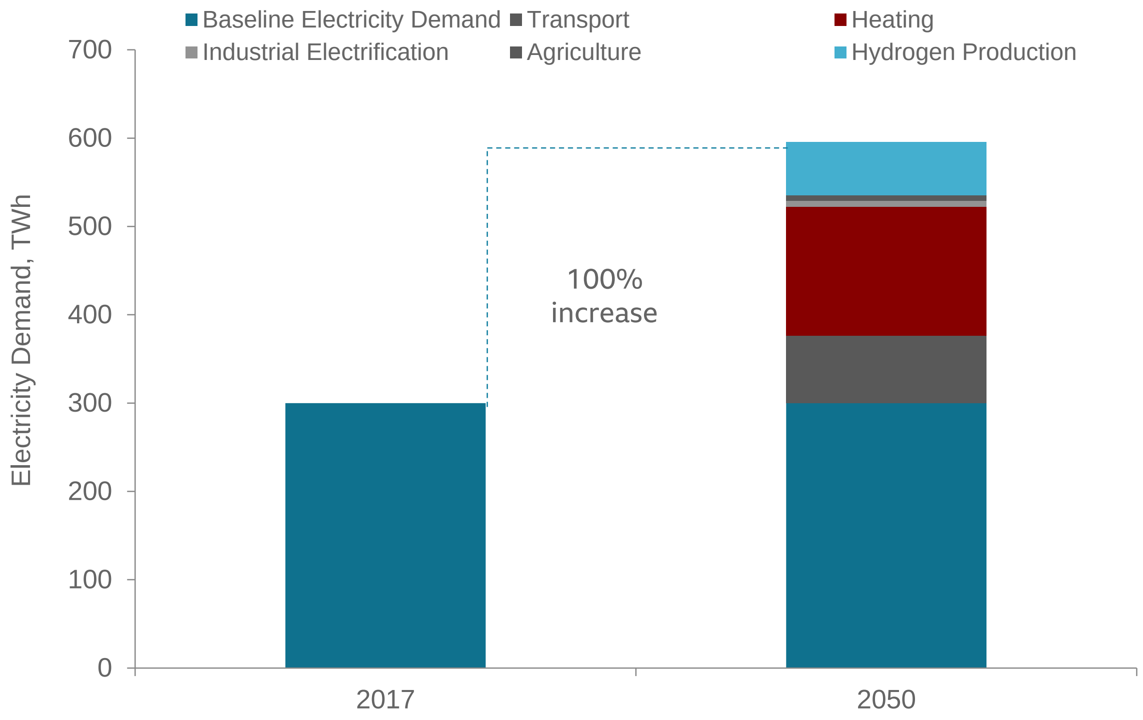
UK electricity sources

- About half our electricity is produced from carbon fuels (gas, coal and oil) and the other half comes from renewable energy sources and nuclear
- Nuclear has generated at least 20% of our electricity for the last 20 years
- Electricity generation from renewables has increased from 10% to around 30% in a decade
- Production using carbon fuels has fallen from 70% to 50% since 2010
- Over the same period, the share of electricity generation from coal has declined from 30% to 7%

BEIS (July 2018) DUKES

The UK's demand for electricity could double by 2050

Annual electricity demand in TWh in 2017 and 2050



The UK in 2050

Committee on Climate Change expects:

- A shift to fully electric vehicles, road haulage switching to hydrogen
- More efficient electric appliances and use of smart meters
- Home heating using hydrogen, home insulation, electric heat pumps and community heating schemes
- Industrial and commercial use of electricity levelling off with more communal heat and power, plus further de-industrialisation

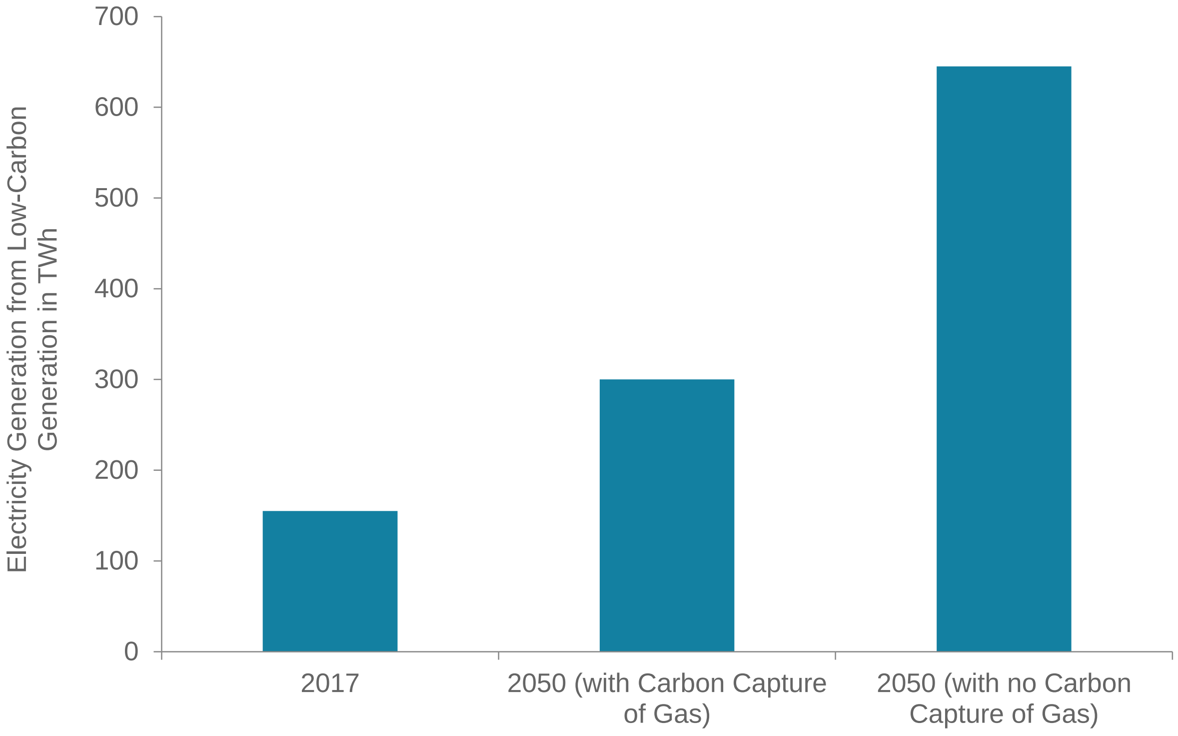
National Grid says:

- Electricity demand will only increase by 41% by 2050, with hydrogen playing a bigger role

CCC (May 2019) Net Zero
National Grid (July 2019) FES

To meet demand for zero-carbon electricity by 2050, generation from renewables and nuclear may have to quadruple

Potential electricity needed from low-carbon generation



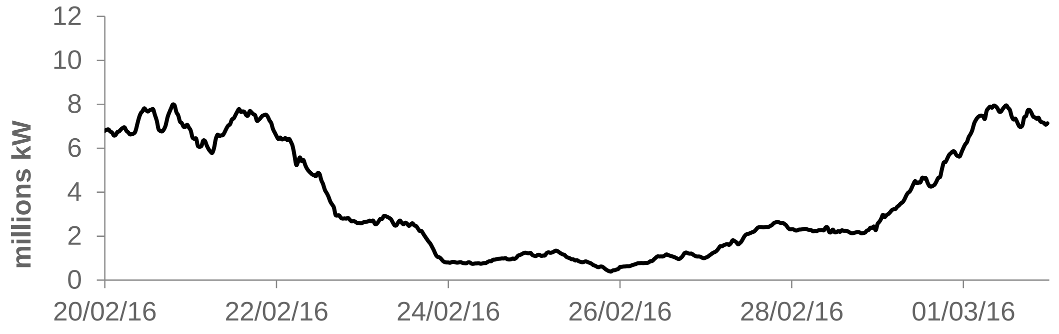
Meeting future electricity needs

- Coal for generating electricity is being phased out by 2025
- Gas must either:
  - be entirely phased out as a source of electricity by 2050, requiring greater development of renewable energy sources, or
  - remain a part of the energy mix, but with its CO_2 emissions captured and stored
- Changes in our electricity supply will also have to meet a 100% increase in demand for electricity by 2050, based on CCC scenarios
- According to the CCC's Net Zero report, a fourfold increase in low-carbon electricity generation could be needed to achieve this

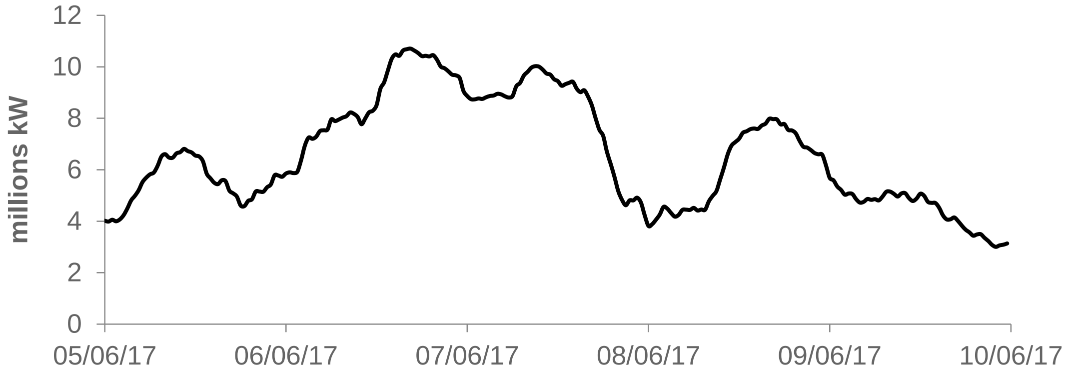
CCC (May 2019) Net Zero

Wind power alone cannot meet electricity demand

Low wind: Wind generation in millions of kW in late February 2016



High wind: Wind generation in millions of kW in early June 2017



BM reports (generation data)

The intermittency of wind power

- On 6 June 2017, the wind generated 50 times more power than on 26 February 2016, an almost windless day
- This kind of unpredictability and intermittency means wind energy:
  - must be stored until it is needed
  - needs alternative energy sources to be available on a still day
- Solar power is another renewable source which must be stored for reasons of intermittency

There is a range of ways to manage the intermittency of renewables

Dealing with intermittency

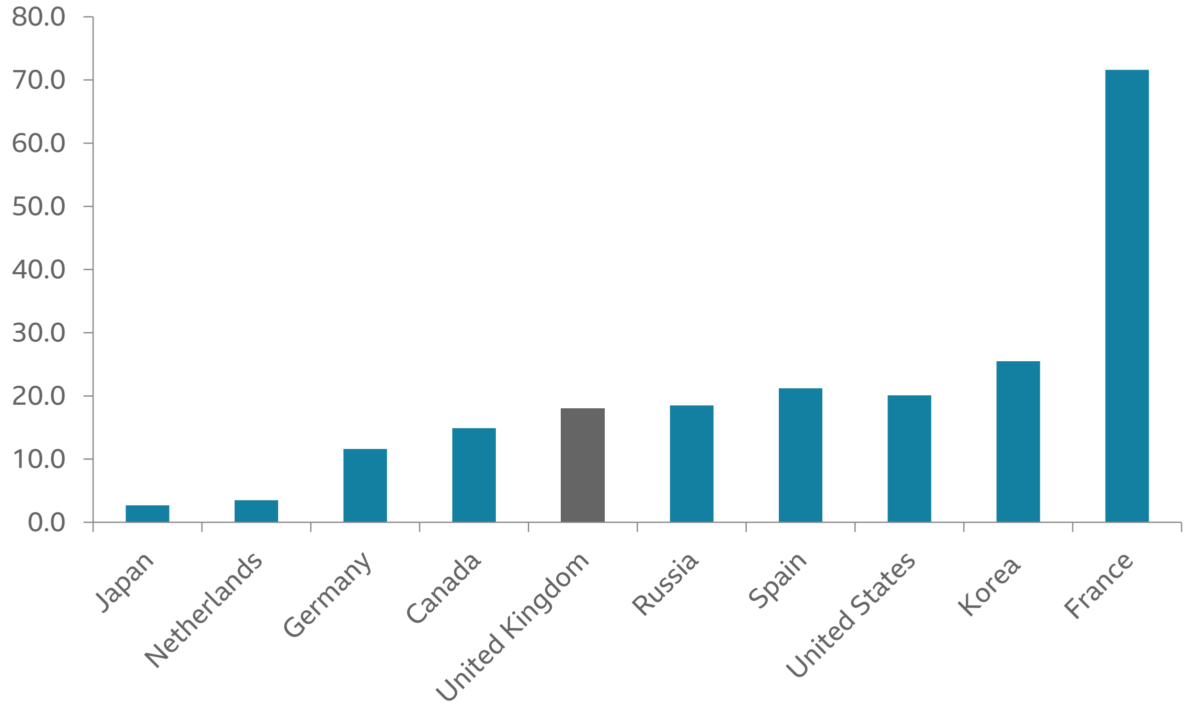
Demand management	Continued use of gas (with carbon capture)	Storage and interconnectors
• Nuclear is sometimes touted as a solution to intermittency but it is too inflexible because it needs to run constantly • Discouraging people from using electricity at peak times and encouraging them to use more off-peak is a sensible way to even out the demands on the grid • Peak and non-peak prices and smart meters can help match daily variations in demand • But this in itself does not deal with the intermittency of renewables	• Gas is very efficient and can provide electricity for peak demand or for filling in gaps in electricity production from renewables • But if we are to control emissions, any residual gas solution would need carbon capture – which estimates suggest could increase the cost of gas generation by up to 50% • Using hydrogen gas to cope with peaks of electricity demand requires the conversion of natural gas to hydrogen, which would also require carbon capture (increasing cost by an estimated 50% to 100%)	• We would need to find ways to store solar and wind power across a day or a week • Storage can be near the point of generation, within the grid or in the home - or a mix of all three • Interconnectors with other countries could deal with some wind intermittency, but not solar (solar would have to come from countries which are in daylight when the UK is dark) • Interconnectors could provide top-up nuclear-powered electricity to meet shortfalls but this requires a joined-up European energy plan • Coping with variations in demand between seasons greatly exacerbates the problems of storage

The UK's nuclear capacity forms a fifth of our electricity supply

Nuclear capacity

- At their peak in the late 1990s, the UK's 19 nuclear power stations provided a quarter of the nation's electricity
- Currently nuclear power provides 21% of UK electricity supply
- This is more than in the United States (19%), but significantly less than in France (79%)
- Typically, nuclear reactors have a life of about 40 years
- The present stock of reactors will be phased out by 2035

Nuclear power share of total electricity production 2018 (%)



World Nuclear Association
OECD/ NEA (2018)

Disposing of long-lasting nuclear radioactive waste is expensive and highly complex

Nuclear radioactive waste

- Nuclear power generation produces radioactive waste
    - Some of it remains radioactive for centuries
    - No fully effective method of nuclear waste disposal has been found yet
    - 80% of UK nuclear waste is stored at Sellafield in “high integrity” stainless steel or concrete containers
    - Nuclear power stations leave a long-lasting and costly decommissioning legacy
- The escalating cost of decommissioning remains uncertain and could be very high
    - The first reactors to shut down are a particular challenge, given the mixed military and civil heritage from half a century ago
    - The industry argues that experience and planning ahead will keep costs of decommissioning reactors down
    - So far, the UK has not developed a long-term deep underground repository which, it is generally thought, the most difficult and long-lasting waste requires

Protesters in the Lake District demonstrate against plans for a nuclear waste storage facility in January 2013

Revived UK government interest in developing nuclear power, which is nearly carbon-free, has hit delays since 2008

The resurrection of nuclear power

- The 2008 UK Government White Paper brought new impetus to nuclear development
- Nuclear produces zero carbon, is deployable at scale and provides jobs in remote parts of the UK
- There is an estimated 100 years' worth of uranium reserves globally
- Nuclear power is not entirely carbon-free – power stations are built with concrete and steel, the fuel transported, the waste handled and the staff moved around
- In 2008 nuclear seemed a relatively cheap source of power compared with the cost of renewable energy
- This revived government interest in nuclear and attracted competing European utility consortiums keen to build new nuclear power stations in the UK
- The global financial crisis of 2008 and the recession, plus escalating costs and construction risks, delayed the programme and caused many utilities to leave the process
- The result was that the first project of this new programme (Hinkley Point C) only reached financial close in 2016, eight years after that White Paper. Hinkley Point C is not expected to be commissioned until 2027 at the earliest – 10 years behind the original schedule

Britain's newest nuclear building project: Hinkley nuclear power station in Somerset

The global nuclear industry is well-established but still faces challenges in building new reactors

The global nuclear industry

- Well-established:
  - 447 operational reactors producing 10% of the world's electricity – though at least 150 due to be decommissioned over the next decade
  - 61 new reactors under construction (primarily outside the OECD – particularly in China)
- Rollout of a new generation of nuclear reactors has stumbled:
  - The Finnish Olkiluoto nuclear station, which uses the same technology as Hinkley Point C, has overrun by nine years at an additional cost of €5.2bn (£4.74bn)
  - The French Flamanville nuclear station, using the same technology as Hinkley Point C, is reported to have overrun by seven years and cost €7.2bn (£6.56bn) more than expected

Reasons for construction difficulties

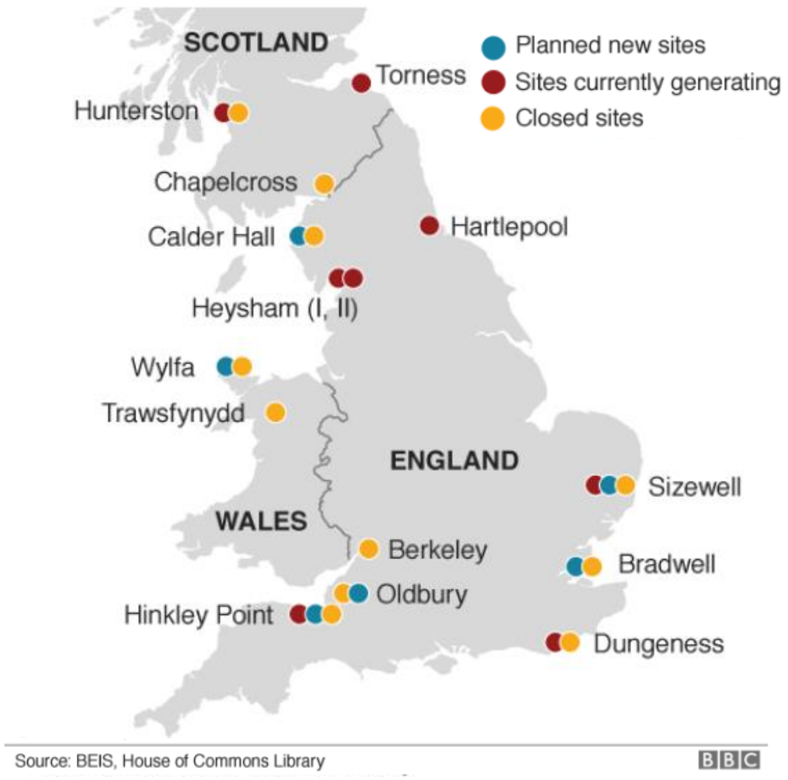
- Lead times for nuclear designs and projects are long
- New regulation and political changes during the lifetime of a construction project can add time and cost
- Projects are large and lengthy and may be undertaken in the private sector for the first time for commercial purposes
- Long timescales make standardised design and construction hard, with approaches changing for new projects
- In Flamanville, for example, new designs and faults in key components have created unexpected problems and delays

The rollout of the UK's new nuclear plan has not been smooth

The UK's nuclear plans

- In 2013, the government's Nuclear Industrial Strategy paper outlined plans to deliver around 16GW of new nuclear domestic builds by 2030
- This commitment translated into building 12 new reactors at five locations: Hinkley Point, Sizewell, Moorside, Wylfa and Oldbury
- In November 2018, Toshiba scrapped its plans to build Moorside due to escalating costs, and had a write-down of $6.3bn (£5.2bn)
- In January 2019, Hitachi became the second firm to scrap plans to build nuclear power plants - at Wylfa and Oldbury
- Together, the three plants would have supplied 15% of the UK's electricity demand
- Despite these blows, EDF Energy, which is developing Hinkley Point C and Sizewell, said its projects were making good progress
- Once completed, Hinkley Point C is expected to deliver 7% of the UK's electricity demand for 60 years

The UK nuclear building programme

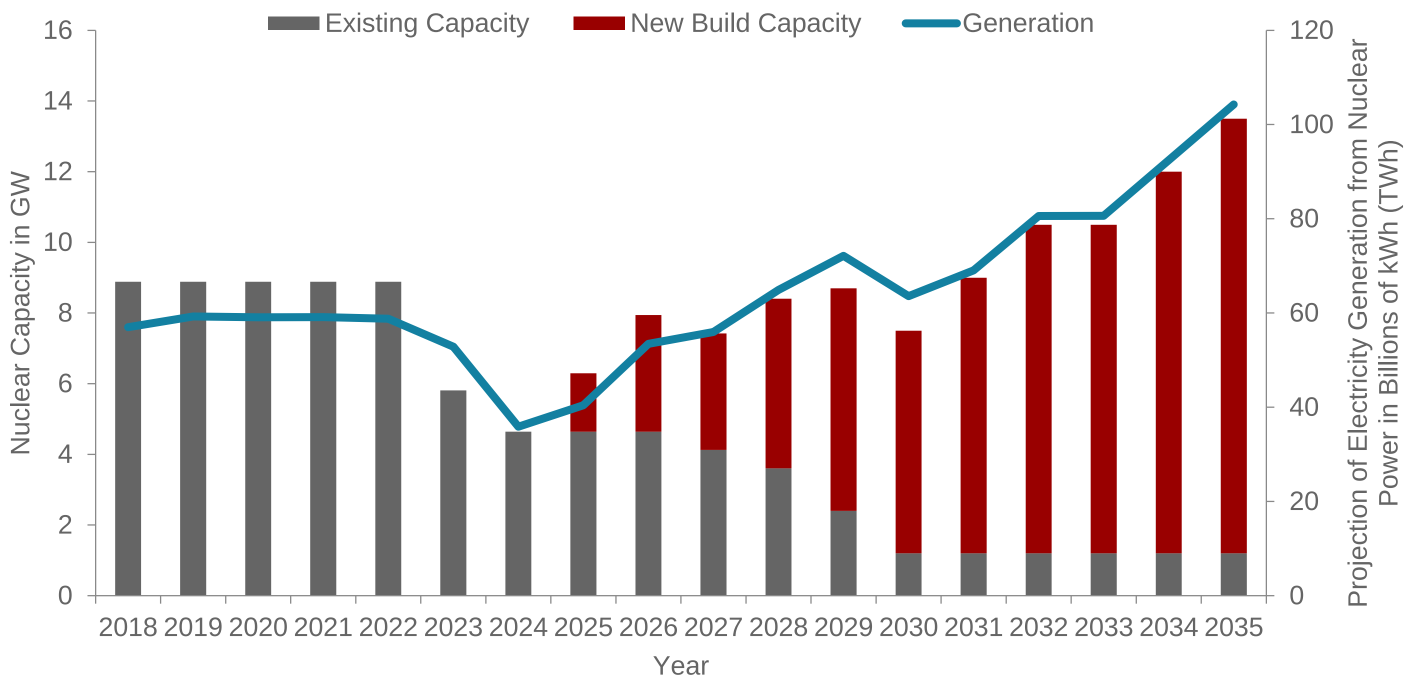


HM Government (March 2013) Nuclear Industrial Strategy:

BBC News

Despite setbacks, the UK government still plans to increase nuclear capacity by 2035

Forecast for nuclear generating capacity in GW (LHS) and projection of electricity generation in billions of kWH (RHS)



New plans for UK nuclear

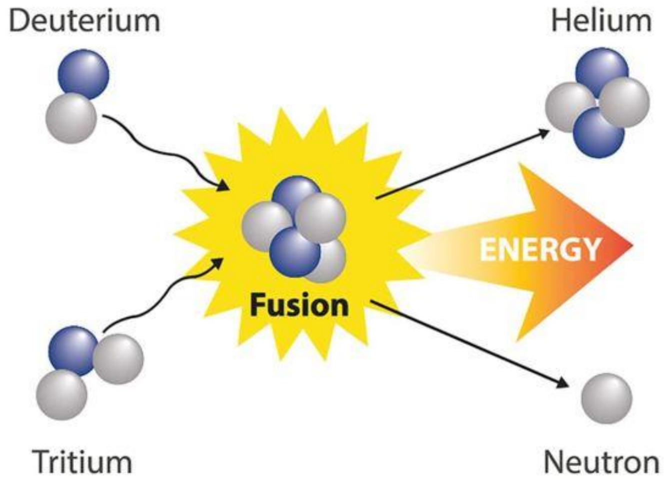
- The original plan, set out in the government's Nuclear Industrial Strategy paper in 2013, aimed to deliver 16GW of nuclear capacity by 2030
- The government's latest projections of capacity and power generation from nuclear are for 12GW of new nuclear capacity in 2035
- These forecasts reflect some of the recent setbacks in building the planned nuclear sites

BEIS (April 2019) Energy and Emissions Projections:

Nuclear fusion would, in theory, provide virtually limitless clean energy but has yet to prove practical

Experimenting with nuclear fusion

- Nuclear fusion is the process by which chemical atoms combine to generate huge amounts of energy. It is different to nuclear fission, the process used in nuclear power stations, in which energy is released by splitting an atom
- Unlike fission, nuclear fusion does not produce long-lasting radioactive waste, making it clean and, in effect, limitless
- Experiments with fusion continue, despite not yet proving commercially viable because of the extremely high temperatures sustained under great pressure. The energy required is currently greater than that generated:
    - In November 2018, scientists in China built a prototype fusion reactor
    - A consortium in France is experimenting with super-heated plasma and hopes to generate power by nuclear fusion by 2035
    - British, American and Canadian enterprises are also experimenting with fusion projects
- Brad Pitt is among the celebrities reported to have invested almost $1bn (£817m) in Industrial Heat, a US start-up promising "cold fusion" without the need for high temperatures, despite the lack of scientific evidence that this is possible



World Economic Forum (May 2019)

BBC Briefing - Energy

Summary

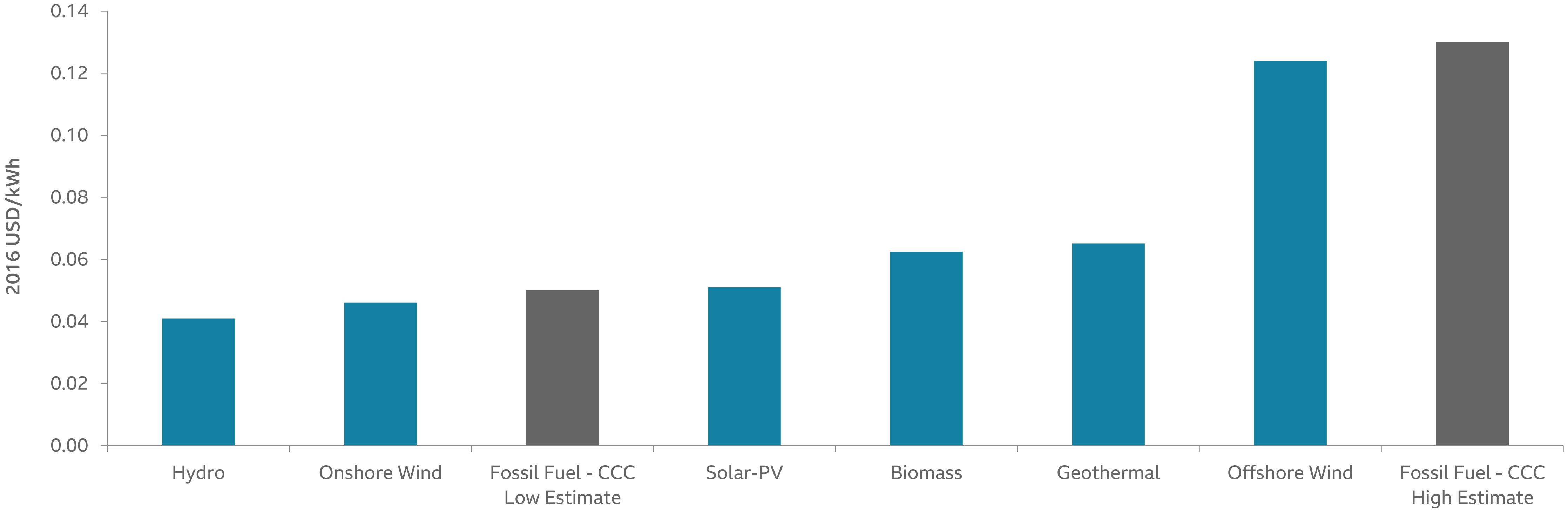
Nuclear Power

Nuclear is back in the UK as a theoretically limitless source of virtually carbon-free electricity but concerns over cost-effectiveness, safety and the long-term legacy of radioactive waste have plagued the project. A decade after nuclear reclaimed its place as a central pillar of UK energy policy, only one new power station has entered construction.

The UK government's plans for future electricity supply depend on doubling the contribution of nuclear power over the next two decades, while decommissioning the existing fleet. Major questions remain as to how the industry can finance and deliver this programme on time and on budget, especially when the cost of renewables is falling.

Global prices for renewable electricity are comparable with fossil fuel generation

Global average auction prices of various renewable sources



The low and high estimates for fossil fuel indicate the range of possible future prices for those fossil fuels

CCC (May 2019) Net Zero

There are seven main renewable energy sources in the UK

Definition of renewable energy

Definitions of renewable energy vary:

- It is generally defined as sources of power generation which do not emit CO_2 and where the fuel source is potentially endless or renews itself
- However, the definition in many countries, including the UK, includes technologies that emit CO_2 but reduce the volume of greenhouse gases by using landfill gas, methane and sewage gas
- The UK definition also includes fuels that emit CO_2, but can be replaced, and - when they are - absorb the CO_2 back again eg biomass

Renewable sources of energy

- Onshore wind
- Offshore wind
- Solar
- Hydro power
- Marine (wave and tidal power)
- Biomass
  - energy from burning natural plant or animal material
- Sewage sludge, landfill gas and anaerobic digestion (biomethane gas)
  - energy derived from gases emitted as natural by-products of bio-degrading
  - anaerobic means this process happens without oxygen (usually underground)

Many countries are naturally endowed with hydro and geothermal energy

Iceland

- Iceland operates on 100% renewable electricity
- The country generates most of its electricity from hydro power
- It also has a natural (and rare) exploitable geothermal resource because of its position straddling two tectonic plates

Norway

- Norway operates on almost 100% renewable power for electricity
- This is despite being a major producer and exporter of oil and gas
- Domestically Norway generates electricity almost entirely from hydro power

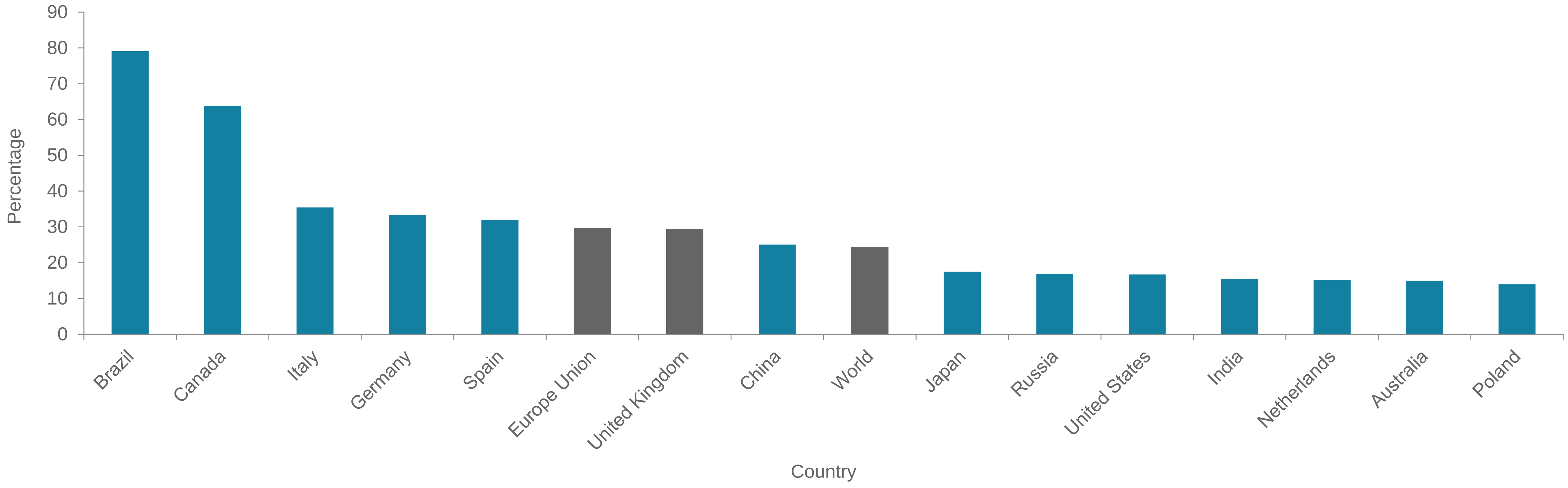
Geothermal power in Iceland

Hydroelectric power in Norway

Norwegian government (May 2016)
NEA Iceland

The UK's use of renewables matches the EU average

Percentage of electricity supplied by renewable sources in 2017



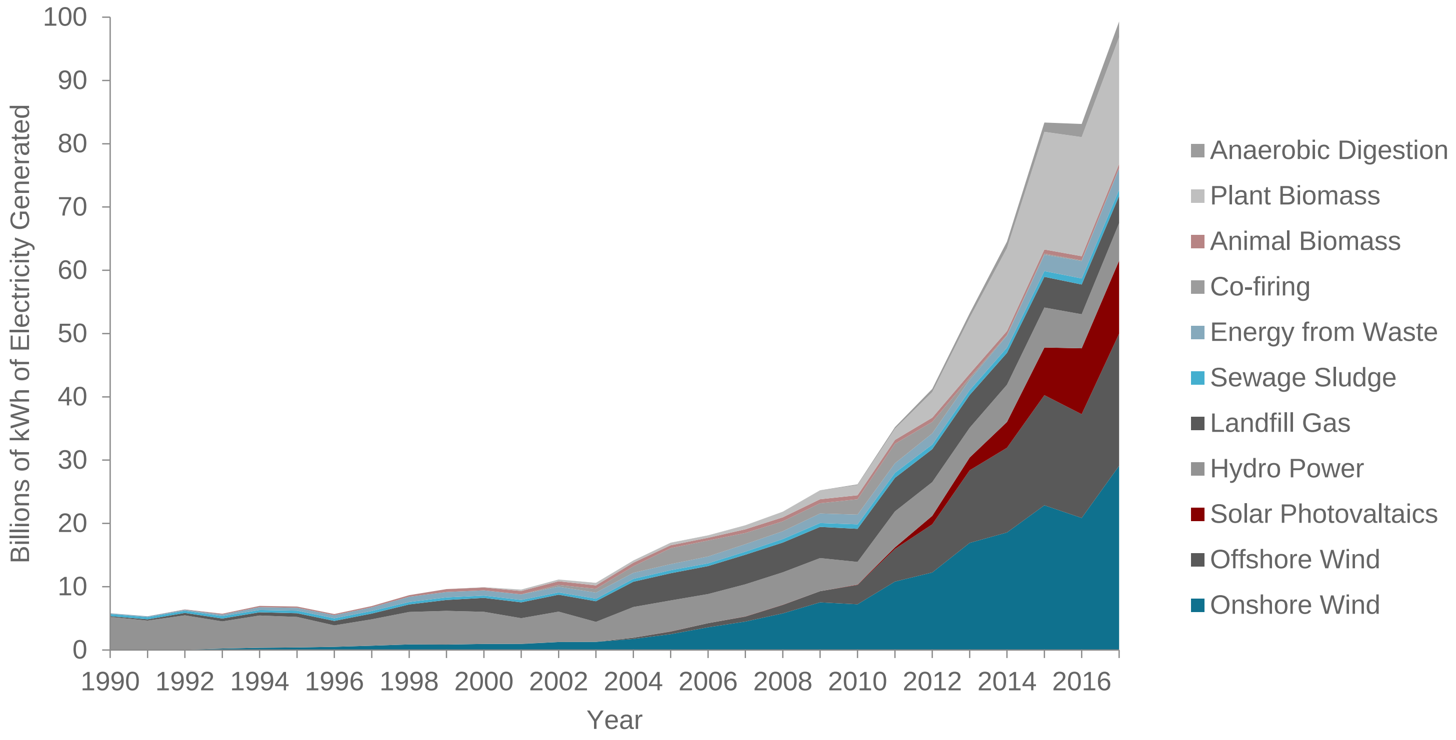
BP (June 2018) BP Statistical Review of World Energy

A new UK subsidy regime for renewables in 2002 stimulated a boom in investment

	The story of UK renewable energy
Pre-1990s	• As with many countries, the UK had largely exploited its potential for hydro power as it built its electricity system, with no contribution from other forms of renewable power
1991-2002	• Very limited support for renewable energy development • Series of auctions for support for renewable energy through the 1990s • Very competitive pricing but limited deployment • No solar, little wind, some development of niche sectors such as landfill gas
2002-2014	• 2002 introduction of a new support regime for renewables • Boom in onshore wind investment • 2009 extra subsidy for offshore wind kick-starts a boom in that technology • 2010 introduction of subsidies for small-scale renewables leads to a boom in solar PV investment
From 2015	• Phased transition from previous subsidy / support regime to a more competitive arrangement through market reform • Effective end to support for onshore wind leads to little new investment • Reduced support for solar PV causes a slowdown in investment • Installation cost of wind and solar falls dramatically around the world • Support for future offshore wind projects provided under auctions instigated by the government

There has been a dramatic growth in wind and biomass power in the UK since the early 2000s, and in solar since 2010

Renewable sources used to generate electricity in billions of kWh 1990-2017



Renewable electricity generation sources in 2018

- Wind and Solar PV: 64%
  - Onshore wind: 28%
  - Offshore wind: 24%
  - Solar PV: 12%
- Hydro: 5%
- Bioenergy sources: 31%
  - Plant biomass: 20%
  - Landfill gas: 4%
  - Energy from waste: 3%
  - Anaerobic digestion: 2%
  - Sewage sludge: 1%
  - Animal biomass: 1%

BEIS (July 2018) DUKES

Bioenergy accounts for about a third of our renewable electricity

Number of installations of renewable energy sources

	Number of installations	Number of projects	Generation capacity	Percentage of renewable electricity production	Percentage of total electricity production
Onshore wind	6,004 turbines	1,210 projects	13.2m kW	27%	9%
Offshore wind	1,497 turbines	28 projects	7.9m kW	24%	8%
Solar	907,597 installations	852,127 small projects	12.9m kW	12%	4%
Bioenergy	There are many small biomass generators in the UK but production is dominated by the converted coal station Drax in North Yorkshire, which has switched four of its six generation units to produce electricity from biomass			32%	11%

Renewable UK wind deployment
DBEIS (July 2018) DUKES
Drax (August 2018)
BEIS (February 2017) Solar deployment

Solar power is likely to play an enhanced role in future UK energy generation

The evolution of solar power

- There are two ways of capturing solar power:
    - photovoltaic cells, which capture sunlight and convert it directly into electricity
    - solar thermal technology, which captures heat (not light) from the sun and converts it into electricity
- Solar power has grown rapidly in the UK since 2010
- By 2019, the installed capacity exceeded 13 GW
- In March 2019, solar provided 4% of UK electricity
- There are about a million solar installations in the UK, but nearly half of UK solar power is provided by 460 large solar farms
- National Grid estimates that in the most optimistic "green" scenarios, solar could account for 20% of UK electricity by 2050
- Intermittency of this energy source remains a limitation, unless storage issues can be overcome and the electricity system can run more flexibly

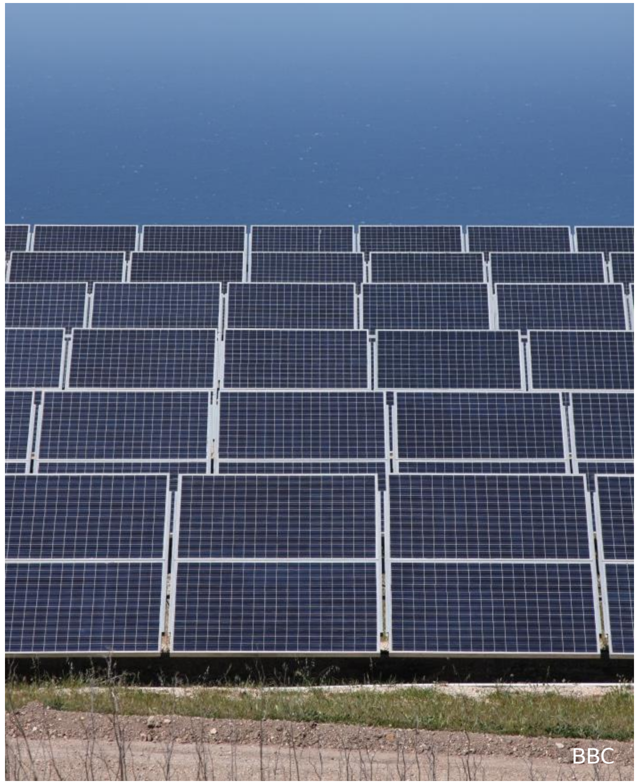
GETTY

BEIS (February 2017) Solar deployment
BEIS (July 2018) DUKES

In May 2019, a new UK record was set for the percentage of electricity generated from solar power

Solar energy records

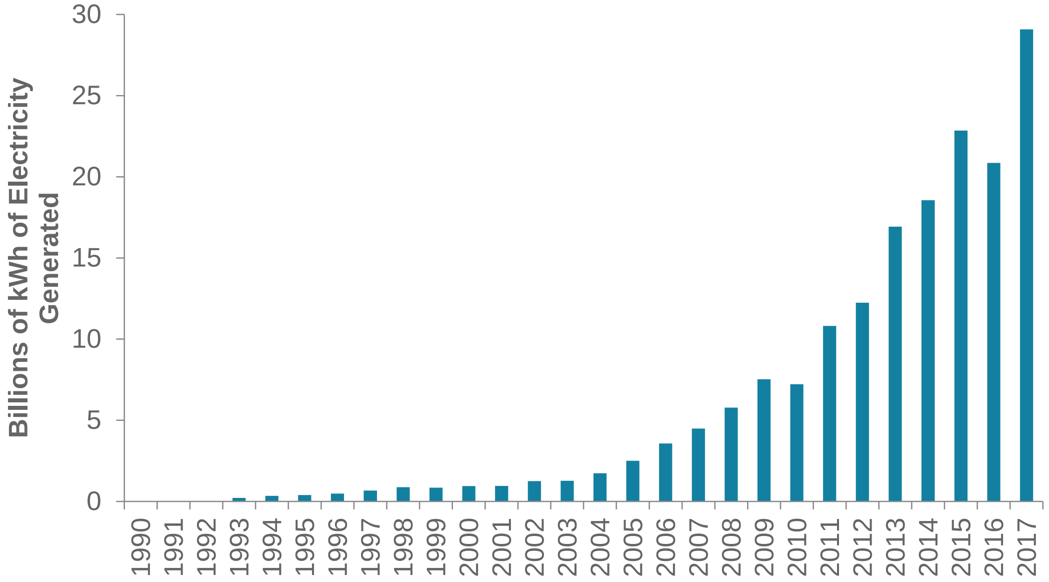
- On 13 and 14 May 2019, solar panels broke their record for energy generation in the UK on two days running. They hit peaks of 9.47 and 9.55 gigawatts (GW) respectively, beating the record previously held since 2017
  - The earlier solar power record was made on 26 May 2017, as the country enjoyed sunshine and temperatures of up to 28C, according to National Grid
  - 8.7 gigawatts (GW) were generated at lunchtime – just over 24% of total generation across the UK
  - Duncan Burt, head of control room operations at National Grid, called it the "beginning of a new era“
  - “We now have significant volumes of renewable energy on the system," he said. "We also have the tools available to ensure we can balance supply and demand“
  - Alongside the contribution from solar that day, 23% of power came from nuclear sources, 30% from natural gas and just 1.4% from coal. Wind, hydro power and biomass were also used



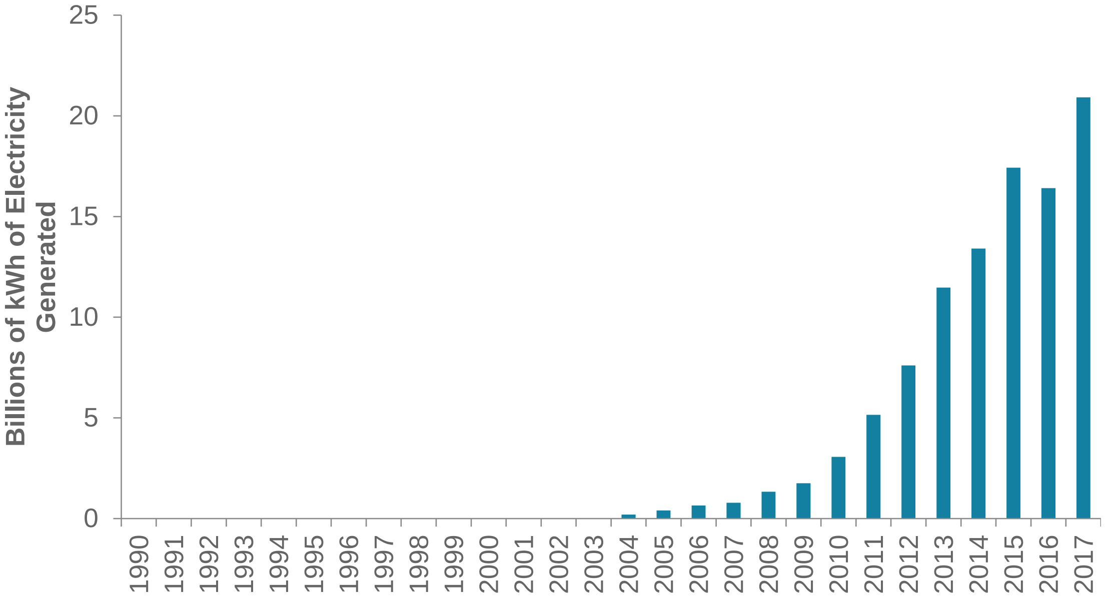
BBC News

Wind energy has expanded substantially over the past 20 years, first on land, then on sea

Onshore wind production in the UK



Offshore wind production in the UK



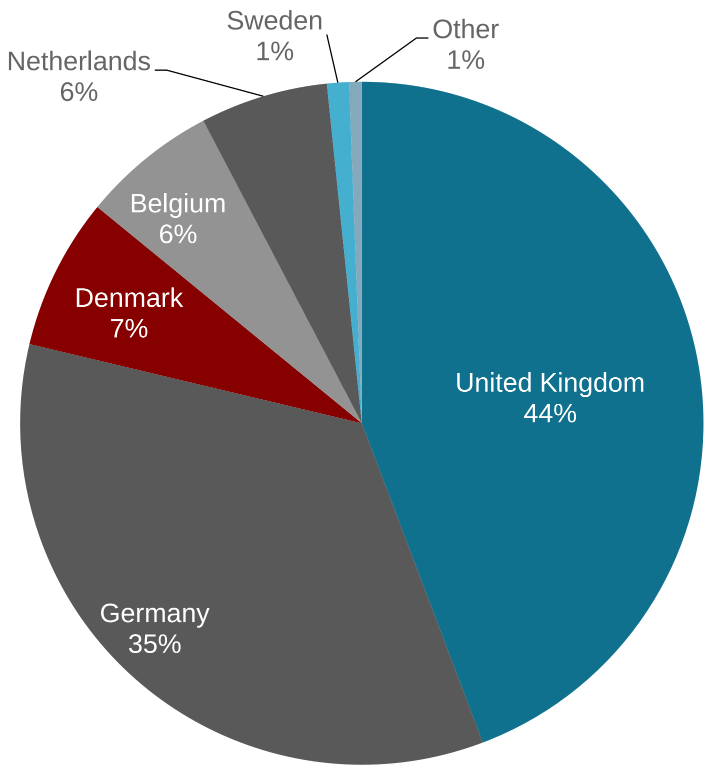
Opposition to onshore wind

- Since 2016, the government has blocked subsidies for onshore wind following opposition from some local communities, although general public support for onshore wind was positive, at about 80% in March 2019

BEIS (July 2018) DUKES
BEIS (march 2019) Public attitudes

The UK has the largest offshore wind capacity in the world

% Offshore wind market share in Europe at the end of 2018



Wind Europe (February 2019) Offshore Wind in Europe

Offshore wind could potentially supply all UK electricity needs but onshore wind would be cheaper

Offshore wind

- Near-shore, shallow water offshore wind (25m depth) has a total theoretical potential of 120m kW, enough to provide the UK's electricity demands. But issues such as safe shipping lanes and wildlife protection mean this resource cannot be fully exploited
- Deep (25-50m) water depth has the theoretical potential of 240m kW - sufficient for several times the current UK electricity demand
- Floating offshore wind turbines have the capacity to exploit wind resources far out to sea in very deep water, and the potential for this technology is enormous. The first test installations have been made in Scotland
- For the UK to supply all current electricity needs from offshore wind requires 60-80m kW of capacity, which is 7.5-10x current (2018) installed capacity
- Offshore wind has been twice as expensive as onshore wind due to the need to build foundations and offshore cables, and a more costly connection to the grid. But this is offset by economies of scale plus higher wind and capacity factors. As a result, the comparative price between offshore is now much closer to that of onshore
- Offshore wind is also being developed in some countries without expensive subsidies

Offshore wind turbines on the mouth of the River Mersey near Liverpool

Sustainability without the hot air – D.J.C. Mackay
The Briefing team calculations

Wave and tidal energy resources have huge potential but the technology is judged to be too expensive

Tidal energy

- Global tidal energy resource is estimated at 1,200 TWh per year
- There are three main types of tidal power stations
  - Barrages installed across tidal estuaries
  - Artificial tidal lagoons
  - Submerged stream generators (underwater turbines)
- Two tidal barrages, La Rance in France and Sihwa in South Korea, accounted for 94% of the global tidal energy capacity in 2015
- Underwater components are vulnerable to damage from salinity and storms, and the difficulty in accessing them for repair results in operation and maintenance costs of 5.8% of capital expenditure annually, compared with 3.7% for offshore wind

Wave energy

- Global wave energy resource is estimated at 29,500 TWh per year
- Wave energy is far less advanced, with no commercial-scale wave power operations currently in operation
- The UK has deployed more wave energy devices than the rest of the world combined, and the UK is home to the European Maritime Energy Centre (EMEC), the world's only dedicated testing centre for marine power
- The UK accounts for 50% of Europe's total wave and tidal stream resource

European Commission - ocean energy
IRENA (March 2017) Ocean energy

Biomass has become an important part of the UK energy mix

Where does biomass come from?

- Biomass is an energy created from naturally occurring renewable organic materials
- It can be burned or processed into biofuels, like ethanol and methane
- In 2017, plant and animal biomass generated 6% of the UK's electricity
- Biomass is derived through:
  - Anaerobic digestion – micro-organisms break down biodegradable material without the presence of oxygen; marsh gas is an example
  - Plants – wood, plant residues and agricultural crops
  - Animals – animal waste products
  - Co-firing – where biomass is burned together with fossil fuels (sometimes natural gas and biogas can be mixed) to produce a more environmentally friendly outcome
  - Waste – municipal waste, household rubbish or sewage sludge
  - Landfill gas – the action of micro-organisms in landfill sites produces gas by-products, mainly methane

Biomass Sources

Forest

Crops

Biomass is burned in power stations to create electricity

Biomass can also be used to create fuels

BEIS (July 2018) DUKES

Sustainability and emissions benefits of biomass are controversial

Sustainability of biomass

- As plants grow, they absorb carbon dioxide from the air and are then harvested and burned to generate electricity
- The whole cycle is carbon neutral – the burning process re-emits the CO_2 that the plants removed from the atmosphere, without emitting any more of it
- The environmental saving against burning coal is significant, according to supporters
- But the sustainability of biomass remains controversial; a 2018 Parliamentary motion signed by 40 MPs said:

  "This House notes… burning wood to generate electricity is a high-carbon power source; further notes that burning biomass to generate electricity damages forests and biodiversity, pollutes communities in source countries and…worsens climate change"

- Critical to the argument about biomass is whether it is harvested sustainably - if the stock of forest which stores the CO_2 from the atmosphere is being replanted and maintained, or being diminished by harvesting the fuel
- Another key factor is the time taken for young trees to absorb the CO_2 emitted by burning old trees

HoC (March 2019) Subsidies for biomass

BBC Briefing - Energy

Summary

Renewables

Renewable energy, in the form of wind, solar and biomass, constitutes a third of UK electricity production.

Solar and offshore wind are the two green technologies with the potential to meet most of the UK's electricity demands.

Wind is variable and does not correlate with demand, and solar production is highly seasonal.

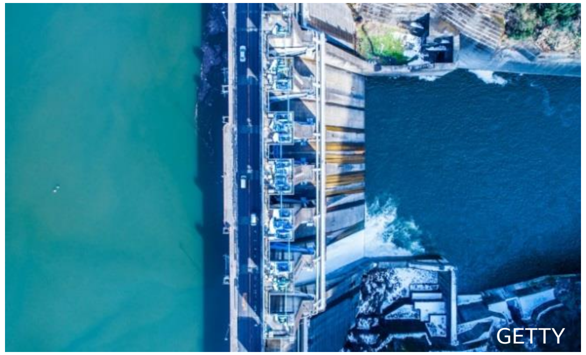
Biomass plays a key part in our energy production but remains controversial over how sustainable it is, and the actual emission benefits of burning it.

So to integrate intermittent renewables more fully, our electricity system needs to have more flexibility in the future. That means more storage, a bigger range of technologies and interconnections, and the ability for generation to meet fluctuations in demand.

Currently, there are four ways of storing electricity…

Options for electricity storage (1)

1. Storing electricity as gravitational energy:
   - This method uses electrical energy to move large masses, normally of water, uphill
   - Those masses are used to generate electricity when later required
   - The UK has 2.7 million kW of pumped storage capacity
   - Most of this is at two locations in Wales
   - Limited additional capacity is expected in the UK due to a lack of suitable mountains and the cost of development
2. Storing electricity as electrical potential energy:
   - Batteries store electricity directly as electrical potential
   - Lithium-ion is currently the most commercial large-scale battery technology
   - Micro-batteries are batteries installed in domestic homes, generally on a small scale
   - They normally operate over short cycles providing short-term storage
   - Batteries have not yet been generally deployed at large scale in the electricity system, but new projects are being developed
   - Developments in electric cars are driving battery development
   - As it is a modular technology, there may be cost reductions similar to those for solar



Hydropower dams store river water that creates electricity when it is released through turbines

Lithium cell batteries

…but the options for renewable electricity cannot yet be deployed on a sufficiently large scale

Options for electricity storage (1)

3. Storing electricity by changing the state of a substance:
   - This process might convert air into a different storable state (eg by compressing or liquefying it)
   - It produces electricity again when converted back to its original state
   - CO_2 and water vapour are removed from the air and the remaining air, mostly nitrogen, is chilled to -190C (-310F) and turns to liquid
   - This provides a compact storage medium that can later draw energy in the form of heat from the environment, but this has not been deployed at scale in the electricity system
   - The constraints are the scarcity of locations and the technically and economically unproven method
4. Creating substances which can later be turned into electricity:
   - This involves creating another substance, say hydrogen or a synthetic fuel, from electricity
   - This substance is then stored and used to deliver energy at a later date
   - Such technologies have the potential to store electricity over long periods
   - For the most part, these technologies are not yet commercially viable or, in most cases, technically proven
   - The exception is hydrogen creation from the electrolysis of water. But this has not been deployed at scale in the power sector

Liquid nitrogen containers

Hydrogen filling station

Improving battery storage would need expanded mining of rare earth metals

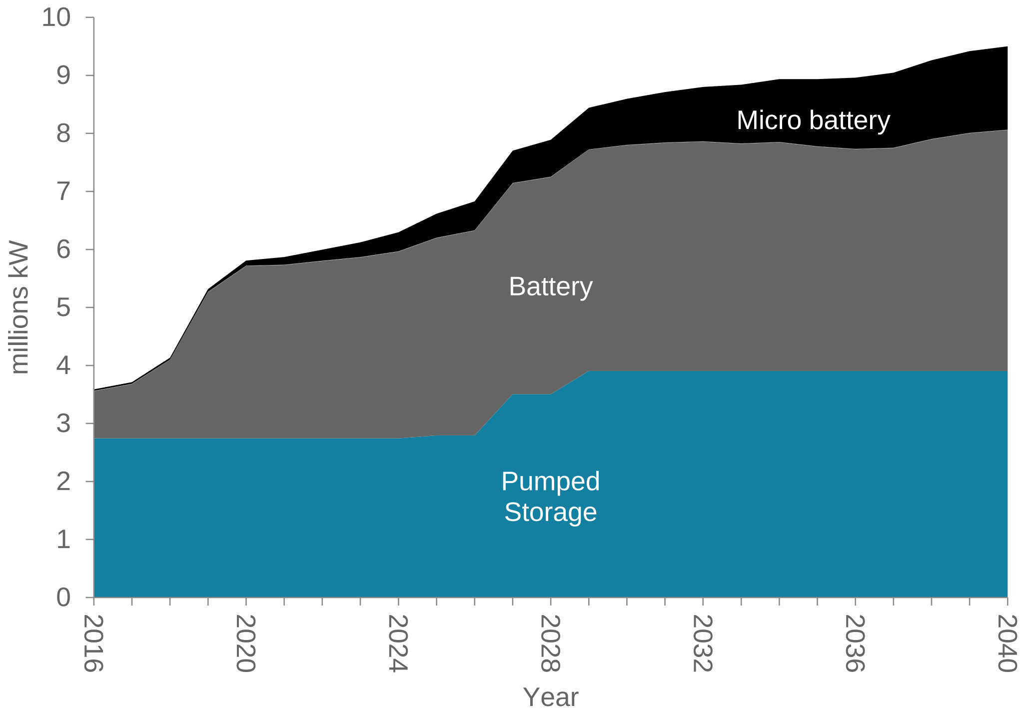
The availability of rare earth metals

- Rare earth metals are essential for battery storage; such metals include neodymium, lithium, cobalt, copper and gold
- Big increases in battery storage would require a huge expansion in mining of these metals
- There are several problems associated with rare earth mining:
    - It is generally under-developed
    - Many critical deposits are located in a handful of countries which could exercise monopoly control; eg 85% of neodymium is found in China, and two-thirds of all cobalt comes from the Democratic Republic of Congo (DRC)
    - Some metals - like copper - are hard to locate and extract
    - Mining conditions in some of these countries do not meet basic human rights standards

Piles of dirt dug in search of gold at a mining site in Burkina Faso

Stored energy is predicted to meet only 10% of UK peak electricity needs by 2040

Storage capacity in National Grid – scenario example



National Grid (July 2017) FES

Building storage capacity

- National Grid predicts that by 2040, only 10% of UK peak electricity needs will be met by stored energy
- It plans to achieve this:
  - mainly through battery storage, primarily lithium-ion batteries
  - by pumped storage and the use of hydro power
  - by including micro-batteries in people's homes; this is seen as a potentially good way to build capacity
  - by using parked electric cars as a source of storage when not being used during peak times of demand, then recharging them overnight when electricity demand is low
- The proportion of storage in the long term will be determined by the proportion of renewables in the production mix

Summary

Electricity Storage Capacity

Large-scale, cost-effective electricity storage would be needed in a fully low-carbon electricity system to help manage the intermittency of renewable power.

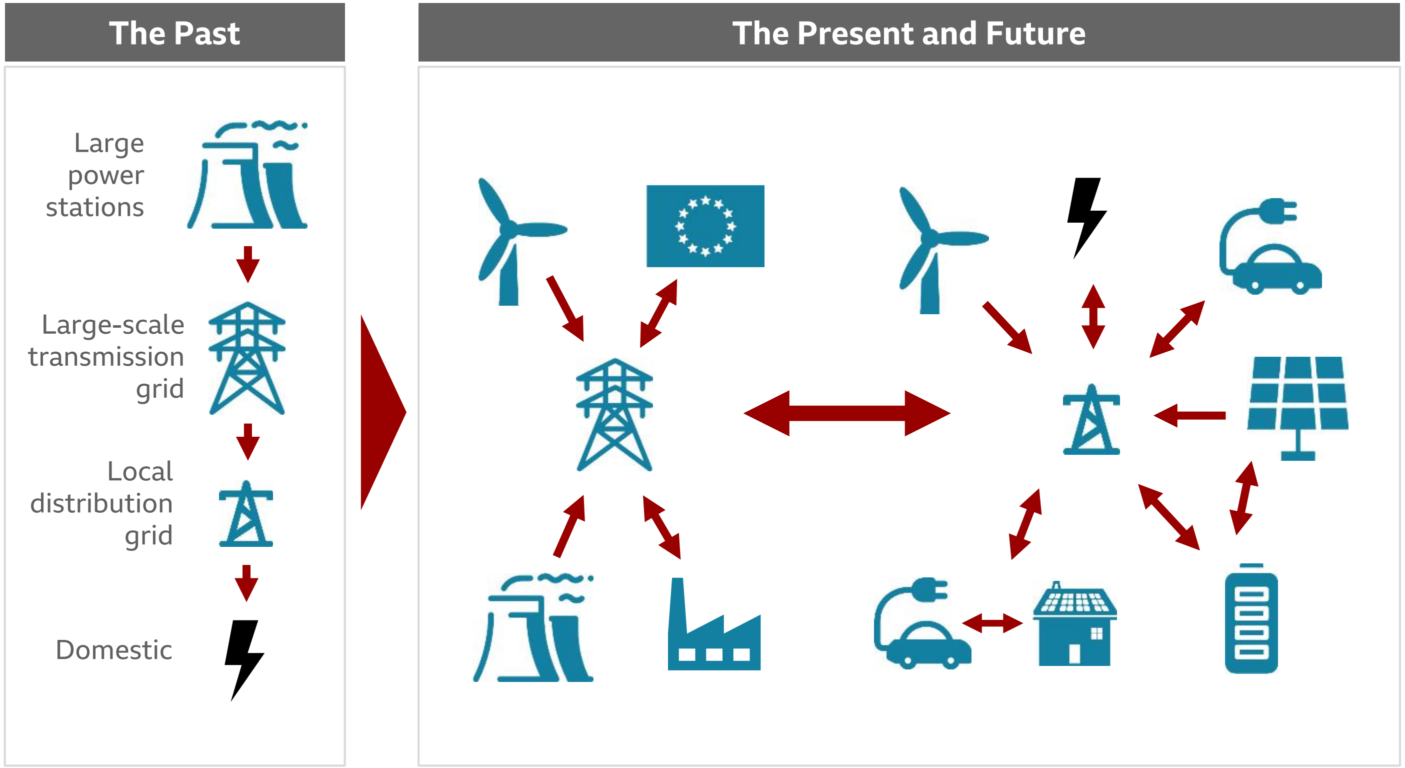
A number of storage technologies exist, none of which has been deployed at the required scale, and many of which are challenged by cost, scalability and technical feasibility.

Battery storage, driven by the development of electric vehicles, has achieved dramatic reductions in cost. It is not yet clear, though, if utility-scale storage can be deployed cost-effectively in a way that would allow a fully renewable and storage-based system.

So existing scenarios for the future of the UK's electricity system do not yet envisage a renewables-only dependent system which relies on sufficient deployment of storage to operate.

The UK grid is being transformed to respond to radical changes in the generation and consumption of electricity

The changing structure of the electricity grid



The past: Centralised system

- Large-scale central generation, often located in coal fields
- The transmission grid takes power to centres of demand
- A local grid distributes electricity to homes and businesses
- It is a simple, one-way flow of energy
- Supply responds to meet changing demand

The present and future

- Multiple, dispersed sources of power, including wind and solar, are connected to the grid
- Increasing amounts of power come via undersea cables from other countries
- The grid uses more power from storage, like batteries
- There are new uses for electricity, particularly electric vehicles
- More power comes from variable or intermittent sources, like wind and solar

BEIS (March 2017) Energy and Emissions Projections)

The electrification of vehicles will be a major test of the electricity network

Electricity demand of electric cars

- The average UK household load is one kW; the charging capacity of some new and high-end electric vehicles is seven to 11 kW. So six electric vehicles could cause local power cuts if connected to the same local area network
- It is likely to cost tens of billions of pounds to upgrade the network to accommodate the rollout of electric vehicles
- EV charging systems could be reversed when plugged into the grid after work to feed electricity back into the system at a time of peak demand – so-called “vehicle-to-grid” technology
- Electric vehicles could then be re-charged during the night at times of low demand
- This would help to increase grid resilience, allow for better exploitation of renewable sources and lower the cost of ownership for EV owners – who could even earn income from their vehicles by selling their services to the energy system

Retail chain Marks and Spencer has been using electric delivery vans to help make its business greener for more than a decade

The electrification of heating will eventually impose extra demand on the national grid

The challenge of electric heating

- Electric heating solutions operate at lower temperatures than existing gas-based systems
- Significant investment needs to go into improving home insulation to maximise electrical heating efficiency
- An efficient electrical heating solution will be the most energy-intensive electrical device in most homes
- Electricity supply has to increase substantially, and the grid strengthened, to accommodate larger peak loads; for example, first thing in the morning, and again in the evening

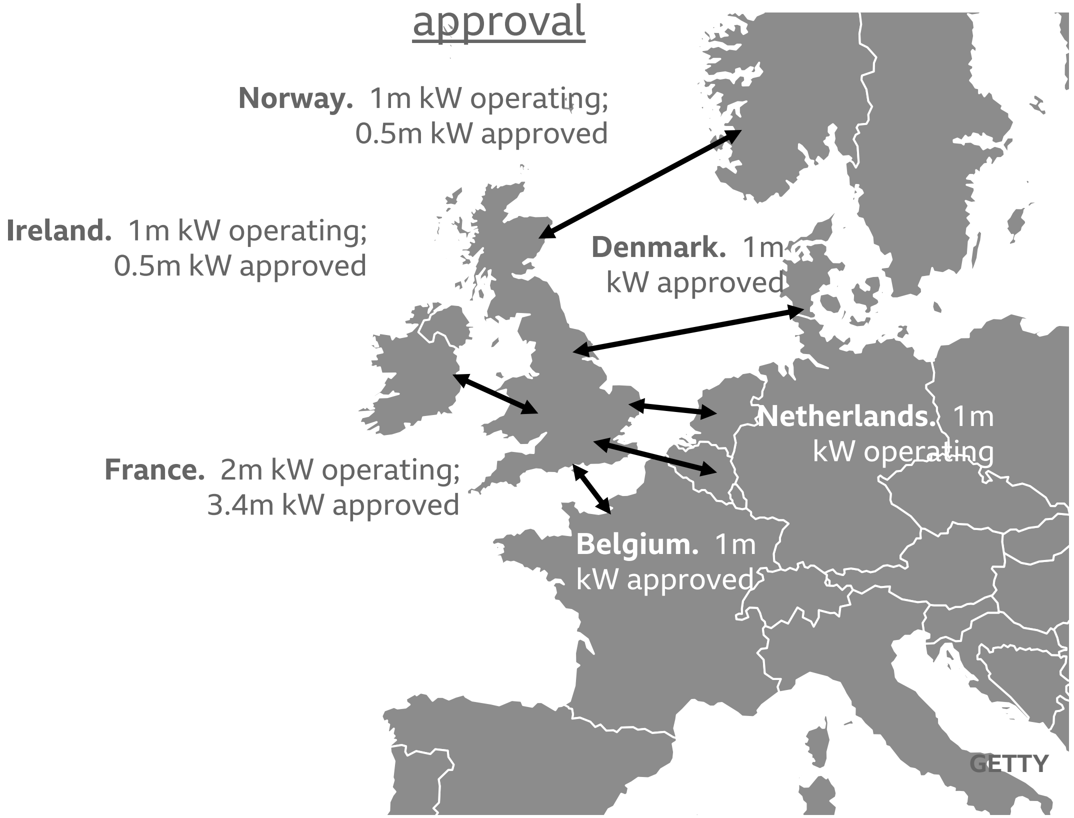

GETTY

The UK has begun trading electricity with neighbouring countries

Electricity trading a growing phenomenon

- Until 2004, the UK was self-sufficient in electricity. But trading and importing it through interconnectors is now a growing aspect of the UK's electricity supply
- The UK currently imports 4% of its electricity
- A current programme of investment may deliver a four-to-fivefold increase in interconnection
- By 2022, the UK will be importing electricity from France, Ireland, the Netherlands, Belgium, Denmark and Norway – much of it carbon-free (for example, French nuclear or Norway hydro power)
- By 2030, it may import around 25% of its electricity via interconnectors with its European neighbours
- However, the UK may also be able to sell electricity in the future, for example from offshore wind during periods when production exceeds immediate need

Current and future interconnectors with regulatory approval



Ofgem

Energy imported through interconnectors offers both advantages and disadvantages

Imported electricity

Advantages

- Importing energy through interconnectors provides a mechanism for balancing supply and demand as a back-up or last resort
- Imported electricity does not add to the UK's carbon emissions and is often cheaper

Disadvantages

- Electricity acquired through interconnectors is not always carbon-free in the exporting country, so there is a risk of merely displacing carbon emissions between the UK and other countries
- The risks for imports over domestic supplies could be different and may potentially mean less UK government control
- Imports may have an impact on the balance of trade and be affected by currency fluctuations
- Trading arrangements, post-Brexit, are not clear


GETTY

Summary

Matching Supply and Demand

For the electricity system to function smoothly, electricity must be delivered when and where needed, and in the right form of power.

The UK's national grid – the system for delivering power via cable right across the country – will need to change to cope with new forms of supply and demand.

It will need to accommodate a growing number of power-generating sources, particularly renewables. It will need to cope with the huge extra demand of heating and vehicle electrification heading our way in the low-carbon era.

The UK will need to ensure that the grid can adequately meet peaks in demand whenever they arise - through storage, demand management and, if necessary, using natural gas with carbon capture equipment too.


ON
Budget
25%
£ 0.11
per hour
£ 0.85
25%
£ 1.30
36%
£
%

Part 7/9

The Cost of Energy Today

Are energy bills in the UK too high for consumers and industry?

If so, what are the main factors influencing what we pay?

High energy bills have recently been a matter of political debate

The government's response

- In March 2017, then Prime Minister Theresa May said:

  "Energy is not a luxury, it is a necessity of life. But it is clear to me – and to anyone who looks at it – that the market is not working as it should"

Labour's response

- In its 2017 party manifesto, Labour proposed a price cap of £1,000 on dual-fuel bills (combined gas and electricity) and the renationalisation of parts of the industry. Labour leader Jeremy Corbyn said:

  "I would want the public ownership of the gas and the National Grid… I would personally wish that the big six were under public control, or public ownership in some form"

The industry response

- In August 2017, British Gas owner Centrica blamed green levies for adding an extra £149 a year to household bills. The firm said green taxes caused "significant pressures" on pricing and there was no option but to pass costs on to customers. Centrica CEO Iain Conn said:

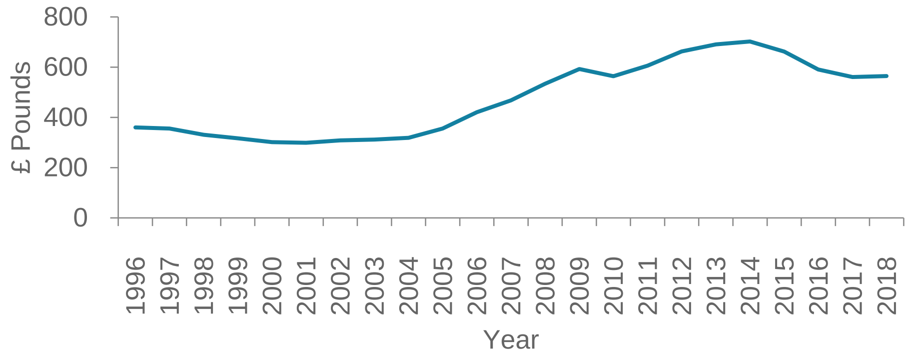
  "It is transmission and distribution of electricity to the home and government policy costs that are driving our price increase"

New government initiative

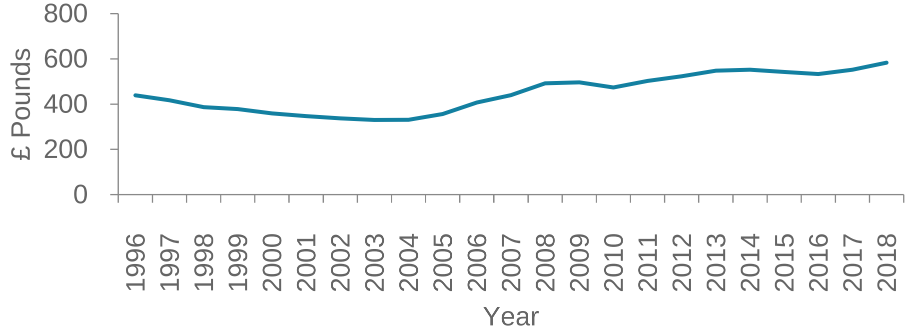
- After a lengthy investigation by the Competition and Markets Authority (CMA), there was a second government review of energy bills, led by Oxford economist Prof Dieter Helm

Household gas and electricity bills have been rising since 2004

Real household bills for gas 1996-2016



Real household bills for electricity 1996-2016



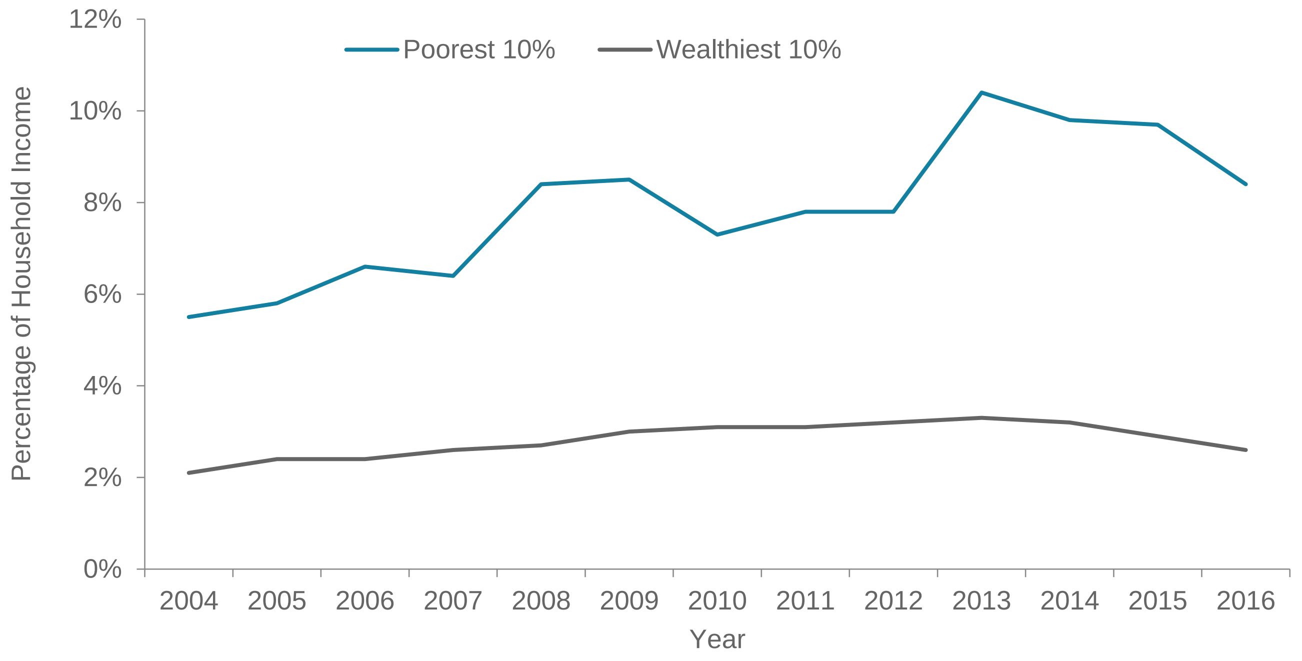
Rising bills

- **Gas** bills have risen by 90% since 2000, despite gas demand dropping by about 10%
- **Electricity** bills have risen by 75% since 2004, despite a fall in demand of roughly 10%
- This is due to supply price increases of 2% above inflation in gas, and 1.5% above inflation in electricity prices

BEIS (March 2018) Quarterly Energy Prices

Rising bills have hit the poorest 10% of households the hardest

% Household income spent on energy (mainly electricity and natural gas) for the richest and poorest 10% of the population



Biggest impact on the poor

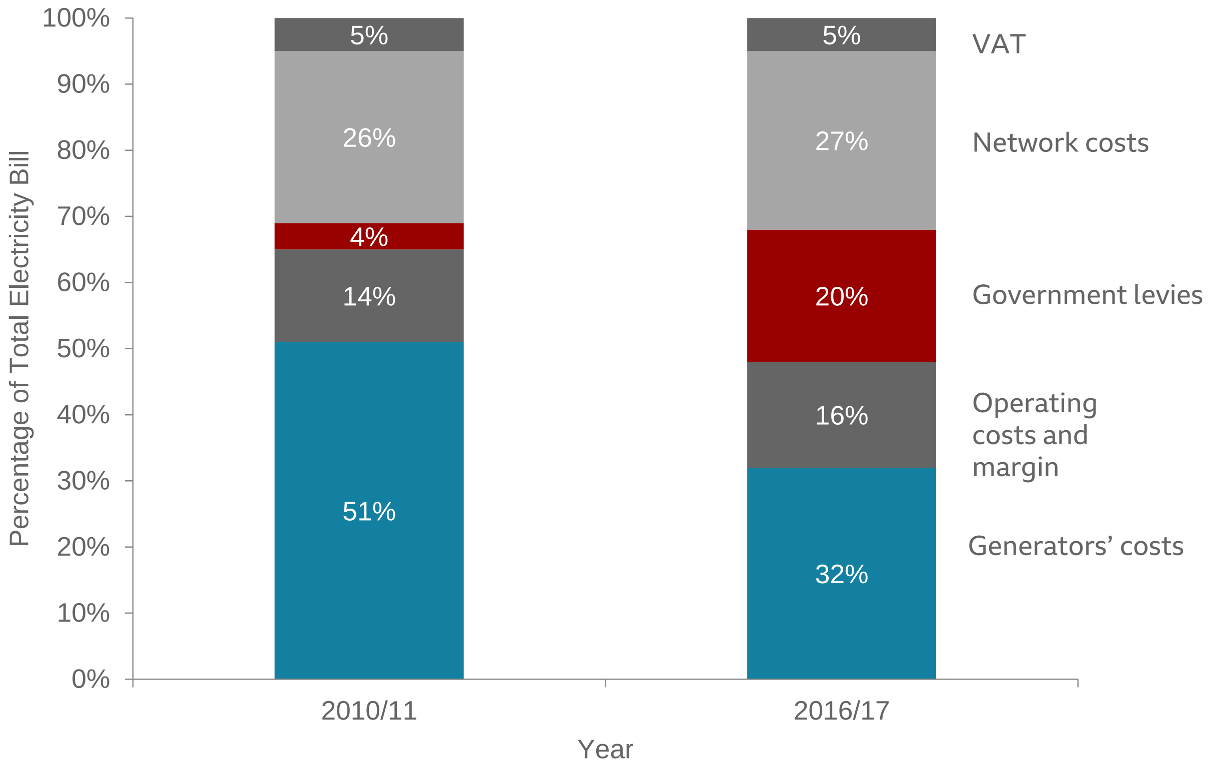
- The poorest 10% of households have seen energy bills rise from about 6% of their income in 2004 to over 8% in 2016


GETTY

Ofgem (June 2018) Energy Spend as a % of Total Household Expenditure

Rising electricity bills in the UK are caused primarily by the increasing cost of converting the system to clean energy

Breakdown of an average domestic electricity bill since 2010-11



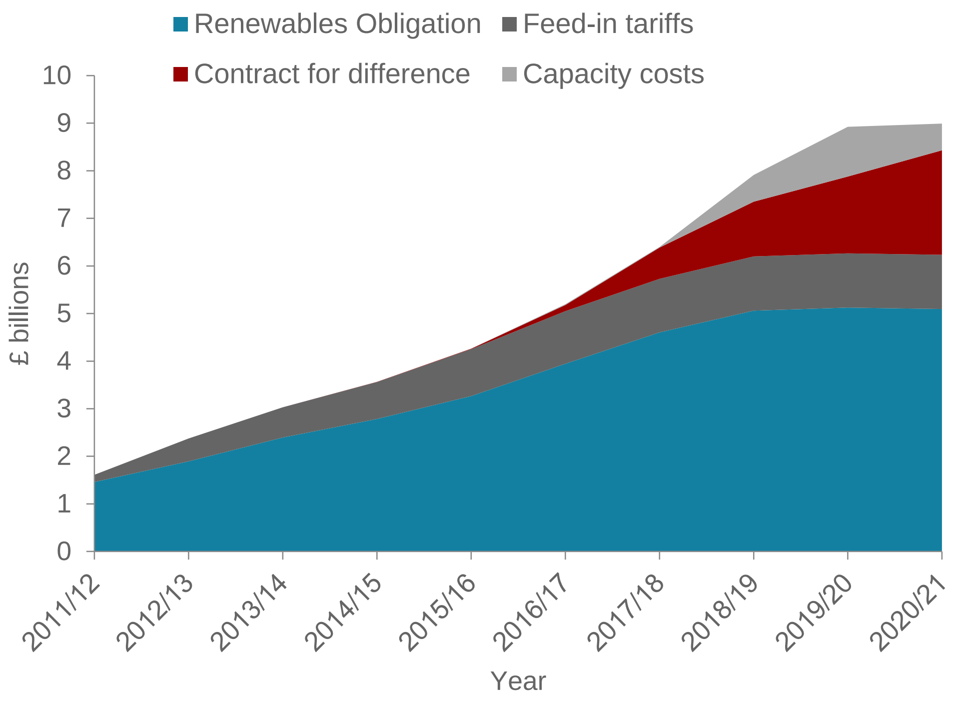
OFGEM (August 2018) Breakdown of an electricity bill)

Why electricity bills are rising

- As a share of total cost:
  - **Network costs,** the cost of modernising national and local transmission networks, have remained constant
  - **Operating costs,** the cost of delivering the supply to the consumer through the transmission system, have remained constant
  - **Generators' costs,** the amount supply companies pay to generating companies for their electricity, have been falling
- However:
  - **Government levies,** to fund clean energy subsidies, have risen substantially in the period. Critics argue these costs should be borne by taxation and not loaded on to bills. This would also help to protect the poor from price rises

The cost of clean energy subsidies added to consumer bills has almost tripled in the last five years, and is set to increase

Cost of consumer funded levies applied to power generation technologies (in 2012 prices)



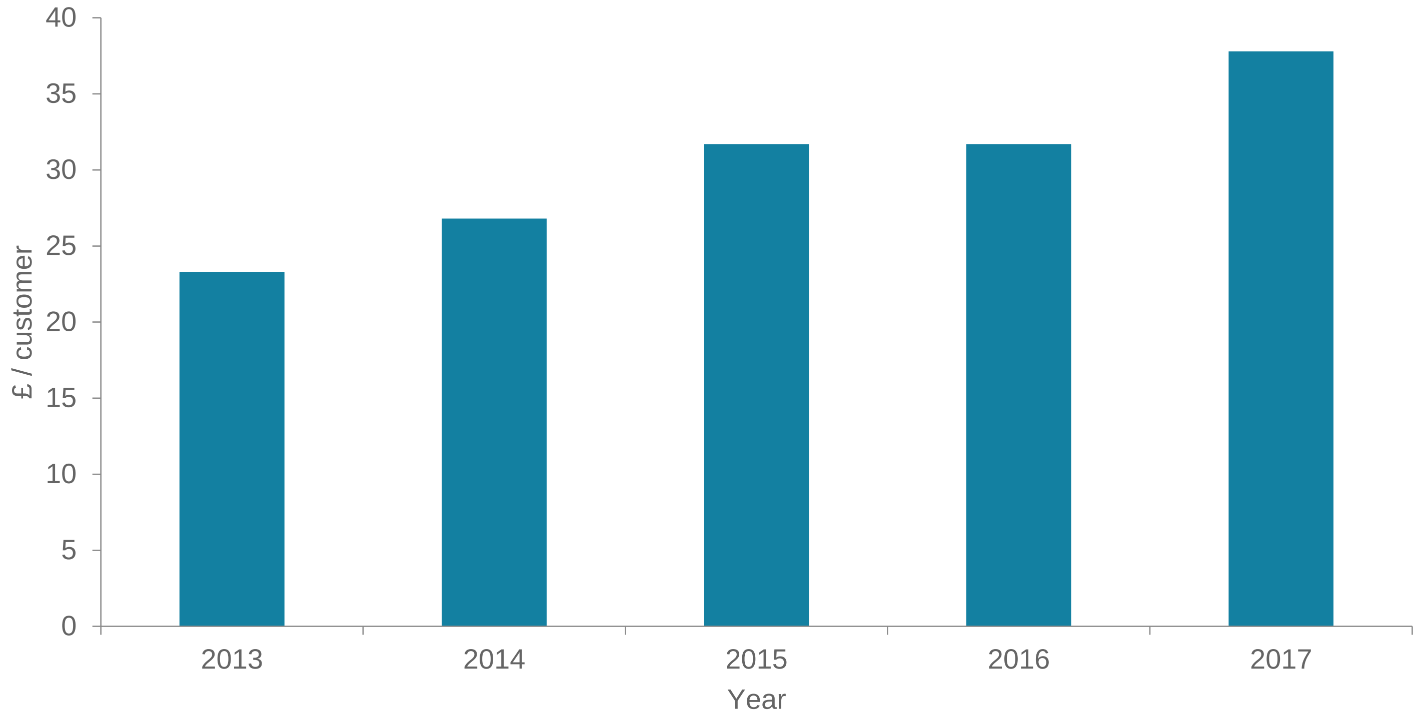
BEIS (November 2016) Consumer funded policies)

Main forms of government levies

Levy	Description
Capacity costs	• Payments to generators irrespective of whether they generate or not • System designed to ensure sufficient capacity is available at all times, and to manage the risk of the intermittency of renewables
Contract for difference	• Recently introduced support for all forms of clean energy including nuclear and renewables • Provides a guaranteed wholesale price (general price of generation) • Top-up payment made if the wholesale price is below the contracted level
Feed-in tariffs	• Support for small scale renewable energy (largely solar PV) • Guaranteed payment level for small-scale generators irrespective of the wholesale price • Price levels set by government
Renewables obligation	• This scheme provided top-up payments to renewable energy generators • Payments are added to the wholesale price • Applied to clean energy generators commissioned before April 2017 • The scheme will continue to make payments to generators until 2035

The cost of operating the UK's national transmission grid has risen by more than 60% over five years

Annual cost per household of national transmission 2013-17



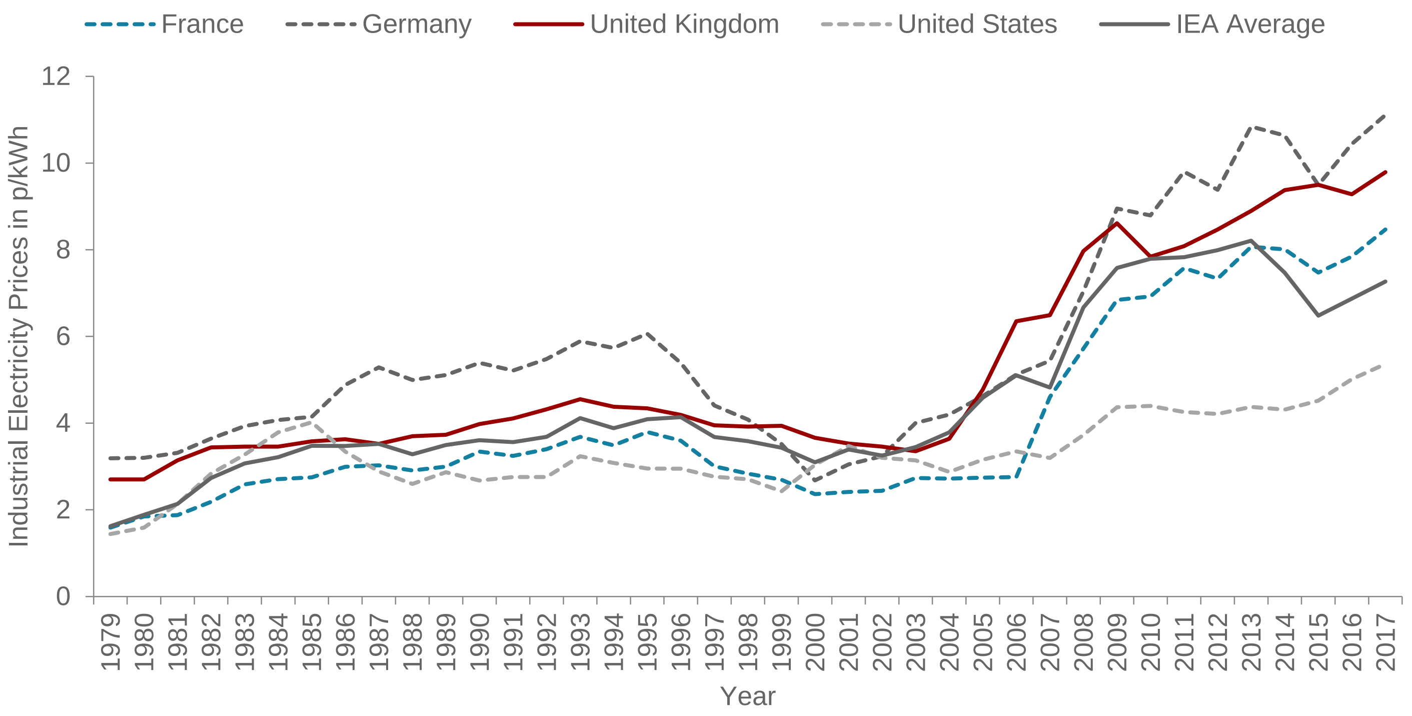
Cost of transmission

- National transmission grid:
  - Transmission costs have risen sharply, mainly to modify the grid to switch from coal to renewables, and from large generators to smaller, widely dispersed generators
- Local distribution grid:
  - Local transmission costs have dropped by 6% in five years as demand for electricity has fallen, largely offsetting the increase in national network costs
  - Network costs account for about a quarter of household electricity bills

OFGEM (March 2019) **Estimated network costs**

UK industrial electricity prices have also risen significantly since 2005

Industrial electricity prices in selected developed countries



UK industrial electricity prices

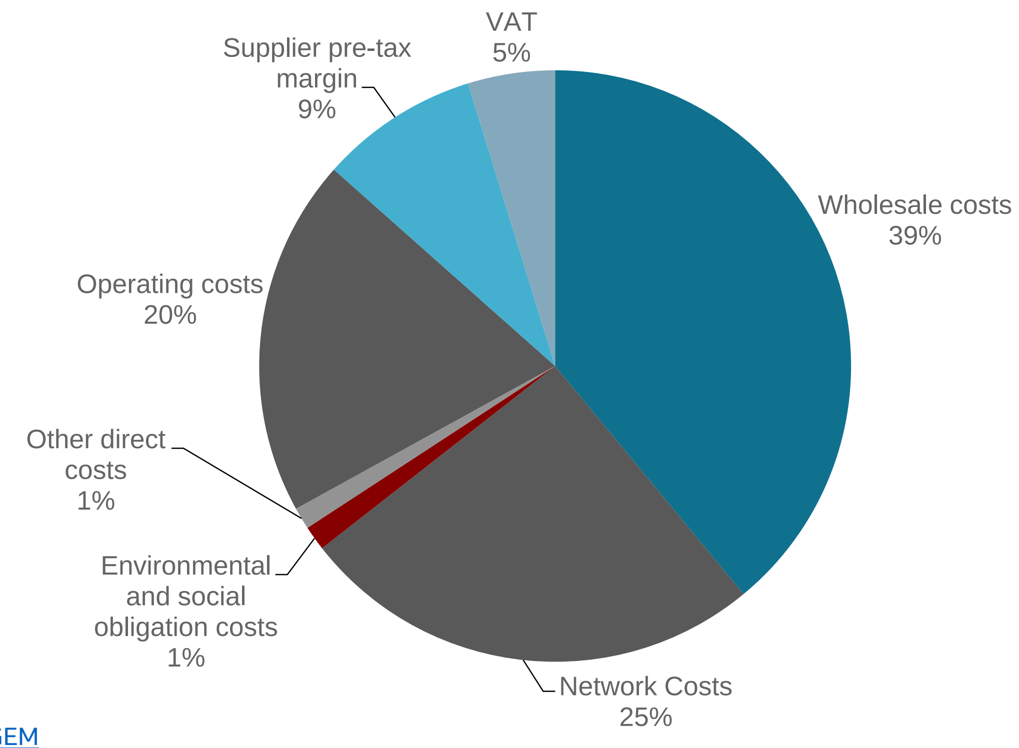
- UK industrial electricity prices are 40% higher than the International Energy Agency (IEA) average of 30 large energy-using countries
- They outstrip prices in the United States by 100%
- Announcing the loss of 720 jobs at Rotherham, Yorkshire, in 2015, then chief executive of Tata Steel Europe, Karl Koehler, said: "*We are disadvantaged by the UK's cripplingly high electricity costs*"
- Industries in many countries get hidden subsidies, which partly explain the UK's lack of competitiveness

BEIS (March 2018) Quarterly Energy Prices

Household gas bills have increased due to higher network and supplier costs and profits

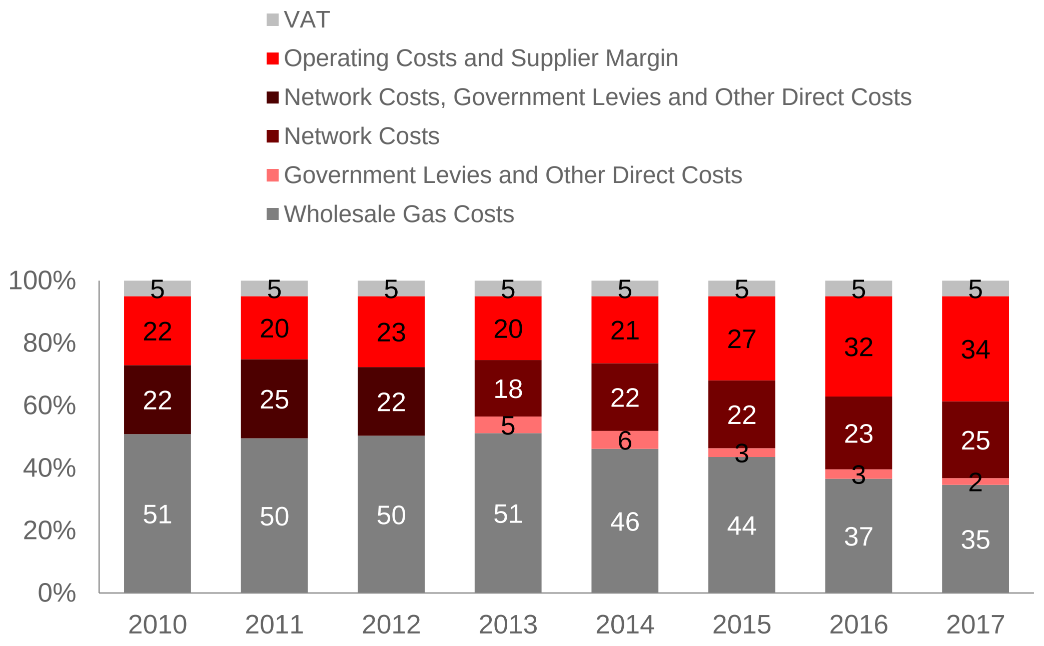
Wholesale gas costs are less than 40% of the average household bill

Breakdown of a typical domestic gas bill August 2018



Network and retail costs have been increasing while government levies and taxes have not

Breakdown of an average British gas bill 2010-17



OFGEM
OFGEM (Febuary 2018) Consolidated Segmental Statement

The CMA probe found no link between high energy prices and supplier profits, but that many customers were over-paying

CMA investigation into UK energy market 2016

- Public discontent over soaring energy bills and the perception of overcharging for profits sparked the probe
- It examined whether the "big six" UK energy suppliers had prevented or distorted effective competition in the sector
- The big six - Centrica, EDF Energy, EOn, RWE Npower, SSE and Scottish Power - accounted for nearly 90% of UK domestic customers
- The CMA found no tacit co-ordination on the size and timing of price rises, and no evidence of excessive profits or pricing
- Customers on restricted meters may have been paying about £1.7bn a year more than they would in a competitive market

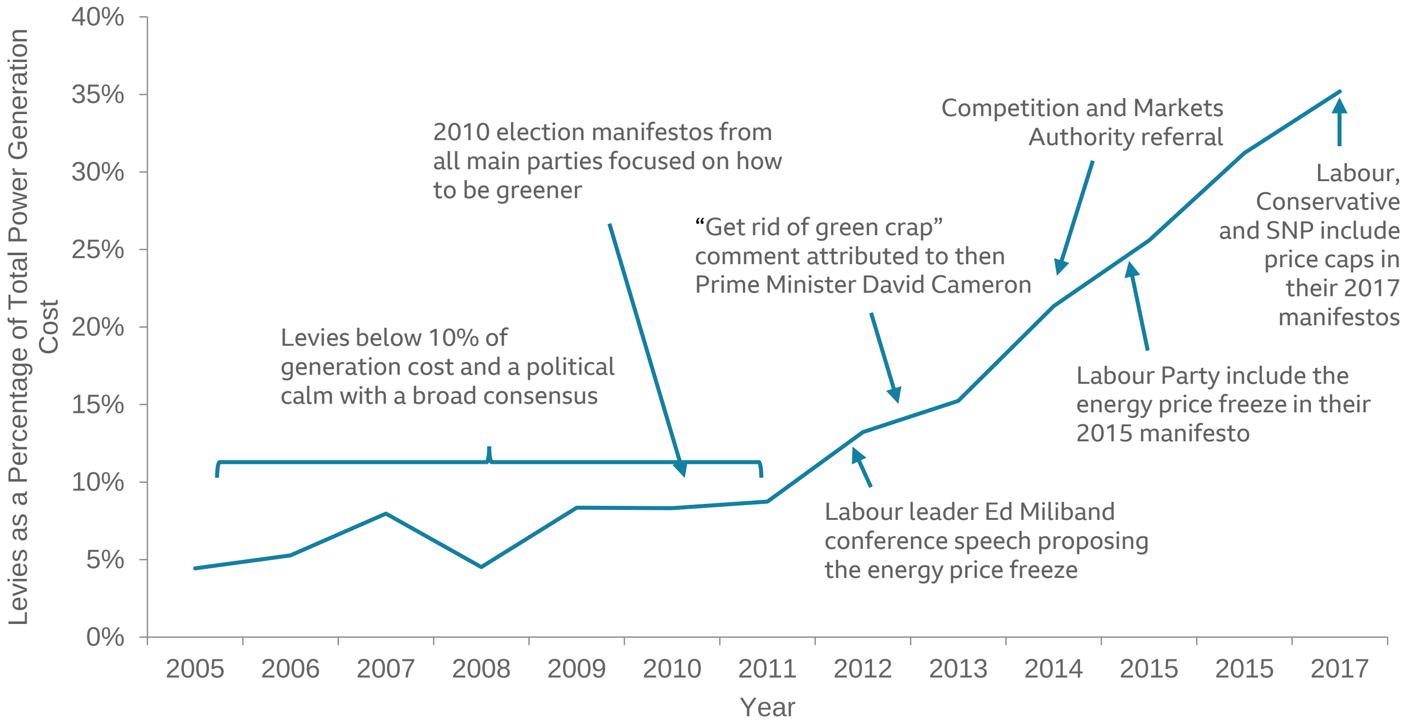
CMA recommendations

- For four million households using pre-payment meters, who find switching harder, it proposed a price cap to protect them until smart meters are rolled out in 2020
- It also proposed:
  - ending the restriction on suppliers to offer just four tariffs
  - strengthening the ability of price comparison services to help consumers find the best deal
  - tackling "rollover contracts", where customers are automatically put on less favourable terms
- Inertia, the CMA said, costs customers over £1bn a year; if 70% of all customers who stay on their supplier's standard default tariff moved, they could save £300-£400 a year

CMA (June 2016) Energy market investigation

Following the CMA review, politicians have continued to focus on energy price capping

Levies as % total power generation cost and political developments



BEIS (March 2017) energy and emissions projections
BEIS (November 2016) Consumer-funded policies report BEIS (July 2016) DUKES

Political response to rising bills

- The major political parties included price capping in their 2017 election manifestos, a year after the CMA review of the energy market
- In 2017, a price cap was introduced by Ofgem, the energy markets regulator, for consumers on pre-payment meters. In 2019, it set a price cap on the standard tariff for consumers who do not shop around for a better rate (known as default standard variable tariff)
- Ofgem says 15 million energy users benefit from price capping
- Caps are reviewed twice a year. In April 2019, the Default Tariff Cap was set at £1,254 per year and the Prepayment Meter Cap at £1,242 per year for the average dual-fuel customer

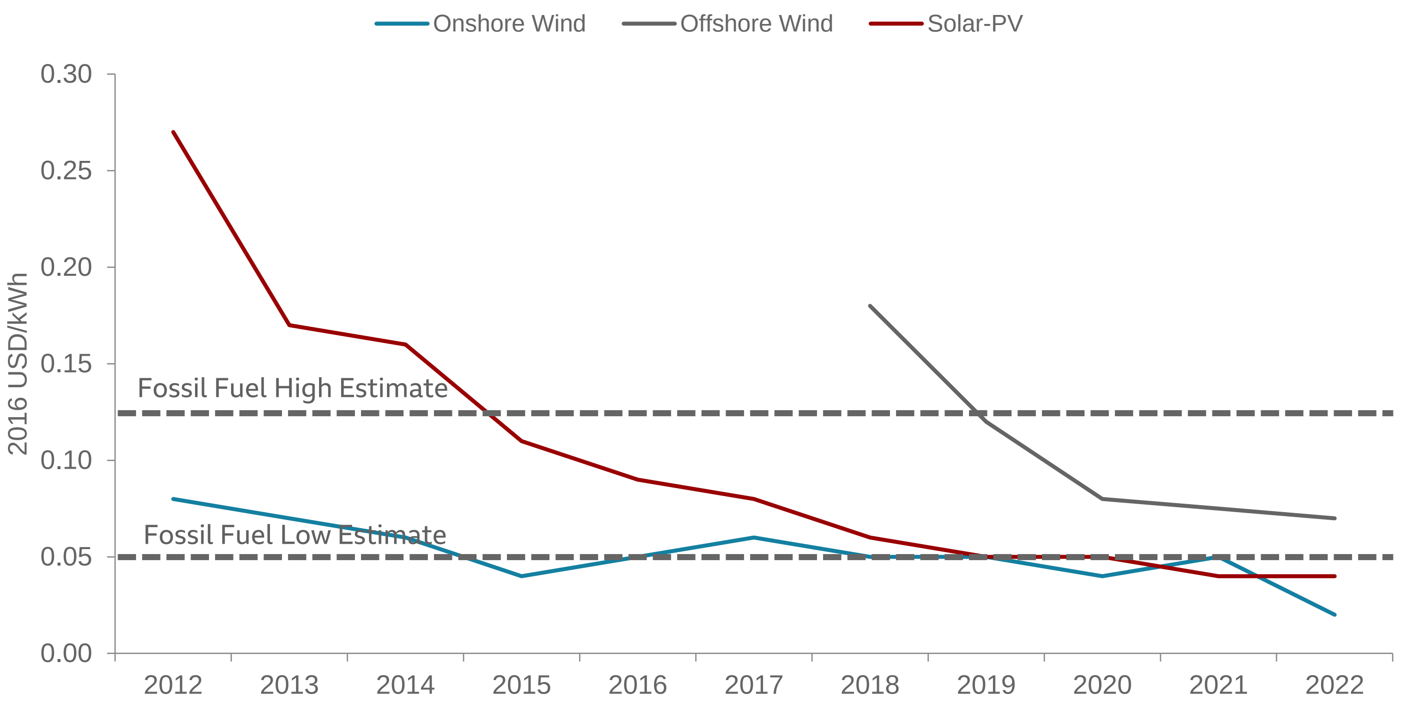
Another independent review of the energy market was published in 2018

The Helm Report (2018)

- Dieter Helm is Professor of Energy Policy at Oxford University and a leading economist and energy expert
- The findings of his review of the energy market were:
  - Government "picking winners" in renewables and preventing more competition for renewable contracts, drove up prices
  - The energy market design may no longer be fit for purpose, and there should be more competition in grid and service supply
- For the future, Dieter Helm proposed:
  - Reform of the carbon tax system, introducing a new single UK carbon tax
  - Selling off old expensive renewables contracts so they stop pushing up prices
  - Future regulation of supplier profit margins and not of retail prices, which are driven by many factors beyond the control of energy suppliers, such as network costs and wholesale fuel costs
  - Reform of the electricity generation internal market to price each source of electricity more effectively

The cost of renewables is falling, so levies and electricity prices may come down

Comparison of global average auction prices of renewable generation and fossil fuels from 2012 to 2022



The falling cost of renewables

- The marginal costs of energy from some renewable sources, such as solar and onshore wind, are already below the fossil fuel alternatives
- The promise of offshore wind coming online in the early 2020s will produce power 66% cheaper than three years ago
- Future renewable energy schemes will not need high levies
- For the next few years, most of our renewable energy will still come from pre-2018 levies

CCC (May 2019) Net Zero

Summary

The Cost of Energy Today

Energy companies only have control over some elements in the average consumer bill.

An investigation by the Competition and Markets Authority (CMA) did not connect rising bills to excessive supplier profits. It recommended a price cap to protect certain types of consumers, and ways of helping customers find the best deal.

Electricity prices have been rising in the UK primarily because of government levies to fund the cost of switching to a clean energy system. These levies should come down in future as the cost of new renewable schemes comes down.

Political pressure over high prices resulted in the introduction of a price cap in 2019.

Part 8/9

The Future Cost of Energy

What will achieving a net-zero carbon target by 2050 cost the country?

Will energy costs in the future rise or fall?

“The total cost of transitioning to a zero-carbon economy is likely to be in excess of a trillion pounds“

Phillip Hammond
Chancellor of the Exchequer
June 2019

The move to net-zero emissions by 2050 will require widespread, far-reaching and costly change

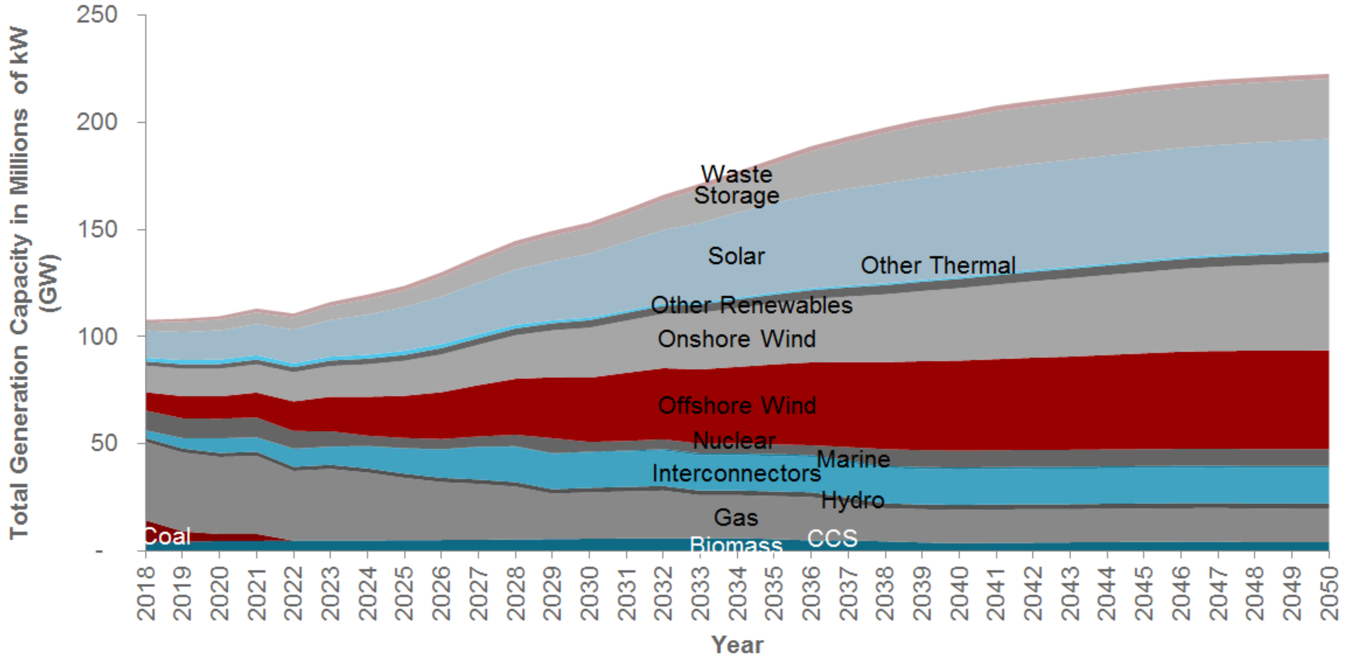
Move to net-zero emissions

- According to the Committee on Climate Change, in 2017 the UK emitted 503MtCO_2e of total greenhouse gases. To reach their 2050 emissions target of residual emissions of 35MtCO_2e, the UK needs to reduce the 2017 level by a further 93%
- A move to net-zero emissions by 2050 would probably necessitate:
  - All cars to be electric or hydrogen
  - The rollout of heat pumps or hybrid heat pumps across the whole UK (homes and businesses)
  - The adoption of resistive electric heating, substantially increasing the total home installation, grid upgrade and power generation costs
  - OR the rollout of hydrogen gas network across the UK with substantial gas grid and in-home equipment costs
  - A complete transfer of the HGV and public transport fleet to hydrogen or hydrogen/electric hybrid
  - Air and water transport to transfer to biofuels or to be allowed to offset through carbon capture or reforestation

BEIS (March 2018) UK Greenhouse Gas Emissions

Future electricity generation will involve more investment in renewables

A National Grid scenario for 2050



National Grid projections

- Much greater role for renewables - especially offshore wind and solar – requires investment. This is without reaching the net-zero target
- Less certain are the roles for nuclear and carbon capture and storage because:
  - the nuclear build programme is behind schedule and several schemes have been abandoned for now
  - carbon capture and storage is expensive and so far contested at scale
  - these uncertainties may increase the requirement for renewables further, which would also expand the need for storage - potentially across seasons
  - A big expansion of solar and onshore wind installations may spark local opposition

The National Grid (July 2019) Data Workbook ES2

As the costs of renewables plunge, it is unclear whether nuclear generation will be a desirable option

	Britain's nuclear future
The Hinkley Point C contract price was below the prevailing cost of renewable energy at the time it was agreed …	• At the time the Hinkley Point C deal was agreed in 2013, the cost of renewable energy was at or above the cost of the Hinkley deal of 9.25p/kWh • Offshore wind projects were awarded similar contracts to Hinkley at 11.5 to 15.5p/kWh in the same period • Onshore wind at the time cost c.8p/kWh • Renewable energy support was awarded for 15-20 years, whereas Hinkley C was committed for 35 years
The evidence from other nuclear plants is that we cannot today know the final cost …	• Under the Hinkley deal all cost and time overruns are at the developer's risk • However, experience in France, Finland and elsewhere has shown that such overruns can be vast, and can be crippling for developers, who will look to governments for rescue • So there is no certainty that the final cost of Hinkley Point C will be as projected
The costs of renewable energy have fallen below the cost of Hinkley, but can they scale sufficiently at low cost?	• The evidence is that the cost of renewable energy at sites with good resources is now well below the contract price for Hinkley • Hinkley is to provide c.7% of UK electricity - as much as each of onshore wind, offshore wind or biomass in 2015 • However, intermittency problems with renewables will incur added costs such as storage, and nuclear may still play a role

The cost of nuclear power in the future may be cheaper if government assumes responsibility for construction risk

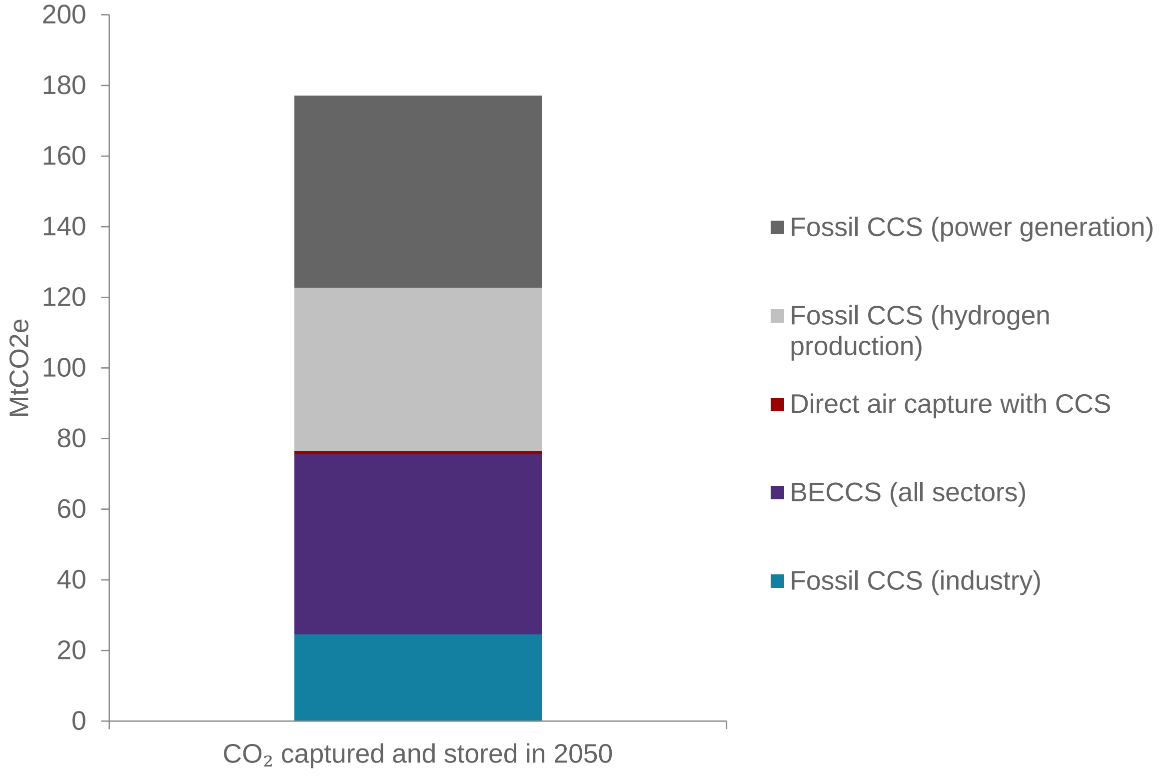
The cost of nuclear power and alternative approaches to building nuclear

- The National Audit Office (NAO) has estimated that lower electricity prices would result if government assumed some or all of the construction and financing risk of nuclear power
- The current deal with EDF for Hinkley Point C sets the wholesale price for electricity from nuclear generation at 9p/kWh
- NAO analysis shows substantial saving in the electricity cost of nuclear in all but one scenario:
  - if government were to take all the construction and financing risk of nuclear power, the NAO predicts that the wholesale price of electricity would be over 50% lower at 4p/kWh
  - only in a scenario where the private sector bears all the construction and financing risk of nuclear is the wholesale price of electricity expected to increase – to 14p/kWh
- The argument for transferring risk to the government is that it would be fairer: poor consumers would benefit at the expense of richer tax-payers
- The government is already considering this idea

NAO (June 2017) Hinkley Point C)

Carbon capture will be an important part of the costs incurred in reaching net zero

Target carbon capture by 2050



Predicted fuel use costs by carbon capture technology type

Technology	Cost in 2025	Cost in 2050
Gas with CCS	79 (£/MWh)	79 (£/MWh)
Hydrogen production with CCS	44 (£/MWh)	39 (£/MWh)
BECCS from UK biomass	125 (£/t)	125 (£/t)
BECCS from imported biomass	300 (£/t)	300 (£/t)
DACCS	450 (£/t)	300 (£/t)

CCS = Carbon capture and storage BECCS = Bioenergy with CCS
DACCS = Direct air carbon capture and storage

CCC (May 2019) Net Zero

Some costs in reaching net zero will increase, and some may yield savings in the long run

	One-off costs?	Additional or just normal replacement cycle?	Extra running cost or not?
Building heating	• Transfer to hybrid hydrogen/ electric heat pumps • Gas network upgrade to take hydrogen • Better insulation • New in-home heating systems – radiator replacement with air outlet systems	• Hybrid heat pumps will be more expensive than replacing gas boilers • In-house insulation would need to be improved	• Electric heat pumps are more efficient • Electricity costs are likely to be higher than for natural gas • Hydrogen is more expensive than natural gas
Private transport upgrade	• Charging points installation • New electric car purchases • The grid must be upgraded to support the extra demand electric cars will place on it	• If properly managed, electric cars will just substitute for normal cars as they need replacing • The upfront costs of electric cars are falling to near petrol car costs	• Electricity is more expensive than petrol, but annual fuel costs should come down as electric cars are more efficient

The impact on future energy costs for the consumer is unclear

Factors which could reduce costs

- Renewable costs are coming down – some are lower than natural gas prices
- Nuclear costs could decline if the government bears the investment risks
- A combination of global reduction in demand and possible increases in supply might eventually lower gas and petrol prices. This could set back our long-term transition to low or net-zero emissions
- Electric cars and electric heat pumps use less energy than their conventional alternatives, which means reduced costs for consumers
- Better insulation and smart meters could further reduce energy usage, which also lowers energy bills for customers

Factors which could increase costs

- Carbon capture adds to gas-based generation costs, as well as to costs of production
- Adding storage to the electricity grid could double the wholesale unit price
- Hydrogen conversion costs could add to household heating costs and car/van fuel costs
- Household energy bills could increase if grid and storage infrastructure costs are paid for by consumers

Brexit brings uncertainty to many aspects of the UK energy market

Uncertainties arising from Brexit

Regulation:

- The UK may be required to abide by EU rules on the internal energy market, but is likely to lose the right to influence how they are set

Ireland:

- The Republic of Ireland receives 85% of its energy via the UK, and it is unclear how the Single Electricity Market (SEM) with Northern Ireland will be affected by Brexit

Interconnectors:

- The transfer of electricity through interconnectors is regulated, tariff-free, under the rules of the EU's Internal Energy Market (EIM)
- A no-deal Brexit will leave the UK outside the market, and so subject to tariffs, pending further negotiations

Nuclear industry:

- The 1957 Euratom Treaty regulates much of the EU nuclear industry, including how the UK acquires nuclear fuels. The UK has said it will withdraw from Euratom as part of Brexit
- The Hinkley Point C deal says developers will be compensated if UK law changes in a way which shuts the plant or makes it uneconomic. The energy company EDF told a parliamentary select committee: "We very much rely on the provisions in the Euratom Treaty to operate our existing power stations and for the future construction and operation of Hinkley Point"
- There have been concerns that supply chain workers would not qualify under stricter immigration controls post-Brexit

Green policies:

- The EU has driven a number of key policies, like the EU emissions trading scheme and targets for renewable energy. The effect of losing this external pressure is also uncertain

HoL (January 2018) Brexit: energy security

The Committee on Climate Change suggests that carbon capture or extraction will be the greatest cost of reaching net zero

Committee on Climate Change cost analysis

Sector	Annual resource cost to 2050
Power Generation	+£2bn
Building	+£13bn
Industry	+£7bn
Transport	-£2bn
Agriculture/ land use change	+£1bn
Aviation and shipping	+£5bn
Engineered GHG removals/ carbon capture	+£8-22bn
Total	**+£38-52bn**

Impact on the whole economy

- In its report, the CCC estimates the cost to the UK economy over time:

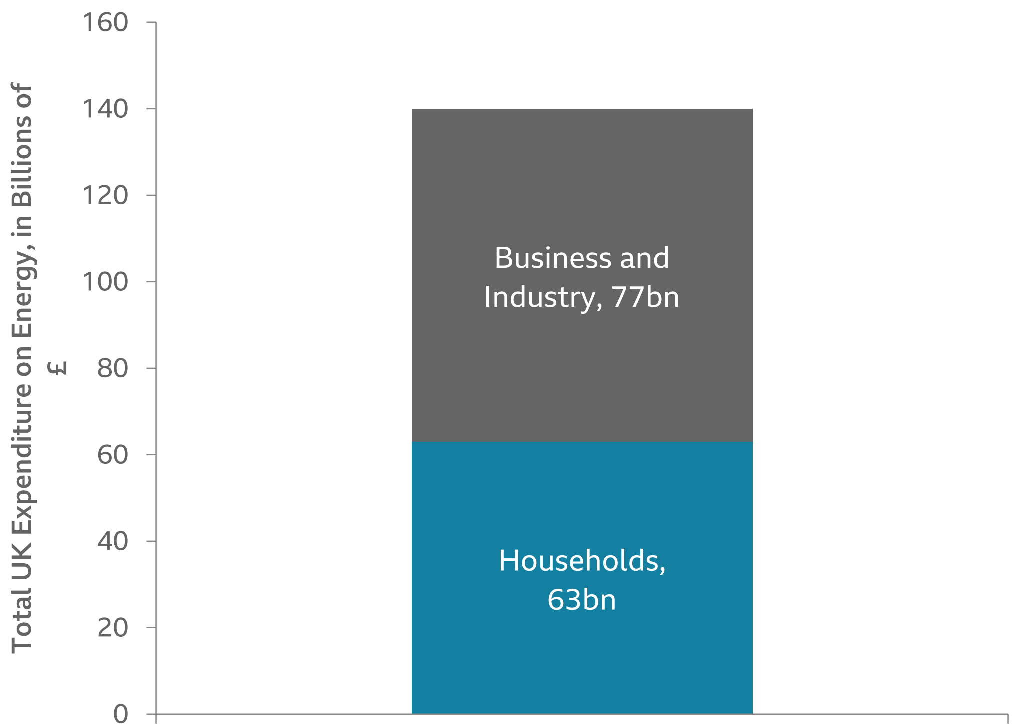
  "We now expect that a net-zero GHG target can be met at an annual resource cost of up to 1%-2% of GDP to 2050"

- Energy (including taxes) currently accounts for 7% of UK GDP
- Some of the net-zero costs are investments and would be expected to earn a return and contribute to economic growth

CCC (May 2019) Net Zero

The final cost of moving towards net zero remains unpredictable

Total UK expenditure on energy by sector



The government's view on costs

- In a letter to Theresa May in June 2019, then Chancellor Phillip Hammond wrote that by 2050 "the total cost of transitioning to a zero-carbon economy is likely to be well in excess of a trillion pounds"
- This figure is broadly consistent with the CCC's estimate – which is £1.35tn (or £45bn a year over 30 years)
- In the same letter, the chancellor referred to a Business Department estimate of £70bn annually, which would produce an even higher total long-term cost to the economy
- The cost of reaching net zero has to be seen in the context of potential costs to the UK of **not** tackling climate change, as the CCC stresses
- It is not yet known how the costs will be divided, and what share the government will actually bear

CCC (May 2019) Net Zero

Summary

The Future Cost of Energy

Electricity prices are likely to increase as a result of the cost of the transition to low-carbon generation, although international trends indicate that renewable generation costs will continue to fall.

The impact on consumers will depend on how overall costs are split between households, industry and government.

Nuclear can provide security of supply in a low-carbon future, although whether government will help to reduce nuclear costs is still undecided. And it remains unclear whether battery storage technology will become cheap enough to deal sufficiently with the intermittency of renewables.

The long-term cost for consumers of a low-carbon energy future remains uncertain.

Part 9/9

The Politics of Energy

How do our politicians propose to create a low-carbon energy system? How will they drive change in the ways we heat our homes and buildings, and how we travel and transport our goods?

How will they manage the cost and other consequences for individuals and for business?

"The environmental challenge that confronts the whole world demands an equivalent response from the whole world. Every country will be affected and no one can opt out. Those countries who are industrialised must contribute more to help those who are not"

Margaret Thatcher (Prime Minister 1979-90)
November 1989

"Only by taking the grid into public ownership can we decarbonise the economy at the pace needed to secure the planet for our children and grandchildren while ending the rip-off, creating good jobs in local communities and making heating and electricity a human right"

Rebecca Long-Bailey (shadow business secretary)
May 2019

The government has to determine how we deliver the energy revolution and who pays

Key delivery challenges

Energy generation

- Deciding which mix of options to back:
  - the role of electricity
  - using non-carbon fuels like hydrogen
  - the mix of renewables, nuclear and carbon capture

Infrastructure

- How far to upgrade the electricity and gas grids
- Whether and how to promote carbon capture
- Whether more interconnectors and energy storage are needed
- Whether to complete electrification of the rail network
- How far to expand electric vehicle charging points

Behavioural and lifestyle changes

- How to expand use of electric vehicles and heating
- How to encourage more energy-saving lifestyles

Financing

- How to share the burden between taxpayers, energy companies, business and industry, and the domestic consumer

Balancing incentives and sanctions

- discounts or grants for electric vehicles
- enhancing public transport
- subsidies for electric heating and insulation grants
- increased subsidies or incentives for renewables
- banning non-electric vehicles
- mandatory conversion of heating systems
- using taxation or extra duties

There has been a series of policy measures in recent years

Legislation and initiatives over the past decade (1)

Date	Action	Provisions
November 2008	Climate Change Act	• Set a legally binding target to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline
December 2009	Smart Meter Rollout	• Announced the government's intention to have smart meters in all homes in Great Britain by 2020
April 2010	Feed-In Tariff Scheme	• Consumers could apply to receive payments from their energy supplier if they generate their own electricity, eg with solar panels or a wind turbine • The scheme was replaced in April 2019, with a less generous Smart Export Guarantee
July 2011	Plug-In Car and Van Grant	• Introduced to help establish the market for electric vehicles by offering consumers up to £4,500 off the price of an electric car and up to £2,500 off the price of a hybrid car • In November 2018, with prices for electric vehicles falling ,the government scrapped subsidies for hybrid cars, while grants for electric cars were cut to £3,500
November 2011	Renewable Heat Incentive	• Incentives for consumers introduced, aiming to help the UK reach the target set in the previous year of sourcing 12% of all its heat from renewable sources by 2020
June 2012	Fuel Duty freeze	• Fuel duty was frozen by then Prime Minister David Cameron, a policy maintained by his successor Theresa May

Policies and initiatives have aimed to increase carbon emission cuts

Legislation and initiatives over the past decade (2)

Date	Action	Provisions
April 2013	Carbon Price Floor	• The Carbon Price Floor taxes fossil fuels used to generate electricity, and is paid for by energy generators through a Price Support Mechanism, to encourage investment in renewables
October 2017	Clean Growth Strategy	• Outlined how £2.5bn will be invested by the government between 2015 and 2021 to support low carbon innovation
October 2017	The Private Rented Property Minimum Standard	• Introduced guidance to landlords of privately rented domestic and commercial properties, insisting they meet 2018 Minimum Level of Energy Efficiency standard (EPC band E)
July 2018	Road to Zero Strategy	• Confirmed the government's commitment to end the sale of new conventional petrol and diesel cars and vans by 2040
July 2018	Automated and Electric Vehicles Act	• Passed to facilitate the expansion of charging points across the country and lay the groundwork for future regulation of electric vehicles infrastructure
January 2019	Nearly Zero Energy Buildings Requirements	• A circular letter that clarified requirements for new public buildings to be nearly zero-energy buildings

Power over energy policy - currently shared by the EU, UK and devolved administrations - could shift with Brexit

European Union (EU)	United Kingdom (UK)	Devolved administrations
• Responsibilities include: • Promoting energy efficiency • Promoting renewables • Internal gas and electricity market regulation • Greenhouse gas emissions trading schemes • Innovation, research and development funding • Trade in nuclear materials (Euratom)	• Responsibilities include: • Regulating gas and electricity markets (Ofgem) • Securing energy supply • Renewable energy and energy efficiency subsidies and grants • Nuclear licensing and nuclear safety • Climate change targets and emissions reduction • Innovation, research and development funding • Supervision and licensing of oil, gas and coal resources	• Responsibilities include: • Most transport policies (including air passenger duty from 2016) • Offshore and onshore energy installations • Fuel poverty support systems • Role in energy efficiency and renewable promotion • Economic development programmes • Housing law and construction regulation

UKERC (April 2019)

The devolved administrations have taken different approaches to energy policy

Scotland and Wales

- The CCC has set an earlier target for Scotland than the UK as a whole, to reach net zero by 2045
- The Scottish government has committed to 100% of electricity generation from renewables by 2020, although by 2018 they still only accounted for 73.9%
- The CCC does not expect Wales to reach net zero by 2050, although the Welsh government wants to
- Both the Scottish and Welsh governments have declared a climate emergency
- However, both have also been criticised for plans to slash air passenger duty

Northern Ireland

- The CCC only expects an 80% reduction from 1990 levels in Northern Irish emissions by 2050
- Only 24% of homes in Northern Ireland are connected to the gas grid, compared with 87% for the UK as a whole, making heat decarbonisation options which rely on the gas network more challenging
- Since November 2007, energy supply is integrated with the Republic of Ireland under EU rules as the Single Electricity Market (SEM), which may change with Brexit
- Since January 2017, devolved government has been suspended, after a dispute between governing parties over a failed renewable energy scheme and ensuing "Cash for Ash" scandal

Scottish Government (June 2019)
CCC (May 2019) Net Zero

Positions of major UK parties on energy strategy

	Conservative/ government	Labour	Liberal Democrat	Scottish National	Plaid Cymru	Green*
Reaching Net Zero	By 2050	2050 or sooner	By 2045	Scotland to reach by 2045	Wales to reach by 2050	By 2030
Nationalising energy and gas suppliers	Oppose	Support	Oppose	Provide public alternatives but not nationalise existing ones	Policy to be decided by Welsh Assembly	Support
Community energy schemes	Support various schemes	Create a network of community-based bodies	Support both public and private schemes	Support	Yes, and create a fast-track way for people to create them	Support and require grid operators to give priority
Home insulation	Through the Help To Heat scheme	£2.3bn annual investment focusing on low income households	Four million homes on low incomes at Band C by 2022, all homes band C by 2035	Warmer Homes Scotland programme of loans and subsidies	Greener Homes programme to be announced	Free insulation for nine million homes nationwide

Positions of major UK parties on power generation

	Conservative/ government	Labour	Liberal Democrat	Scottish National	Plaid Cymru	Green*
Shale gas (Fracking)	Support new schemes	Complete ban	Complete ban	Complete ban	Complete ban	Complete ban
North Sea Oil & Gas Extraction	Support continued extraction	Unknown	Maintain current supply while slowly phasing out	Support continued extraction	No policy	End investment in new infrastructure and phase out
Onshore wind	Oppose subsidies	Reinstate subsidies	Reinstate subsidies	Reinstate subsidies	Reinstate subsidies	Reinstate subsidies
Nuclear Power	Support new schemes	Support new schemes	Support new schemes but with no public subsidy	Oppose new schemes	Unknown	Oppose new schemes

Positions of major UK parties on transport issues

	Conservative/ government	Labour	Liberal Democrat	Scottish National	Plaid Cymru	Green*
Heathrow Airport Expansion	Support	Oppose current plan	Oppose	Oppose	Oppose	Oppose
Rail Electrification	Cancelled three major projects in 2017, current position unclear	Further electrification	Full electrification where possible by 2035	75% of passenger miles in Scotland on electric track by 2020	Further electrification	At least 73% electrification, on par with Sweden
Motorway expansion	Support, building more than 1,300 additional lane miles 2015-20	Case by case support	No plans to support	Support schemes in Scotland	Support relief roads while reducing car use	Oppose - focus on improving public transport

*The Green Party of England and Wales
**To the best of our knowledge, parties have been consulted
***The Brexit Party has not outlined any energy-related policies

New environmental movements have pushed tackling emissions back up the political agenda

Youth movements

- Swedish activist Greta Thunberg gained international attention in 2018 when she decided not to attend school in protest at what she felt was inadequate climate policy
  - This spawned a wave of "school strikes", with an estimated one million students striking across 110 countries, with strikes across 125 towns and cities in the UK
- The Go Fossil Free Campaign has taken off at universities and other institutions since 2011, with more than 1,000 institutions committing to divest from fossil fuels. In the UK they include the University of Glasgow, the British Medical Association and Oxford City Council

Extinction Rebellion

- In April 2019, Extinction Rebellion initiated 10 days of protests in London, blocking off and paralysing key areas, including Parliament Square
- More than a thousand police were drafted in and more than a thousand activists were arrested
- Greta Thunberg participated in the action, and galvanised activists with her speeches
- Ms Thunberg told parliamentarians they had stolen the future from her generation
- She criticised the government's claims on recent climate change achievements as "misleading"

Greta Thunberg protesting in Stockholm, Sweden in 2019

Summary

The Politics of Energy

There is consensus among the political parties on the desirability of achieving a net-zero target. But on detailed energy policy – particularly on the role of nuclear, fracking, transport and on the extent of state ownership – there are now significant differences.

While politicians ponder these questions, popular pressure for more radical policies is growing. The emergence of new environmental movements may shift the debate further.

In Conclusion

There is widespread agreement that there needs to be a vast reduction in CO_2 emissions if the extremes of climate change are to be averted. But the pathway to achieving low or zero emissions has yet to be defined – not least because so many of the technologies involved are not yet available commercially or have uncertain costs. What is certain is that achieving net zero will require fundamental change in many aspects of our lives – how we heat or cool our homes, how we power our planes, trains and cars, and how we generate electricity by non-carbon means.

How to encourage, incentivise, require and finance these changes – whether directly by individuals or via taxpayer funding – is a challenge for the government. There are too many variables for us yet to be clear what the overall costs to society will be, though they will be high. This needs to be offset, though, against the costs of *not* acting to combat climate change.

It is important for the UK to work with other nations in this enterprise. One country cannot solve the problems on its own.

But if the UK and other nations combine to embrace net zero, the prize is a mighty one; to maintain and safeguard the Earth and the natural world as we know it.

Glossary A-E

Afforestation	Planting trees to cover a prescribed area	**Community Energy**	Heat or power produced and distributed in a locality
Biofuel/ biomass	Fuel derived from living matter, including biomethane	**Deindustrialisation**	Reduction in industrial activity, especially manufacturing
BECCS	Bioenergy power generation, combined with CCS	**Demand management**	Efforts to reduce energy consumption
Capacity	The maximum possible energy output at a given time	**Devolved nations**	Scotland, Wales and Northern Ireland
Carbon capture	Carbon trapped and stored (CCS) or used (CCU)	**Direct air capture**	Carbon capture of CO_2 already in the atmosphere (DACCS)
Carbon-based fuel	Fuel containing carbon including fossil fuels, biofuels	**Electricity**	A form of energy typically distributed through wires
CCC	The UK Committee on Climate Change	**Electrification**	Conversion from other energy sources to electricity
Climate Change Act	The main UK law regulating emissions targets	**Energy**	Power multiplied by the time period, measured in kWh
CMA	The UK Competition and Markets Authority regulator	**Energy efficiency**	Energy used as a proportion of energy supplied
CO_2	Carbon dioxide, a greenhouse gas	**Energy mix**	Range of a country's different energy sources

Glossary F-N

Fossil fuels	Geological fuels including oil, gas and coal	**Hydrocarbons**	Compound chemicals found in carbon-based fuels
Fracking	Injecting liquid at high pressure into rock to extract fuel, especially shale gas	**Hydrogen**	A common element which can be used as fuel
Fuel cell	A cell producing electricity from chemical reactions	**Infrastructure**	Physical and organisational structures and facilities
Fuel poverty	Having to spend an excessive proportion of income on energy	**Interconnectors**	Physical links allowing energy transfers between national networks
GDP	Gross domestic product - a country's economic output	**Intermittency**	Irregular supply - not continuous at the same rate
Greenhouse gas	Gases contributing to the warming of the climate	**Levies**	Taxes imposed on a good or service, eg energy
Grid	Physical infrastructure distributing gas or electricity	**National Grid**	A public company controlling utility supply
Heat pumps	Reverse refrigeration transferring heat into a building from outside	**Nationalisation**	Bringing private companies under government control
HGVs	Heavy goods vehicles eg lorries	**Natural gas**	Hydrocarbon gas-based fossil fuel
Home insulation	Altering the home to prevent heat loss	**Net-zero**	Removing as much greenhouse gas as is emitted

Glossary O-Z

OECD	Organisation for Economic Co-operation & Development	**Smart meter**	Device recording electricity consumption and communicating it digitally to suppliers
Offshore wind	Wind power installations located out to sea	**Storage, of energy**	Capturing energy for use at a later time
Onshore wind	Wind power installations located on land	**Storage heater**	Electrical heater storing energy during the evening, when electricity tariffs are lower
Passenger miles	Miles travelled by all passengers in a time period	**Subsidy**	Money provided by government to reduce prices for companies or individuals
Per capita	Per person, usually within a country	**Sustainable energy**	Energy which does not negatively affect the climate
Power	The rate at which energy is generated or used, measured in kW	**Tariffs, peak**	More expensive fixed price which consumers pay during periods of high demand
Pump price	The price paid for fuel by drivers at petrol stations	**Tariffs, off-peak**	Cheaper fixed price which consumers pay during periods of low demand
Renewables	Sources of energy that will never run out, eg wind	**ULEVs**	Ultra Low Emissions Electric Vehicles
Shale gas	Natural gas fuel contained within shale sediments	**Unit price**	Cost of energy per a particular unit, eg kWh
Smart home	Home in which appliances can be controlled remotely		